Towards the long term enhancement of shellfish beds in the Whangarei Harbour

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Towards the long term enhancement of shellfish beds in the Whangarei Harbour
Part One: Identifying suitable habitat and methodologies for reseeding

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Executive Summary

Northland Regional Council (NRC) has identified several areas of Whangarei Harbour to be considered for assessment of their suitability for shellfish reseeding. These include the intertidal areas of Takahiwai River, Otaika River, Parua Bay, Blacksmith Creek, Skull Creek, Limestone Island and Mangapai River. In January 2003, NIWA was commissioned to assess each area and recommend action for the future stages of this work.

We proposed to conduct this work in several phases, over a period of at least 5 years. Year 1 has involved:

1. A review of the existing information on the intertidal benthic communities (specifically shellfish) and habitat types at each of the above locations identified by NRC, and discussions with members of the Kaitiaki Roopu on the history of these areas.

2. Visits to each of these locations. As the available information on the benthic communities in (1) contained no recent, quantitative data useful to this work, we conducted additional quantitative sampling to assess the current levels of the resident shellfish populations and the general habitat characteristics.

This information was used to recommend suitability of these areas for shellfish (i.e., cockle or pipi) reseeding operations. In doing so we have focused on enhancing numbers of harvestable individuals. For cockles this includes individuals larger than 35 mm, and for pipi individuals larger than 50 mm.

We have identified two sites for cockles (Skull Creek and the Takahiwai mid-shore area) and a potential site for pipi that requires further investigation (the outer Skull Creek area), where restoration activities may enhance the numbers of harvestable-sized individuals in the existing populations. We have also briefly discussed the potential sources of cockles and pipi for reseeding operations.

We recommend that prior to beginning any restoration activities, it is vital that the community agrees on common goals, as the efforts required for a successful outcome are labour intensive, and will require a long term commitment. Once these goals are defined, decisions on the species and areas to be restored can be made.

The areas visited are good examples of their present habitat type, with a good diversity and abundance of shellfish and other fauna present, and an abundance of bird life. However, old reports and discussions had during the course of this study indicate that some areas now have very different habitats compared to that of many years ago. Unfortunately, these habitat changes mean that cockles and pipi are unlikely to grow as large or be as abundant in these places as they were in the past.

1. Introduction

Northland Regional Council (NRC) has identified several areas of Whangarei Harbour to be considered for assessment of their suitability for shellfish reseeding. These include the intertidal areas of Takahiwai River, Otaika River, Parua Bay, Blacksmith Creek, Skull Creek, Limestone Island and Mangapai River (Figure 1). In January 2003, NIWA was commissioned to assess each area and recommend action for the future stages of this work. This included a meeting with the Kaitiaki Roopu of Whangarei Harbour, later discussions of the harbour's historical shellfish resources, and visits to each location.

A number of shellfish restoration projects have been/are being conducted around the world, and have met with variable success. Growth and survival of shellfish is affected by a number of factors, from the physical environment (e.g., waves, substrate), to water quality, pollution, and the biological environment (e.g., predation, competition, food). A number of decisions need to be made on the actual processes employed for restoration (e.g., where on the shore do you plant? what size and densities of shellfish? what time of year is best?; see Turner et al. (1998) for more examples and guidelines on the steps involved in community-based shellfish restoration projects). These decisions are complicated by the fact that different life history stages of the same species will have different requirements for optimum growth and survival. For many species, knowledge of their particular requirements is limited. Therefore, to date there is no one 'recipe' for a successful restoration effort, and to a large extent they involve trial and error. For example, a recent review of a 20 year long community-based restoration project in the U.S. documents a multitude of different methods which were trialed throughout the project, using both transplants of adult stock and distribution of hatchery seed (MacFarlane, 1998). It is estimated that during this project a total of about 9 million seed were added to the waters (MacFarlane, 1998). Thus, restoration projects are labour intensive and generally require a long term commitment before any benefits are realised. These issues will need to be addressed as part of any future restoration efforts in Whangarei Harbour.

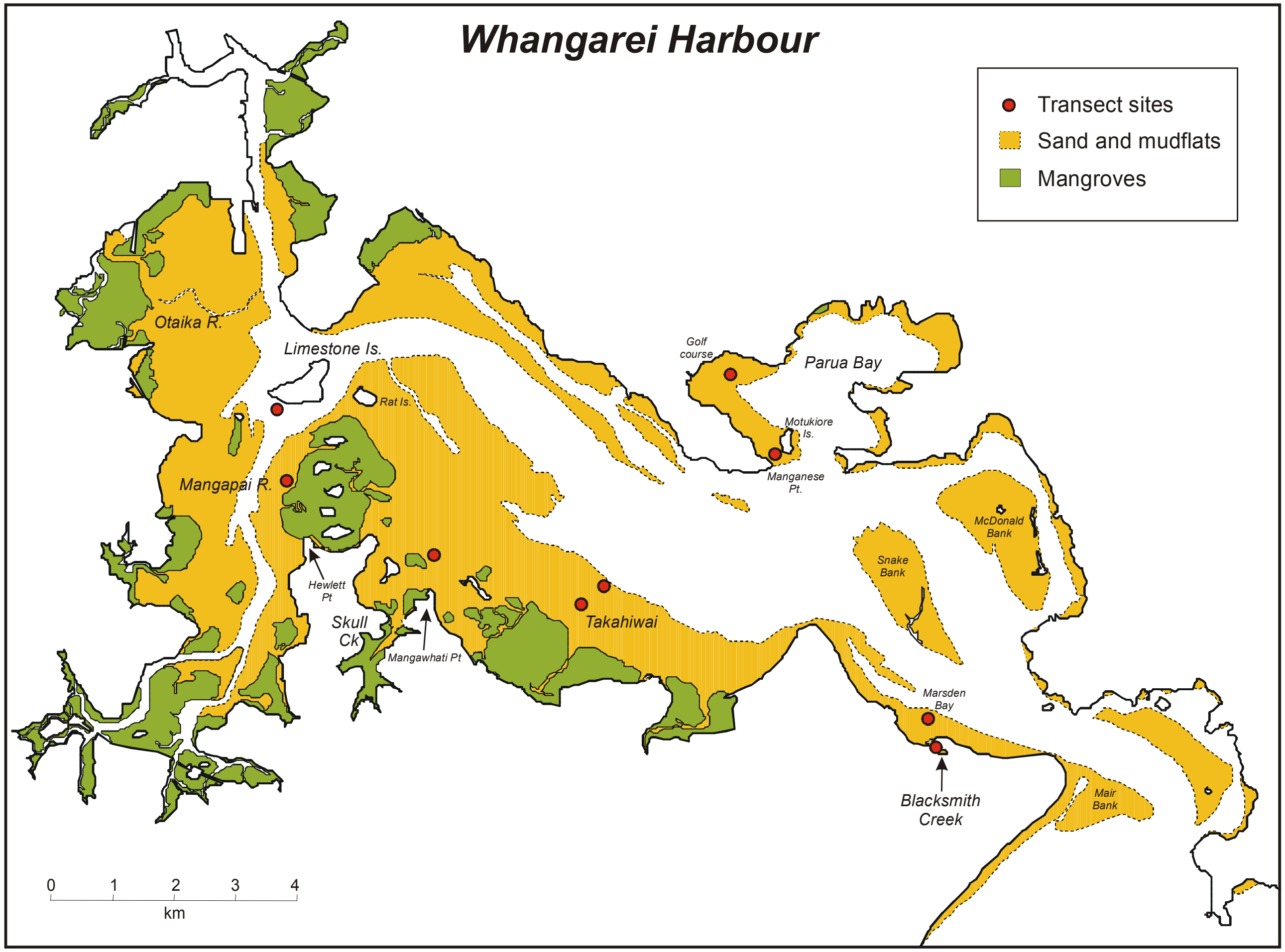

Figure 1. Map of Whangarei Harbour showing the locations and sites assessed for suitability of future shellfish reseeding.

2. Methods

We proposed to conduct this work in several phases, over a period of at least 5 years. Year 1 has involved the following:

1. A review of the existing information on the intertidal benthic communities (specifically shellfish) and habitat types at each of the above locations identified by NRC.

2. Visits to each of these locations to confirm the validity of this information. Where appropriate, we have conducted additional quantitative sampling to assess the current levels of the resident shellfish populations and the general habitat characteristics. A general assessment of factors likely to negatively impact on the success of any restoration attempts was also made. The selection of specific sites to be sampled within each location took into account comments made by various members of the Kaitiaki Group during harbour visits.

Quantitative sampling was conducted from March 18th-21st 2003, in the following manner: A metal quadrat (0.5 m x 0.5 m) was pushed into the sediment, and the contents excavated to a depth of approximately 10 cm. The sediments removed from the quadrat were sieved (4 mm mesh), and the animals retained on the sieve were counted. Any shellfish collected were also assigned to one of the following size classes: 4-10 mm, >10-20 mm, >20-30 mm, >30-40 mm, >40-50 mm, >50-60 mm.

Quadrats were located along a transect at each site. From 3 to 9 quadrats were arranged along each transect, with quadrats separated by 40-100m, depending upon the location and beach morphology (Table 1). Otaika River was the only location identified by NRC that was not quantitatively sampled, for reasons outlined in the Results.

Table 1. Details of the transects and quadrats sampled at each location.

Location	Transect	Transect length	Number of quadrats	Distance between quadrats
Blacksmith Creek	Creek	360 m	7	60 m
	Low shore	360 m	7	60 m
Takahiwai	Low shore	300 m	6	60 m
	Mid shore*	240 m	5	60 m
Skull Creek	Outer	560 m	9	60 or 100 m
Mangapai River	Outer	180 m	4	60 m
Limestone Island	South	180 m	4	60 m
Parua Bay	Manganese Pt	160 m	5	40 m
	Golf course	120 m	3	60 m

* Cockles only were counted/measured along this transect.

3. Using the information gained in 1 and 2 above to determine the suitability of each area for shellfish reseeding, and the most appropriate species for reseeding.

3. Results and Discussion

3.1 Review of existing information

While there have been a number of reports written on the ecology of the Whangarei Harbour, the majority of these are now dated, and those more recent studies are not directly relevant to the areas identified by NRC for shellfish enhancement. It has, however, been possible to gain a history of the ecological values of some of these areas, and how they have changed over the years.

The intertidal flats of the harbour have been recognised as important habitats for feeding and roosting of wading birds. The south side of the harbour from Mangapai River, through Skull Creek, to Takahiwai, to Blacksmiths Creek and Marsden Pt were ranked as nationally outstanding by the Wildlife Division of the Department of Conservation (Whangarei Harbour Study, 1989). Limestone Island is specifically noted as being an important breeding area for the New Zealand dotterel, Caspian tern and variable oystercatcher.

The Otaika Creek and mudflats are also important fish and bird habitats, while Parua Bay contains prime flatfish habitat (Mason and Ritchie, 1979).

The general view is that the industrialisation and urbanisation of the harbour (particularly the port and oil refinery development, discharge of fine sediments from Portland Cement works, channel dredging and dredge spoil dumping, and the subsequent redistribution of both Portland discharges and dumped dredge spoil, farm drainage) has had a detrimental effect on the harbour's ecology (Mason and Ritchie, 1979; Dickie 1984; Whangarei Harbour study, 1989).

Existing information relevant to each area is summarised below.

Blacksmith Creek

Blacksmith Creek is located in Marsden Bay. Marsden Bay has been noted for its ecological diversity, as an important bird roosting area (Mason and Ritchie 1979), and as a nationally outstanding bird habitat (Whangarei Harbour Study 1989).

Recent surveys have identified the bay as a source of considerable numbers of large sized cockles (Cryer et al. 2003; Poynter and Keesing 2002), and as the only area of the harbour apart from Snake Bank where very large (>35 mm) cockles (*Austrovenus stutchburyi*) occur in significant numbers (Cryer et al. 2003). Although an early report noted the occurrence of good pipi (*Paphies australis*) beds in Marsden Bay (Mason and Ritchie, 1979), a recent survey identified only sparse beds (Poynter and Keesing 2002). Thus, while there is recent quantitative information on the shellfish populations in Marsden Bay, there is no information pertaining to populations in Blacksmith Creek itself, or its immediate vicinity.

Takahiwai

Takahiwai once supported extensive, dense scallop beds (Mason and Ritchie, 1979; Whangarei Harbour Study 1989; Grant Pirihi, pers comm.). There were also extensive beds of eelgrass, which were reported to have disappeared in the mid-late 1960's (Mason and Ritchie, 1979, and references therein; Dickie, 1984).

Pipi and cockles were once found in abundance at the mouth of the Takahiwai Stream, but now there are very few shellfish of edible size in this area (Pirihi, 1997). Other residents also remember an abundance of cockles, pipi and scallops on Takahiwai Beach, along with much sandier sediments than the present day (Mira Norris, pers comm.). A pre-1984 survey found no cockles on the Takahiwai shoreline (Dickie, 1984), and inferred that this may have been due to a combination of direct smothering by dredge spoil dumping and high turbidities associated with the Portland cement works. We could find no recent, quantitative information on shellfish populations in the Takahiwai area.

Skull Creek

Skull Creek has been recognised as one of the harbour's important bird roosting areas, and also as an important recreational fishing area for snapper and flounder (Mason and Ritchie, 1979; Whangarei Harbour Study, 1989). The sand bank off Mangawhati (Frasers) Pt near Skull Creek was previously a favourite cockle gathering place, but in the mid 1990's an investigation failed to find any cockles present (Pirihi, 1997). There is no recent quantitative information available on shellfish in the Skull Creek area.

Mangapai River

Mangapai River has been ranked as a nationally outstanding bird habitat by the Wildlife Division of the Department of Conservation, as well as an important area for recreational snapper and flounder fishing (Mason and Ritchie, 1979; Whangarei

Harbour Study, 1989). Mangapai has been severely affected by siltation due to discharges from Portland Cement (Mason and Ritchie, 1979; Dickie, 1984). Due to the tidal current regime in the river, there has been less build up of these discharges on its eastern cf. western side (Dickie 1984). The tidal flats are fringed by mangroves, and while there were many oysters (*Crassostrea gigas)* present throughout the area in a pre-1984 survey, bivalves were typically absent from the western side of the river (Dickie, 1984). Except in the vicinity of Hewletts Pt on the eastern side, sediments are generally very muddy (Dickie, 1984). In the latter area, Dickie (1984) found densities of cockles of 130-883/m^2, and noted an abundance of small (12-15 mm) individuals. There is no recent quantitative information available on shellfish in the Mangapai area.

Limestone Island

Limestone Island provides important habitat for fish and birds (Mason and Ritchie, 1979), and is specifically noted as being an important breeding site of the New Zealand dotterel, Caspian tern and variable oystercatcher today. Scallops were once abundant in the channel between Limestone and Rat Islands (Te Ihi Tito, pers comm.). There is no recent quantitative information on shellfish populations around the island.

Parua Bay

An early study noted that Parua Bay contained prime flatfish habitat, a diverse array of habitat types, and was an important area for shellfish gathering (Mason and Ritchie, 1979). Over 25 years ago, some of the main cockle beds in Whangarei Harbour were in Parua Bay, including areas on the western and eastern sides of the bay. Similarly, some of the harbour's main pipi beds were noted at The Nook and near the bay's western entrance (Mason and Ritchie, 1979). A pre-1984 survey found The Nook beach supported pipi densities of 710/m^2, while the western entrance had 253/m^2 (Dickie 1984). There has been an oyster farm operating in Parua Bay since the early 1970's (Whangarei Harbour Study 1989).

The bay is reported to have been affected by deposition of fine sediments from the Portland Cement discharges; although these discharges originally settled elsewhere in the harbour, they appear to have been redistributed by tidal currents following subsequent dredging of the main harbour channel (Dickie 1984, and references therein). There is no recent, quantitative information on shellfish populations in Parua Bay.

Otaika River

The Otaika River estuary has been extensively modified by the input of fine sediments from the Portland Cement works and their subsequent redistribution around the upper harbour (Dickie 1984). It has also been physically modified by continuous maintenance dredging of the shipping channel on its eastern boundary (Dickie 1984). In the upper reaches of the creek, sediments have become muddier, and channels have narrowed, and shellfish are no longer abundant (Mira Norris, pers comm.). The Otaika Creek and mudflats were recognised as containing important fish and bird habitat (Mason and Ritchie, 1979), and as areas for recreational snapper and flounder fishing. There is no recent quantitative information on shellfish populations in the area.

3.2 Location visits

Location visits were made on March 19-21, 2003. At each location, transects were established and quadrat sampling conducted. Locations of these transects are indicated on Figure 1, and the GPS coordinates of selected quadrats along each transect are listed in Appendix 1.

Site characteristics and the populations of cockles and pipi found (Table 2 and 3), are discussed below. Detailed results of counts and sizes of cockles and pipi found in each quadrat are given in Appendix 2. We also counted and measured individuals of the wedge shell, *Macomona liliana*, and noted the presence of a variety of other bivalve, gastropod and crab species (Appendix 2). As these are not considered 'significant' species in the context of this report, they are not discussed here. However, this information will prove valuable in terms of providing site-specific data on potential predators of shellfish, which need to be considered in any future stages of this work.

Table 2. Summary of cockle, *Austrovenus stutchburyi,* abundances at each site at each location. N = number of quadrats along transect. Abundances given are number of individuals per 0.5 x 0.5 m quadrat.

Location	Transect	N	Range	Average	Standard error
Blacksmith Creek	Creek	6	76-188	130.3	14.6
	Low shore	7	14-328	104.1	38.3
Takahiwai	Low shore	6	0-2	0.3	0.3
	Mid shore	5	2-16	9.2	2.1
Skull Creek	Outer	9	6-64	26.1	6.0
Mangapai River	Outer	4	41-58	48.8	3.9
Limestone Island	South	4	23-517	230.0	98.1
Parua Bay	Manganese Pt	5	159-268	215.8	16.0
	Golf course	3	5-126	64.7	28.5

Table 3. Summary of pipi, *Paphies australis*, abundances at each site at each location. N = number of quadrats along transect. Abundances given are number of individuals per 0.5 x 0.5 m quadrat.

Location	Transect	N	Range	Average	Standard error
Blacksmith Creek	Creek	6	0-13	4.5	1.8
	Low shore	7	3-28	10.4	3.6
Takahiwai	Low shore	6	0	0.0	0.0
Skull Creek	Outer	9	0-3	0.7	0.3
Mangapai River	Outer	4	0	0.0	0.0
Limestone Island	South	4	0-13	5.8	2.4
Parua Bay	Manganese Pt	5	22-218	87.2	32.8
	Golf course	3	0-1	0.3	0.3

Blacksmith Creek

Blacksmith Creek is located in Marsden Bay, a sandy bay situated between Marsden Pt. and One Tree Pt. The creek is surrounded by mangroves at its upper end, and at its lower end merges with the high-shore of the bay's sandflat. Seaward of the mangroves, the sediments adjacent to the creek are sandy and firm underfoot. Two transects were sampled at this site, a 'creek' transect, and a 'low shore' transect.

The creek transect ran parallel to the creek, beginning where it emerges from the edge of the mangroves (Quadrat 1) and ending where it enters the bay (Quadrat 6). High numbers of cockles were found in all quadrats (76–188 individuals; mean = 130 individuals/quadrat; Table 2). Most of these (60–80%) were in the >10-20 mm size range; we found no individuals larger than 30 mm (Appendix 2). Relatively high proportions of smaller individuals (4-10 mm) were found in the middle region of the transect (i.e., 14 and 16%, quadrats 3 and 4, respectively), with the highest proportion of the largest individuals (>20-30 mm) in Quadrat 6 (i.e., 27%). Low numbers of small pipi were found at this site (0-13 individuals/quadrat), with only 1 individual larger than 20 mm collected (Table 3, Appendix 2).

The low shore transect was situated low on the Marsden Bay shore, parallel to the main channel of Whangarei Harbour. The transect began at the Marsden Pt end of the bay (Quadrat 1), and ran towards One Tree Pt. Cockles were again the dominant shellfish found along this transect (mean = 104 individuals/quadrat; Table 2). They ranged in abundance from 14–328 individuals/quadrat, with the highest numbers found near the middle of the bay, in quadrats 5, 6 and 7. Highest numbers were found in the vicinity of the bay's main drainage channel (Quadrat 6, 328 individuals). Individuals were larger than those found along the creek transect, with >30-40 mm cockles comprising 7-35% of the population in each quadrat (Appendix 2). Pipi were also more abundant at this site (3-28 individuals/quadrat, mean = 10.4 individuals/quadrat; Table 3), and a wide range of sizes were found (Appendix 2). Quadrats 2, 3, 5 and 7 all had 1 individual in the >50-60 mm size range. A number of small individuals (4-10 mm) were noted in Quadrat 5 (i.e., 19 individuals).

Takahiwai

Takahiwai is an extensive sandflat between One Tree Pt and Mangawhai (Frasers) Pt. Our investigations were limited to the area off the end of Pirihi Rd, in the vicinity of Takahiwai River. We sampled two transects at this location: one low and one mid shore.

The low shore transect was situated parallel to the main harbour channel, beginning at the One Tree Pt end (Quadrat 1) and running towards Mangawhai Pt. Sediments are fine sand, and the dominant shellfish was the tiny nut shell, *Nucula hartvigiana*. We found very few cockles (i.e., 2 cockles in Quadrat 1 only) and no pipi along this transect.

At the mid-shore transect we confined our hunt to cockles only. Sediments here are muddy sand with a considerable amount of shell hash. Like both of the Blacksmith Creek transects, the majority of the individuals in each quadrat were >20-30 mm in size. Numbers ranged from 2-16 per quadrat (mean = 9.2; Table 2), and only 1 individual larger than 30 mm was collected (Appendix 2).

We also noted a number of small patches of eelgrass on this sandflat.

Skull Creek

Skull Creek is the inlet west of Mangawhai Pt. While the upper reaches of the creek contain significant stands of mangrove, the outer reaches of the creek has extensive sand banks. There is a large high shore bank with small mangroves situated to the north of the creek's outer reaches. Our transect here was situated at about mid-tide level, began on a small sandbank in the middle of the bend of the outer creek (Quadrat 1), and ran along the northern edge of the creek towards where it drains into the main harbour. Sediments are mostly fine sand, but become slightly sandier closer to the end of the transect (Quadrat 9). There were small patches of live oysters on the sandflat near the creek, as well as dead shell patches higher up the shore. Some were also found growing on small mangrove plants on the northern side of the creek. This area is accessible to cattle: many cows were seen on the sandflat while we sampled, and there was considerable evidence of their presence (i.e., foot prints, droppings).

Cockles were reasonably abundant at this location, with 6-64 individuals/quadrat collected. Highest abundances were found near the beginning of the transect (Quadrats 3 and 4; Appendix 2), with Quadrat 4 also containing significant numbers of large individuals (i.e., 21 individuals >30-40 mm; Appendix 2). A total of 6 pipi were collected along this transect, most of which were from quadrats in the outer region of the creek (Quadrats 8 and 9; Appendix 2). One of these was an individual in the >50-60 mm size range. It is likely that more pipi would be found closer to the mouth of the creek (where we were unable to sample due to a rapidly rising tide) as the sediments become sandier and the area more exposed – conditions more suitable for pipi. However, this would need to be confirmed.

Mangapai River

A trip was made up the Mangapai River, but the only location considered suitable for finding shellfish was on the sandflat north-west of Hewlett Pt. The transect was situated high on the shore, approximately 100 m below an extensive area of small sized mangroves. Lower down on the shore, closer to the channel, the sediments are very muddy. We found consistent numbers of cockles in each of the quadrats sampled (mean = 48.8 individuals). While the majority of the individuals in each quadrat were >20-30 mm in size, a considerable proportion (22-35%) of juveniles (4-10 mm) were also found. Pipi did not occur at this site.

Limestone Island

Limestone Island is a DoC reserve in the inner Whangarei Harbour, near Onerahi. It is only accessible by boat. Our investigation of the intertidal area surrounding the island revealed that only the sandflat on the south side of the island would be likely to contain significant numbers of shellfish. Sediments on this sandflat are variable: close to the channel they are very muddy, while at mid-high shore level they are predominantly muddy-sand. A transect was set up at mid-shore level, parallel to the channel between Limestone and Rabbit Islands, running from the Rat Island end of the sandflat (Quadrat 1) towards Whangarei city centre.

Cockles were the dominant shellfish on this sandflat, with 23-517 individuals/quadrat collected (Table 2). Quadrats 3 and 4 contained the highest numbers (512 and 303 individuals, respectively), and most of these were small (i.e., $\leq$20 mm) (Appendix 2). 0-13 pipi were found in quadrats at this site, and these included a few larger specimens (>30-60 mm; Appendix 2).

We also investigated the Limestone Island side of Rat Island. The only suitable intertidal habitat was a very narrow band high on the shore, and this contained only very low numbers of cockles and pipi.

Parua Bay

Parua Bay is a large bay in the northern Whangarei Harbour. Within the bay are a number of smaller bays. We concentrated our sampling efforts on two sites in the western side of the bay: the area between Motukiore Island and Manganese Pt, and the sandflat adjacent to the golf course.

A sandbar joins Motukiore Island with the mainland at Manganese Pt. A transect was located on the northern side of this sandbar, running from the island (Quadrat 1) to the mainland. The sediments here are mostly sandy, with slightly muddier sand at the mainland end of the bar. Abundances of cockles and pipi were very high at this site. Cockle numbers ranged from 159-268 (mean = 215.8 individuals/quadrat, Table 2). In all cases the majority of these individuals were in the >20-30 mm size class. However, there were also significant numbers of juvenile (4-10 mm) cockles in the quadrats closest to the mainland (Quadrats 3-5; Appendix 2). >30-40 mm cockles were found only in quadrats 1 and 2, closest to the island (i.e., 8 individuals; Appendix 2); all other cockles at this site were $\leq$30 mm in size. This site contained by far the highest numbers of pipi of any sites sampled during the study (22-218 individuals/quadrat, Appendix 2; mean = 87.2, Table 3). Many of these were large individuals (i.e., >40-60 mm); in Quadrat 3, this size class constituted over 50% of the population.

The sandflat adjacent to the golf course in Parua Bay is comprised mainly of muddy sand. High on the shore is a band of mangroves, which are most extensive in the vicinity of a small creek at the southern end of the golf course. The sediments in the area covered by the transect are muddy sand, and contain a considerable amount of shell hash. The transect ran from the Manganese Pt end of the golf course towards the road (i.e., north-east). The first quadrat on this transect contained only 5 cockles and 1 pipi. Although this was the only quadrat on this transect which contained a pipi, the cockle numbers were considerably lower than those in the remaining quadrats (i.e., cf. 63 and 126 individuals in Quadrats 2 and 3, respectively). Cockles were small at this site (≤20 mm; Appendix 2).

Between the golf course and Manganese Pt the sandflat narrows and there are several rocky areas which contain remnants of oysters.

Otaika River

Otaika River is situated in the upper Whangarei Harbour, close to the city centre. While we visited this area, it was not sampled due to its extremely muddy substrates. Although it may conceivably contain cockle populations in some areas, these are not likely to be significant. It is definitely not suitable as a shellfish restoration site.

3.3 Site comparisons and suitability for reseeding operations

From our site visits to assess habitat suitability and existing shellfish populations, we can now consider the suitability of these areas for shellfish (i.e., cockle or pipi) reseeding operations. These decisions may need to be revised in light of the outcomes of current discussions on Aquaculture Marine Areas.

In making these recommendations we have focused on enhancing numbers of **harvestable** individuals. For cockles this includes individuals larger than 35 mm, and for pipi individuals larger than 50 mm.

The only areas visited which we do **not** consider worth attempting to re-seed cockles or pipi (due to unsuitable habitat) are Mangapai River, Otaika River, and the golf course area of Parua Bay.

<u>Cockles:</u>

Considering their habitat types, the cockle populations found at each site reflect what would be expected in each area. Good populations of cockles were found at all sites except Takahiwai, where abundances were low (≤16 individuals/quadrat). However, the population size class structure at the Takahiwai mid shore site does reflect that found elsewhere in the harbour, and one individual at this site was larger than 30 mm, (Appendix 2) indicating that the habitat may be suitable for large individuals. Moderate cockle abundances were found at Mangapai River, and the Parua Bay golf course site. As noted for Takahiwai, the population structure at the Mangapai River site reflected that of elsewhere in the harbour, with 1 cockle larger than 30 mm, and the majority of individuals >20-30 mm in size. At the Parua Bay golf course site, the majority of individuals were small (>10-20 mm). Limestone Island also had high numbers of small cockles, although two of the four quadrats also contained many >20-30 mm individuals. The highest abundances of all sites visited were found at Limestone Island, and on the Manganese Pt – Motukiore Island sandbar in Parua Bay. Despite the high numbers at the latter site, very few cockles were very large (i.e., >30-40 mm). This lack of larger individuals could be due to harvest pressure (likely in the Parua Bay case), or to high suspended sediment levels affecting growth. Highest numbers of large (>30-40 mm) individuals were collected from Skull Creek (21 individuals in Quadrat 4) and the low shore (Marsden Bay) Blacksmith Creek site (7-35% of the population in each quadrat). We do not believe the population at the latter site needs enhancing, although if harvest pressure changes this should be revised.

Restoration activities to enhance the abundances of larger sized cockles in the existing populations at Skull Creek and the Takahiwai mid-shore area could be considered.

Pipi:

Pipi were not found at all at Takahiwai or Mangapai, and were found in very low numbers at the Parua Bay golf course and Skull Creek sites. Reasonable numbers of small individuals were noted at the Blacksmith Creek 'creek' and Limestone Island sites (both contained 0-13 individuals/quadrat). While at Blacksmith Creek all pipi collected were small (<20 mm), at Limestone Island a few individuals were larger (>40-60 mm). Large (>50-60 mm) individuals were also observed at the Blacksmith Creek low shore (Marsden Bay) site, where total abundances were patchy (3-28 individuals/quadrat). Highest abundances were noted at the Manganese Pt - Motukiore Island site in Parua Bay (22-218 individuals/quadrat). High proportions of the populations at this site were in the >40-50 mm size class, but only 8 larger (>50-60 mm) individuals were found.

We consider that the Parua Bay and Blacksmith Creek low shore (Marsden Pt) sites contain the habitats most suited to pipi growth and survival (and this is obviously reflected in the numbers found there). Due to the already high numbers at these sites, enhancement is not required; however harvesting should be carefully monitored in order to maintain these populations. However, due to the fact that these sites are both routinely visited by recreational pipi gatherers, and are therefore under some harvest pressure, restoration activities here would need to be carefully considered and controlled. Potentially, the outer Skull Creek area (which was not sampled) may also be worth considering for pipi reseeding, as it appears to have habitat suitable for growth and survival of large individuals. We do not consider the habitats at any of the other sites visited to be suitable for restoration of harvestable sized individuals, for a variety of reasons (e.g., muddy sediments, sheltered aspect). This is particularly unfortunate in the case of Takahiwai, which supported abundant pipi populations in the past (Mira Norris, pers comm., Pirihi 1997).

Pipi are known to utilise different habitats within an estuary, dependent upon their life history stage (Hooker 1995a; Cummings, pers obs.). Smaller individuals often inhabit muddy-sand, sheltered areas, while high densities of harvestable-sized adults are found on sandy, exposed banks. This is illustrated by the relatively high proportion of small individuals in populations from the Blacksmith Creek 'creek' and Limestone Island sites, compared to the dominance of large individuals at Manganese Pt-Motukiore Island site in Parua Bay and on Mair Bank. Thus it is also important to maintain the habitats where the smaller individuals are found.

3.4 Potential sources of shellfish for reseeding operations

There are two main options for sourcing the stocks for reseeding: hatchery-reared individuals, or transplanting existing individuals from elsewhere in Whangarei Harbour. Large-scale reseeding operations depend on a plentiful supply of the target species.

<u>Hatchery reared shellfish:</u> Presently there are no hatcheries in New Zealand producing any of our common shellfish species. While NIWA has successfully spawned and reared both cockles and pipi in the past, for cockles this was difficult and time consuming (and therefore, costly), and to our knowledge it has never been attempted with pipi on a large scale. However, there is now potential to rear shellfish at NIWA's Bream Bay hatchery.

<u>Transplanting from elsewhere in the harbour:</u> The supply site needs to be carefully assessed to ensure sufficient numbers and sizes are available, and that this will not result in depletion of stocks at the site, cause considerable site disturbance, or have adverse effects on the existing benthic community. The option of obtaining cockles and pipi from the existing fisheries on Snake and Mair banks, respectively, could be explored. Recent work has suggested that transplanting adult cockles in the 25-32 mm size range is most likely to meet with success, as at this stage in their life history, the cockles are less likely to move from their transplanted site (Stewart and Creese, 2002).

In the case of pipi, the size class of shellfish to be used for reseeding will require careful investigation, as both juvenile and adult stages of these shellfish are known to be mobile (Hooker 1995a, b).

Thus, at this stage, the option of transplanting existing stocks from elsewhere in the harbour is likely to be favoured.

3.5 Community goals

While we can help by recommending the methodology for future reseeding, and monitoring its subsequent success, it is the local community group which will be driving the restoration efforts in the longer term. Thus a number of very important factors need to be considered by the community.

1. What is the major community goal of the restoration/enhancement effort?

   It is important to define and agree on this prior to embarking on any restoration/enhancement project. The efforts required for a successful outcome are labour intensive, and **will** require a long term commitment (i.e., lots of work over a long period of time, and many years before the benefits are reaped!). Results will also depend on natural conditions, which can often be erratic and result in disruption of restoration/enhancement efforts (e.g., storms). For example, if transplanted shellfish are initially caged to help them get established, these cages will need regular checking and cleaning to prevent them silting up, and the shellfish dying.

   Once these goals are defined, the following questions can be addressed.

2. What species do you want to restore?

3. What size area do you want restored?

4. Conclusions and Recommendations

This study has reviewed the existing information on the intertidal benthic ecology of specific areas of Whangarei Harbour, and found no recent, quantitative data useful to this work. Therefore visits were made to each of the areas identified by NRC with Kaitiaki Roopu representatives who gave insights into the historical populations found here. Quantitative sampling of resident shellfish populations was then conducted, with a view to future restoration efforts. Subsequently, we have identified two sites for cockles (Skull Creek and the Takahiwai mid-shore area) and a potential site for pipi that requires further investigation (the outer Skull Creek area), where restoration activities may enhance the numbers of harvestable-sized individuals in the existing populations. These decisions may need to be revised in light of the outcomes of current discussions on Aquaculture Management Areas. We have also briefly discussed the potential sources of cockles and pipi for reseeding operations.

We recommend that prior to beginning any restoration activities, it is vital that the community agrees on common goals, as the efforts required for a successful outcome are labour intensive, and will require a long term commitment. Once these goals are defined, decisions on the species and areas to be restored can be made.

Finally, historical information and old reports provide indications of degradation of Whangarei Harbour. When speaking with various people in the course of this study, we were given the impression that the ecology of the harbour was not in 'great shape'. This emphasises the importance of harbour-wide management in order to improve it. However, although the ecology of the harbour is not considered as 'good' as it was a generation ago, we were pleasantly surprised during our site visits at the diversity and abundance of shellfish and other fauna present. All locations contained benthic populations characteristic of the habitats found there, and an abundance of bird life was particularly noticeable at the majority of sites visited. Thus while the areas visited are good examples of their present habitat type, some have changed from what they were many years ago (e.g., sandflats have become muddy-sandflats, disappearance of eelgrass). Unfortunately, these habitat changes mean that cockles and pipi are unlikely to grow as large or be as abundant in these places as they were in the past.

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Appendix 1

GPS coordinates of selected quadrats along each transect at each location.

Location	Transect	Quadrat number	South	East
Blacksmith Creek	Creek	2	35°50.221'	174°28.660'
		6	35°50.171'	174°28.594'
	Low shore	1	35°49.972’	174°28.537’
		7	35°49.941’	174°28.434’
Takahiwai	Low shore	1	35°49.407’	174°25.775’
		6	35°49.387’	174°25.604’
	Mid shore	3	35°49.473’	174°25.624’
		5	35°49.455’	174°25.558’
Skull Creek	Outer	1	35°48.812’	174°22.659’
		9	35°48.703’	174°22.939’
Mangapai River	Outer	1	35°48.341’	174°21.292’
		3	35°48.313’	174°21.286’
Limestone Island	South	1	35°47.254’	174°21.424’
		4	35°47.246’	174°21.329’
Parua Bay	Manganese Pt	1	35°47.439’	174°26.744’
		5	35°47.440’	174°26.659’
	Golf course	1	35°46.949’	174°25.949’
		3	35°46.901’	174°25.942’

Appendix 2

Abundance of common shellfish species in each 0.5 x 0.5 m quadrat along each transect. The presence of other benthic fauna at the site is also noted at the bottom of each table. These fauna include the bivalves *Nucula hartvigiana, Felaniella zelandica, Mactra ovata* and *Crassostrea gigas* (Pacific oyster)*, the gastropods Zeacumantus lutulensis*, *Diloma* sp. *Cominella glandiformis, C. adspersa*, *C. maculosa* and *Xymene plebius,* the limpet *Notoacmea helmsi*, the crabs *Halicarcinus whitei* and small mud crabs (*Macrophthalmus hirtipes* or *Helice crassa*).

A. Blacksmith Creek – creek site

	Q1	Q2	Q3	Q4	Q5	Q6
Paphies australis						
4-10 mm	2	3	0	2	0	10
>10-20 mm	5	0	0	0	2	2
>20-30 mm	0	0	0	0	0	1
>30-40 mm	0	0	0	0	0	0
>40-50 mm	0	0	0	0	0	0
>50-60 mm	0	0	0	0	0	0
Total	**7**	**3**	**0**	**2**	**2**	**13**
Austrovenus stutchburyi						
4-10 mm	0	9	21	12	13	13
>10-20 mm	93	109	121	58	140	61
>20-30 mm	30	23	10	6	35	28
>30-40 mm	0	0	0	0	0	0
Total	**123**	**141**	**152**	**76**	**188**	**102**
Macomona liliana						
4-10 mm	0	0	2	0	0	0
>10-20 mm	0	0	0	0	0	0
>20-30 mm	0	0	3	0	0	0
>30-40 mm	0	0	18	0	0	0
>40-50 mm	0	0	0	0	0	0
Total	**0**	**0**	**23**	**0**	**0**	**0**

Zeacumantus lutulensis and small mud crabs were present in all quadrats, *Cominella glandiformis* in quadrats 1-4 and 6, *Diloma* sp. in quadrats 3 and 5 and *Nucula hartvigiana* in Quadrat 5.

B. Blacksmith Creek – low shore (Marsden Bay)

	Q1	Q2	Q3	Q4	Q5	Q6	Q7
Paphies australis							
4-10 mm	0	0	3	0	19	6	0
>10-20 mm	1	3	3	0	0	12	0
>20-30 mm	2	2	0	3	5	4	0
>30-40 mm	0	0	0	1	2	0	1
>40-50 mm	0	0	0	0	1	0	1
>50-60 mm	0	1	1	0	1	0	1
Total	**3**	**6**	**7**	**4**	**28**	**22**	**3**
Austrovenus stutchburyi							
4-10 mm	4	0	3	3	9	1	0
>10-20 mm	6	3	12	4	4	3	4
>20-30 mm	38	10	35	12	109	272	58
>30-40 mm	5	1	7	8	33	52	33
Total	**53**	**14**	**57**	**27**	**155**	**328**	**95**
Macomona liliana							
4-10 mm	0	0	0	1	2	0	0
>10-20 mm	1	0	0	0	1	3	0
>20-30 mm	3	0	0	5	6	2	0
>30-40 mm	0	0	0	0	7	3	0
>40-50 mm	1	2	0	0	0	0	0
Total	**5**	**2**	**0**	**8**	**16**	**8**	**0**

Diloma sp. was present in all quadrats, *Zeacumantus lutulensis* in quadrats 1, 2 and 5-7, *Cominella adspersa* and *C. maculosa* in quadrats 1, and 3-5, *C. adspersa* in Quadrat 6, *C. maculosa* in Quadrat 6, and *Nucula hartvigiana* in Quadrat 3.

C. Takahiwai – low shore

	Q1	Q2	Q3	Q4	Q5	Q6
Paphies australis						
4-10 mm	0	0	0	0	0	0
>10-20 mm	0	0	0	0	0	0
>20-30 mm	0	0	0	0	0	0
>30-40 mm	0	0	0	0	0	0
>40-50 mm	0	0	0	0	0	0
>50-60 mm	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**
Austrovenus stutchburyi						
4-10 mm	2	0	0	0	0	0
>10-20 mm	0	0	0	0	0	0
>20-30 mm	0	0	0	0	0	0
>30-40 mm	0	0	0	0	0	0
Total	**2**	**0**	**0**	**0**	**0**	**0**
Macomona liliana						
4-10 mm	0	1	0	0	5	2
>10-20 mm	5	3	13	1	2	0
>20-30 mm	1	0	8	3	8	0
>30-40 mm	1	2	8	2	4	1
>40-50 mm	0	0	0	0	0	0
Total	**7**	**6**	**29**	**6**	**19**	**3**

Felaniella zelandica was present in all quadrats, *Zeacumantus lutulensis* in quadrats 2, 4 and 6, *Cominella adspersa* and *Cominella maculosa* in quadrats 2, 3, 4 and 6, *Halicarcinus whitei* in quadrats 1, 2, 4 and 5, *Nucula hartvigiana* in quadrats 1-5, *Diloma* sp. in quadrats 2-4, and *Mactra ovata* in Quadrat 3.

D. Takahiwai – mid shore (cockles only)

	Q1	Q2	Q3	Q4	Q5
Austrovenus stutchburyi					
4-10 mm	0	0	0	2	0
>10-20 mm	6	2	0	3	0
>20-30 mm	6	5	9	10	2
>30-40 mm	0	0	0	1	0
Total	**12**	**7**	**9**	**16**	**2**

E. Skull Creek – outer

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
Paphies australis									
4-10 mm	0	0	0	0	0	0	0	0	0
>10-20 mm	0	0	0	0	0	0	0	0	2
>20-30 mm	0	0	0	0	1	0	0	1	0
>30-40 mm	0	0	0	1	0	0	0	0	0
>40-50 mm	0	0	0	0	0	0	0	0	0
>50-60 mm	0	0	0	0	0	0	0	0	1
Total	**0**	**0**	**0**	**1**	**1**	**0**	**0**	**1**	**3**
Austrovenus stutchburyi									
4-10 mm	4	0	0	8	3	8	8	4	0
>10-20 mm	3	4	8	5	3	10	6	5	1
>20-30 mm	2	2	56	17	15	5	9	8	14
>30-40 mm	1	0	0	21	2	0	2	0	1
Total	**10**	**6**	**64**	**51**	**23**	**23**	**25**	**17**	**16**
Macomona liliana									
4-10 mm	4	0	1	1	4	5	1	2	1
>10-20 mm	0	3	1	3	1	2	1	1	4
>20-30 mm	0	3	2	14	16	5	14	36	21
>30-40 mm	0	4	0	5	0	1	1	0	30
>40-50 mm	0	0	0	0	0	0	0	0	0
Total	**4**	**10**	**4**	**23**	**21**	**13**	**17**	**39**	**56**

Cominella glandiformis and large numbers (>200) of *Nucula hartvigiana* were observed in all quadrats. *Zeacumantus lutulensis* were present in quadrats 4-6, 8 and 9, crabs in quadrats 4, 6 and 9, *Diloma* sp. in quadrats 1-6, *Mactra ovata* in Quadrat 2, and *Crassostrea gigas* in Quadrat 3.

F. Mangapai River – outer

	Q1	Q2	Q3	Q4
Paphies australis				
4-10 mm	0	0	0	0
>10-20 mm	0	0	0	0
>20-30 mm	0	0	0	0
>30-40 mm	0	0	0	0
>40-50 mm	0	0	0	0
>50-60 mm	0	0	0	0
Total	**0**	**0**	**0**	**0**
Austrovenus stutchburyi				
4-10 mm	20	12	12	13
>10-20 mm	1	10	3	8
>20-30 mm	37	33	26	19
>30-40 mm	0	0	0	1
Total	**58**	**55**	**41**	**41**
Macomona liliana				
4-10 mm	9	9	10	14
>10-20 mm	3	1	0	0
>20-30 mm	2	2	0	1
>30-40 mm	1	1	0	1
>40-50 mm	0	0	0	0
Total	**15**	**13**	**10**	**16**

Zeacumantus lutulensis, Diloma sp. and large numbers (>200) of *Nucula hartvigiana* were present in all quadrats. *Cominella* sp. were observed in all quadrats: both *C. maculosa* and *C. glandiformis* in quadrats 2 and 3, only *C. maculosa* in Quadrat 1, and only *C. glandiformis* in Quadrat 4. *Halicarcinus whitei* was present in Quadrat 1.

G. Limestone Island – south

	Q1	Q2	Q3	Q4
Paphies australis				
4-10 mm	0	0	4	0
>10-20 mm	0	1	0	0
>20-30 mm	0	0	9	3
>30-40 mm	0	1	0	0
>40-50 mm	0	3	0	1
>50-60 mm	0	1	0	0
Total	**0**	**6**	**13**	**4**
Austrovenus stutchburyi				
4-10 mm	8	38	82	42
>10-20 mm	5	2	269	183
>20-30 mm	8	36	166	78
>30-40 mm	2	1	0	0
Total	**23**	**77**	**517**	**303**
Macomona liliana				
4-10 mm	4	3	1	3
>10-20 mm	4	5	3	0
>20-30 mm	16	11	1	1
>30-40 mm	0	0	0	1
>40-50 mm	0	0	0	0
Total	**24**	**19**	**5**	**5**

Zeacumantus lutulensis, Nucula hartvigiana and *Diloma* sp. were present in all quadrats, *Cominella maculosa* in quadrats 2 and 3, *C. glandiformis* in Quadrat 4, *Halicarcinus whitei* in quadrats 1 and 2, and *Mactra ovata* and *Xymene plebius* in Quadrat 1.

H. Parua Bay - Manganese Point to Motukiore Island sandbar (north side)

	Q1	Q2	Q3	Q4	Q5
Paphies australis					
4-10 mm	0	1	10	2	1
>10-20 mm	4	8	6	5	9
>20-30 mm	6	10	34	6	14
>30-40 mm	8	50	53	3	31
>40-50 mm	4	40	113	6	4
>50-60 mm	0	4	2	1	1
Total	**22**	**113**	**218**	**23**	**60**
Austrovenus stutchburyi					
4-10 mm	15	0	38	37	65
>10-20 mm	56	7	58	38	71
>20-30 mm	489	195	137	84	79
>30-40 mm	8	2	0	0	0
Total	**268**	**204**	**233**	**159**	**215**
Macomona liliana					
4-10 mm	0	0	1	0	2
>10-20 mm	0	3	0	7	3
>20-30 mm	0	1	9	1	0
>30-40 mm	0	0	4	0	0
>40-50 mm	0	0	0	0	0
Total	**0**	**4**	**14**	**8**	**5**

Zeacumantus lutulensis, Cominella glandiformis, Nucula hartvigiana and *Diloma* sp. were present in all quadrats, *Notoacmea helmsi* in quadrats 3 and 5, chitons in quadrats 3-5, *Halicarcinus whitei* in Quadrat 1, *Felaniella zelandica* in Quadrat 4.

I. Parua Bay - golf course

-	Q1	Q2	Q3
Paphies australis			
4-10 mm	0	0	0
>10-20 mm	0	0	0
>20-30 mm	1	0	0
>30-40 mm	0	0	0
>40-50 mm	0	0	0
>50-60 mm	0	0	0
Total	**1**	**0**	**0**
Austrovenus stutchburyi			
4-10 mm	4	9	22
>10-20 mm	1	53	104
>20-30 mm	0	1	0
>30-40 mm	0	0	0
Total	**5**	**63**	**126**
Macomona liliana			
4-10 mm	0	0	4
>10-20 mm	0	0	5
>20-30 mm	0	0	6
>30-40 mm	0	0	0
>40-50 mm	0	0	0
Total	**0**	**0**	**15**

Diloma sp. were present quadrats 2 and 3, and *Zeacumantus lutulensis* and *Nucula hartvigiana* in Quadrat 3.