NIWA
Taihoro Nukurangi

FRESHWATER BIOREMEDIATION USING KĀKAHI

Guidance on the stocking of kākahi in rafts for bioremediation of freshwater environments

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We recognise that whānau and hapū across Aotearoa have an extensive range of names for their freshwater taonga species. In this resource we have drawn on the most commonly used names, but please check with your local hapū for the te reo that is relevant to your area.

Why kākahi for freshwater bioremediation?

Freshwater mussels (known as kākahi, kaaeo or torewai) throughout much of Aotearoa are considered a taonga species. They were an important mahinga/hauaanga kai resource – and are still collected today. They feed by filtering large quantities of water at an approximate rate of 1.5 litres per mussel per hour.

There are indications that populations are declining in many streams and lakes (including Lake Ohinewai) – they are however, thriving in other locations (e.g., Lakes Karaapiro and Taupō).

Meanwhile many shallow lakes, especially in the Waikato are severely degraded because of factors such as increasing nutrient inputs. The lakes have "flipped" into a state, characterised by algal blooms, where rooted aquatic plants can no longer survive. The lake sediments are no longer held in place by the aquatic plants and so the lake waters remain permanently muddy (or turbid) – and this is made worse by the presence of pest fish species like koi carp and catfish.

Our project was inspired by the observation of abundant kākahi populations in small shallow lakes with excellent water quality. This observation made us wonder if freshwater mussels could be part of the restoration process.

What are kākahi and where are they found?

Kākahi are native species of freshwater mussels found in Aotearoa.

Three species of freshwater mussels have been identified in Aotearoa (*Echyridella menziesii, Echyridella onekaka and Echyridella aucklandica*).

Kākahi live in freshwater environments ranging from small fast-flowing streams to large lakes. They are long-lived, with one species (*E. menziesii*), estimated to live on average between 12-30 years, but can live as long as 50-60 years. Kākahi use their foot to move around and burrow into sediment. Unlike adult marine mussels, kākahi do not produce byssal threads (or a 'beard') to attach themselves to rocks.

What makes kākahi unique?

- Kākahi are long-lived.
- Kākahi can use their foot to move around and burrow into sediment. In Rotorua they have been nicknamed carvers of the lake bed, due to the beautiful patterns they make (see above image).
- Kākahi larvae (glochidia) parasitise on fish as part of their lifecycle. (see lifecycle on page 14)

Echyridella menziesii

The most common species, found all over New Zealand.

- **At risk, declining status**

Echyridella aucklandica

An uncommon species found in the North Island from Waikato northwards and in isolated pockets of the lower North and the South Island.

- **Threatened, nationally vulnerable status**

Echyridella onekaka

A very rare species found only in the northwest of South Island.

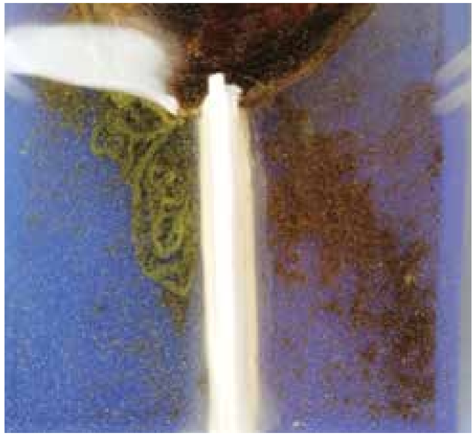
- **Data deficient**

Locations based on Te Papa records.

Why are kākahi important?

Kākahi are a bioindicator in freshwater environments and are important for the water quality of freshwaters.

Kākahi are filter feeders. They feed on algae, zooplankton and other micro-organisms in the water. They also feed on sediment particles covered in bacteria. To filter-feed they draw water into their shells (through their inhalant siphon) and small particles are collected on their gills. This process produces a current which circulates across their gills and out the exhalant siphon.



Pseudofaeces (left) and faeces (right).

Faeces and pseudofaeces

Waste products, called faeces and pseudofaeces, are deposited by kākahi. Filtered, but not ingested material is rejected as pseudofaeces, waste produced after food passes through the digestive tract is faeces.

How much water do kākahi filter?

Kākahi feed by filtering large quantities of water at an approximate rate of one and a half litres per mussel per hour. However, this rate is highly variable depending on the environment the kākahi are living in.

How do environmental conditions influence filtration and waste production rates?

Laboratory trials showed that increasing the concentration of total suspended sediment (TSS), algae or cyanobacteria decreased the particle clearance rate and increased the proportion of pseudofaeces to faeces:

- Adult kākahi cleared approximately 1.5 litres per hours at 10 mg/L TSS or 12.5 ug/L chlorophyll *a* (chl*a*). This rate more than halved at 22 mg/L TSS or 25 ug/L chl*a* (algae) and at 100mg/L TSS or 50 ug/L chl*a* the particle clearance rate was as low as 0.25 L/kākahi/hour
- Clearance rates of different cyanobacteria concentrations, ranging from 1-8 ug/L chl*a* phycocyanin, were all less than 0.5 L/kākahi/hour
- There was no detectable pseudofaeces production at 4.6mg/L TSS or 12.5 ug/L chl*a* (algae) or at cyanobacteria concentrations ranging from 1-10 ug/L chl*a* (phycocyanin). However, at 10 and 46 mg/L TSS there was almost two times and 10 times more pseudofaeces than faeces, respectively.

Lab-based studies with kākahi examine their filtration rates, faeces and pseudofaeces production under different loads (concentrations) of suspended sediment. In the bottom photo you can see the faeces (end compartment) and the pseudofaeces beside the mussel.

These results indicate that high total suspended sediment, or cyanobacteria concentrations cause kākahi to become inefficient and use energy to process particles that they are getting no nutritional value from.

Can kākahi be used to clean-up freshwater?

Can the filter feeding of kākahi, stocked on rafts, be used to assist the return of degraded, turbid shallow lakes towards a clearer water/healthier condition?

Why use rafts?

Placing adult kākahi in rafts moves them from the low oxygen (hypoxic) lakebed and may extend their survival and filtering efficiency, in a degraded lake environment. In the future we could stock rafts with thousands of young, farmed mussels bred from surviving resident mussels to promote lake restoration.

Design considerations

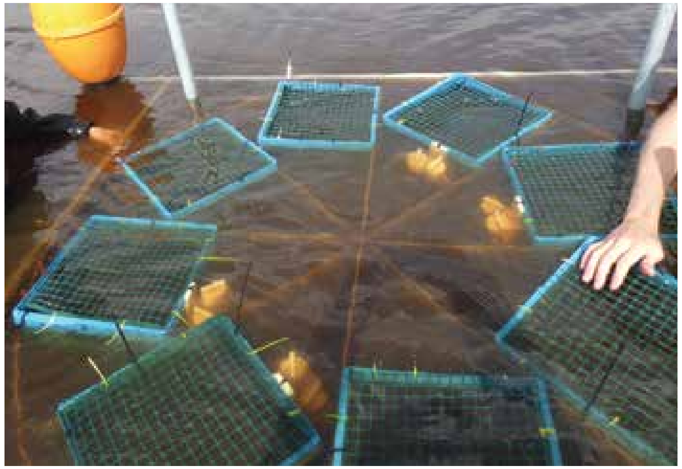
Design constraints include raft transportability and durability, adequate water movement for food supply for the kākahi and mitigation of potential exposure to extreme temperature or low dissolved oxygen events.

Three designs, with two types of baskets/cages were evaluated. All rafts were designed to raise and lower the kākahi with water level changes/fluctuations.

Rafts one and two were circular with offset baskets to maximise water exchange, but only raft two rotated with water/wind movement.

Raft three was a series of baskets in parallel. Half the baskets had a layer of lake sediment and half had none.

The people of Matahuru Marae supported this project at Lake Ohinewai and were involved in providing advice about the lake, surveys, monitoring and raft deployment. They also inspired this project with their long-held desire to reintroduce kākahi to Lake Waikare, and their early work on kākahi culture.



Baskets prepared ready for kākahi (top), circular raft installed (middle) and parallel raft before installation (bottom). Mesh lids were secured in place to restrict access by potential predators.

Kākahi lifecycle

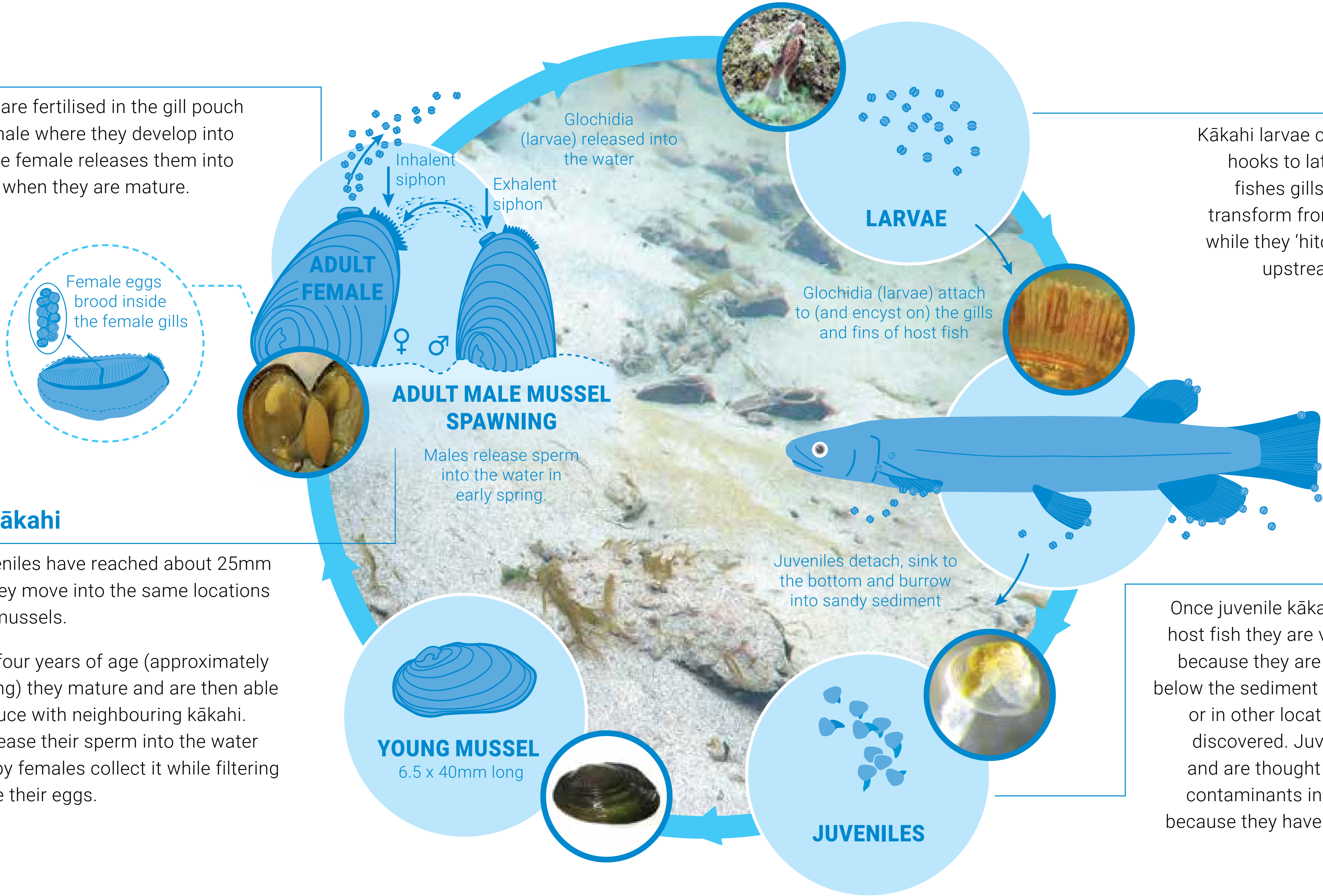
Kākahi depend on native fish, because for part of their unusual lifecycle they become fish parasites by attaching themselves to the gills or fins of the host fish.

Eggs

The eggs are fertilised in the gill pouch of the female where they develop into larvae. The female releases them into the water when they are mature.

Larvae

Kākahi larvae called glochidia use hooks to latch on to a passing fishes gills or fins. There they transform from larvae to mussel while they 'hitch a ride', hopefully upstream to good habitat.



Adult kākahi

Once juveniles have reached about 25mm length, they move into the same locations as adult mussels.

At about four years of age (approximately 40mm long) they mature and are then able to reproduce with neighbouring kākahi. Males release their sperm into the water and nearby females collect it while filtering to fertilise their eggs.

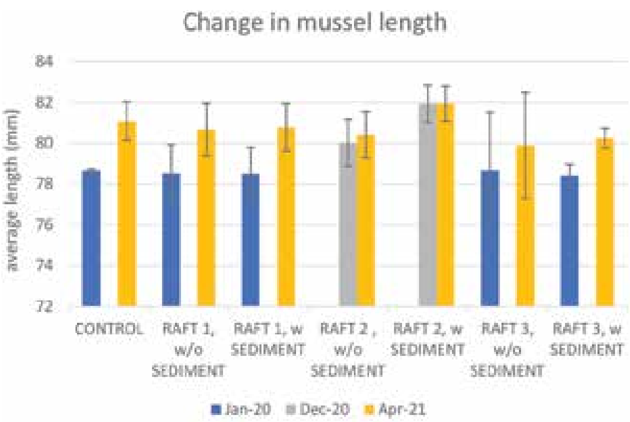
Juveniles

Once juvenile kākahi detach from the host fish they are very difficult to find because they are very small and live below the sediment surface in streams or in other locations we haven't yet discovered. Juveniles grow rapidly and are thought to be vulnerable to contaminants in the water possibly because they have a different feeding mode to adults.

Can kākahi survive on rafts?

In very challenging environmental conditions kākahi survival rates were high (97%) and did not differ between raft or basket type, and reference sites on the bottom of the lake over the study period (15 months). However, there were some indications (worn shells) that longer periods may lead to shell damage if there is insufficient protection for kākahi from damage on hard surfaces (e.g., plastic edges). Protection of kākahi on the rafts, in the form of adding lake-sediment, hessian matting or felting, or less exposed raft sites requires consideration for long term deployment.

What about the growth response?



The experimental rafts contained 12 mussels in each basket (approximately 0.1 m^2), with up to eight baskets per raft. Our data show kākahi on all three rafts were growing, as evidenced by their increase in length.

Now that we know mussels survive and grow on the rafts, raft design and stocking rates could easily be improved.

How many kākahi are needed to influence water quality?

Experimental and environmental data was used to run model simulations. The Aquatic Ecosystems Model (AEM3D) is a 3-D hydrodynamic and thermodynamic model simulating velocity, salinity and temperature in waterbodies. AEM3D was coupled to CAEDYM (computational aquatic ecosystem dynamics model) for the purpose of resolving horizontal distributions of biological and chemical variables (including mussels).

Model simulations of varying densities of kākahi had a large impact on lake water quality, generally reducing nutrient concentrations and chlorophyll a. The largest impacts were simulated with mussel density greater than 40 individuals per square metre.

In contrast, kākahi were only found in one area of Lake Ohinewai and there were less than two kākahi per square metre.

Kākahi were tagged, so they could be identified for monitoring.

What did the lakeside studies show?

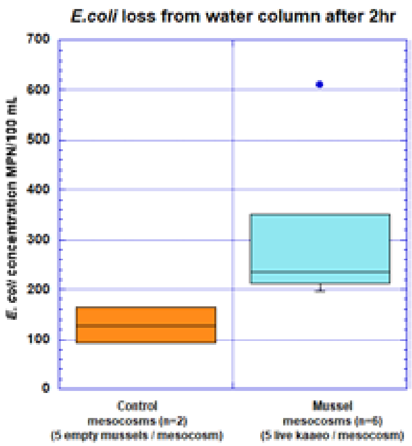
Lakeside studies at Ohinewai found that kākahi can measurably reduce levels of *Escherichia coli* (the indicator bacteria for faecal microbial contamination of freshwaters) from lake water.

The capacity of kākahi to clear lake water of *E. coli* varied between mussels ranging from 500 to 24,000 *E. coli* bacteria removed from the water per hour by each mussel.

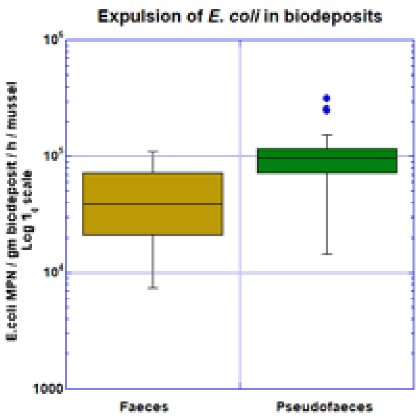
Significant bioaccumulation of *E. coli* was found in biodeposits (faeces and pseudofaeces) due to kākahi filtration activities. Most of the *E. coli* were ejected in pseudofaeces indicating substantial removal of the bacteria from lake water was due to flocculation of *E. coli* bound in mucus.

Additionally, chlorophyll *a* (a measure of phytoplankton biomass), and suspended sediment are also reduced by kākahi. Rates of chlorophyll *a* (chl*a*) and suspended sediment (SS) removal were approximately 6 µg of chl*a*/mussel/hr and 6 mg of SS/mussel/hr.

Although kākahi filter feeding activities can be highly variable, water processing by kākahi can play a significant role in clearing lake water of particulate contaminants and improving water quality.



E. coli loss from the water column after two hours with live kāhahi was at least double that of the control (empty shells).



Significant bioaccumulation of E. coli was found in biodeposits (faeces and pseudofaeces) due to kāhahi filtration activities. Most of the E. coli were ejected in pseudofaeces.

Recirculating flow-through experimental system for testing kākahi clearance of E. coli bacteria from lake water.

Where can kākahi be sourced or collected?

Permission must be obtained for collecting or transferring aquatic life. Check the DOC and MPI websites for regulations.

Kākahi may appear abundant in some places, but many populations are also declining and no juvenile or young kākahi are present. Of the three recognised species, all have threat classifications, with *E. menziesii* 'At risk – declining' and *E. aucklandica* 'threatened – nationally vulnerable', while *E. onekaka* is considered 'data deficient' and is likely to be the most threatened of the three species.

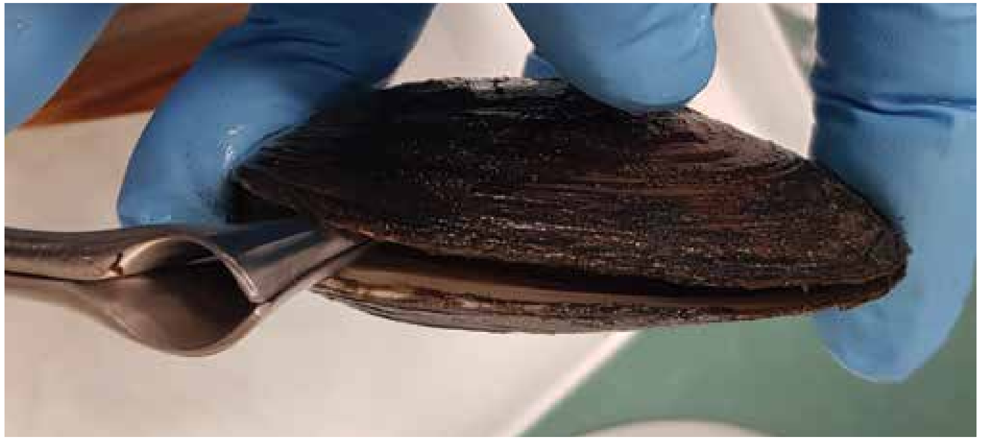
The relatedness, or genetic structure of populations, is important for conservation and should be understood before considering if kākahi could (from a genetic perspective) be moved from one location to another.

During this project sampling was undertaken to understand how populations of kākahi (*E. menziesii*) are genetically related to one another.

A method was developed to take swabs (mucus) from the inside of kākahi that is not harmful to the animals. These swabs were used for the genetic analyses. Results show highly differentiated populations, with low gene flow between catchments.

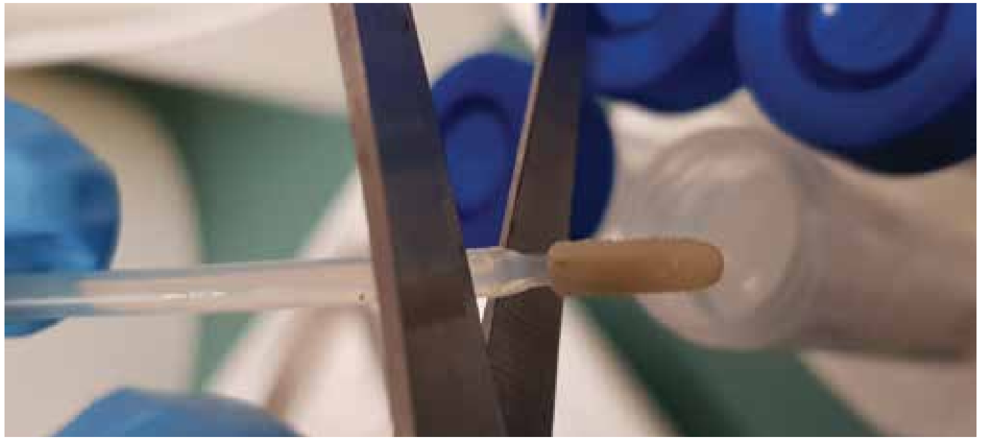
Waikato populations have a high number of private haplotypes and a high level of diversity compared to the rest of Aotearoa.

The results mean that decisions to move kākahi for restoration should carefully consider the potential genetic implications of translocation.

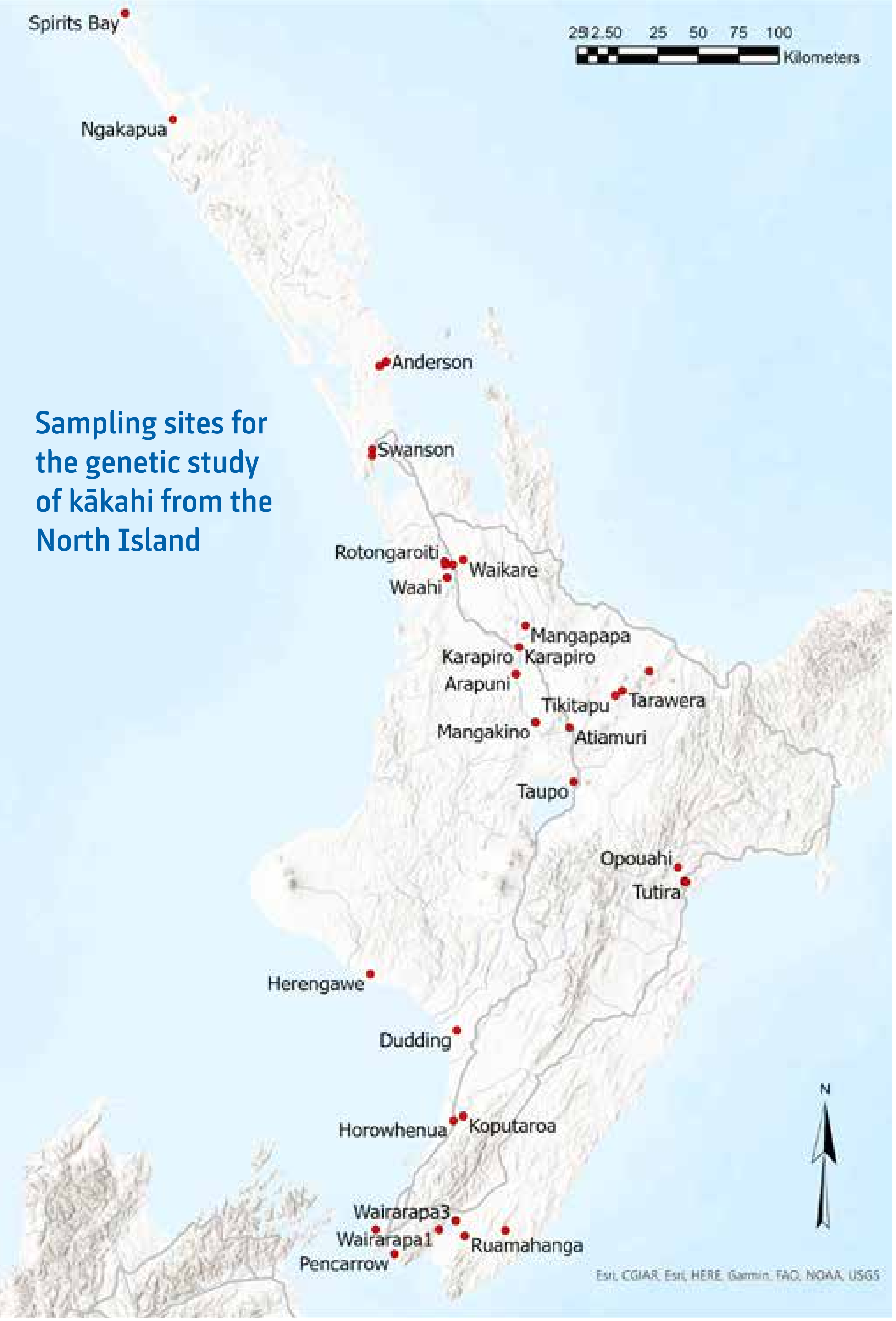


Gently opening the kākahi.

Taking a swab sample.



Cutting the end off the sampler and putting it into a labelled tube, for genetic analyses.



Sampling sites for the genetic study of kākahi from the North Island

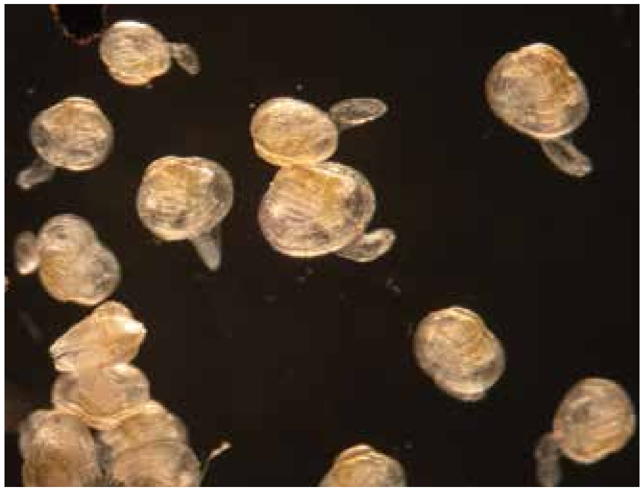
Can kākahi be grown in the laboratory for use on rafts?

Because some kākahi populations are only comprised of older animals, with no evidence of juveniles, or young kākahi, research also focussed on producing and growing juveniles in the lab.

Culturing kākahi in the lab is not a simple process, because the kākahi life cycle requires a fish host, for its larvae to transform into a juvenile mussel. (see life cycle diagram page 14)

With a combination of initial laboratory culture and moving the juvenile kākahi to outside tanks when they were still very small, juvenile kākahi have been reared to seven months of age (640 μm in size).

Laboratory grown kākahi bred from remnant lake populations could potentially be used to stock rafts in the future.



These kākahi juveniles are still growing. After seven months, 44% of juveniles have survived in a laboratory.

What needs to be considered?

Kākahi in large numbers have a positive influence on water quality and on local biodiversity.

Before collecting or moving kākahi, or installing rafts, check with local authorities including iwi, to ensure that the necessary permissions are in place.

Longer term deployments should include careful consideration of raft design and site for water movement, and the need for protective materials to ensure that shells are not damaged.

Protection from predators when on the rafts requires consideration. For example, rats have been known to consume kākahi from lake beds.

It is important to regularly check and maintain cages/rafts to ensure that predators are restricted, and the kākahi are thriving.

✓	CONSIDERATION
	Have the project goals been identified?
	Have all interested parties been identified?
	Are kākahi present in the waterbody, and if not what local populations exist?
	Has the feasibility of translocation been considered?
	Are there suitable sites to secure or anchor rafts on the waterbody?
	Have all necessary permissions been obtained?

Acknowledgments

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