
**Taonga and mahinga kai species of the
Te Arawa lakes: a review of current
knowledge - kakahi**



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1. Kākahi in the Te Arawa lakes - past and present

1.1 Historical knowledge

The kākahi or freshwater mussel was once a valuable food source for Te Arawa (Bidwill, 1841; Hiroa, 1921). Despite it being considered the least appetising of the fisheries resources in the Te Arawa lakes it was the most important in story, song and proverb. Kākahi were collected from all the lakes but were most plentiful and easily harvested in the shallower lakes such as Rotorua, Rotoehu and Rotokākahi. Kākahi were collected throughout the year, but were best in winter (Hiroa, 1921). Kākahi were eaten raw, lightly boiled or dried in the sun for use in stews. They were also used in the feeding of motherless infants and as a food for the sick (a rongoā or medicine) (Hiroa, 1921).

The kākahi shell was also had a number of uses including cutting adults hair, cutting the umbilical cord of new-born children (Hiroa, 1921), scraping vegetables (Papakura, 1938) and as rattles on kites (Bennett, 1958).

‘In preparing a meal at Whakarewarewa, the women would first scrape the sweet potatoes (kūmara) or potatoes (rīwai) with the half of a kākahi (freshwater mussel) shell, the potato being held between the thumb and the first and second fingers, and the shell between the thumb and first two fingers of the right hand, about midway of the shell. A woman would waruwaru (scrape) a basketful in a very short time’ (Papakura, 1938).

‘This resulted in a much stronger cord than a plaited one. At times bunches of tuangi (cockle) or kākahi (freshwater mussel) or kuku (mussel) shells were tied to the usually lengthy tails attached to kites in order to produce a rattle as the kite moved about in the air’ (Bennett, 1958).

In shallow waters, kākahi were easily gathered by ruku (diving) and hand (and foot). Kākahi were considered to be a readily available source of protein and if required could be kept alive for considerable periods of time if kept moist (Tūwharetoa evidence in Habib, 2001).

In deeper waters dredging was used to collect large quantities of kākahi. The large dredge rakes called kapu or mangakino were comprised of a toothed frame, a heheki (net) and a rou (long handle). Successful dredging was considered a great skill and was inherited by certain families. Hiroa (1921) describes the kapu and its use in great detail.

1.2 Present day

Kākahi are still consumed today but are not as popular or as important as they were in the past. This is mainly due to the taste of the kākahi rather than a decline in harvestable quantities. Moreover, there is also a perception that kākahi may be unhealthy to eat as they accumulate pollutants, heavy metals and toxins (pers comm., Ngāti Pikiao hui, 2006). In fact, the reduction in the importance of kākahi as a food resource was noted in the early 20th Century by Newman (1904) who wrote:

‘That as other foods became available as a result of European colonisation, that central north Island Māori became less dependent on kākahi as a food source. Wielding the dredge was hard work, and kākahi were not particularly tasty.’

This is supported by Hiroa (1921) who wrote that the kapu (kākahi dredge) and its use were gradually being abandoned by the 1920’s.

Today, kākahi harvest and consumption of kākahi is limited to a few whānau (mainly Ngāti Pikiao). The lack of suitable recipes has been cited as one reason why kākahi are no longer consumed in any great quantity (pers comm., Te Arawa hui workshops, 2006). Interestingly, a modern day recipe for kākahi soup was published by Paul (1996) in *The Māori Cookbook*.

Kākahi (freshwater mussels), pāua or pipi can be used as a substitute.

Kākahi Soup
2 large cups kākahi
2 large onions
1 cup grated carrot
2 tablespoons brown sugar
2 tablespoons worcestershire sauce
2 tablespoons vinegar
Dash of cayenne pepper
Salt and pepper to taste
Cornflour

Boil kākahi until well cooked, then strain, retaining the juice for soup. Fry onions in peanut oil until light and transparent. Add the onions and all remaining ingredients to the mussel juice, and bring to the boil. Thicken to desired consistency with cornflour, add chopped parsley and serve.

2. Overview of scientific information about kākahi in the Te Arawa Lakes

Conventional studies of benthic macroinvertebrates in the Te Arawa lakes have generated some information about kākahi (Forsyth, 1978). On the basis of these studies, they were found to be present in Lakes Rotokākahi and Ngāpourī, but not in Lake Ōkātina, Rotomā, Tikitapu, Ōkareka, or Ōkaro (Forsyth, 1978). Subsequent surveys have recorded kākahi from Lakes Rerewhakaaitu, Rotoehu, Rotoiti, Rotomā, Rotorua, Tarawera and Tutaeinanga (Table 1). A recent review by Walker et al. (2001) provides a useful summary of current knowledge on freshwater mussels worldwide, with specific information on New Zealand species also presented.

Table 1.1: Kākahi presence in the Te Arawa lakes.

| Lake | Mussels recorded* |
|---------------|--------------------|
| Ōkareka | no ^{1,2} |
| Ōkaro | no ¹ |
| Ōkātina | no ¹ |
| Rerewhakaaitu | yes ¹ |
| Rotoehu | yes ¹ |
| Rotoiti | yes ^{1,2} |
| Rotokākahi | yes ¹ |
| Rotomā | yes ^{1,2} |
| Rotomāhana | no ¹ |
| Rotorua | yes ^{1,2} |
| Tarawera | yes ^{1,2} |
| Tikitapu | no ^{1,2} |
| Ngahewa | ? |
| Ngāpourī | yes ¹ |
| Tutaeinanga | yes ¹ |

* Source – ¹ LakeSPI surveys 1981-2004; ² Happy (2006).

2.1 Kākahi biology

Freshwater mussels are under threat and are declining, both in New Zealand and worldwide (Byrne, 1998; Walker et al. 2001; Brainwood et al. 2006). This decline has been attributed to the loss of habitat associated with river regulation, eutrophication and other types of pollution, and possibly through loss of the host fish, on which completion of

the life cycle depends (Walker et al. 2001; McDowall, 2002) (see also discussion of life cycle in section 2.2).

The freshwater mussel family Hyriidae is represented in New Zealand by two genera and three species/sub-species - *Hyridella menziesi* (Figure 1), *Hyridella aucklandica*, *Cucumerunio websteri* / *Cucumerunio websteri delli*. Recent evidence indicates that other species may also be present (Fenwick and Marshall, 2006). *H. menziesi* is common and widespread throughout New Zealand in habitats ranging from small, fast-flowing streams to lakes. In contrast, *H. aucklandica* and *C. websteri* are restricted to the northern North Island, near Auckland. Little is known about these two species (Walker et al. 2001).



Figure 1: The kākahi or freshwater mussel, *Hyridella menziesi*.

Adult kākahi are long-lived (over 50+ years in Lake Waipori (South Island), with a mean age of 20-25 years) (Grimmond, 1968) and reasonably hardy, so that residual adult populations may be present but do not necessarily indicate viable, self-sustaining

populations. Mussels of more than 100 mm length have been recorded in New Zealand (Ogilvie, 1993) and ages reported for large individuals range from 13 years (61 mm) in Lake Taupō (James, 1985) to 33 years (84 mm) in lakes on the Waikato River (Roper and Hickey, 1994). This species lacks a byssal thread commonly found in other mussel species as a mechanism of attachment to the substrate; instead it partially buries itself into soft sediment. There are many factors that influence their distribution and abundance and these are discussed in section 6.

2.2 Life cycle

The life cycle of mussels is complicated and involves a parasitic larval stage on a host fish. There is little or no published information on mussels in the Te Arawa lakes, on larval and juvenile life history stages, or on potentially major controlling factors. Figure 2 summarises the status of current knowledge of the biology of kākahi.

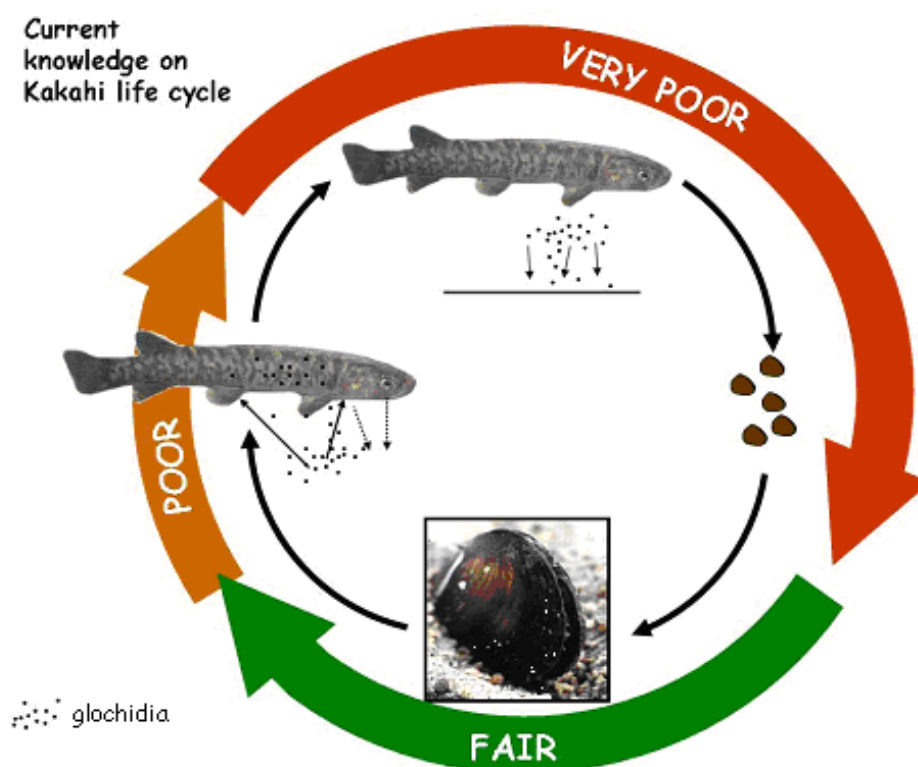


Figure 2: Current status of knowledge on different stages of the kākahi life cycle.

The sexes are separate, eggs of the female are laid into the space above her gills and are fertilised by sperm ejected into the open water by the male and then drawn in with the water current generated by the female. Spawning occurs in summer. Larvae are brooded in the mantle cavity of the female, developing into tiny larvae known as glochidia (about 3 mm). After being released from the females in spring, the glochidia attach themselves to the pectoral fins, head, and mouth of eels (Hine, 1978) and small native fish, including kōaro, giant bully (*Gobiomorphus gobioides*) and common bully (Percival, 1931; Roper and Hickey, unpublished data), using a tooth on the shell. They drop off later to develop further independently. Large individuals dominate population studies and it is rare to find juvenile mussels (Grimmond, 1968; James, 1985; Roper and Hickey, 1994). It is possible that juvenile mussels occur in a different habitat from the adults and undergo a migration as they develop. For example, Grimmond (1968) found juvenile mussels near the mouths of inflowing rivers.

3. Parasites and predators

A chironomid species, *Xenochironomus canterburyensis*, first recorded in Lake Taupō in 1978, is entirely dependent on mussels for its development (Forsyth, 1983). The first instar larvae have a short free-living stage which is spent searching for a mussel host. In late summer, one or two second instar larvae appear inside the mussel, where they feed on sloughed-off cells on the outer surface of the body and on material swept in from the lake water. By early winter the third instar larva moves towards the shell margin and in November, the change to fourth instar coincides with mussel annual growth that causes the membranes at the shell margin to rupture and the chironomid larvae is released to open water. The larva then pupates and rises to the lake surface to emerge as an adult. Roper and Hickey (1994) found that dead individuals of this species can become embedded and result in kākahi shell abnormalities.

P. planifrons has been reported to prey on mussels (CW Hickey, unpublished data). It is also possible that birds and fish may take this species, as anecdotal evidence from overseas reports this for other species (e.g., Vestjens, 1973; Van Tets, 1994). There is anecdotal evidence that rats may predate kākahi, with records of “bitten off” shells from Lake Ototoa (M. de Winton, pers. comm., May 2007; see also Figure 3), as well as direct observations of rats underwater (C. Hickey, pers. comm., May 2007).



Figure 3: “Bitten off” kakahi shells from Lake Ototoa, Kaipara Heads.

4. Shell morphology

The adult has a highly variable growth form and this causes confusion in separating the three New Zealand species. *H. menziesi* is known to show strong variation in shell form (Walker et al. 2001). Figure 4 illustrates some examples of changes in shell morphology. Variation in other characteristics, e.g., physiology and behaviour, have also been reported. For example, *H. menziesi* varies in glycogen levels, oxygen consumption, heart rate and patterns of valve movements (Hiscock, 1950; Walker 1981, Hickey et al. 1995; CW Hickey, unpublished data). The causal mechanisms for such variability may be simple (e.g., riverine versus lake forms, McMichael and Hiscock, 1958) or may involve complex interactions between physical, chemical and biological factors (Roper and Hickey, 1994).

Effects on shell shape & form

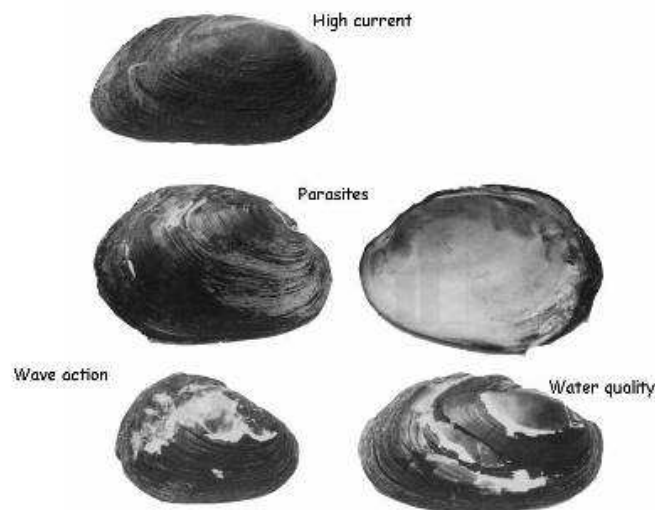


Figure 4: Examples of changes in shell morphology in kākahi. (Roper and Hickey, 1994).

5. Biomonitoring

There have been numerous studies into the potential use of mussels as biomonitors. Burggraaf (1996) investigated the use of mussels as bioindicators of metals and resin acids, a common component of kraft pulp and paper mill effluent. Mussels tested from Lake Taupō in winter, spring, summer, and autumn recorded low levels of mercury, copper, lead, cadmium, and chromium but relatively high levels of arsenic (33-50 mg/kg). Significant seasonal changes in metals occurred for potassium, zinc and cadmium. Mussel lipid values varied seasonally, being lowest after spawning in early autumn. Mussels incubated in kraft pulp and paper mill effluent accumulated resin acids in their tissues rapidly.

Mercury speciation in water, mussels and sediment was investigated at lakes Taupō, Aratiatia, Ohakuri, Whakamaru in the Waikato river system (Hickey et al. 1995). Mercury burden increased with mussel size. *H. menziesi* can therefore be considered as a useful biomonitor for trace levels of mercury.

A study on the toxicity of arsenic to the Dipteran *Chironomus zealandicus* and mussel was undertaken by McKinney (1995). There was no significant difference in survival, growth or condition between mussels suspended in test chambers containing sediments that were contaminated with arsenic (Lake Rotoroa) and sediments without known arsenic (Lake Ngaroto). Mussels did not exhibit avoidance behaviour to sediments with arsenic from Lake Rotoroa. Levels of arsenite in solution at 1200 mg/l decreased the time *H. menziesi* spent respiring and filtering and complete closure of valves occurred at 2400 mg/l. However, there is some evidence to suggest that chronic (long-term) impacts may have resulted in the loss of kākahi from Lake Rotoroa following the application of a sodium arsenite in 1959 (Henriques (1979; Tanner and Clayton, 1990).

6. Physical factors influencing distribution

A number of physical factors influence the density of mussels (James, 1985; James et al. 1998). Sediment type and stability has been suggested as a dominant factor, but bed slope, wave action, temperature (associated with depth), oxygen availability and presence of toxins are also important (James et al. 1998). Presence of macrophyte beds is also known to limit the availability of habitat to kākahi (James, 1985).

Mussels require soft sediment for burial, generally sand or mud, although fine silt has been found to be unsuitable due to potential for clogging of filtering mechanisms (James, 1985 & 1987).

Water level variability typically results in areas that periodically dry out. Lakes with large water level variations are likely to support mussels only in the deeper regions (Ogilvie, 1993). Similarly, areas of regular wave action are unlikely to support settlement of juveniles and even adults are likely to be adversely affected (James, 1985).

In Australian species, the viability and development of glochidia are temperature-dependent (Walker, 1981), as is glochidia release from the fish host (Atkins, 1979). However, this has not been investigated in New Zealand species.

James et al. (1998) suggested that DO levels above 5mg/l are likely to be a threshold concentration for long term viability of mussel beds. Available habitat for mussels is therefore likely to be restricted in lakes that stratify and record DO levels below 5mg/l.

The presence of toxins in lake sediments may also be a consideration (James et al. 1998) and limit the areal extent of mussel beds in some lakes, particularly where geothermal activity is found.

Growth and reproduction in *Hyridella* species appears to be sensitive to eutrophication (Roper and Hickey, 1994; Byrne, 1998). Byrne (1998) found that reproductive output was higher in eutrophic than in oligotrophic lakes.

Availability of a suitable fish host is of paramount importance for successful development of the glochidia (see discussion above on life cycle in section 2.2). Therefore an understanding of the factors influencing distribution and abundance of the fish host is also required for the establishment of a self-sustaining mussel population. Appendix 1C highlights knowledge gaps in one host species, kōaro.

No mussels are present in Lake Tikitapu, where calcium concentrations are as low as 0.7 mg l⁻¹ (Forsyth, 1978). A minimum calcium requirement of at least 1 mg l⁻¹ is suggested by their presence in Lake Rotokākahi, which has a calcium level of 1.9 mg l⁻¹ and supports *H. menziesi* and other molluscs (Forsyth, 1978; Timperley, 1987). Environmental calcium has also been implicated in reducing bioavailability and metal toxicity in freshwater mussels (Jeffrey et al. 1993).

7. Critical knowledge gaps

There is much we don't know about the kakahi (freshwater mussel) in the Te Arawa lakes and, in particular, the glochidal and juvenile stages. The group to which these animals belong (Unionids) is in decline in New Zealand and worldwide. This group is unique in that the life-cycle includes a parasitic larval (glochidial) phase on a fish host. The glochidia attaches to the fish for about 3 weeks and then drops off (<0.5mm in size). We know very little about what happens to them after this and they are not detected in their natural environment until they are at least 5mm in length. We have developed laboratory techniques to produce glochidia, parasitize trout and collect and rear juveniles. We need to undertake experiments to improve our understanding of the factors potentially limiting the survival of this critical early life-stage.

There is growing interest in the culturing of kakahi for restoration (e.g., Hauraki Iwi Environment Plan, Anon (2004); A. Hopkins, pers comm., July 2007). While there has been considerable research and practical application in this area overseas (e.g., Bishop et al. 2007) similar research is largely lacking for New Zealand species. For example, we have very limited knowledge on the quality and quantity of food or the habitat requirements most suitable for on-growing juveniles in culturing environments.

Recent research has shed some light on the fish host preference of glochidia (C. Hickey, pers comm., 2007). However, there are key gaps in our understanding of some aspects of preferred species, such as the koaro (see section below). Glochidia have been shown to parasitize other fish species in the laboratory, albeit at lower infestation rates, and we are unable to predict the long term consequences of a loss of the preferred fish host on viability of juveniles or sustainability of adult populations.

The potential for biomanipulation and subsequent improvement of water quality using kakahi has been recognised (Ogilvie and Mitchell, 1995; White 2000). A recent report addressed the potential for their use for this purpose in the Te Arawa lakes (Phillips, 2007). Their use in biomanipulation, however, is limited to either the translocation of large numbers of adults or the culturing of juveniles.

Macrophyte beds are a significant and growing component of Te Arawa lake ecology. Overseas studies show that macrophytes can detrimentally affect adult kakahi but out-competing for lake bed habitat, interfering with food delivery, causing nocturnal dissolved

oxygen depletion and inducing high diurnal pH and modifying sediments within and adjacent to the macrophyte bed (Burlakova and Karatayev, 2007). These relationships have not been investigated for kakahi.

As for koura, we know nothing of the effects of cyanobacteria on kakahi, which are known to accumulate microcystin.

Finally, the effects of Chironomid infestation on the long term viability of kakahi populations is unknown. While it is known that this organism causes no harm to the adult kakahi, we do not know whether sub-lethal effects, such as reduced overall condition, result from infestation. Research to address some aspects of this question is currently underway.

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