# Wairarapa Moana Kākahi Survey 2012


Kākahi (*Echyridella Menziesi*) in Lake Pounui.

Prepared for

## Wairarapa Moana Wetlands Group

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**Contents**

## 1. Executive summary

- As a group, freshwater mussels are one of the most threatened in the world. These organisms are particularly vulnerable to water pollution, sedimentation and declines in certain fish species, which are needed to support the parasitic mussel larvae and thus allow them to complete their life cycle. The endemic New Zealand freshwater mussel or kākahi is classed as a threatened species and is known to be present in the waterbodies of Wairarapa Moana. Kākahi are a valuable traditional food for maori and play an important ecosystem role as water filterers.

- Concern exists regarding the effects of land use changes in the Ruamahanga Catchment on local kākahi populations however virtually nothing is known regarding population distributions, sizes and stability in Wairarapa Moana. The uniform size of kākahi that has been noted by anecdote suggests that recruitment (successful supply of juveniles into the population) may be compromised or lacking. This study aimed to sample a variety of locations throughout Wairarapa Moana to provide baseline data for further work and to obtain information regarding kākahi population characteristics, health and sustainability.

- Eight sites covering five waterbodies across Wairarapa Moana were surveyed over January and February 2012 using traditional wading methods. Kākahi were found at five of the eight sites: Barton's Lagoon, three sites in Lake Wairarapa and in Lake Pounui. The highest density of kākahi was found in Lake Pounui, which could represent either natural differences or population declines in the more human-impacted Lake Wairarapa.

- All kākahi found during surveying belonged to the widespread species *Echyridella menziesi* except for a small number of a different species (referred to here as *E. aucklandica*) found at the northern shore of Lake Wairarapa. The two species could be naturally co-occurring or the latter could be the result of a recent human-

mediated introduction. If so, the introduced species could be competing for resources with *E. menziesi*.

- Lake Pounui kākahi showed the highest degree of shell erosion, and Barton's Lagoon and Lake Wairarapa east populations showed the least. The former is likely due to the large substrate particles present in Pounui Lagoon combined with the thinner, more brittle shells evident in this population. The latter is likely due to physical environment stability combined with uniform, fine substrates.

- Limited size variation was present in the Barton's Lagoon and Lake Wairarapa east populations. All others showed uniform size distributions, with no small individuals found. Similarly, age variation was present, but no young individuals were found. This shows that recruitment (supply of juveniles into the population) has apparently ceased into all populations surveyed, likely primarily due to declines of host native fish.

- Without sufficient recruitment, the kākahi of Wairarapa Moana will continue to age, populations will collapse and this species could be locally xtinct in less than 50 years. Artificial propagation of freshwater mussel larvae has been investigated overseas and, while possible, would be complicated and potentially resource-intensive. While this approach could provide an "ambulance at the bottom of the cliff", it does not address the problem of lack of host native fish species in Wairarapa Moana.

## 2. Recommendations

- Given the high likelihood of population collapse or even local extinction of Wairarapa Moana kākahi populations within 50 years, action needs to be taken if this species is to be preserved. Such action must have a broad, ecosystem-level focus. Annual population status monitoring should be implemented immediately.

- It is important to investigate whether kākahi glochidia are parasitizing the common bully in Lake Wairarapa. It would also be of interest to ascertain whether introduced species such as perch and rudd are hosting larvae. Further, more intense sampling, particularly at sites with a range of kākahi sizes present would be useful to detect whether recruitment is occurring at very low levels.

- Further investigation of the Lake Wairarapa north kākahi community, which contains two species, is important to determine whether *E. aucklandica* has been introduced by boat transfer to Lake Wairararapa and is competing with the local *E. menziesi* and thus posing a threat to its persistence. Such work should focus on relative densities and sizes, distributions and habitat use.

- Ground-truthing of the age estimation method used in this study (by real-time, repeat sampling of a population subsample) would be useful to confirm ages reported in the present study and to inform further research.

- Appropriate water quality measurements from Lake Pounui would be of interest to investigate whether the thin, brittle shells and high erosion characteristic of the kākahi population are related to water chemistry factors.

## 3. Background

Freshwater mussels are one of the most threatened taxa in the world (Lydeard et al 2004). Species' declines have been attributed to sedimentation (Brim Box & Mossa 1999), chemical pollution (Naimo 1995), introduced molluscs (Williams et al 1993) and declining numbers of host fish for mussel larvae (Watters 1996) which are parasitic. Across New Zealand, land clearance has resulted in 2 - 7 times more sediment entering freshwater ecosystems than in the past (Quinn & Stroud 2002), in addition, declines in native freshwater fish populations are widespread (Allibone et al 2010). Both of these are likely having negative influences on kākahi populations and kākahi are included on the New Zealand threatened species lists as category 5 – Gradual Decline (Hitchmough et al 2005).

Wairarapa Moana consists of Lakes Wairarapa & Onoke, and their associated remnant wetlands and forest fragments located in the Southern Wairarapa Valley. Lake Wairarapa is a large (18km long; 6km wide), shallow (mostly <2.5m deep) supertrophic lake located in the lower North Island, New Zealand. Historically, the Ruamahanga River flowed through both Lake Wairarapa and Lake Onoke – a system that contained extensive wetland areas and provided habitat and access for large numbers of diadromous[1] native fish species. As a flood-protection initiative completed in 1974, the Ruamahanga was diverted away from Lake Wairarapa and barrage gates were installed at the southern end of the lake. These changes appear to have severely affected the ability of many species to migrate and native fish populations in Lake Wairarapa have dramatically declined or been apparently extirpated as a result (Hicks 1993; McEwan 2010). In addition, exotic non-diadromous species have been introduced to Lake Wairarapa, creating further significant changes in the indigenous fish community. These changes are important to kākahi as kākahi larvae (glochidia) need to attach themselves to the gills of native

[1] Diadromous: an aquatic animal that completes part of its life cycle in freshwater and part in saltwater. New Zealand has a high proportion of diadromous species in its native freshwater fauna.

fish species in order to complete their life cycle. If these fish species are now absent or rare, freshwater mussel reproductive success will be lowered. Lake Onoke now links the Ruamahanga River directly to the sea, as well as providing the link between the sea and Lake Pounui. Lake Onoke is periodically blocked off from the sea by wave action on the Onoke spit - as a result, land managers artificially manage the bar opening to avoid farmland becoming inundated. The absence of flushing flows from the Ruamahanga River combined with increased sediment loads coming down the Tauherinikau River (which flows into the northern end of Lake Wairarapa are thought to be causing increased sediment buildup on the lake bed. This has implications for benthic (bottom-dwelling) organisms such as kākahi.

Kākahi are present in the waterbodies of Wairarapa Moana although virtually nothing is known regarding population distributions, sizes and stability. Concern exists regarding the uniform size of kākahi noted by anecdote which suggests that recruitment (successful supply of juveniles into the population) may be compromised or lacking. This study aimed to sample a variety of locations throughout Wairarapa Moana to provide baseline data for further work and to obtain information regarding kākahi population characteristics, health and sustainability. The eight sites that were selected for surveying (Fig. 1) included 4 sites in Lake Wairarapa (northern, western, southern and eastern); 1 site in Barton's Lagoon – a remnant wetland at the northern end of Lake Wairarapa; 1 site each in Boggy Pond and Matthew's Lagoon – remnant wetlands on the eastern shore of Lake Wairarapa; and 1 site in Lake Pounui – the surrounding land of which has retained forest cover (not been cleared for farming) so maintains better water quality than other Wairarapa Moana waterbodies.

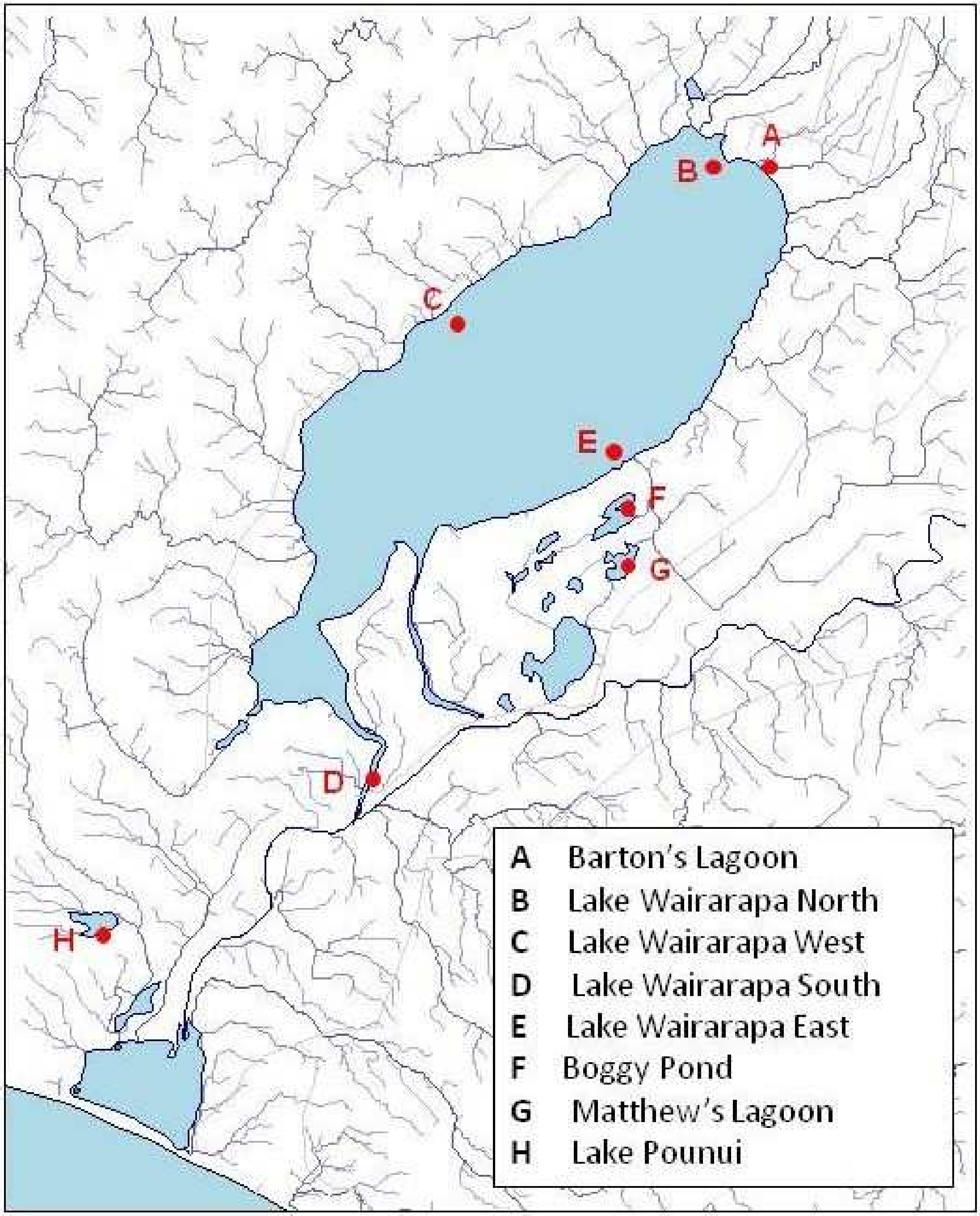


**Figure 1.** Map showing the waterbodies of Wairarapa Moana. Sites that were surveyed for kākahi over January and Febrary 2012 are noted in red.

## 4. Materials and methods

### 4.1 Survey protocols

All sites were surveyed over January and February 2012. Kākahi were searched for by wading and dredging the substrate with hands and feet, in accordance with traditional methods (McDowall 2011). At each site, substrate composition was recorded and the presence or absence of kākahi shells was noted. Prior to searching, 2 separate search areas were identified and the first was then waded for 30 minutes. If kākahi were found then quadrat searching was carried out (10 quadrats) in randomly selected locations within the second search area. All kākahi were measured for anterior to posterior length (AP) and umbo to margin length (UM) to the nearest 0.1mm using vernier callipers. In addition, the extent of shell erosion was recorded for each individual (using the erosion classes described in Roper & Hickey 1994; Fig. 2).


**Figure 2.** Examples illustrating the four different levels of shell erosion used to classify kākahi

If no kākahi were found during the 30 minute search then quadrat counts were not conducted. Subsamples of each population were retained for weight and age analyses. Targeted 30 minute searches for juvenile kākahi were also carried out at each site. This involved careful searching of habitats like boulders, submerged logs and the stems and roots of aquatic macrophytes. Water depth was measured at 3 randomly selected locations across the overall search area and averaged. Water clarity was measured using a 1 metre clarity tube. Comprehensive decontamination procedures were followed using saline solution and sunlight exposure to eliminate the possibility of organism transfer between sites.

## 4.2 Lab protocols

Two length measurements and two weight measurements were recorded for each kākahi taken from the field. AP length and UM length were recorded to the nearest 0.1mm using vernier calipers and total weight (TW; wet weight of shell and mussel) and soft tissue weight (SW; wet weight of mussel with shell removed) were recorded to the nearest 1g. The method used to estimate mussel age was adapted from Grimmond (1968) and was based on the existence of dark lines present in nacre that represent slowed or halted growth during winter. First, a mussel was broken along the hinge line and the valve with least erosion was sawed through with a fine-bladed hacksaw (32T), from the umbo to the margin, at a right angle to the hinge line (The concavity of the shell was filed with modeling clay to avoid crushing). The cut edge with the least damage was worked up on coarse (120) then fine (180) aluminium oxide stone in conjunction with multi-purpose oil (3-in-one™), and then mounted on modeling clay so that the cut and polished surface was facing up at the lens of a binocular microscope. The distance between winter rings was recorded with vernier calipers to the nearest 0.1mm. Additional distances recorded were: distance from the umbo to the end of the shell erosion (U-Y; interruption lines were not visible on eroded prismatic layers); distance from Y to the first interruption line (Y-1) and distance from the last interruption line to the margin (X-M). As interruption lines tended to be closer together nearer the margin (mussel growth appeared to slow or shell material was deposited at the same rate

but over a wider area as the shell grew bigger), U-Y and Y-1 distances were estimated using the average distance between the first three interruption lines and X-M was estimated using the average distance between the last three interruption lines. Kākahi with large amounts of shell erosion (erosion class IV) were not able to be aged.

# 5. Results

## 5.1 Overall

104 kākahi were found at 5 out of the 8 sites surveyed (Table 1). Kākahi were found occupying a wide range of substrate types, from silty mud at the northern and western shores of Lake Wairarapa, gravel and sand in Barton's Lagoon and the eastern shore of Lake Wairarapa and cobbly substrate in Lake Pounui.

**Table 1.** Results of kākahi surveying across 8 sites within Wairarapa Moana in January and February 2012.

| Site | Water clarity (cm) | Water depth (cm) | Total number kākahi found (juveniles) | Kākahi / $m^2$ | Kākahi / hour | Size range (length: mm) |
|---|---|---|---|---|---|---|
| **(A) Barton's Lagoon** | 83 | 44 | 7 (0) | 0.2 | 10 | 57-82 |
| **(B) Lake Wairarapa north** | 11 | 55 | 16 (0) | 0.1 | 30 | 56-65 |
| **(C) Lake Wairarapa west** | 4 | 48 | 87 (0) | 0.9 | 156 | 50-68 |
| **(D) Lake Wairarapa south** | 48 | 69 | 0 (0) | 0 | 0 | - |
| **(E) Lake Wairarapa east** | 12 | 22 | 13 (0) | 0.1 | 24 | 58-81 |
| **(F) Boggy Pond** | +100 | 53 | 0 (0) | 0 | 0 | - |
| **(G) Matthew's Lagoon** | +100 | 60 | 0 (0) | 0 | 0 | - |
| **(H) Lake Pounui** | +100 | 79 | 71 (0) | 3.8 | 66 | 57-73 |

## 5.2 Site A: Barton's Lagoon

The survey site at Barton's Lagoon contained mostly firm, sand and small gravel substrate with regions of deep (~40 cm) silt around the edges (Fig. 3). Turf plants and submerged wood were present. Floating and submerged macrophytes were present, along with raupo at the waters edge. The average depth of the area surveyed was 44.3 cm and water clarity was high (83.2 cm). Five kākahi were found during 30 minutes of wading (10/hour) and 2 were found during quadrat sampling (0.2/$m^2$). Most kākahi were found occupying the firm substrates, although 2 were found in the silty areas. All individuals were measured and 2 were taken for age analysis. Levels of shell erosion were very low, with most scoring only 1 (Fig. 4). No juvenile kākahi were found during targeted searching of plant stems and roots and submerged wood.

**Figure 3.** The survey site at Barton's Lagoon (site A).

**Figure 4.** Kākahi found in Barton's Lagoon during surveying in January 2012. Picture shows the low levels of shell erosion present in the individuals found.

### 5.3 Site B: Lake Wairarapa north

The survey site at the northern shore of Lake Wairarapa contained patchily distributed benthic environments, with substrates ranging from cobbles and large gravel to shallow (~10 cm) silt over hard clay bottom (Fig. 5). Submerged wood was present. Beachcast macrophytes were observed but none were seen during surveying. The average depth of the area surveyed was 55 cm and water clarity was low (11.3 cm). Fifteen kākahi were found during 30 minutes of wading (30/hour) and 1 was found during quadrat sampling ($0.1/m^2$). All kākahi were found occupying the silty substrates. Two species were found to be present at this site (see section 6.2). Seven individuals were measured and taken for age analysis. Levels of shell erosion ranged between 1 and 3. No juvenile kākahi were found during targeted searching of submerged wood, boulders and beachcast macrophytes.

**Figure 5.** The survey site at Lake Wairarapa north (site B).

### 5.4 Site C: Lake Wairarapa west

The survey site at the western shore of Lake Wairarapa comprised mostly shallow (~10cm) silt substrate covering a firm bottom although large cobble areas were present very close to the shore (Fig. 6). Submerged wood was present. No submerged or floating macrophytes were observed and lake edges were bordered by large reeds. The average depth of the area surveyed was 48 cm and water clarity was very low (4.4 cm). A total of 78 kākahi were found during 30 minutes of wading (156/hour) and 9 were found during quadrat sampling (0.9/m$^2$). All kākahi were found occupying the silty substrates. The per-hour statistic was inflated for this site due to an exceptionally high density of kākahi found associated with a submerged log (all tucked under the side facing away from the shore). Fifty nine individuals were measured and 12 (a range of sizes were selected) were taken for age analysis. Levels of shell erosion at this site were intermediate, with most individuals scoring 2 or 3, although examples of both 1 and 4 were also found. No

juvenile kākahi were found during targeted searching of plant stems and roots and submerged wood.

**Figure 6.** The survey site at Lake Wairarapa west (site C).

## 5.5 Site D: Lake Wairarapa south

The survey site at the southern shore of Lake Wairarapa comprised mostly shallow - deep fine sediment over compact mud/clay substrates and submerged wood was abundant (Fig. 7). Submerged and floating macrophytes were superabundant and raupo and grass were present around the edges. The average depth of the area surveyed was 69 cm and water clarity was medium (48 cm). No kākahi were found during 30 minutes of wading. No juvenile kākahi were found during targeted searching of macrophytes and submerged wood.

**Figure 7.** The survey site at Lake Wairarapa south (site D).

### 5.6 Site E: Lake Wairarapa East

The survey site at the eastern shore of Lake Wairarapa was a wide, shallow area with firm sandy substrates (Fig. 8). Large areas of shore were exposed on the day of surveying, most of which would usually be covered by water, as evidenced by embedded kākahi shells and turf plants. Cattle tracks were also present on the exposed land (Fig. 9). Turf plants were widespread in the submerged areas and wood was present, although not common. The average depth of the area surveyed was 22 cm and water clarity was low (12.3 cm). Twelve kākahi were found during 30 minutes of wading (24/hour) and 1 was found during quadrat sampling (0.1/m$^2$). All kākahi were found occupying sandy substrates. Seven individuals were measured and taken for age analysis. Levels of shell erosion at this site were low, with all individuals scoring 1 or 2. No juvenile kākahi were found during targeted searching of plant stems and roots and submerged wood.

**Figure 8.** The survey site at Lake Wairarapa east (site E).

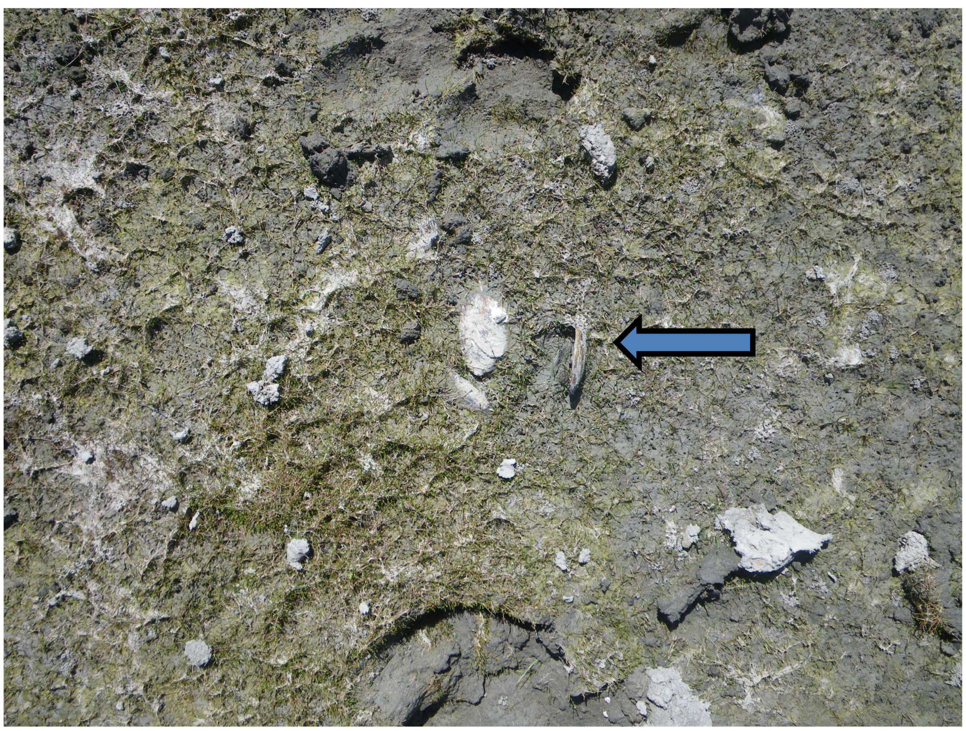

**Figure 9.** Exposed substrate at the eastern shore of Lake Wairarapa containing embedded kākahi shells and showing cattle tracks.

### 5.7 Site F: Boggy Pond

The survey site at Boggy Pond comprised mostly compacted mud substrates with submerged wood abundant (Fig. 10). Submerged and floating macrophytes were superabundant and raupo was present around the edges. The average depth of the area surveyed was 52.7 cm and water clarity was very high (+ 1 m). No kākahi were found during 30 minutes of wading. No juvenile kākahi were found during targeted searching of plant stems and roots and submerged wood.

**Figure 10.** The survey site at Boggy Pond (site F).

### 5.8 Site G: Matthew's Lagoon

The survey site at Matthew's Lagoon comprised mostly compacted mud/clay substrates with submerged wood abundant (Fig. 11). Submerged and floating macrophytes were superabundant and raupo was present around the edges. The average depth of the area surveyed was 60 cm and water clarity was very high (+ 1 m). No kākahi were found during 30 minutes of wading. No juvenile kākahi were found during targeted searching of plant stems and roots and submerged wood.

**Figure 11.** The survey site at Matthew's Lagoon (site G).

## 5.9 Site H: Lake Pounui

The survey site at Lake Pounui comprised mostly cobble/gravel substrates with a small amount of fine sediment (Fig. 12). Turf plants were abundant and moderate to high amounts of benthic and floating algae were present, including on and around kākahi (Fig. 13). Large reeds were growing around the lake edges. The average depth of the area surveyed was 78.7 cm and water clarity was very high (+ 1 m). Thirty three kākahi were found during 30 minutes of wading (66/hour) and 38 were found during quadrat sampling (3.8/m$^2$). All kākahi were found occupying cobble/gravel substrates in deeper water (+ 1 m). Twenty five individuals were measured and 11 were taken for age analysis. Levels of shell erosion at this site were high, with most individuals scoring 3 or 4 (Fig. 14). Shells with class 1 erosion were rare. No juvenile kākahi were found during targeted searching of plant stems and roots and cobbles.

**Figure 12.** The survey site at Lake Pounui (site H).

**Figure 13.** Kākahi in Lake Pounui with benthic algae growing on shells.

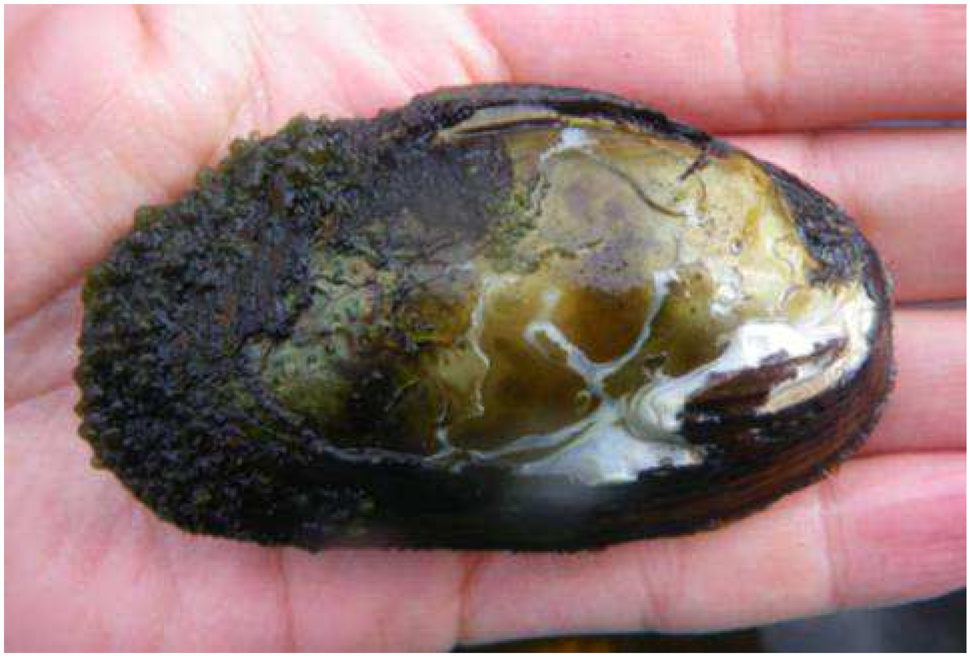

**Figure 14.** High shell erosion typical of kākahi found in Lake Pounui.

# 6. DISCUSSION

## 6.1 Population distributions

Kākahi were found at five of the eight sites surveyed (Fig. 15). They were found at all Lake Wairarapa sites except the southern edge and they were also found in Lake Pounui. No evidence of kākahi (including empty shells) was present at Boggy Pond or Matthew's Lagoon. The highest numbers of kākahi were recorded in Lake Pounui (3.8/$m^2$) and the lowest numbers at the northern and eastern sites of Lake Wairarapa (both 0.1/$m^2$).

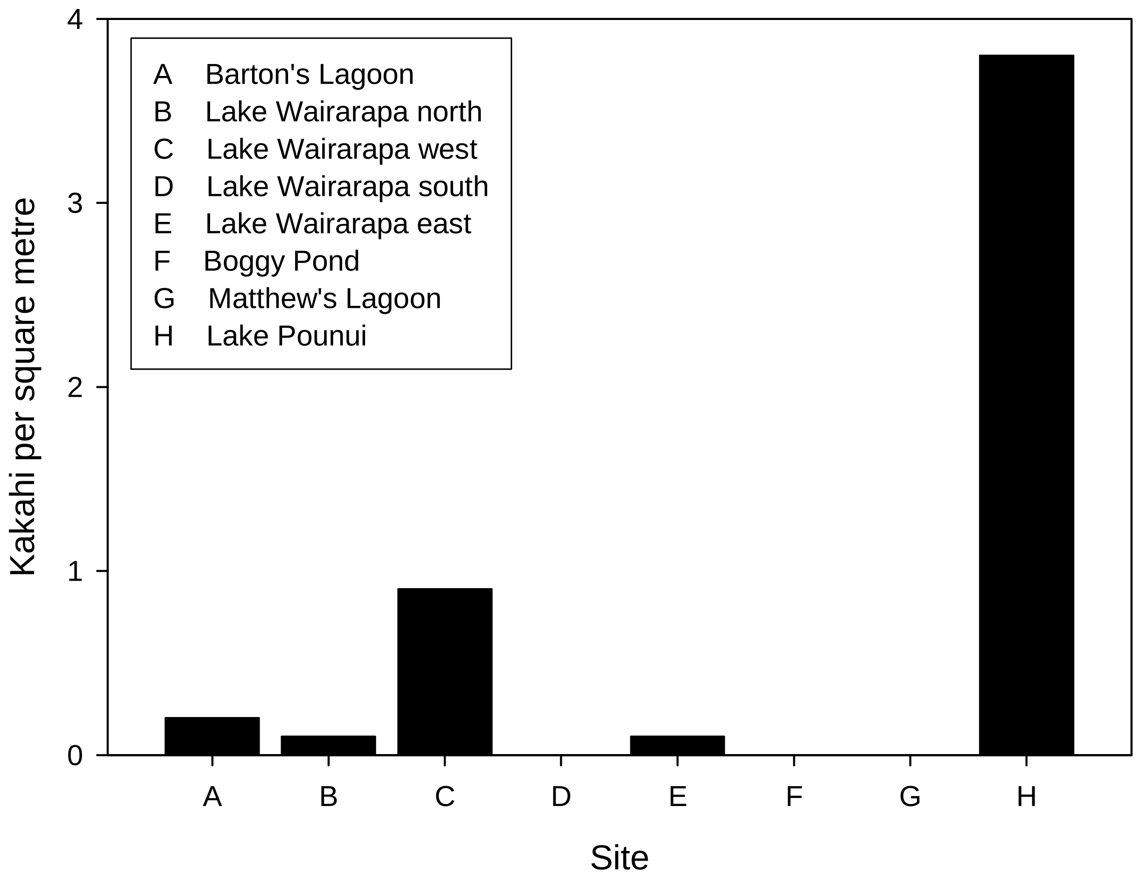


**Figure 15.** Number of kākahi/m$^2$ collected from eight sites across Wairarapa Moana in 2012.

Lake Pounui is currently supporting the densest population of kākahi in Wairarapa Moana. It would be of interest to know whether this is a naturally occurring phenomenon or whether it can be attributed to ecological changes that have occurred within Wairarapa Moana due to human impacts. It is possible that Lake Wairarapa previously supported higher densities of kākahi and numbers have declined due to proportionally greater impacts in Lake Wairarapa of factors such as sediment and chemical pollution and host native fish decline (see section 6.7). However, it is also possible that this difference is natural and related to algal food supply in a clear lake as opposed to a turbid one. Significant algal blooms occur in Lake Pounui (Alton Perrie, Pers. comm.), resulting in large amounts of suspended algae being present in the water. It is possible this extra food is supporting a

larger population than in Lake Wairarapa, where high turbidity (due to wind-driven sediment re-suspension) is more likely to suppress algal growth (through inhibition of sunlight penetration). Ogilvie and Mitchell (1995) found that kākahi were significant feeders of nuisance algae in a shallow lake in the south island and actually suppressed algae growth to levels far lower than expected.

## 6.2 Kākahi species

With the exception of the northern edge of Lake Wairarapa, all kākahi found in Wairarapa Moana belong to the species *Echyridella menziesi*. The additional species found at Lake Wairarapa north (Fig. 16) is currently known as *Cucumerunio websteri websteri* although pending revisions will result in it being reassigned to *Echyridella* as *E. aucklandica* (Mark Fenwick Pers. Comm.)[2]. While *E. menziesi* is distributed throughout New Zealand, *E. aucklandica* was previously only known from sites near Auckland and Whanganui (Fenwick & Marshall 2006). This led to speculation that the species' presence in Lake Wairarapa was a recent human-mediated introduction. This argument is strengthened by the fact that *E. aucklandica* has only been found at the northern edge of the Lake - the same location as the boating club. More recently however, this species was found in a lake near the bottom of the South Island, thus it is also possible that its occurrence in Lake Wairarapa is natural and a result of range contraction from a previously much wider distribution. If this is the case then *E. menziesi* and *E. aucklandica* are existing in sympatry in Lake Wairarapa and it can thus be assumed that they are occupying separate ecological niches. This is difficult to confirm as virtually nothing is currently known regarding the habitat use of either species.

[2] Hereafter referred to as *E. aucklandica*. Two individuals were collected from Lake Wairarapa north – these were excluded from appropriate morphological analysis due to the likely presence of species-specific differences. All analyses in this document report on *E. menziesi*.

**Figure 16.** Two species of kākahi found at the northern edge of Lake Wairarapa: Top: *Echyridella menziesi*; Bottom: *Echyridella aucklandica*. This site was the only location at which *E. aucklandica* was found.

It is important that this be investigated further, as, if *E. aucklandica* has been introduced by boat transfer to Lake Wairararapa then they may have the same or similar resource requirements as *E. menziesi* and may be competing with them. The winter interruption lines of the *E. aucklandica* sampled during the present studies tended to be further apart than those of *E. menziesi*, indicating that this species grows faster and could thus have the potential to outcompete the slower growing local *E. menziesi*. In addition, the *E. menziesi*, collected from this site had a low soft tissue weight: total wet weight ratio (see section 6.4)

compared to other sites, which could indicate lowered food availability in the Lake Wairarapa north population.

## 6.3 Shell erosion

Lake Pounui kākahi showed the highest degree of shell erosion, with a large number of individuals in erosion class IV (Fig. 17). Lake Wairarapa north and east were intermediate among the sites sampled and Barton's Lagoon and Lake Wairarapa east showed the least erosion, with no kākahi in class III and IV.

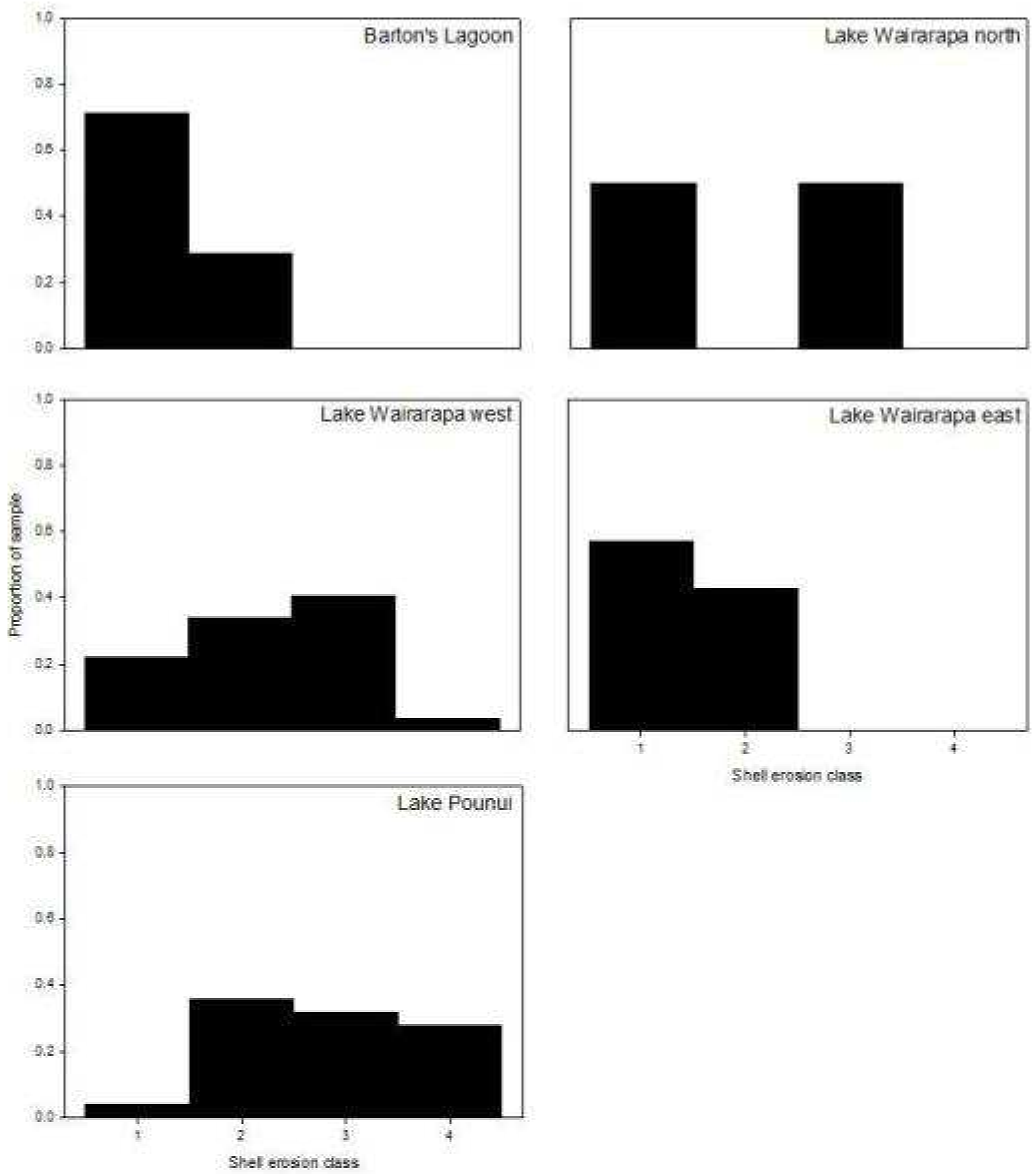


**Figure 17.** Kākahi shell erosion at five sites within Wairarapa Moana.

Roper & Hickey (1994) found that age was partially responsible for higher degrees of shell erosion in Waikato kākahi. While Lake Pounui kākahi were, on average, older than Lake Wairarapa kākahi (see section 6.5), the two oldest individuals across all samples (from Barton's Lagoon and Lake Wairarapa west) were both in erosion class I. Thus, age is likely less important than other factors in driving the high levels of erosion found in the Lake Pounui population. Coker et al (1921) suggested that shell erosion could be driven by local water chemistry. Lake Pounui is potentially more acidic than Lake Wairarapa due to the higher proportion of its catchment being in forested areas–resulting in higher input of leaf matter. The collection of appropriate water quality measurements would be of interest in this regard. However, Hinch & Green (1988) showed that erosion was driven primarily by physical processes such as water turbulence. Substrate type too, will be important as larger particles such as cobbles would be more likely to cause shell damage in turbulent conditions. Lake Pounui was distinctive in that the substrate was composed predominantly of cobble-sized particles and this, combined with the thinner, more brittle shells evident in this population (see section 6.4) is likely responsible for the high levels of shell erosion found here. The very low levels of shell erosion found in the Barton's Lagoon and Lake Wairarapa west populations are likely due to a combination of factors. Barton's lagoon is spring-fed and thus fairly stable although, is likely subject to wind-driven turbulence in open water areas. This stability, combined with the soft mud/sand substrates is likely responsible for the low levels of erosion in the kākahi population. The western shore of Lake Wairarapa, while subject to frequent high winds, is a wide and very shallow stretch of water with a gradual slope thus wave action is limited. This, combined with the uniform, sandy substrate present is likely responsible for the low levels of erosion in this population as well.

## 6.4 Kākahi size (length and weight)

Kākahi length (AP) ranged from 50 to 82mm (Fig. 18). The smallest individual was found at the western shore of Lake Wairarapa and the largest was found in Barton's Lagoon. Kākahi from Barton's Lagoon and Lake Wairarapa east displayed the most size variation, while those from Lake Wairarapa north, Lake Wairarapa east and Lake Pounui were more uniform sized. This could reflect either greater recruitment or a tendency towards greater ages in the Barton's and Lake Wairarapa east populations or could be an artifact of sampling. This is unlikely however, at least on the western shore of Lake Wairarapa, where large numbers of kākahi were found and all were a uniform, small size.

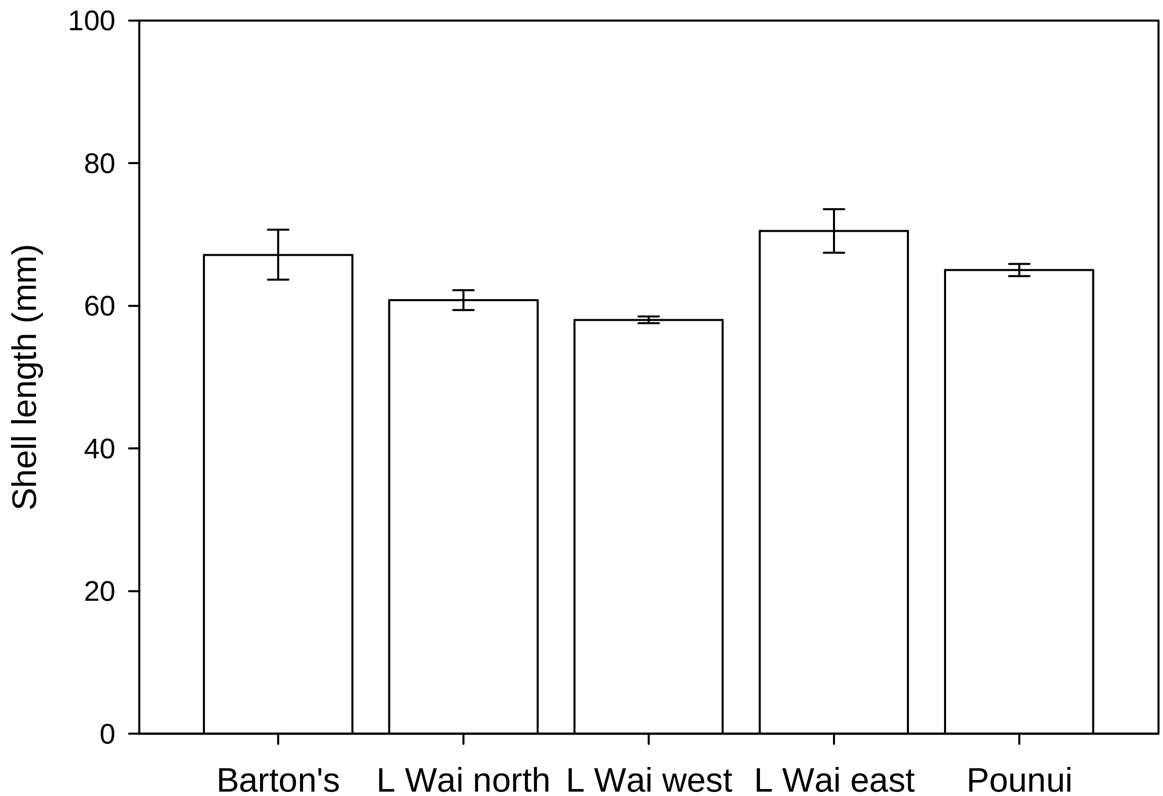


**Figure 18.** Average kākahi shell length (anterior to posterior edge) from five sites. Barton's Lagoon n = 7; Lake Wairarapa north = 6; Lake Wairarapa west = 59; Lake Wairarapa east = 7; Lake Pounui = 25.

Kākahi total weight showed similar patterns to shell length (Fig 19). While the northern and western populations of Lake Wairarapa and Lake Pounui were lighter and of a more uniform weight, kākahi from Lake Wairarapa east were heavier and showed more variation in weight. Only one individual was available for weighing from Barton's Lagoon.

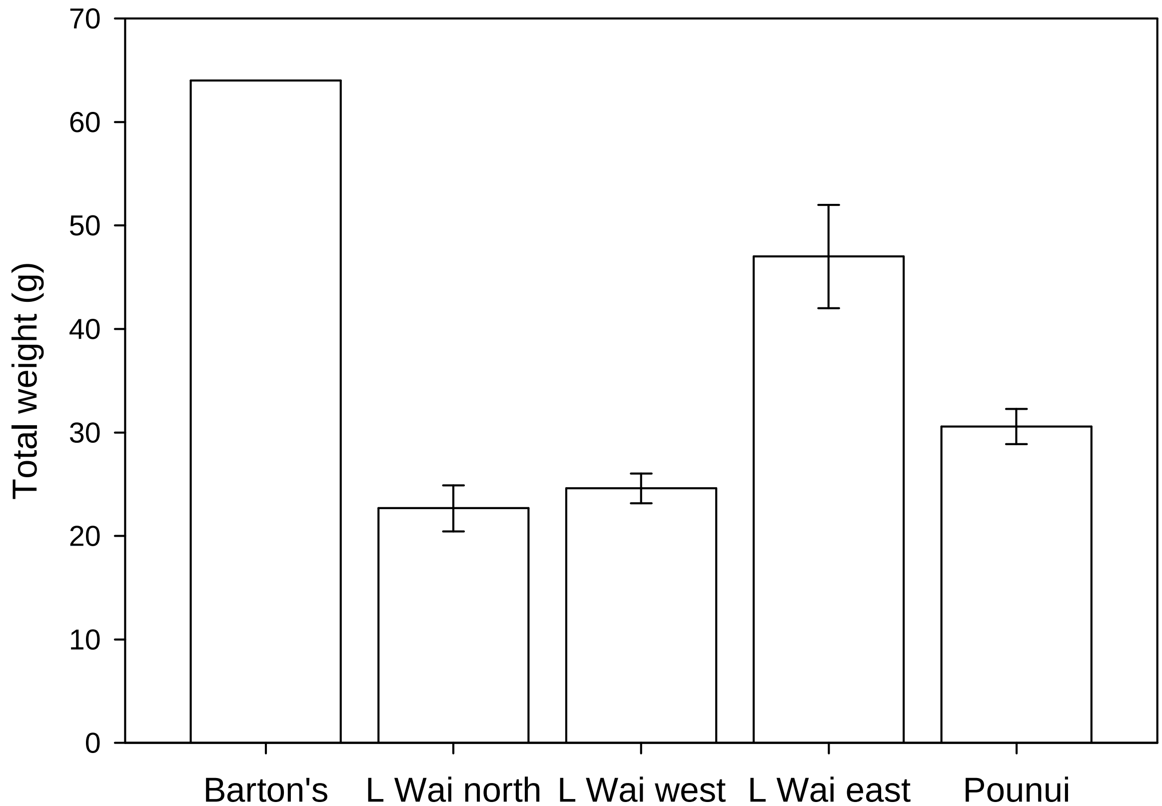


**Figure 19.** Average kākahi total weight (soft tissue plus shell wet weight) from five sites. Barton's Lagoon n = 2; Lake Wairarapa north = 3; Lake Wairarapa west = 9; Lake Wairarapa east = 7; Lake Pounui = 7.

The relationship between shell length and shell width gives information regarding shell shape. *Echyridella menziesi* is known to have a highly variable shell shape and numerous ecological "forms" have been found in various locations (Winterbourn 1973). While all kākahi from Wairarapa Moana were the same general shape, there were small differences between sites present (Fig. 20). The differences between Lake Pounui and Lake Wairarapa west in particular could show that speciation is occurring, due to low or no gene flow between these waterbodies. This is supported by the findings of Fenwick (2006) who reported numerous haplotypes in geographically close populations in the Waikato.

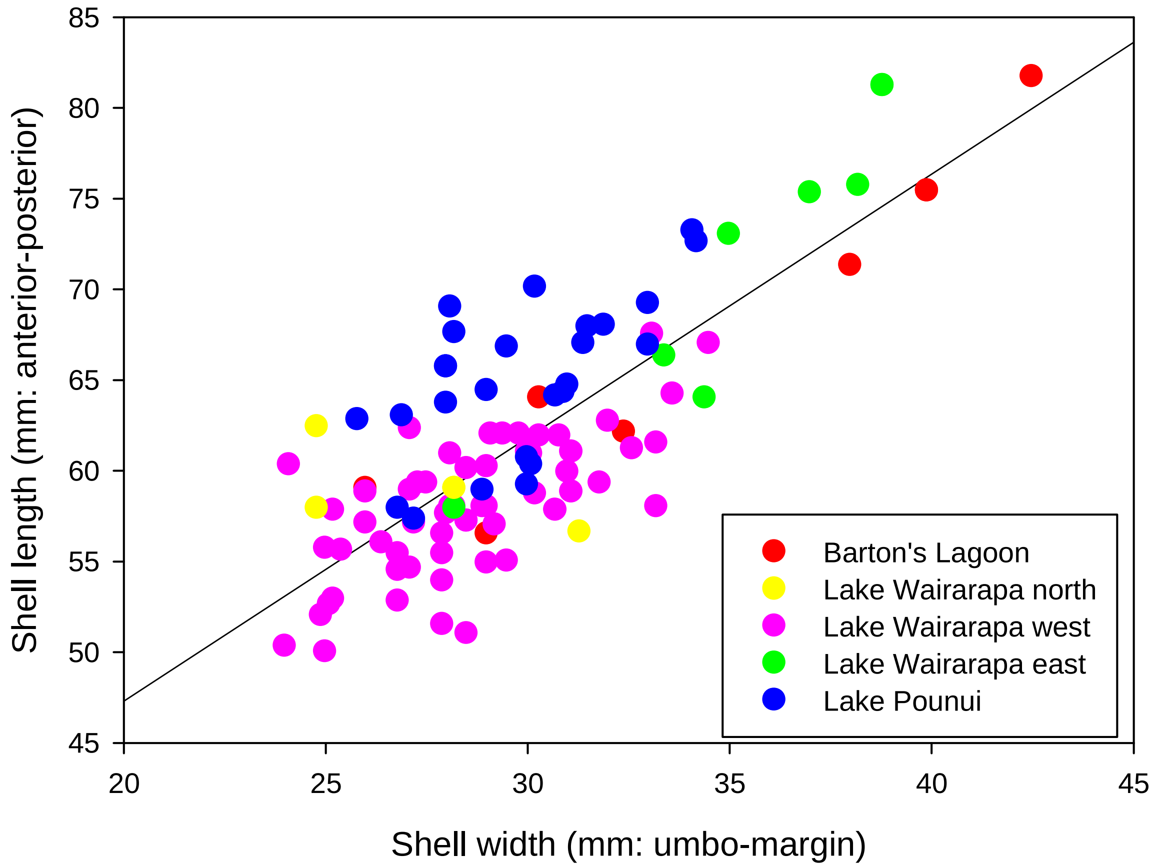


**Figure 20.** Kākahi shell length and width plotted against each other to illustrate shell shape.

The relationship between soft tissue weight and total weight illustrates the relationship between body weight and shell weight. The asymptotic shape of the curve formed by

Wairarapa Moana kākahi shows that as total weight increases, the proportion of that weight made up of soft tissue decreases – i.e. as individuals grow larger, their bodies grow proportionally smaller and their shells proportionally larger (Fig. 21).

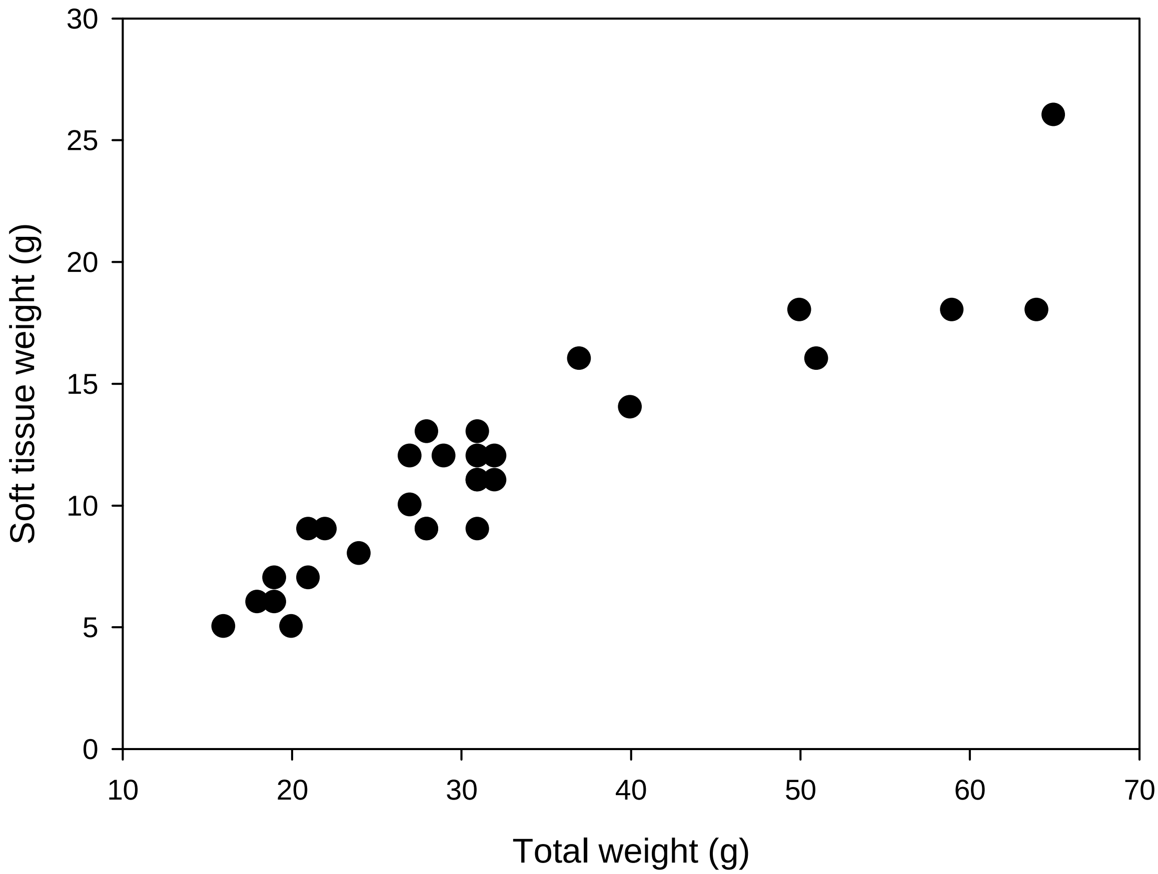


**Figure 21.** Kākahi soft tissue weight and total wet weight plotted against each other to illustrate the relationship between body weight and shell weight.

Although all sites overall generally conformed to the trend, there were differences between sites present (Fig. 22). Kākahi collected from the northern edge of Lake Wairarapa had the lowest soft tissue weight: wet weight ratio–showing that these individuals either had proportionally light bodies or proportionally heavy shells. As the shells were not noticeably heavy, it is likely that this is a reflection of comparatively small body weight of

kākahi at this site. This could potentially highlight a local health issue such as low food availability. As only three individuals were taken from this site for weighing, it would be useful to confirm this observation with further samples. Kākahi from Lake Pounui had the highest soft tissue weight: total wet weight ratio. During sectioning for ageing, it was observed that these kākahi had thinner, more brittle shells compared to those from other sites. This could be a reflection of the water chemistry of Lake Pounui and warrants further investigation. The shells of the largest two individual kākahi collected across all sites (from Barton's Lagoon and Lake Wairarapa east) were notably heavy, thick and robust.

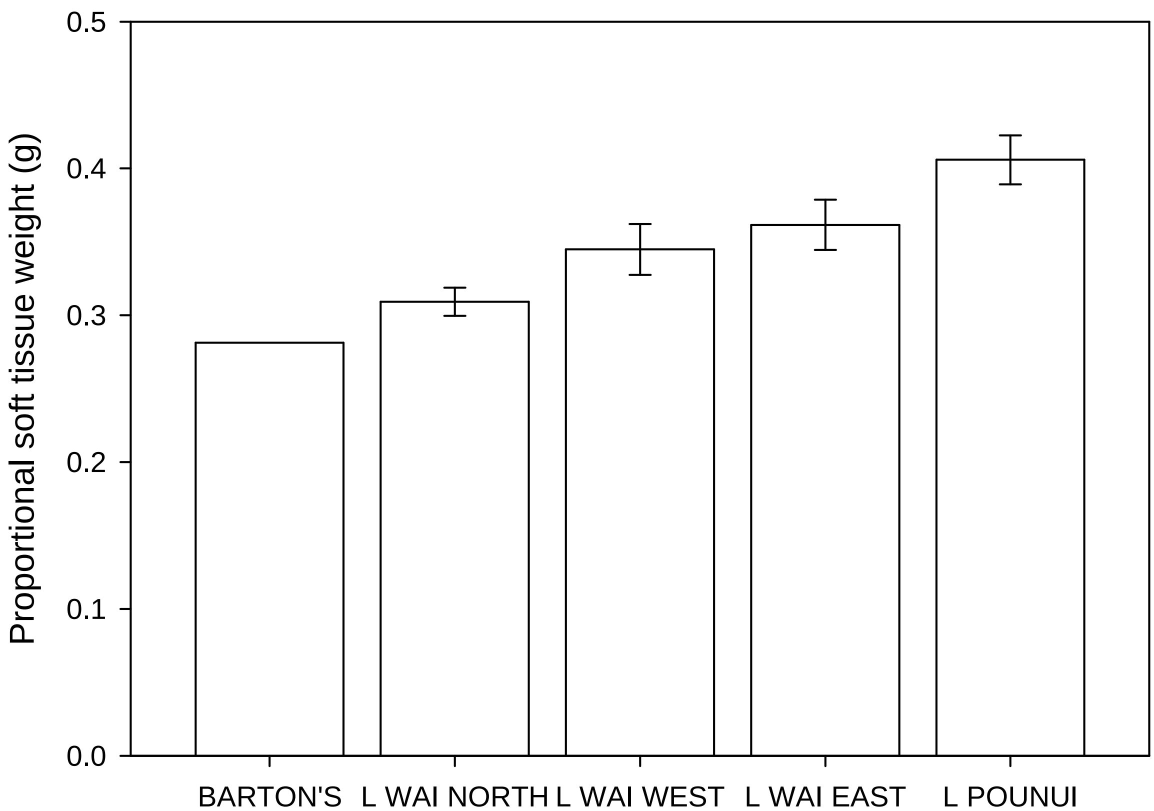


**Figure 22.** Average kākahi proportional soft tissue weight (calculated as a proportion of total wet weight) to illustrate differences between sites regarding body weight and shell weight. Barton's Lagoon n = 1; Lake Wairarapa north = 3; Lake Wairarapa west = 9; Lake Wairarapa east = 7; Lake Pounui = 7.

## 6.5 Kākahi age

The estimated ages of sampled kākahi ranged between 17 and 44 (Fig. 23). The youngest was found at the northern edge of Lake Wairarapa and the oldest two (both 44 years old) in Lake Wairarapa East and Barton's Lagoon. No individuals younger than 17 were found across all sites. The greatest age range was present at Barton's Lagoon – while only two individuals were retained for ageing, they turned out to be both the oldest and the second-youngest. Kākahi from the western shore of Lake Wairarapa were younger and uniformly aged.

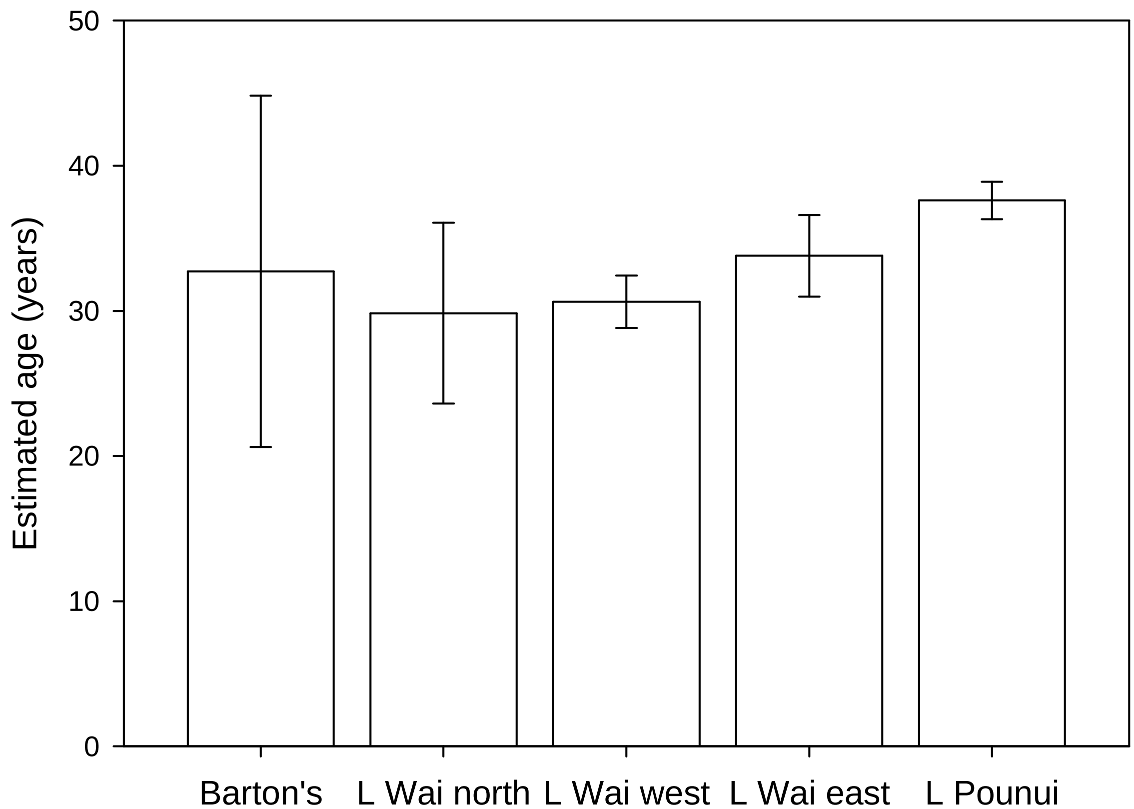


**Figure 23.** Average kākahi estimated age. Barton's Lagoon n = 2; Lake Wairarapa north = 3; Lake Wairarapa west = 9; Lake Wairarapa east = 7; Lake Pounui = 7.

When looked at overall, kākahi from Lake Pounui were older than kākahi from Lake Wairarapa (Fig. 24). This could be a reflection of the colder water temperatures experienced in Lake Pounui, which is a deeper, oligotrophic lake compared with shallow, supertrophic Lake Wairarapa. Other researchers have found that freshwater mussel species grow faster in warmer water temperatures (e.g. Negus 1966; Singer 2010).

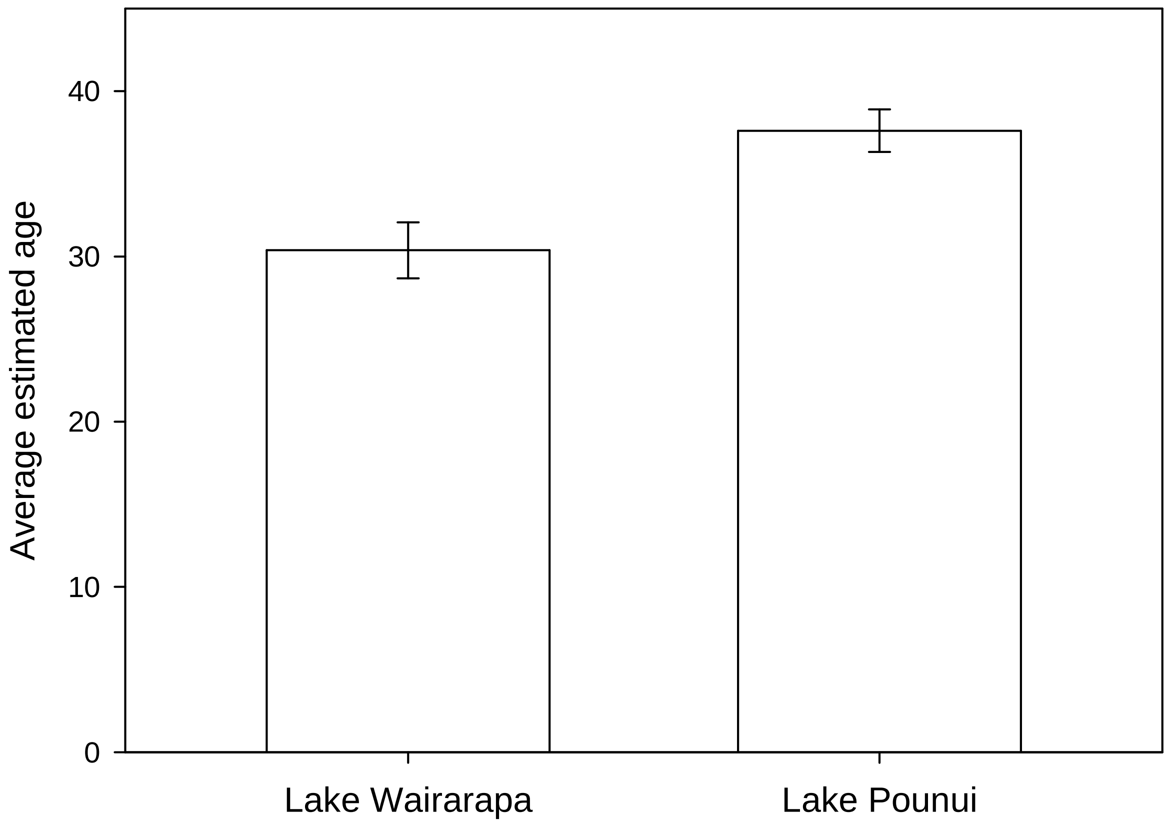


**Figure 24.** Average kākahi estimated age in two Wairarapa Moana lakes. Lake Wairarapa n = 21; Lake Pounui = 7.

Significant variation was observed in the relationship between shell length and estimated age (Fig. 25). Larger individuals from Lake Wairarapa east and from Barton's Lagoon deviated the furthest from the general trend. This could reflect the existence of faster

growth of some individuals sharing the same local environment (due presumably to variations in individual fitness), or could reflect errors in the age estimation method with particularly large individuals. Grimmond (1968) found higher concordance between shell length and estimated age although this author used mussels all from the same environment (Lake Ellesmere) and with minimal shell erosion. In contrast, Roper & Hickey (1994) found considerable scatter in length-age relationships of kākahi from seven sites in the Waikato River system. Ground-truthing of the age estimation method used here (by real-time, repeat sampling of a population subsample) would be useful. Young & Isley (2006) describe a successful method of repeat sampling freshwater mussels using PIT tags – a method subsequently used successfully in the field by Singer (2010).

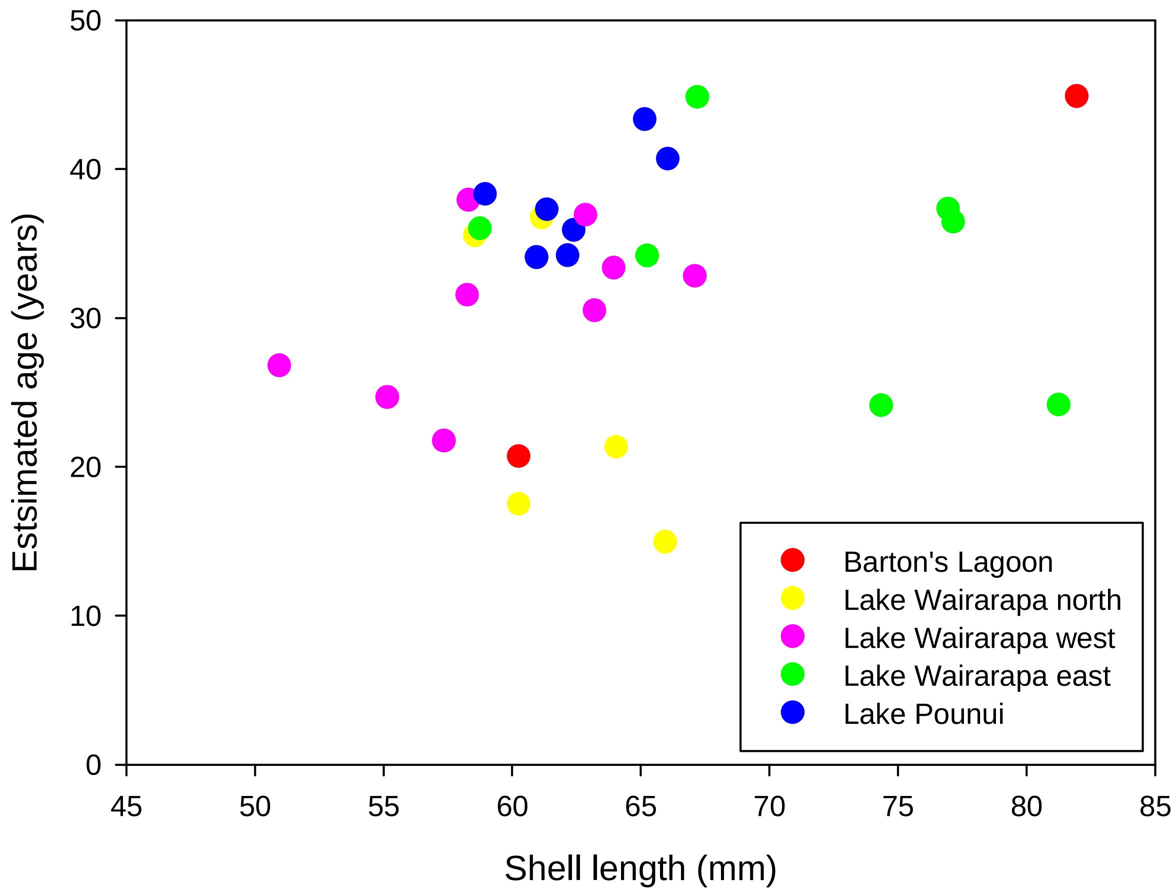


**Figure 25.** Estimated kākahi age plotted against shell length to illustrate the relationship between age and growth.

### 6.6 Water clarity

No relationship was evident between kākahi distributions and water clarity across the sites sampled (Fig. X).

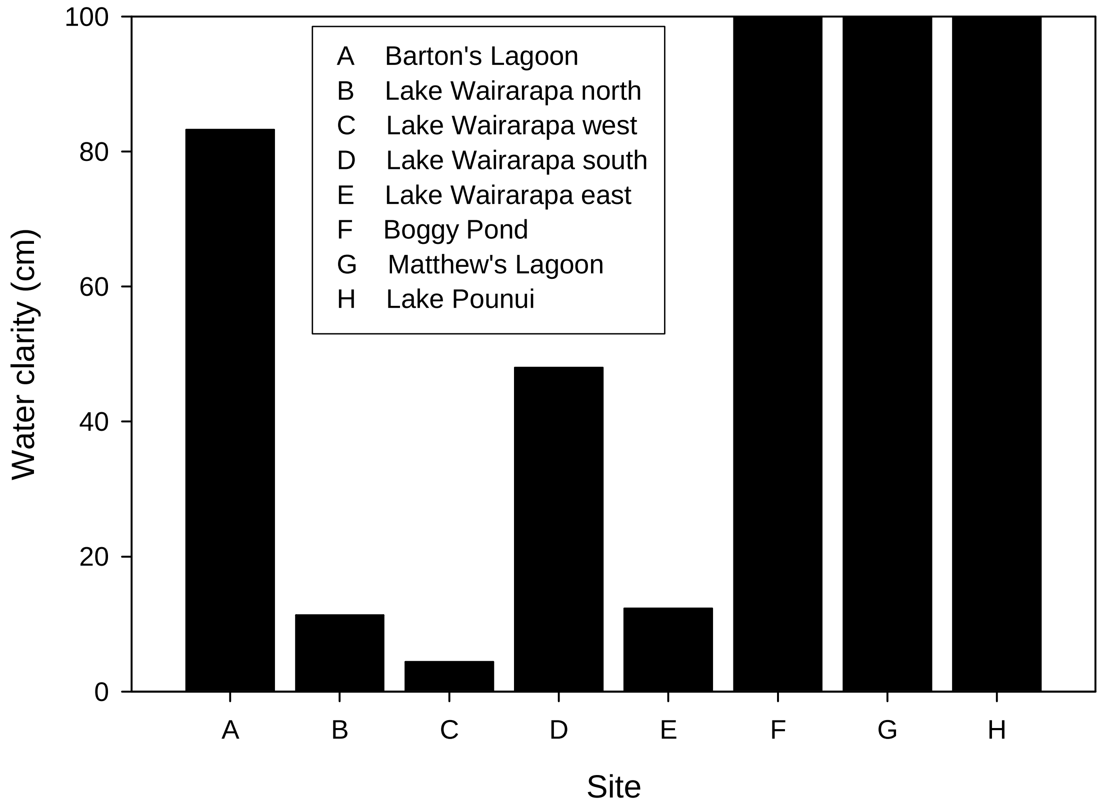


**Figure 26.** Water clarity at each site – measured using a 1m clarity tube. Kākahi were found at all sites except D, F and G. Sites F, G and H both measured +1m.

There has been interest in using mussels as biomanipulation tools i.e. to control phytoplankton (Ogilvie and Mitchell 1995; Phillips 2006) and to control sediment (Mark Fenwick, Pers. Comm.) Kākahi are prodigious filterers: in Lake Tuakitoto the kākahi population was estimated to be filtering the entire volume of the lake every 32 hours (Ogilvie and Mitchell 1995). Rainforth (2008) showed that adult kākahi can continue to filter during extremely high concentrations of suspended sediment, at least for short periods. They are capable of clearing sediment from the water column by fixing it in pseudofaeces but this has an associated energy cost and it is assumed that elevated

pseudofaeces production over the long term could have sub-lethal effects (Rainforth 2008). Kākahi could potentially play a biomanipulation role in further Wairarapa Moana restoration however much further research would be needed.

### 6.7.Population recruitment and sustainability

Samples from the eastern shore of Lake Wairarapa and from Barton's Lagoon showed a reasonable range of sizes were present in these populations while the other sites showed strongly unimodal size distributions (Fig. 27). Previous work on kākahi populations in New Zealand used the definition of juvenile as those less than 5 years old or less than 38mm long (James 1985; Roper & Hickey 1994; Rainforth 2008). These authors worked in Lake Taupo, the Waikato River and the Whanganui River respectively. Low numbers of juvenile kākahi were found in Lake Taupo and in the Whanganui River, however none were found in sites surveyed in the Waikato River. Similarly, no juvenile kākahi were found at any site during the present survey. This is unlikely to be due to lack of searching. James (1985) found juveniles in areas with clean coarse sand, while Rainforth (2008) found juveniles in fine silty substrates – both in the same general areas in which adults were found. It has been suggested that very young (post-glochidia) kākahi utilize quite separate habitats to older individuals, possibly even as attached mussels (see Rainforth 2008). For this reason, separate searches were carried out, specifically targeting juveniles, in alternative habitats such as submerged wood, boulders and aquatic macrophyte roots and stems (Figs 28–33).

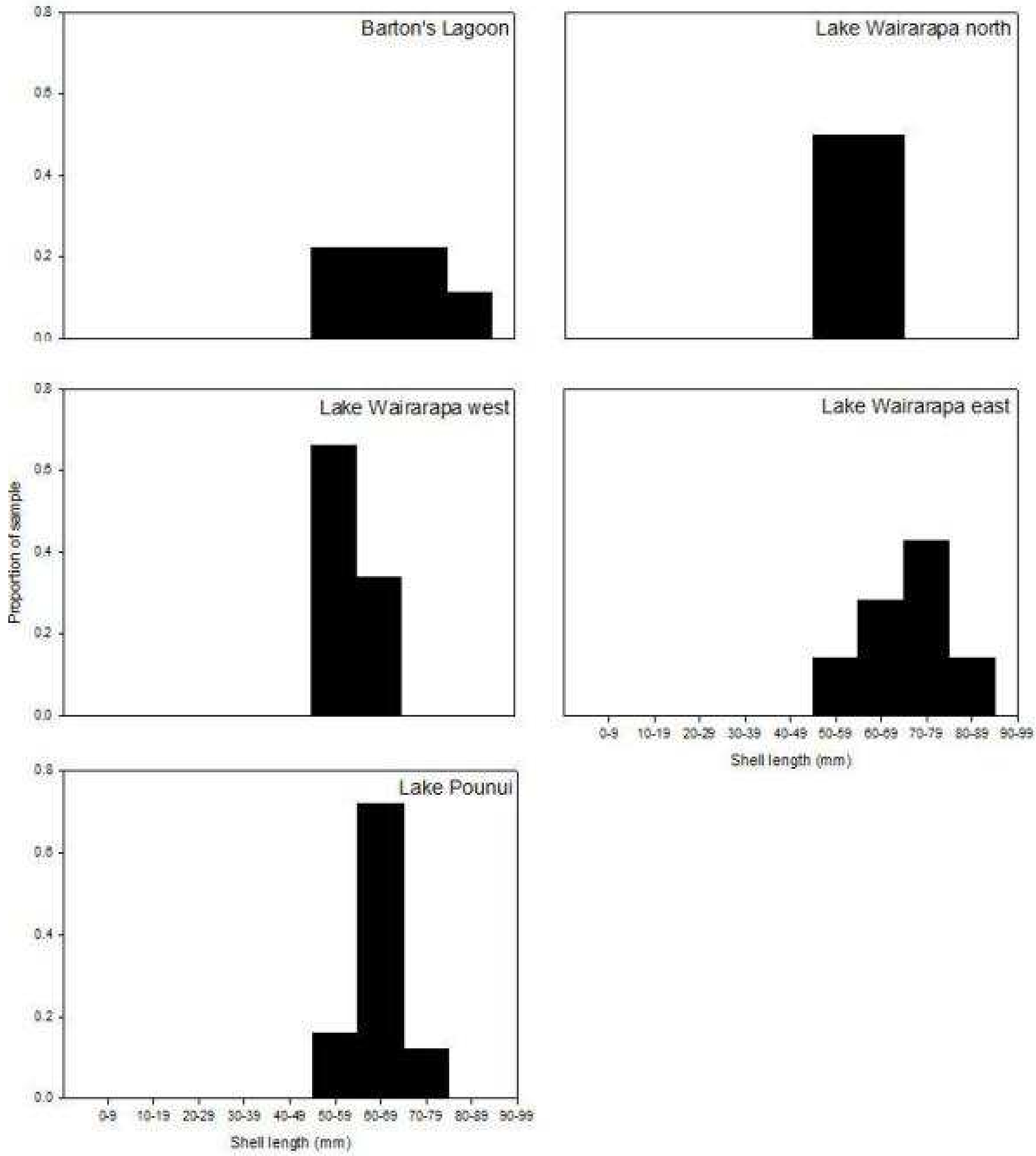


**Figure 27.** Distributions of shell lengths for all sites.

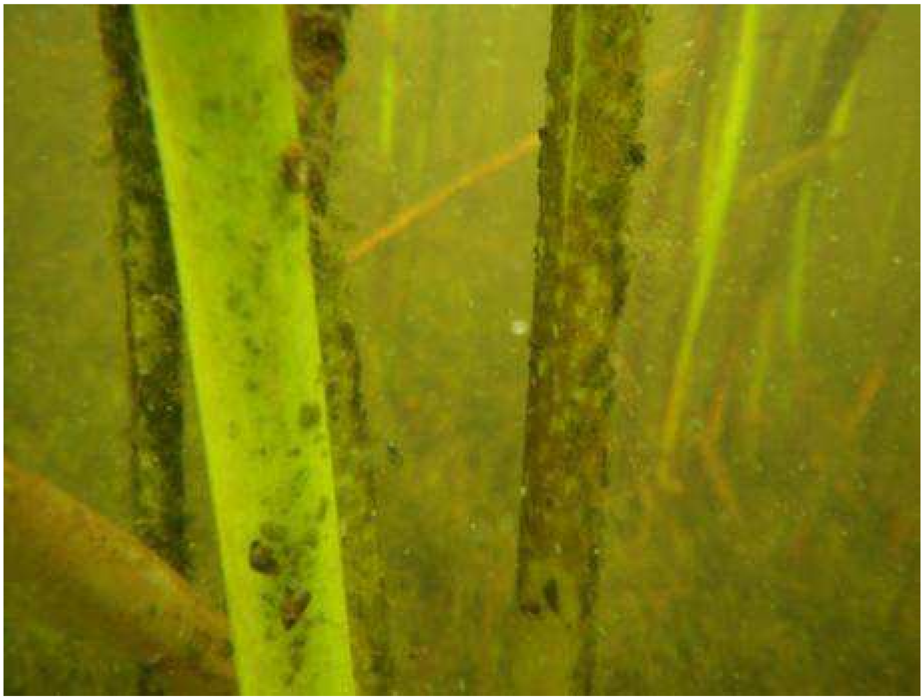

**Figure 28.** Underwater reed stems that were searched for the presence of juvenile kākahi during surveying in Wairarapa Moana over January-February 2012.

**Figure 29.** Submerged boulders in Wairarapa Moana that were searched for the presence of juvenile kākahi during surveying in Wairarapa Moana over January-February 2012.

**Figure 30.** Beachcast macrophytes that were searched for the presence of juvenile kākahi during surveying in in Wairarapa Moana over January-February 2012.

**Figure 31.** Bases of raupo stems (inside stems) that were searched for the presence of juvenile kākahi during surveying in Wairarapa Moana over January-February 2012.

**Figure 32.** Submerged wood that was searched for the presence of juvenile kākahi during surveying in Wairarapa Moana over January-February 2012.

**Figure 33.** Roots of emergent macrophytes that were searched for the presence of juvenile kākahi during surveying in Wairarapa Moana over January-February 2012.

Thus, according to the work conducted in this survey, kākahi recruitment appears to have ceased or be at such low levels as to be undetectable at all sites surveyed across Wairarapa Moana. Both size and age measurements are well above previously used definitions for juveniles: the smallest kākahi found in Wairarapa Moana was 50mm and the youngest estimated age was 17.4 years. This means that the lack of recruitment could be considered severe. Recruitment failure could be due to one or a combination of the below factors:

- **Sedimetation**

  While kākahi are known for their ability to filter large amounts of sediment (see section 6.6), this ability may vary with age and juvenile kākahi may not be capable of withstanding prolonged exposure to high levels of suspended sediment. Other researchers have reported a number of parameters within which it is evident that juvenile freshwater mussels are less tolerant of sediment than adults (Widdows et al. 1979; Bricelj et al. 1984; Hatton et al. 2005) and Rainforth (2008) concluded it was likely that suspended sediment affects juvenile growth, survival and recruitment into a population. Levels of suspended sediment in Lake Wairarapa have likely increased significantly in recent years, due to land clearance and the diversion of the Ruamahanga River and this may be partially responsible for the apparent lack of recruitment in Lake Wairarapa kākahi. The Lake Pounui catchment however, is still forested and sediment levels in this waterbody will be very low so sedimentation is unlikely to be responsible for the lack of recruitment apparent in this population.

- **Chemical pollution**

  It has recently been discovered that freshwater mussels are particularly sensitive to ammonia poisoning (U.S E.P.A 2009), and juveniles (particularly glochidia) may be more vulnerable than adults. Ammonia can enter freshwater environments through municipal wastewater discharges and through the inputs of nitrogenous wastes from animals, both of which are current issues in Wairarapa Moana. The Lake Pounui catchment however, has good water quality and has no known impacts

that would cause raised ammonia levels, so chemical pollution is unlikely to be responsible for the lack of recruitment apparent in this population.

- **Lack of host native fish species**

  Currently known hosts for kākahi glochidia are kōaro (Galaxias brevipinnis), the giant and common bullies (*Gobiomorphus gobioides and G. cotidianus*), and eels (*Anguilla* spp.; Percival 1931; Hine 1978; Phillips 2006). While the giant bully has never been recorded in Wairarapa Moana, longfin eel numbers have declined (McEwan 2010) and koaro are likely absent or infrequent visitors due to the migratory barrier presented by the barrage gates. There is a significant population of land-locked common bullies present in Lake Wairarapa however.

In summary, as recruitment failure is evident in Lake Pounui as well as Lake Wairarapa kākahi populations and the former is unlikely to be due to sediment or chemical pollution, the lack of host native fish species is likely the most important factor responsible for the lack of juveniles in Wairarapa Moana. It is important to investigate whether kākahi glochidia are parasitizing the common bully in this situation. It would also be of interest to ascertain whether introduced species such as perch and rudd are hosting larvae. Further, more intense sampling, particularly at sites with a range of kākahi sizes present would be useful to detect whether recruitment is occurring at very low levels.

Without sufficient recruitment, the kākahi of Wairarapa Moana will continue to age, population collapse will occur and this species could be locally extinct in less than 50 years. Annual population status monitoring would be straightforward and should be implemented immediately: by measuring a population subsample each year it could be inferenced whether the population is ageing (average size increases incrementally) or is incorporating new recruits (average size remains static). Artificial propagation of freshwater mussel larvae has been investigated overseas and, while possible, would be complicated and potentially resource-intensive. While this approach could provide an “ambulance at the bottom of the cliff”, it does not address the problem of lack of host native fish species in Wairarapa Moana.

## 7. ACKNOWLEDGEMENTS

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## 9. APPENDIX

Raw Data from all kākahi encountered in the field:

| | | | | | |
|---|---|---|---|---|---|
| **SITE** | (A) Barton's Lagoon | | | | |
| **DATE** | 30.01.2012 | | | | |
| **Substrate** | mud over hard bottom at edges, raupo and myriphyllum abundant. Azolla. Hard bottom with sandy mud and small gravel - wee bottom plants here. Most mussels here, 2 in shallower muddy layer. Empty shells all in deep mud layer at edge | | | | |
| **Empty shells present?** | Yes, 4 (smallest was UM = 18; AP = 35.6) | | | | |
| **Clarity** | 84.5 | 82 | | | |
| **Depth** | 51 | 43 | 39 | | |
| **Total kākahi** | 7 | | | | |
| **Kākahi/hour** | 10 | | | | |
| **Kākahi/m$^2$** | 0.2 | | | | |
| **Juveniles?** | No | | | | |
| | | | UM: | Umbo-Margin | |
| | | | AP: | Anterior-Posterior | |
| | | | | | |
| **30 minute** | **Length UM (mm)** | **Length AP (mm)** | **Shell erosion** | | **NOTES** |
| 1 | 39.9 | 75.4 | ii | | |
| 2 | 38 | 71.3 | i | | |
| 3 | 26 | 59 | i | | |
| 4 | 30.3 | 64 | i | | |
| | 29 | 56.5 | i | | |
| **Quadrat** | | | | | |
| 2 | 42.5 | 81.7 | ii | | |
| 6 | 32.4 | 62.1 | i | | |
| | | | | | |
| | | | | | |

| | | | | |
|---|---|---|---|---|
| **SITE** | (B) Lake Wairarapa north | | | |
| **DATE** | 11.02.2012 | | | |
| **Substrate** | patchy, alternating between cobbles/large gravels to shallow silt over hard clay/sand bottom (mussels here). Overall substrate firm | | | |
| **Empty shells present?** | yes in shallows and on shore - small long one found | | | |

| | | | | | |
|---|---|---|---|---|---|
| **Clarity** | 12.5 | | 10 | | |
| **Depth** | 39 | 53 | 73 | | |
| **Total kākahi** | 16 | | | | |
| **Kākahi/hour** | 30 | | | | |
| **Kākahi/m$^2$** | 0.1 | | | | |
| **Juveniles?** | No | | | | |
| | | | UM: | Umbo-Margin | |
| | | | AP: | Anterior-Posterior | |
| | | | | | |
| **30 minute** | **Length UM (mm)** | **Length AP (mm)** | **Shell erosion** | | **NOTES** |
| 1 | 24.8 | 62.4 | i | | |
| 2 | 27.2 | 64.1 | i | | No erosion |
| 3 | 31.3 | 56.6 | iii | | |
| 4 | 22.7 | 64.6 | iii | | |
| 5 | 24.8 | 57.9 | iii | | |
| | | | | | |
| **Quadrats** | | | | | |
| 5 | 28.2 | 59 | i | | |
| | | | | | |
| | | | | | |

| | | | | |
|---|---|---|---|---|
| **SITE** | (C) Lake Wairarapa west | | | |
| **DATE** | 02.02.2012 | | | |
| **Substrate** | large cobbles/firm snady mud further out - where mussels are. Submerged wood sort of common. Reed margins koura! Very dense mussel batch tucked under lake edge of long piece of submerged mud, none on shore side - sheltered? Mussels have algae growing on dorsal | | | |

| | | | | | |
|---|---|---|---|---|---|
| | 'end' | | | | |
| **Empty shells present?** | yes on tideline, not as many as I've seen before. | | | | |
| **Clarity** | 4.4 | | 4.4 | | |
| **Depth** | 27 | 46 | 71 | | |
| **Total kākahi** | 87 | | | | |
| **Kākahi/hour** | 156 | | | | |
| **Kākahi/m$^2$** | 0.9 | | | | |
| **Juveniles?** | No | | | | |
| | | | UM: | Umbo-Margin | |
| | | | AP: | Anterior-Posterior | |
| | | | | | |
| **30 minute** | **Length UM (mm)** | **Length AP (mm)** | **Shell erosion** | | **NOTES** |
| 1 | 28.1 | 60.9 | i | | |
| 2 | 28.1 | 58 | i | | |
| 3 | 27.2 | 57.2 | i | | |
| 4 | 33.6 | 64.2 | iii | | |
| 5 | 29.2 | 57 | ii | | |
| 6 | 33.1 | 67.5 | i | | |
| 7 | 24.1 | 60.3 | i | | |
| 8 | 32.6 | 61.2 | ii | | |
| 9 | 27.1 | 62.3 | ii | | |
| 10 | 28 | 57.6 | iii | | |
| 11 | 28.5 | 51 | iii | | |
| 12 | 31.8 | 59.3 | ii | | |
| 13 | 26.8 | 54.5 | iii | | |
| 14 | 28.5 | 60.1 | iii | | |
| 15 | 30.1 | 60.9 | iv | | |
| 16 | 26 | 57.1 | i | | |
| 17 | 32 | 62.7 | ii | | |
| 18 | 24.9 | 52 | iii | | |
| 19 | 27.9 | 53.9 | iii | | |
| 20 | 26.8 | 52.8 | iii | | |
| 21 | 31.1 | 61 | iii | | |
| 22 | 29 | 60.2 | ii | | |
| 23 | 30.2 | 58.7 | iii | | |
| 24 | 25.2 | 57.8 | iii | | |
| 25 | 25 | 50 | ii | | |
| 26 | 33.2 | 61.5 | i | | |
| 27 | 26 | 58.8 | i | | |
| 28 | 25.2 | 52.9 | ii | | |
| 29 | 25.1 | 52.6 | i | | |

| | | | | | |
|---|---|---|---|---|---|
| 30 | 27.2 | 57.1 | i | | |
| 31 | 27.3 | 59.3 | iii | | |
| 32 | 27.9 | 55.4 | ii | | |
| 33 | 30.8 | 61.9 | ii | | |
| 34 | 25 | 55.7 | iii | | |
| 35 | 30 | 61 | iii | | |
| 36 | 29.1 | 62 | iii | | |
| 37 | 27.5 | 59.3 | ii | | |
| 38 | 29 | 54.9 | ii | | |
| 39 | 30.3 | 61.9 | iv | | |
| 40 | 29.5 | 55 | i | | |
| 41 | 30.7 | 57.8 | iii | | |
| 42 | 27.1 | 54.6 | ii | | |
| 43 | 24 | 50.3 | iii | | |
| 44 | 26.8 | 55.4 | iii | | |
| 45 | 27.9 | 51.5 | iii | | |
| 46 | 27.9 | 56.5 | ii | | |
| 47 | 29.4 | 62 | iii | | |
| 48 | 29.8 | 62 | ii | | |
| 49 | 25.4 | 55.6 | i | | |
| 50 | 26.4 | 56 | ii | | |
| | | | | | |
| **Quadrat** | | | | | |
| 4 | 28.5 | 57.2 | ii | | |
| 6 | 27.1 | 58.9 | i | | |
| 7 | 31 | 59.9 | ii | | |
| 8 | 29 | 58 | iii | | |
| 8 | 31.1 | 58.8 | iii | | |
| 9 | 33.2 | 58 | ii | | |
| 10 | 28.9 | 58 | iii | | |
| 10 | 28.2 | 58 | iii | | |
| 10 | 34.5 | 67 | ii | | |
| | | | | | |

| | | | | |
|---|---|---|---|---|
| **SITE** | (D) Lake Wairarapa south | | | |
| **DATE** | 25.02.2012 | | | |
| **Substrate** | shallow-deep silt over hard mud/clay. Submerged and floating macrophytes abundant. Submerged wood abundant. Raupo around edges | | | |
| **Shells present?** | no | | | |

| | | | | | |
|---|---|---|---|---|---|
| **Clarity** | 47 | 49 | | | |
| **Depth** | 52 | 76 | 80 | | |
| **Total kākahi** | 0 | | | | |
| **Kākahi/hour** | 0 | | | | |
| **Kākahi/m$^2$** | 0 | | | | |
| **Juveniles?** | No | | | | |
| | | | UM: | Umbo-Margin | |
| | | | AP: | Anterior-Posterior | |
| | | | | | |
| **30 minute** | **Length UM (mm)** | **Length AP (mm)** | **Shell erosion** | | **NOTES** |
| | | | | | |
| | | | | | |

| | | | | |
|---|---|---|---|---|
| **SITE** | (E) Lake Wairarapa east | | | |
| **DATE** | 18.02.2012 | | | |
| **Substrate** | hard sandy mud with turf plants submerged wood sparse. Shallow water, no mussels where birds are - eating them? Mussels in ripple-striated sand about mid calf deep. | | | |
| **Empty shells** | yes, lots, many buried in shore substrate. Lots around bird areas - eating | | | |

| | | | | | |
|---|---|---|---|---|---|
| **present?** | them? | | | | |
| **Clarity** | 13 | | 11.5 | | |
| **Depth** | 16 | 23 | 27 | | |
| **Total kākahi** | 13 | | | | |
| **Kākahi/hour** | 24 | | | | |
| **Kākahi/m$^2$** | 0.1 | | | | |
| **Juveniles?** | No | | | | |
| | | | UM: | Umbo-Margin | |
| | | | AP: | Anterior-Posterior | |
| | | | | | |
| **30 minute** | **Length UM (mm)** | **Length AP (mm)** | **Shell erosion** | | **NOTES** |
| 1 | 33.4 | 66.3 | ii | | |
| 2 | 38.2 | 75.7 | i | | |
| 3 | 28.2 | 57.9 | ii | | |
| 4 | 37 | 75.3 | ii | | |
| 5 | 34.4 | 64 | i | | |
| 6 | 35 | 73 | i | | |
| | | | | | |
| **Quadtrat** | | | | | |
| 8 | 38.8 | 81.2 | i | | |
| | | | | | |
| | | | | | |

| | | | | |
|---|---|---|---|---|
| **SITE** | (F) Boggy Pond | | | |
| **DATE** | 01.02.2012 | | | |
| **Substrate** | hard mud with lots submerged wood. Submerged and floating macrophytes superabundant. Raupo edges | | | |
| **Empty shells present?** | No | | | |

| | | | | | |
|---|---|---|---|---|---|
| **Clarity** | + 1 metre | | | | |
| **Depth** | 41 | | 60 | | 57 |
| **Total kākahi** | 0 | | | | |
| **Kākahi/hour** | 0 | | | | |
| **Kākahi/m$^2$** | 0 | | | | |
| **Juveniles?** | No | | | | |
| | | | UM: | Umbo-Margin | |
| | | | AP: | Anterior-Posterior | |
| | | | | | |
| **30 minute** | **Length UM (mm)** | **Length AP (mm)** | **Shell erosion** | | **NOTES** |
| | | | | | |
| | | | | | |

| | | | | |
|---|---|---|---|---|
| **SITE** | (G) Matthew's Lagoon | | | |
| **DATE** | 01.02.2012 | | | |
| **Substrate** | hard mud/clay substrate with lots submerged wood. Submerged and floating macrophytes superabundant. Hornwort, some potamageton. Some Chara. Praying mantis weed abundant. Raupo edges | | | |
| **Empty shells** | No | | | |

| | | | | | |
|---|---|---|---|---|---|
| **present?** | | | | | |
| **Clarity** | + 1 metre | | | | |
| **Depth** | 32 | | 76 | | 72 |
| **Total kākahi** | 0 | | | | |
| **Kākahi/hour** | 0 | | | | |
| **Kākahi/m$^2$** | 0 | | | | |
| **Juveniles?** | No | | | | |
| | | | UM: | Umbo-Margin | |
| | | | AP: | Anterior-Posterior | |
| | | | | | |
| **30 minute** | **Length UM (mm)** | **Length AP (mm)** | **Shell erosion** | | **NOTES** |
| | | | | | |
| | | | | | |

| | | | | |
|---|---|---|---|---|
| **SITE** | (H) Lake Pounui | | | |
| **DATE** | 03.02.2012 | | | |
| **Substrate** | cobbles, small amount fine sediment. Deeper is sand gravel where mussels are. Lots settled algae in shallows, some filamentous. Algae on mussels dorsal end in deeper water. Suspended algae abundant, large particles. Abundant and varied turf community. reeds emergent around | | | |

| | | | | | |
|---|---|---|---|---|---|
| | edges. | | | | |
| **Shells present?** | Yes | | | | |
| **Clarity** | + 1 metre | | | | |
| **Depth** | 37 | 101 | | 98 | |
| **Total kākahi** | 71 | | | | |
| **Kākahi/hour** | 66 | | | | |
| **Kākahi/m$^2$** | 3.8 | | | | |
| **Juveniles?** | No | | | | |
| | | | UM: | Umbo-Margin | |
| | | | AP: | Anterior-Posterior | |
| | | | | | |
| **30 minute** | **Length UM (mm)** | **Length AP (mm)** | **Shell erosion** | | **NOTES** |
| 1 | 33 | 66.9 | iv | | |
| 2 | 30 | 60.7 | ii | | |
| 3 | 34.1 | 73.2 | iv | | |
| 4 | 29 | 64.4 | iv | | |
| 5 | 31 | 64.7 | ii | | |
| 6 | 26.8 | 57.9 | iii | | |
| 7 | 30.1 | 60.3 | ii | | |
| 8 | 27.2 | 57.3 | iii | | |
| 9 | 28.9 | 58.9 | ii | | |
| 10 | 30 | 59.2 | iii | | |
| 11 | 33 | 69.2 | iv | | |
| | | | | | |
| **Quadrat** | | | | | |
| 8 | 28 | 65.7 | iii | | |
| 8 | 31.9 | 68 | ii | | |
| 8 | 25.8 | 62.8 | iii | | |
| 8 | 28.1 | 69 | iv | | |
| 8 | 28.2 | 67.6 | iii | | |
| 8 | 26.9 | 63 | iii | | |
| 8 | 28 | 63.7 | iii | | |
| 8 | 31.5 | 67.9 | Ii | | |
| 9 | 31.4 | 67 | Ii | | |
| 9 | 30.9 | 64.3 | I | | |
| 9 | 30.2 | 70.1 | Ii | | |
| 9 | 29.5 | 66.8 | Iv | | |
| 9 | 30.7 | 64.1 | Ii | | |
| 10 | 34.2 | 72.6 | Iv | | |
| | | | | | |
| | | | | | |

**Raw data for lab kākahi:**

| Kakahi | Wet weight | Shucked weight | Umbo-margin | Anterior-Posterior | Estimated age |
|---|---|---|---|---|---|
| BAR1 | MT! | | 30.25 | 60.3 | 20.6 |
| BAR2 | 64 | 18 | 40.65 | 82 | 44.8 |
| LWE1 | 51 | 16 | 38.55 | 77.2 | 36.4 |
| LWE2 | 65 | 26 | 39 | 81.3 | 24.1 |
| LWE3 | 37 | 16 | 30.8 | 67.25 | 44.8 |
| LWE4 | 40 | 14 | 32.2 | 65.3 | 34.1 |
| LWE5 | 27 | 10 | 29.85 | 58.8 | 35.9 |
| LWE6 | 59 | 18 | 38.2 | 77 | 37.2 |
| LWE7 | 50 | 18 | 34.6 | 74.4 | 24.0 |
| LWN1 | 21 | 7 | 28.8 | 57.3 | Eroded |
| LWN2 | 31 | 9 | 30.6 | 61.2 | 36.7 |
| LWN3* | 18 | 6 | 26 | 64.1 | 21.3 |
| LWN4* | 19 | 7 | 29.6 | 66 | 14.9 |
| LWN5 | 28 | 9 | 28.8 | 58.6 | 35.5 |
| LWN6 | 19 | 6 | 28.3 | 60.3 | 17.4 |
| LWW1 | 29 | 12 | 30.9 | 64 | 33.3 |
| LWW10 | 28 | 8 | 32.35 | 63.3 | Eroded |
| LWW11 | 20 | 5 | 25.7 | 55.2 | 24.6 |
| LWW12 | 28 | 9 | 28.8 | 58.35 | 37.8 |
| LWW2 | 16 | 5 | 26.6 | 51 | 26.7 |
| LWW3 | 22 | 9 | 27.1 | 57.4 | 21.7 |
| LWW4 | 23 | 9 | 24.4 | 52.45 | Eroded |
| LWW5 | 21 | 7 | 27.55 | 67.15 | 32.7 |
| LWW6 | 24 | 8 | 28.1 | 58.3 | 31.5 |
| LWW7 | 32 | 11 | 32 | 63.25 | 30.4 |
| LWW8 | 31 | 12 | 32.6 | 62.9 | 36.8 |
| LWW9 | 21 | 7 | 26.8 | 54.15 | Eroded |
| POU1 | 34 | 12 | 31.55 | 70.55 | Eroded |
| POU10 | 43 | 20 | 35.25 | 73.7 | Eroded |
| POU11 | 31 | 13 | 29.25 | 65.2 | 43.3 |
| POU2 | 31 | 11 | 31.25 | 66.1 | 40.6 |
| POU3 | 21 | 9 | 28.6 | 61 | 34.0 |
| POU4 | 28 | 13 | 32.9 | 62.45 | 35.8 |

| | | | | | |
|---|---|---|---|---|---|
| POU5 | 27 | 12 | 32.4 | 62.2 | 34.1 |
| POU6 | 33 | 17 | 32.8 | 68.15 | Eroded |
| POU7 | 25 | 12 | 27.7 | 60.2 | Eroded |
| POU8 | 31 | 11 | 30.1 | 61.4 | 37.2 |
| POU9 | 32 | 12 | 28.7 | 59 | 38.2 |
| | | | | | |