Biosecurity New Zealand
Tiakitanga Pūtaiao Aotearoa

Technical Advisory Group Report

Biosecurity Response to *Corbicula fluminea* in the Waikato River

Biosecurity New Zealand Discussion Paper

Prepared for Biosecurity New Zealand
By Technical workstream *Corbicula* response

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1 Executive Summary

During five Technical Advisory Group (TAG) meetings on different topics, several important themes were evident regardless of the topic of the meeting.

- *Corbicula* has never been successfully eradicated elsewhere in its invaded range. It is extremely unlikely that it is eradicable in the Waikato Catchment, however there are some options that could be effective in containing and suppressing *Corbicula* populations to keep long term eradication on the table.
- This could involve enforced movement controls to aimed at containing *Corbicula* within its current distribution – encouraging best biosecurity practices, especially Check, Clean, Dry messaging.
- Testing combinations of established tools to understand synergistic effects in a structured manner is strongly recommended. Investigation of new tools for control of *Corbicula* in the known infested area of the Waikato River is also important.
- Any action taken to reduce *Corbicula* abundance will reduce populations and decrease propagule pressure, lowering the likelihood of spread outside of the Waikato.
- New surveillance tools should be developed and trialled to maintain wide ranging surveillance (across space and time), to detect any new populations early enough to attempt site-specific elimination immediately upon discovery. Environmental DNA (eDNA) is likely an important tool.
- A different suite of tools is available for managing impacts in an enclosed infrastructure environment.
- It is important for facilities and companies to start developing their own context-specific Standard Operating Procedures (SOPs) to mitigate potential impacts of *Corbicula*. Infrastructure assessment should evaluate whether any retrofitting of equipment is required. So far impacts on infrastructure are not significant but being prepared will help reduce any worse future impacts that may result if the population of *Corbicula* grows, and further range expansion occurs.
- Messaging to the public and industry regarding actions and behaviours that reduce the likelihood of *Corbicula* spread is very important as part of a long-term management strategy.
- Supporting kaitiaki, water sports clubs, anglers and other user groups to encourage and promote good biosecurity behaviour, and to develop specific messaging is a powerful approach.
- There are tools and treatments available to maintain culturally significant practices such as elver transfers in a biosecure manner, but these should be tested before the next transfer event.
- Translocating kākahi or other vulnerable native species (“arking” them) into long term quarantine or away from *Corbicula* invaded areas should be considered on a case-by-case basis. In the early stages of *Corbicula* suppression there are likely to be interim measures that are less complex (*e.g.* identifying suitable destination sites and shifting kākahi downstream from control areas). In the interim, developing methods and SOPs to clean and/or purge them of *Corbicula* can be worked on if research demonstrates purging is necessary.

2 Background to the Biosecurity Response

Initial events leading to the response being activated

0n 01 May 2023, BNZ was notified of the potential presence of *Corbicula fluminea* (hereafter referred to as *Corbicula*) in the Waikato River at Bob's Landing. The notification came from two researchers undertaking ecology field work in the area on 19th April 2023, where they found 10 empty shells. They shared images of the findings with two other scientists who suggested the shells may be from be one of two invasive species within the *Corbicula* genus.

On 2 May 2023, one of the researchers visited Bob's Landing again and collected live samples. This indicated a potential breeding population. On the 5th of May 2023, the species was confirmed as a species form the genus *Corbicula*. As the taxonomy of *Corbicula* is unresolved and following overseas convention and the fact that no other species in this genus is established in New Zealand it was agreed to name this species *Corbicula fluminea*.

Corbicula has a high reproductive potential, and a single individual can produce 400 juveniles a day under favourable conditions, with greater than 70,000 juveniles being produced per annum. The presence of the species could have significant potential impacts on the native ecosystem within the Waikato River and Lake Taupo, as well as further in Aotearoa New Zealand if it spreads.

Organisms in the *Corbicula* genus are known to cause serious issues for human activities, including blockage of water channels, factory infrastructure, irrigation pipes, storm water infrastructure, water treatment facilities and power stations.

The Waikato River is 452km long and includes Lake Taupo, a 616 km² waterbody. This is a substantial area of potential habitat suitable for *Corbicula* to establish.

The Waikato River has eight hydro dams along its length with numerous major water extractors and there is a significant risk that heavy infestation of *Corbicula* in the Waikato River could disrupt these operations.

There are currently no known effective treatment tools available to eradicate *Corbicula* populations, although there are population suppression tools available. Any suppression tool used to detrimentally impact *Corbicula* will also likely detrimentally impact native fauna in the Waikato.

See the Rapid Risk Assessment for further information.

3 Purpose of the Technical Advisory Group

Biosecurity New Zealand (BNZ) convened a Technical Advisory Group (TAG) made up of national and international scientists with extensive experience specifically in freshwater invasion ecology, mollusc control and specific experience with *Corbicula.* In addition, representatives from the iwi groups in the Waikato region were invited to share their important knowledge of place and perspectives.

The TAG was convened early in the biosecurity response before specific questions were identified for the TAG to answer. As such, a small Pre-TAG meeting was held with three local scientists to determine key issues that could be addressed by a TAG.

Based on information from this Pre-TAG, concerns expressed by iwi or stakeholders and work happening within the biosecurity response, five broad topics were identified as TAG meeting subjects. Due to the large membership of the TAG, not all participants attended all of the five meetings.

3.1 TAG membership

Complete TAG membership was the list of people as shown below, of which a subset was present at each meeting.

Name	Organisation	Area of expertise
Tracey Burton	Land Information New Zealand	Freshwater ecology
Adam Daniel	Fish and Game New Zealand	Freshwater ecology, Fish & Game Freshwater Invasive Species Coordinator
Sue Clearwater	Department of Conservation	Aquatic Toxicology, Freshwater ecology
Ian Duggan	University of Waikato	Biological invasion vectors and pathways
Calum MacNeil	Cawthron Institute	Freshwater and invasion ecology, environmental protection
Jaimie Dick	Queen's University Belfast	*Corbicula* management, invasion ecology, impacts of invasive species
Neil E. Coughlan	University College Cork	*Corbicula* management, freshwater ecology and control of invasive aquatic organisms
Mark Fenwick	National Institute of Water and Atmospheric Research	Freshwater and marine biology, ecology and genetics, kākahi taxonomics Mātauranga at place
Deborah Hofstra	National Institute of Water and Atmospheric Research	Freshwater biology, ecology and biosecurity
Frances Lucy	Atlantic Institute of Technology - Sligo	Aquatic Invasive Species, Fisheries Science and water quality

3.2 TAG subjects

3.2.1 Pre-TAG meeting

The main objective of this meeting was to understand how to best make use of a broad forum of experts to gain valuable information for the *Corbicula* response.

It was thought that learning from the experience of experts in a country where a *Corbicula* incursion had occurred to understand their "lessons learned" - and based on this, what the key messages would be to Aotearoa New Zealand regarding what should be done (or not), how to do it and how best to approach an incursion of *Corbicula fluminea*.

Other key discussion points from the pre-TAG were;

- The consensus was that it is highly unlikely that *Corbicula* will be eradicated from the Waikato River system, and containment would be a difficult but worthwhile. However, site-specific elimination of new populations may be possible if detected early enough. Therefore, site-specific elimination and catchment-level suppression could be a long-term goal.
- Tools and treatments that currently exist for controlling *Corbicula* are non-specific and likely to have significant impacts on non-target species. However, some tools and treatments are worth considering but require testing and further development in Aotearoa New Zealand. The consensus opinion was that visual surveillance was the most effective tool for detection of *Corbicula* for delimiting its distribution, although it was acknowledged that there is a possibility of missing populations given the narrow depth profile that it is possible to cover (currently wadable depths). Similarly, eDNA was discussed as a tool that needs development and validation work before becoming an effective surveillance tool.
- Delimiting existing populations and ongoing surveillance in other unconnected freshwater bodies is important, to 1) understand the species distribution and 2) to ensure early detection of any newly established populations.
- Actions to ensure preservation of taonga species could be necessary. *Corbicula* is a highly effective ecosystem engineer and the ecological niche it will occupy in Aotearoa New Zealand may have less interspecific competition from native species than in other invaded regions overseas, therefore the impacts on native species may be greater than in other invaded regions.

3.2.2 TAG #1 – International experience

Key Questions;

- What was the experience in your country with a *Corbicula* incursion?
- What actions were taken, and did they work?
- Knowing what you do now, what would you have done differently?
- How does the Aotearoa New Zealand situation resemble something you are familiar with?
- What could you recommend that could help us prepare to deal with the *Corbicula* incursion?

Desired outcome: An understanding of international experiences with *Corbicula*, and what would be the best course of action, based on historic examples from other invaded countries, for us to take.

3.2.3 TAG #2 – Tools and treatments

Key Questions;

- Which tools have been proven to work for what?
    - Costs and benefits of these tools.
- Which tools or treatments need field testing?
- Which tools should we try and employ now, in which environments?
- How to work within the Waikato catchment?
- Should surveillance include a "search and destroy" effort?
- How geographically wide should surveillance go?
- What may be trigger or decision points to move from eradication/elimination to containment?

Desired outcome: A plan for which tools, or combination thereof, to apply to specific areas in the Waikato River where *Corbicula* has been detected, for control and future surveillance.

3.2.4 TAG #3 - Infrastructure Impacts and Solutions

Key Questions;

- What are types of infrastructure that are most likely to be impacted? Do we have analogous systems in Aotearoa New Zealand?
- What are the biggest impacts?

    - How can these be mitigated?
- Within systems – what are the risk areas to target for treatments?
- Treatment options?
    - Are there any easy fixes?
    - Short term versus Long term fixes?

Desired outcome: Identification of the most practical, effective treatments and controls for different types of infrastructure.

3.2.5 TAG #4 – Check, Clean, Dry and behaviour change

Key Questions;

- What was effective or not effective in social behaviour campaigns overseas?
- How do we find balance between enforcement and voluntary actions?
- How can we prevent people from suffering "cleaning fatigue"?
- Have we identified all the different users and target audiences?
- Where and how to get the key messages across in the best, most effective way?
- What are the most practical and easy to use, but effective treatments to recommend to the public?

Desired outcome: Identification of the core messages and management of the social behaviour change programme to get the most value out of it.

3.2.6 TAG #5 - Translocations

Key Questions;

- Understanding risks and benefits of translocations for:
    - Elvers
    - Taonga species, using kākahi as an example
- In terms of:
    - Biosecurity risks of transfers happening versus not happening (baseline scenario)
    - Implications on population genetics
    - Protection of the species to ensure long-term survival

Desired outcome: Understanding how to support the continuation of culturally significant practices (such as the transfer of elvers) whilst mitigating the risks of spreading *Corbicula*. Collate ideas and expert thoughts on the critical factors from biological, ecological, and cultural perspectives on the translocation of native species that may be threatened by *Corbicula*.

4 International experience

4.1 *Corbicula* life history and the environment

It was noted by scientists who have worked both in Aotearoa New Zealand and other countries where *Corbicula* has invaded, that freshwater macroinvertebrate diversity here is lower. This may result in increased ecological impacts here than overseas due to less competition with and predation of *Corbicula.*

To be able to understand likely spread patterns of *Corbicula*, understanding the substrate preferences locally is important. *Corbicula* prefers sand and gravelly substrates, but dense populations have also been recorded on hard substrates, including concrete and man-made structures especially in high oxygen environments and fast flowing water (Lucy *et al*., 2012; Kelley *et al.,* 2022; Robb-Chavez *et al.,* 2023).

The Waikato River is a very altered and anthropogenically modified river system and is far from uniform and consists of a series of reservoir lakes with river sections connecting them. All possible substrates (*e.g.* mud, silt, degraded habitats all the way through to gravel and rocks) can be found in varying parts of the rivers (Gibbs *et al.,* 2023). Silt can be up to 40cm deep in places.

Floodplains with complex wetlands also exist in the lower Waikato. Wetlands could be an area where it is difficult to detect, eradicate or manage *Corbicula*. If they are found there, it would be important to prevent large populations building up in these wetland areas. Habitat mapping and hydrodynamic modelling of the Waikato will be important to help identify sites to survey and understand invasion patterns, especially for juveniles.

In invaded areas (where asexual reproduction is more commonly observed) there is no strict delineation between juvenile and adult *Corbicula* (Gomes *et al.,* 2016). *Corbicula* juveniles are effectively fully formed individuals that are 0.25 mm across and connected to a mucilaginous byssal thread that enhances their ability to drift in fast moving or turbulent water, as well as allowing them to adhere to substrate or material that can aid its spread (*e.g.,* aquatic vegetation; Minchin & Boelens, 2018).

The Waikato River includes geothermal habitats. In Ireland and the Netherlands and other countries correlations were seen between higher temperatures and increased *Corbicula* abundance (*e.g.* thermal discharges from power stations with warmer temperatures have increased *Corbicula* density compared to the surrounding areas; Minchin, 2014; Morgan *et al.,* 2004; Bespalaya, 2021). This is likely due to increased temperatures accelerating growth rates and increasing food availability. Temperatures range from 9-25^{o}C in the Waikato River (NZ EPA Report), and it does not freeze in winter, which is important to note as freezing has assisted some eradication attempts overseas in lake environments (Ruggles *et al.,* 2023).

Low temperatures will not prevent the establishment of juveniles or adults but may affect long-term reproductive success (Sousa *et al.,* 2008). It is likely seasonal temperature fluctuations relate to the number of reproductive events *Corbicula* undergoes annually in the Waikato River, as *Corbicula* requires water temperatures above 15 ^{o}C for reproduction (Modesto *et al.,* 2023). *Corbicula* is very tolerant of gradual temperature changes, between almost freezing and up to 36 ^{o}C, which is why sudden thermal shock is required to negatively impact them (Coughlan *et al.,* 2018; Coughlan *et al.,* 2019a; Coughlan *et al.,* 2019b; Coughlan *et al.,* 2021). Under favourable conditions, *Corbicula* can begin reproducing while still quite small (6-10 mm) and relatively young (3-6 months post-release from the parent) (Modesto *et al.,* 2023).

Lake depths also vary (up to 34 m in lake Karāpiro). Limited reports suggest that *Corbicula* can survive at depths greater than 100 m, however its favourable environment is more likely in shallower areas (Paschoal *et al.,* 2013). It points to a further need to delimit the depths to which *Corbicula* can be found in the Waikato River.

Natural vectors of spread do exist, especially for transference upstream such as waterfowl or gut passage through fish (Coughlan *et al.,* 2017). Newly emerged juveniles can readily adhere to potential vectors, substrate, or sediment with a single mucus byssal thread (Modesto *et al.,* 2023). Adults will only manage to temporarily adhere to surfaces if they manage to grip with their closed shell (e.g., clams will grip fishing nets), but this form of adherence only lasts while the clam maintains remains closed on the item caught between its shell. It should be noted that such “natural” spread is a minor contributor to *Corbicula* spread compared to human-mediated spread (Coughlan *et al.,* 2017).

There is no experience in Ireland of the effect of macrophyte beds in supporting *Corbicula* populations or enabling its spread. There are large, deep macrophyte beds in Lake Karāpiro, but it is uncertain what this might mean for the *Corbicula* population in the lake. If *Corbicula* can cling to aquatic plants this provides a pathway for spread. If aquatic plan fragments (with juvenile *Corbicula* stuck to it) attach to boats (*e.g.* ropes, anchors, propellers, etc) and isn't cleaned off, it may facilitate transport to other water systems. Juveniles are more likely to float than adults, especially in the weeks following their release after being brooded within the parent (Sousa *et al.,* 2008).

Small adults (7-14 mm) can use water pumping and mucus float lines to float downstream (Prezant & Charlemwat 1984). This behaviour can occur in response to water currents. In some locations they have been shown to move seasonally prior to the reproductive season (Williams & McMahon 1989). *Corbicula* are more likely to drag themselves along the substrate (Labaut *et al.,* 2021). River currents would be a greater factor impeding upstream dispersal, especially moving against anything stronger than low flows. It is thought that any natural upstream spread will be quite slow (possibly up to 1 meter per year by self-propulsion) and most upstream spread will be via anthropogenic activity (Voeltz *et al.,* 1998; Pereira *et al.,* 2017). Although boats and human-mediated movement are the most well-known anthropogenic pathways, sand and gravel extraction for industrial purposes and its movement can also be a big spread risk, as are irrigation tankers (Britton *et al.,* 2023). *Corbicula* adults can survive more than 30 days out of water if kept damp (Guareschi & Wood, 2020).

Corbicula may promote mass kākahi die-offs (through multiple avenues including competition for resources, higher filtering capacity and competition for substrate), possibly setting up a positive feed-back loop that results in making conditions more conducive to further *Corbicula* spread (Mouthon & Daufresne 2010; Labaut *et al.,* 2021). *Corbicula* have a rapid growth and reproduction rates, and quickly recolonise disturbed areas. In contrast kākahi, like native freshwater mussels (unionids) overseas have slow growth and reproduction. Thus, if *Corbicula* invades their biological niche and slowly reduces the kākahi biomass, it may further impact the ability of kākahi to survive any potential interventions taken to reduce *Corbicula* populations, as well as natural habitat variability and climate change.

4.2 Introduction pathways

In Ireland, the initial introduction of *Corbicula* was thought to have been deliberate for use as a food resource with subsequent spread likely being natural or accidental (via boats, fishermen (gear or live bait) or other human activity) (Caffrey *et al.,* 2016). Other invasive species, such as the zebra mussel (*Dreissena polymorpha*), have arrived in Ireland and Northern Ireland (either on the outside or via ballast water). For the incursion in Aotearoa New Zealand we as yet do not know the pathway of entry, however possible avenues are via internal ballast water in boats or the online trade of aquarium animals.

4.3 Actions taken

In the Irish experience, relatively little action was taken in “wild” open water systems (Sheehan *et al.,* 2014). The extent of the incursion was delimited for each river system affected following initial detection, and some local level movement restrictions were put in place. However, the impression was that as there was no mechanism of enforcing any restriction, they were largely ineffective. Of note, for one river that was resurveyed years later failed to detect *Corbicula*. The (unproven) hypothesis was that local flooding caused blackwater events and the subsequent anoxic conditions severely impacted the *Corbicula* population within the river.

Based on international experience, many of the group expressed that eradicating *Corbicula* from the Waikato River would be almost impossible based on the effectiveness of available eradication techniques. Containing *Corbicula* effectively within the Waikato catchment (in the areas where it is already established), to keep eradication (even in the long term) on the table was considered very important. It is also important to be clear in understanding the difference is between containment, local elimination and eradication. The consensus was that the elimination of any *Corbicula* populations detected outside the current known infested areas if they are detected early and not well established may be possible. This will require continuous surveillance across space and time to ensure any new *Corbicula* population is detected as early as possible to ensure the best chance of eliminating it.
Due to the non-specific nature of the control tools available, any actions taken will have impacts to the ecosystem and other non-target species that will need to be considered (Modesto *et al.,* 2023).

The necessity of rapid decision-making and action was considered imperative when dealing with this invader by the group. New decisions and new actions may be necessary as the situation evolves. The example used was the experience from *Didymo,* where without effective action it spread rapidly throughout the South Island. *Corbicula* has the potential to spread more widely given its biology, and much of Aotearoa New Zealand is considered suitable habitat based on climatic modelling (Torres *et al.,* 2018).

4.3.1 Cost Benefit Analysis (CBA)

In terms of decisions to be made on appropriate actions to take, it is important to take a long term, whole system view applied to the wider economy, environment and culture (an example was used of a €1 to €52 cost-benefit ratio from the InvaCost Global database) of the cost-benefit for eradicating invasive species when compared to the counterfactual or status quo scenario (doing nothing) (Haubrock *et al.,* 2021; Cuthbert *et al.,* 2022). The services of Ross Cuthbert at Queens University Belfast (r.cuthbert@qub.ac.uk), to set the scene for a CBA Invasion curve were recommended as a high cost of acting now may in the long term be a more economic option.

Potential CBA of any tools and/or interventions requires thinking about both a wider system view and a site-specific view (such as site-specific elimination, complete eradication from Aotearoa New Zealand or ongoing site-specific or wider control and population suppression). There is a need to consider timelines far beyond the immediate needs, impacts or costs. For example, what would the wider cost be to Aotearoa New Zealand in the long-term if no action is taken? Could it dwarf the costs of eradication attempts now? Any CBA must additionally include impacts on native species and impacts on traditional culture and way of life.

4.3.2 Research Gaps

The importance of identifying and addressing research gaps was highlighted, which would include the development of new tools and techniques for control and surveillance. This will aid early detection of new *Corbicula* populations, provide more options for management (suppression or local elimination) of any newly discovered populations, provide options to control the population more effectively in the Waikato River, and be of benefit to managing any other similar freshwater non-indigenous species in the future. Additionally, a better understanding of juvenile life stages was highlighted as a research gap, particularly what kills them effectively, and what is their survivorship time outside water.

5 Tools and treatments

5.1 Population control

Although recognised that eradication of *Corbicula* is unlikely in the Waikato River, there was a strongly expressed desire to act now - this would at least suppress the population. Any reduction in the *Corbicula* population will result in lowered propagule pressure (the number of juveniles in the waterway capable of spreading within the Waikato or further afield), thus reducing population spread and growth, as well as decreasing impacts on native biota and infrastructure (Sousa *et al.,* 2008; Ricciardi *et al.,* 2010).

Tools that currently exist to control or kill *Corbicula* are dependent on the habitat (depth, substrate, lotic/lentic, waterflow, etc), as well as the life stage of the organism. Chemicals (including molluscicides) are not as effective as physical removal given that *Corbicula* can close its valves and seal itself off, effectively avoiding exposure to externally applied chemicals (Coughlan *et al.,* 2019a). Additionally, when deployed in the environment, chemicals are rapidly diluted and result in off-target effects in the environment. Juveniles are more sensitive to chemical treatment, however the discussion clearly identified thermal treatments as the most effective way to kill *Corbicula* in the laboratory or in an isolated situation (infrastructure, boats, water sports or fishing gear). In an environmental or 'wilder' situation, benthic barriers were discussed as the most effective tool to suppress *Corbicula* populations, with the caveat that they also kill anything else under the barrier (Allen *et al.,* 2017).

The international TAG members had completed significant lab-based research on tools to kill *Corbicula*, but none were thought to be clear options for eradication on the scale that would need to be deployed in the Waikato River, but some could be useful for population suppression (Rosa *et al.,* 2015; Coughlan *et al.,* 2019a; Coughlan *et al.,* 2019b). It was suggested that in the local context, it would be worth field testing some of these tools and treatments (for example dry ice). There is an inherent difficulty in treating *Corbicula* in a 'wild' situation, as there is the ability for small juveniles to disperse during treatment or preparation for treatment, resulting in persistence of the population or spread downstream (Wittmann *et al.,* 2012). It was also noted that whilst a variety of tools had been tested separately, it would be worth understanding in the field how these may be applied synergistically (for example, adding dry ice below benthic barriers to increase initial kill and speed up anoxia). It was suggested that heavily infested and easily accessible parts of the Waikato River could be used to test treatments and combinations thereof.

The discussion of specific tools that could be useful for controlling or killing *Corbicula* populations covered the following points;

1. When *Corbicula* are fully exposed, then they can be killed with the direct application of thermal shock treatments such as with dry ice or direct exposure to flame (i.e., cold and hot temperature treatments, respectively). This is effective in killing but can be labour intensive and may be very difficult to scale up. The efficacy of dry ice and open flame is impacted by layering of other shellfish and certain substrates. It requires direct contact and may miss *Corbicula* buried in the substrate (which can be up to 15 cm). The substrate can be rotavated or ploughed to bring *Corbicula* to the surface, but there may be some risk associated with potential further spread by excessive disturbance (Coughlan *et al.,* 2018).

2. Hot water is a practical, simple version of temperature shock treatment to kill *Corbicula*. A minimum of a 5-minute immersion in >45 ºC water is needed to kill *Corbicula*. At >60 ºC the time comes down to a 1-minute immersion (Coughlan *et al.,* 2019a; Coughlan *et al.,* 2019b).

3. Benthic barriers were considered an effective tool to use. These can also be used in deeper waters and in faster flowing water if they either have valves are sufficiently weighted down and strong enough to cope with the build-up of anoxic gases that will occur as organisms die in the oxygen depleted environment beneath them. Benthic barriers will need to be made of a heavy rubber matting, so they are strong enough not to rip and are also impermeable. Gas permeable vs impermeable barriers were discussed, but to maximise efficacy impermeable barriers should be used. There was acknowledgement that there will be impacts on non-target species, but that the possibility of surveying the area and moving some native species (*e.g.* kākahi) from the area proposed to be covered is an option (Wittmann *et al.,* 2012; Allen *et al.,* 2017). Initial clam mortality rates are high (circa. 98-100%) within 1-2 months, but benthic barriers must be maintained for 3 months to increase the probability of achieving 100% mortality (Wittman et al 2012). At Lake Tahoe clam densities were 98% reduced after barrier removal and a year later remained >90% lower than in the control treatment, as did most other invertebrate species, aside from chironomid (midge) larvae which had increased (Wittman et al 2012).

4. Suction or mechanical dredging can be effective in shallow or deeper water and has had mixed success where used overseas. This is due to discontinuation (Ireland), and the ability of *Corbicula* to rapidly re-establish after suction dredging has occurred (USA). To provide sustained control (particularly where high concentrations are present), dredging needs to be repeated at any given site or combined with other control methods to maintain population suppression, but is an effective method to quickly reduce populations by 95% (Sheehan *et al.,* 2014). A plan to biosecurely dispose of all the *Corbicula* and material removed from the river is also required (Wittmann *et al.,* 2012; Sheehan *et al.,* 2014). Dredging could be useful in the Waikato context (e.g., at Lake Karāpiro) to markedly reduce populations thus reducing colonisation rates downstream and reducing the risk of transfer out of the Waikato. Lake Karāpiro is one of the most popular water sports venues in New Zealand and hosts national and international events. Follow-up with further dredging and control methods would be essential.

5. High-pressure water has been used on fish passages and weirs in canals in Europe, as well as on screens and intakes of plants to clear *Corbicula*. In some examples, this was used in conjunction with steam to kill *Corbicula* (high-pressure water will remove, but not kill *Corbicula*).

6. In some cases, chemical control and water blasting in enclosed localised industrial environments have been effective to remove *Corbicula.* Again, water-blasted *Corbicula* are not dead and their biosecure discharge and/or disposal must be planned for (Sheehan *et al.,* 2014).

7. High pressure steam is effective for localised treatments, especially in contained places such as power plants and other infrastructure. It is often used on an annual basis to decontaminate closed settings (*e.g*. industrial pipes) (Coughlan *et al.,* 2020; Coughlan *et al.,* 2021).

For points 5, 6 and 7 these are methods that will need repeating as *Corbicula* populations are likely to build up again over time as they re-colonise these environments if steps to retrofit infrastructure with fine screens or sand filters at water intakes are not taken.

8. Reducing the pH might be effective, but as with any chemical treatment the difficulty is effectively exposing *Corbicula* as, like most bivalves, they can close their shells for extended periods. The lowest observed pH tolerated within a wild population is 5.6 (Karatayev *et al.,* 2005). Low pH treatments are also likely to be highly detrimental to other macroinvertebrates/fish and may only have utility in closed systems.

9. Under certain circumstances hand picking of *Corbicula* might be of benefit.

10. The use of concentrated brine solution was considered. Currently there is no data on how effective it may be against *Corbicula*, or an understanding of how it may be deployed in the field (Roden, 2018; Coldsnow & Relyea, 2018). Laboratory trials would be necessary to establish brine toxicity. If used in conjunction with benthic barriers it might help to increase efficacy of the barriers in killing *Corbicula*, but again it would be a non-specific tool that may impact many native freshwater species. Salt treatments where *Corbicula* were exposed to salinities twice that of seawater resulted in limited mortality (Barbour *et al.,* 2013).

5.2 Decontamination

To decontaminate water sports or similar equipment, steam is considered the best method to ensure the organism is killed, with application of heat through immersion in hot water a close second. There is some data on Virkon being reasonably effective at killing juveniles, but any recommendation would emphasise hot water treatment for efficacy and practicality (Coughlan *et al.,* 2020).
Currently Check, Clean, Dry is promoted at boat ramps on the Waikato River due to several highly invasive species being present. However, there are no means available for the public to properly clean their watercraft on site as there are no washdown facilities at Lake Karāpiro boat ramps.

5.3 Surveillance tools

In the overseas experience, eDNA was not a tool that was used in surveillance. There was agreement that significant validation work in assay development, validation and refining sampling protocols would be required for it to be a useful tool for Response decision-making (Cowart *et al.,* 2018; De Brauwer *et al.,* 2023). Some discussion ensued about whether eDNA could be useful for tracking the original point of incursion of *Corbicula* spatially – this is likely very difficult. eDNA will likely be important in surveillance going forward, however, and the use of historic water samples could help detect *Corbicula* DNA without the need to physically return to sites. Additional molecular work using *Corbicula* DNA from the invaded population to build phylogenies could aid in tracing the origin of the Waikato incursion which may aid in identifying the pathway of entry. However, the genetic taxonomy of the *Corbicula* genus lacks clarity, so it may not be easy to do this work and is not regarded as an urgent priority (Sousa *et al.,* 2008).

The use of surveillance tools other than visual surveillance of wadeable areas or eDNA was discussed.

1. Dive and snorkelling surveys could be a useful way to search in areas that are deeper than wading allows, and to additionally understand the depth profile of *Corbicula* in the Waikato.

2. Colonisation surveys could be done by using a small, contained sand or gravel trap or something similar that can be placed in fixed locations and pulled out periodically to be examined for the presence of *Corbicula*. Some experimentation will be needed to determine what the best substrate is, but being a cheap and easy method of surveillance, these colonisation samplers can be deployed in quite a variety of environments and act as sentinels for early detection. They also work well where access to the river is difficult, or water conditions make visual or eDNA surveillance impossible. They are also suitable for citizen science groups and local stakeholders.

3. Grab or dredge sampling was suggested. A type of open frame net with a metal opening, or a small equivalent of a benthic sled could be used to throw from the side of the river and be dragged back to shore after which the trapped sediment could be sieved and examined for presence of *Corbicula*. What type of sampling frame is used at a given location will be determined by the substrate in that area that the frame will be dragged across.

When designing a long-term surveillance plan, a range of different methods will be required to increase confidence of detection. For example, man-made structures and geothermal areas might be surveyed in a different way or at a different frequency than some other sites due to them being suitable habitat for *Corbicula*. For waterways outside of the Waikato, prioritising sites (*e.g.* boat ramps at popular recreational lakes) connected by human activity to Lake Karāpiro or infested parts of the Waikato will be important (Schmidlin *et al.,* 2012).

5.4 Impact of killing *Corbicula*

Where *Corbicula* populations are dense, significant *Corbicula* mortality events (and large amounts of decaying shellfish) will add protein, carbon and nutrients and cause short periods of over-nutrification and eutrophication in areas where these mortalities occur which may lead to other negative impacts. Thus, thought needs to be given to extracting and disposing of dead *Corbicula* biomass, rather than leaving it in-situ (McDowell & Sousa, 2019). One possible impact of over-nutrification following a *Corbicula* mortality event is increased risk of avian botulism in wetlands, although scientific literature doesn't document high densities of *Corbicula* in wetland environments. In large lakes and areas with high flows (*e.g.* Lake Karāpiro), low oxygen and nutrient pulses will be less of a concern due to rapid dilution (*e.g.* when benthic mats are lifted).

Long-term releases of carbon, nitrogen and phosphorus into the ecosystem may also occur when there is a mass mortality of *Corbicula* from shell break down. Also, the presence of large amounts of shells provides hard surfaces for settlement and colonisation by a wide range of other organisms which can have both positive and negative effects. The 'shell surface' effect would have occurred prior to *Corbicula* death but will also create long term changes to substrates long after each clam is dead. Such rapid environmental changes following mass mortality events have been shown to facilitate other invaders in overseas contexts (McDowell & Sousa, 2019). If necessary, for example in shallow lakes, removal of *Corbicula* to covered landfill or offal pits on farms are methods to biosecurely dispose of dead biomass and associated material in the event of mass mortality events resulting from natural die-offs or due to a treatment being deployed. If not dead upon extraction, the *Corbicula* needs to be killed after removal. Tanks of hot water were identified as the easiest method for this purpose. Burial and or composting could also be effective, and shells may be used for fertilizer if biosecurity concerns were addressed.

5.5 Legal tools

Under the Biosecurity Act, if *Corbicula* was designated an Unwanted Organism (UO) or a pest in a regional pest management plan, this would provide some legal tools for managing risk movements. River iwi also could put a Rāhui in place to stop activity in an area. It was noted that enforcement of these tools was of equal importance to make them effective, especially based on the experience of the international experts.

6 Infrastructure impacts and mitigations

6.1 Understanding the infrastructure impacts of *Corbicula*

There are a large number of water takes from the Waikato River and given the impacts *Corbicula* has had on water take infrastructure overseas, there is a need to understand possible impacts in the Waikato (Isom, 1986).

Some specific concerns mentioned were:

- The motility, particularly of juvenile *Corbicula* in the water column may result in its entry into cooling systems of the Mercury Energy hydro plant (or other infrastructure), possibly resulting in the blockage of small end plates, as well as any diffusers and grates. Currently the cooling system is on a 4-year maintenance cycle and there was concern that this might need to be changed.
- Having a pump system into a 6 km long pipe, which is the case with one of the facilities, could be a point of vulnerability.
- The screens on pressure reducing valves are likely to be blocked, especially in plants using membrane filtration, where solids and particles will not get through.
- Concern about any wastewater and how and if it should be treated, especially as a potential vector of *Corbicula*.
- The 3 Waters sector is already under-resourced, and there are concerns that additional maintenance will mean significant impacts.

The water intakes at the Mercury Energy plant are 3 m below the surface, and 7 m above the lake bottom, which may already limit intake of *Corbicula*. International experts noted that the impacts seen thus far (in the Waikato River) seemed minimal. They made the point that if *Corbicula* has been here for quite some time already (>2 years), it is possible that the impacts don’t significantly increase, especially if mitigation measures are pre-emptively implemented at individual industrial water takes now. The group noted preparatory work was extremely important. It is expected that *Corbicula* will accumulate in infrastructure, wherever sediment accumulates.

Of note, when developing Standard Operating Procedures (SOPs) and maintenance regimes, is that in other invaded areas *Corbicula* impacts on infrastructure have been very context dependent (Modesto *et al.,* 2023). In some cases, water takes from heavily infested areas have not resulted in significant uptake of *Corbicula* into infrastructure, and vice versa. Context-specific solutions will likely be required using knowledge of the specific infrastructure and the local environment. In areas where impacts were felt, the initial burdens were much higher than subsequently, when SOPs were developed and implemented.

When using treatments that kill *Corbicula in-situ*, the flesh degrades easily and rots, impacting water quality, and resulting chemical changes can cause corrosion to internals metals and pipework. Accelerated metal corrosion will result in shorter asset lifespans. The breakdown of *Corbicula* shells into smaller particles can penetrate further within infrastructure systems, and shell fragments are sharp and abrasive which can cause damage. Therefore, when developing mitigation protocols, the dead *Corbicula* should be both killed and removed from the system. Preventing entry in the first instance is more effective.

Many water treatment plants do not currently have process to remove taste and odour compounds, they are set up to remove organic and particulate material, and thus there may be additional impacts from decaying *Corbicula* in water treatment plants.

Corbicula density in the Waikato River has been reported to be in the hundreds of individuals per square metre, and highly infested sites overseas are 10,000-20,000 per square metre (Pereira *et al.,* 2016). This indicates the potential for significantly higher *Corbicula* impacts than those observed thus far.

Application of the framework on ecological economics of *Corbicula* (Sousa, 2008) to estimate costs to infrastructure operators may help gauge economic impacts on infrastructure in the Waikato.

Understanding the life cycle of *Corbicula* can help predict how, when, and in what volumes *Corbicula* can enter the infrastructure and determine subsequent management actions. The life cycle may be dependent on seasonality, local water conditions and other context-dependent factors unique to the given infrastructure (Sousa *et al.,* 2008).

Mapping the seasonality and temperature-dependence of the *Corbicula* life cycle onto Aotearoa New Zealand's seasons estimates that reproduction peaks will be Nov-Dec and Feb-Mar (Figure 1). This, however, requires validation through research in Aotearoa New Zealand. Of note, any warm water plumes (industrial discharge, geothermal etc) may stimulate 'out of season' reproduction. Also, temperatures in the Waikato River are relatively mild, thus almost continuous release of juveniles may occur, particularly through summer.

Season	**WINTER**			**SPRING**			**SUMMER**			**AUTUMN**			**Source**
Month	J	J	A	S	O	N	D	J	F	M	A	M	
Adults		>7mm disperse	>7mm disperse				>7mm disperse	>7mm disperse					1
Adults						Release juveniles	Release juveniles		Release juveniles	Release juveniles			2
Adults				When >15^{o}C biomass maintained but R & shell G increase.		Biomass decreases as release juveniles			Biomass decreases as release juveniles				1
Lake Karāpiro water temperature		15^{o}C					20-22^{o}C	23^{o}C					3

Fig 1. A proposed life cycle calendar of *Corbicula* in New Zealand (S. Clearwater, TAG communications, based on William & McMahon (1989) and Sousa *et al.,* (2008)). Adult clams >7 mm shell length will actively disperse downstream, secreting a mucus thread to float in water currents (Prezant & Charlemwat, 1984). G= Growth; R = Reproduction.

6.2 Mitigation measures

There is not a single fix or mitigation to prevent *Corbicula* causing major impacts in infrastructure – they must be both killed and removed from the system. Once in a system, reproduction and growth can lead to an increase in biomass, so decontamination processes must include removal of visible adults as well as possibly difficult to detect juveniles, which unlike adults may adhere to surfaces of internal infrastructure using their byssal thread.

6.2.1 Prevention

Of primary importance is to stop *Corbicula* entering systems via water intakes.

1. Screening at the intake
    a. New plants in areas where *Corbicula* is prevalent often have moveable baskets on intakes that filter *Corbicula* and are removed and cleaned periodically. Note retrofitting to existing infrastructure can be more difficult and expensive.
    b. Sand filters can be added at water intakes to block *Corbicula* from entering – note this will affect intake flows.
        i. Most water treatment plants use sand filters already located above flood level and require screens, pumps and treatment processes pre-filters. These will all be impacted by *Corbicula*.
    c. Hydrocyclones were suggested, with an example of the Waipā water treatment plant, as an option. These are used to exclude sediment and pumice, but no information exists on their efficacy in excluding *Corbicula* from water intakes (Nielson *et al.,* 2012).

2. Smaller, newer plants that use membrane filtration or take water from below the riverbed have different risk and impact profiles, as these would stop *Corbicula* entry. However, the high-pressure pumps that are required before membrane filtration are subject to *Corbicula* impacts.

3. Trying to minimise areas where sediment is trapped or settles within infrastructure – as *Corbicula* adults preferentially burrow a little bit in sediment or sit upon it rather than adhere to surfaces (Robb-Chavez *et al.,* 2022). They will settle where sediment settles.

4. Juveniles do stick to surfaces, but surface type is irrelevant as they adhere to anything their mucous strands can attach to.

5. Physical removal is required of larger *Corbicula*, especially as those already in the system as they may reproduce. High pressure water could be used to flush the system (noting killing and disposal of flushed *Corbicula* will still be required).

6.2.2 *In situ* treatments to kill *Corbicula*

In all cases where *Corbicula* is killed *in situ* removal of biomass is still required.

Physical methods

1. Steam causes mortality in 30 seconds, but it could be difficult to maintain temperature over the entire internal surface of pipework (Coughlan *et al.,* 2020).

2. Hot water is a good option for killing *Corbicula* (>45 °C for at least 5-10 minutes) but needs to be tested to ensure temperatures can be maintained across time and space in an industrial setting. Note possible difficulties in retrofitting heating elements to existing infrastructure, and the necessity of water discharge back into the Waikato River being below 35 °C.

3. Hot air was considered as a treatment option. Heat treatments (hot water and steam) as above are generally very effective. Hot air has not been trialled with reference to *Corbicula*, and likely a long exposure to a continuous jet of hot air would be required to ensure mortality, and a range of temperatures would need to be trialled. Required temperatures delivered are likely to need to be greater that 500 °C, for example a Bosch Heat Gun PHG 500–2 killed zebra mussels within 10 seconds (Coughlan *et al.,* 2020).

4. Water blasting plus chlorine treatments have been used to kill other molluscs. There is a dependency of chlorine treatments on water pH and temperature as well as immersion time, so these need to be considered, as well as managing any discharges.

5. In reticulation pipes, **saline ice** has been used in scheduled cleaning (for scouring). Would **saline and/or dry ice** work to kill *Corbicula*?
   a. There was no reported experience with saline ice, but dry ice would likely not flow through piping, and it is more likely that the solid ice pellets would clog and bind together.
   b. Dry ice is the solid form of CO_2 at -75 °C, it will bypass the liquid stage to gas as it sublimes. Dry ice is effective in killing *Corbicula* but is not useful in piped infrastructure (Coughlan *et al.,* 2018).

Note – points 1-5 are likely impractical for drinking water treatment plants.

6. UV light
   a. There is currently no real data on how long exposure would need to be to be effective.
   b. Unlikely to be effective against adults, as the UV doesn't penetrate deeply and therefore wouldn't kill *Corbicula* as the shell blocks UV irradiation of the tissue.
   c. UV systems are likely very effective at killing incoming juveniles when placed directly behind intake pumps – this requires testing.

Chemical methods

Chemical methods are not the preferred options for killing *Corbicula* as, like other bivalves, they can close their shells and protect themselves from the chemical for extended periods of time. However, in a closed environment, it is worth trialling a variety of chemical options in different contexts, especially in conjunction with physical methods (Lucy *et al.,* 2012; Meehan *et al.,* 2013).

1. Chlorine/hypochlorite is cheap and effective in a closed system if used at the right concentration for the right exposure time (Meehan *et al.,* 2013; Rosa *et al.,* 2015).
   a. 0.3 ppm could be used throughout the breeding season. If you are treating at end of the breeding season and can hold water in enclosed areas with a concentration of 1 to 2ppm for a week or two this may be effective. Testing of chlorination chemical by-products is also required before deployment, as Waikato River water has some unique organic compounds.

   b. Shock chlorination would entail 8-40 ppm for 4-6 hours – would require dichlorination before return to the environment.
   c. Weekly chlorination treatment of 1 ppm for 30 min has anecdotally been shown to be effective unless there is silt deposition that interferes with the chemistry.
   d. 2 ppm was used in Ireland, but the efficacy is context dependant (the individual plants and local water quality etc).

2. Biobullets
   a. Unsuccessful in open water systems but could be successful in closed systems such as pipes. They have been available for 10-15 years but have shown to have mixed results in terms of efficacy (Tang & Aldridge, 2019).
   b. There may be regulatory issues with the use of biobullets.
   c. Not enough evidence to suggest they will be practical or effective in the Waikato River.

7 Social Behaviour

7.1 Campaigns overseas

The Zebra Mussel incursion which was the first big biosecurity campaign in Ireland (late 1990s, early 2000s) was discussed as an example from which to learn. This campaign was resourced by multiple agencies and primarily consisted of lots of posters and a large amount of publicity. Local radio was used to get messaging out, as well as nature programmes on both radio and TV. Radio was found to be very effective. Ireland had Check, Clean, Dry messaging, but it was not used consistently, and sometimes it was known as Check, Clean, Disinfect, Dry. A lot of UK messaging was adapted and used in Ireland.

Some resources for messaging can be found here:

Check-Clean-Dry - National Biodiversity Data Centre (biodiversityireland.ie) and
EASIN - European Alien Species Information Network (europa.eu)

In Ireland there was inadvertent spread of *Corbicula* despite public messaging. Some of the key issues they faced were that it was hard to sustain messaging and due to historic and cultural reasons, people like to do their own thing and don't enjoy being told what to do. As such, there were negative feelings about being asked to change behaviour, so people still moved boats on trailers to other lakes/locations, and without readily available facilities to clean them. This made it unlikely that people would take appropriate actions. Besides boats, one of the biggest risks was felt-soled boots and waders (note – banned in Aotearoa New Zealand).

There was no regulation around managing *Corbicula* and it was thought that even if the regulation did exist it would be difficult to enforce. Maintaining impetus is one of the biggest challenges – people suffer "cleaning fatigue", or good intentions wane after a while despite messaging. In terms of targeting campaigns, it can be complex to predict where invasive species will spread, so difficult to identify areas to concentrate the messaging effort.

In Ireland they had lost the historic community stewardship of lakes, but in the past decade have formed river trusts. Ireland has a new national steering group for managing Invasive Species. *Corbicula* was not as big news as Zebra Mussel was, and there were no posters.

7.2 Campaigning in Aotearoa

Sustaining programmes is dependent on enthusiastic champions of the programmes, who come from within and are respected by their communities. A big strength in Aotearoa New Zealand is iwi that are intrinsically connected to place and are guardians of their sections of the river. Therefore, iwi kaitiaki/guardians or champions are well-placed to spread this message, and to define the appropriate manner of messaging to their iwi, hapu and whānau. Iwi would like to have their own ambassadors to target and educate the groups they interact with. As such, they can determine an effective engagement strategy on their awa – and their own strategy for Communications and Engagement around *Corbicula* biosecurity. Some additional notes when considering messaging for iwi:

- A key user group in the Maniapoto rohe are tamariki swimming.
- Maniapoto have a kura Taiao (environment learning group) – a small group of rangitahi (youth) who share information, including on *Corbicula*.
- It was recommended that messaging about the whakapapa (origins) of *Corbicula* is important when communicating how to manage them, incorporating Mātauranga where possible.
- Whilst having a desire to keep eradication on the table, there is also a need to learn and understand how best to live with what is currently in the Taiao.
- River iwi are working collaboratively on other kaupapa, so they have the networks in place with iwi environmental managers.
- One messaging approach could be sharing the video of *Corbicula* infestation at hui. This would be a very clear deterrent for public and regular users of the awa and other areas, giving the message that this is what our river or Te Arawa Lakes will look like if no one cares enough to take precautions.
- The tradition of river iwi, their culture and day-to-day connection to the awa will greatly help the biosecurity work.

There is also the example of Bay of Plenty (BoP) Regional Council and Te Arawa Lakes Trust (who are Check, Clean, Dry partners) where a compliance and enforcement approach is being trialled.

- See boat check sheet (Boat ramp self-certification (boprc.govt.nz))

The BoP Regional Pest Management Plan 2020–2030 requires that all boat ramp users Check, Clean, Dry - and then certify that their boat is free from freshwater pests, fish, and weeds (BoP Report, 2023). The boat then may be checked by biosecurity ambassadors that are active around the boat ramps. Additional use of "scare tactics" such as big signs in the water (two-sided so they are visible as one is heading out or coming back in) was discussed. It was noted that messaging will likely be slightly different (specifically for *Corbicula*) if you are entering or leaving a waterway, and whether that waterway is known to be infested or not.

7.2.1 Target audiences and messaging

Various stakeholder groups were engaged in Europe to spread the message to specific user groups: aquatic plant trade, ornamental fish, hikers/trampers, local anglers, boaters etc. In a similar manner to the iwi ambassadors described above, identifying ambassadors or champions within different stakeholders' groups and tailoring messages and messaging will increase awareness and stakeholder buy in. For example, messages, stakeholder groups and ambassadors may be different for Lake Karāpiro compared to the Te Arawa Lakes.

Risk groups and key river users in the Waikato that may be accidentally (or deliberately) transferring *Corbicula* to other areas of Aotearoa New Zealand were identified as including;

- Wakeboat users (ballast water in wakeboats are a high-risk pathway).
    - Including Wakeboarders.
- Jet skiers
- Other boaters, kayakers, rowers, canoers etc.
- Food cultivators who may deliberately move *Corbicula* to nearby waterways to increase its availability as a food source.
- Anglers, fishers using fyke nets etc.
    - *Corbicula* used as bait is an additional risk pathway.
- Hunting groups or trampers - crossing waterways in remote areas.
- Government agencies and University groups doing research or surveys.
- Casual aquarium collectors or people just picking up interesting shells.

Aquarium owners like *Corbicula* for the pretty colours and aquarium trade was identified as a risk pathway. It was noted that this risk is not addressed via Check, Clean, Dry messaging, and messaging that has been used in the past by the Department of Conservation (DOC) is appropriate: "Pests not pets".

Check, Clean, Dry communications should be tailored to specific communities. Using this cleaning, washing and draining/drying methodology is a good approach, as even if it does not always kill *Corbicula*, it will significantly reduce passive vectoring (Barbour *et al.,* 2013). Ideally one should also prioritise high-use and high-risk areas such as boat ramps to deploy messaging and cleaning stations.

Currently the hydro lakes and river are open to the public and given this is unlikely to change, there is a lot of opportunity and need for signage and increasing public awareness. This includes the private and semi-private dam areas that are used for water sport. It would not be possible to limit access without legal enforcement.

It is also important to consider communication with industry bodies. If *Corbicula* starts to impact infrastructure in the Waikato River, or spreads to other regions, providing information to Water Utilities Managers will be important to mitigate infrastructure impacts. This could be done via groups such as the 3 Waters Suppliers, Civil Contractors Federation, and the Water Services Mangers Meeting (https://www.waternz.org.nz/events).

There is the need for clear, consistent messaging to provide to the public. It is also important to keep other invasive species in mind, so that the same programme can be used in the event of similar incursions to *Corbicula*. The best way to begin messaging for waterside biosecurity is to promote the use of the basics – Check, Clean, Dry. The incorporation of a disinfection step, whilst not totally effective for *Corbicula*, may be considered as it may work effectively for other invaders, and getting these processes ingrained in users is important, preparing the public for other biosecurity threats where disinfection may be critical.

Note resources from Ireland

Invasive Alien Species (IAS) - Atlantic Technological University Sligo (itsligo.ie)
EASIN - European Alien Species Information Network (europa.eu)

Developing messaging

To target different river users, co-creation should be the basis to develop communications tools and materials that specific ambassadors can share with their people. This co-development needs to be done in a safe space without judgement. Whilst some work may be required to get different groups around the table to discuss and work collaboratively, it is a better way to sustain change. The messaging needs to be targeted because one can put up thousands of signs and not get the message through. Different forms of communication appropriate for each group, and saturation of the messaging space are needed.

Building partnerships with boating/fishing/water sports clubs to ensure they can champion biosecurity – maybe including cleaning stations as part of their infrastructure – was proposed. This could also include club requirements to Check, Clean Dry.
As many river/lake users often don't realise they are creating a risk, material targeted for specific risk groups including specific examples of risky actions/behaviours typical of their group, simple ways to mitigate that risk, and the outcomes of not practising good biosecurity would likely be effective.

Types of messaging

Encourage positive 'peer pressure' amongst water users. Peer pressure can be very powerful if promoted as a culture of “good biosecurity behaviour” through positive reinforcement.

Kids are good ambassadors and can exert pressure on adults (their whānau especially). Outreach with kids is an important and powerful tool, especially bringing some aspects of *Corbicula* and freshwater biosecurity into the classroom. Within the Kura kaupapa Māori curriculum there are already elements of teaching about biosecurity. Targeting schools to build positive peer pressure via children to adults and the community may be a valuable avenue to pursue.

It is important to harness activities that increase ownership and a feeling of community in different waterbodies, whether known to be infested or not. Some examples are:

- For rowing, angling or other water-user clubs, offering biosecurity awards for their own internal biosecurity champions.
- At Lake Wairarapa there are Kākahi measuring days each year that are now run by Kahungungu iwi. This brings the community together around the lake.

It is equally important to discourage people from seeing the *Corbicula* as a useful resource in case it creates a perverse incentive to spread it. From early in the *Corbicula* response people were discouraged from eating *Corbicula* due to its ability accumulate toxins and bacteria. Food safety experts advise eating such an organism taken from a clean water environment only. “Invasivorism” (or control via harvest for food) has not been shown to be effective at controlling spread of invasive organisms.

Messaging needs to include following every step of the Check, Clean, Dry process to be effective. To help this, people do need to understand that the juvenile life stages may be invisible to the naked eye, as reminder to continue with Clean and Dry, even if the Check revealed nothing. In messaging, need to emphasise “just because you can’t see *Corbicula* on your gear, doesn’t mean they aren’t there”.

Wakeboats

Residual water left in ballast bladders or tanks on boats (particularly wakeboats) after they have been pumped is potentially a major vector for *Corbicula* with no clear approach to its management. There are no real treatments available, as hot water will be instantly cooled down and any chemicals would be diluted. Thus, existing Check, Clean, Dry messaging is unlikely to be effective for these types of boats with internal ballast tanks that are not readily accessible or drainable. A way to manage this risk may include regulations that restrict operation of a given boat to a specific zone or waterbody. Many boat users don't realise there are different river catchments within close proximity, so may not be aware that they are moving to a different catchment.

Wakeboat clubs could help manage this by making boats available for users that remain in specified waterbodies and are available to club members wanting to use different lakes or rivers. Wakeboating clubs already have boats at the clubs available for member’s use – increasing and publicising this may be one way of preventing boat movement and allowing people to enjoy their hobby. Clubs could additionally be engaged to promote and use their sites for cleaning and certification of cleaning of boats.

An import risk assessment is being done for wakeboats as it has been identified that if they have been used in water before being imported there will probably be residual water present. For example, some manufacturers pre-test a new boat by running it in water.

It will be important to reach out to wakeboat users and include them in any co-design process at the beginning, when developing messaging, regulations, tools, and treatments to manage this risk.

7.3 Enforcement

It was noted by Irish TAG participants that the efficacy of Check, Clean, Dry messaging requires more than education, it also requires enforcement. It is important to develop a real deterrent for deliberate spread. Ideally, one would stop all movement of boats and other anthropogenic movements from the infested system – this, however, may not have community buy in.

The example of an enforcement approach (self-certification of compliance) being undertaken at Te Arawa Lakes has already been noted.

There may be alternate ways to enforce movement controls without a specific legal tool. Using the *Didymo* example, on big stations in the South Island, there were requirements in the DOC permits issued for field work that vehicles would be sprayed down at each river crossing. Permitting requirements for certain activities can be modified to include conditions that limit spread of *Corbicula*. This may need co-operation with other government agencies.

7.4 Practical treatment for public to use as part of Check, Clean, Dry

Hot water is clearly the best, most effective treatment for the public to use at the Clean step, with immersion in hot water ≥45 °C for 5 minutes, or ≥60 °C for 1 minute and both are highly effective in inducing *Corbicula* mortality. The challenge is how to make it accessible for people to ensure ease of use. Providing any sort of infrastructure at boat ramps (or similar) for people to use could be expensive, create health and safety issues and would be subject to vandalism without constant oversight.

Although there is much discussion about chemical treatments, most of these have been shown to have limited or no ability to kill *Corbicula* which simply close their valves to avoid the chemical. Household washing powder and dishwashing detergent are not effective. Virkon has 93% efficacy for juveniles only but is not effective against adult *Corbicula* (Barbour *et al.,* 2013; Coughlan *et al.,* 2019), meaning it lacks utility as a generic control treatment. Messaging to the public needs to be generic and simple, so there needs to be a treatment that is effective against all life stages (and then will be the default treatment against a suite of other invaders).

If cleaning stations were developed, their location is of prime importance.

- Whether they are in infested places or uninfested places (stop *Corbicula* spreading out, or keep *Corbicula* from coming in).
- "Pop-up" cleaning stations at events could be effective in reaching large numbers of people in high-use areas.

There could be a requirement at certain waterbodies or events for people to come with "certificates of cleanliness".

- They can use mechanisms such as a high-powered spray and the certificate is proof to show that they have cleaned the boat before arriving at an uninfested lake. Boats could be cleaned at cleaning stations on the route to a lake.
- There is a need to manage run-off from cleaning, both from cleaning stations and from individuals cleaning or draining their boat at home to ensure run-off doesn't enter a stormwater drain and subsequently a local creek. This is where messaging regarding the juvenile 'invisible' life stage is important. Hosing (with tank or tap water) whilst exiting the water at an already infested site with run-off re-entering the already infested waterway is lesser of two evils compared to vectoring to a new site.
- An option to stop re-entry of run-off back into an infested waterway could be high-pressure washing with cold water on concrete or plastic sheets with run-off collected and channelled through a fine filter (*e.g.* sand) before returning to the waterway.

8 Translocations

8.1 How can the trap and transfer programme of elvers in the Waikato River continue safely?

8.1.1 History

Tuna (eels) are top predators in lakes and streams. There are three species in Aotearoa New Zealand, and they are of huge importance to iwi and hapu who are connected via whakapapa (a variety of relationships, depending on place). The history of eel fisheries is intertwined with the history of River Iwi and eels are considered a taonga, as they sustain their way of life and are highly nutritious. They were an everyday meal and very common, but after commercial harvesters began to extract them, there was a significant decrease in eel populations and availability. Human impacts such as pollution, development and climate change have also contributed to a reduction in eel abundance.

Mātauranga contains extensive information on ecology, biology and more relating to eels. The Waikato region is most celebrated in Aotearoa New Zealand for its quantity and quality of eels. All river iwi have fish and eel conservation management plans. The Karāpiro dam is a major blockage that impacts the migration of closely packed shoals of elvers moving upstream (Baker *et al.,* 2020). To complete their life cycle, elvers are transferred from below the dam to several hydro lakes above the dam, as well as some locations in the Waipā River.

The first elver transfer happened in 1987. From 1996-2022 the elver transfers were managed by commercial eel fishers and transfer data is recorded. Last year (2022) iwi took over the elver trap and transfer programme and it became more inclusive. Mana whenua involved schools and other community organisations and took the opportunity to educate the whole community on the importance of eels.

From a Māori perspective there are positive impacts for hapu that are the receivers of translocated eels - to be able to share food and welcome guests to their marae. These transfers have also brought the Waikato River iwi closer together via co-operating in this programme, and it is an important cultural practice that needs to continue.

8.2 How to mitigate risks associated with elver transfers?

Eels should not (and are not) transferred out of the catchment because of the risk of spreading disease. The ecological risks associated with translocations are greatly lowered when movements are confined to the same catchment (MacNeil, 2021).

There remains a possibility that *Corbicula* was transferred when moving eels, as the process involves taking eels and water from an infested zone to potentially uninfested zones. There is a need to continue this important cultural practice in a biosecure manner.

The elver transfer season normally starts around the beginning of December, continuing into February, but is dependent on the arrival of elvers at the base of the Karāpiro dam. It will be important to understand the life cycle of *Corbicula* in the Waikato, and whether at this time *Corbicula* juveniles may be floating in the water column and end up in the collection infrastructure for elver transfers.

To mitigate the risk of co-translocating *Corbicula* hitch-hikers, transfer water will need to be analysed, a key question for future research being “how many juveniles may be in the water at a given time, in a given volume of water?”

Treatment of transport and transfer tanks and the water therein will also be needed. This may be more difficult when there is a lot of sediment (which may harbour *Corbicula*).

8.2.1 Treatments

Treatments are required that won’t harm elvers but kill juvenile *Corbicula*. Several options were discussed:

- Virkon aquatic is harmless to fish (and larger *Corbicula*) but kills juveniles in the water column and was used in a similar elver transfer program (Fisheries Ireland Report, 2021). Virkon Aquatic is currently not registered for use in Aotearoa New Zealand, only Virkon-S. There is a plan in place for registering Virkon Aquatic soon (possibly this year). It may be worth trialling Virkon-S on elvers and *Corbicula* juveniles.

- Formalin is another option to kill juvenile *Corbicula* but leave elvers unharmed. This is used in Victoria, and a protocol exists along with information on the toxicity of formalin to *Corbicula* (McKinnon, 2006; Layhee *et al.,* 2014)
- Iodine and vinegar/acetic acid were also identified as treatments worth investigating. Both would require some experimental work for use in this context (Cahill *et al.,* 2021).
- Saline treatment was an option noted that would likely kill *Corbicula* but not elvers, as elvers likely have a far higher salinity tolerance than *Corbicula*. Experimental validation would be needed (Crean *et al.,* 2006; Coldsnow & Relyea, 2018).
- To decontaminate water entering through the sluice gates at the Mercury Energy elver traps, it may be possible to fit UV treatment that would decontaminate water as it enters, this was thought likely to be effective against juvenile *Corbicula*.
- Within any trials, testing the synergistic effects of various treatments would be a good idea (*e.g.* the synergistic effects of multiple treatment mechanisms in series, such as UV then Virkon).
- Additional options may come from studying fish depuration processes (*e.g.* using ultrasound, gold nanoparticles, UV) and methods used at aquaculture facilities to disinfect surfaces for their efficacy in killing juvenile *Corbicula*.
- The Cawthron Institute have produced protocols over the last 10 years for moving cultured fish around the country and managing potential 'hitchhikers', as well as for decontamination of bivalves. These could be trialled for the elver transfer process (Tremblay *et al.,* 2017; Cahill *et al.,* 2021).
- When adult eels are moved, awareness is needed of the potential for co-translocations in the gut as *Corbicula* survives gut passage for up to 40 days in some fish (Coughlan *et al.,* 2017). There will be a need, if adult eels (or any other fish species) are moved from infested areas of the Waikato for a transition through biosecure quarantine to ensure gut contents are purged (depurated) before relocation.

8.3 The use of "arking" and translocations to protect populations and genetic diversity of kākahi and other native species

This concept was discussed with relation to possible impacts if *Corbicula* populations increase to levels where they severely impact native species. There may then be a requirement to translocate native species to preserve their unique genetics (Germano *et al.,* 2015). In the event this is required, plans should be prepared to mitigate biosecurity risks of *Corbicula* spread and ensure genetic diversity in both the translocated and destination populations are maintained, and that origin and destination sites are prepared in a culturally appropriate manner. Kākahi were discussed as an exemplar of this process, but many of the principles are relevant for other native species that may be impacted by *Corbicula* populations.

8.3.1 Background

Each waterway can be considered a distinct hapu of genetics for kākahi, as the geographic isolation of populations creates diversity. This is also seen in limpets and other bivalves. Kākahi translocations have been made successfully to Zealandia to preserve genetics and test translocation methods. An established protocol for freshwater translocations from the UK was adapted for use in this study (Killeen & Moorkens, 2016). However, this unique genetic diversity can be swamped when populations are translocated, as has been observed in fish populations in UK and Europe and is a natural effect of population mixing. The counterfactual is doing nothing and the possible loss of these kākahi populations in infested areas may be far worse than the loss of genetic diversity. The questions of where and when to translocate are regarded as decisions for iwi and hapu to make, guided by their interests.

There may be other reasons for translocating kākahi or other native species, for example to shift them temporarily out of the way of while benthic barriers or other *Corbicula* control tools are being trialled. This would also allow one to protect some of the kākahi within the same part of the lake or river when conducting any experimental trials for control work.

8.3.2 Risks and benefits and the "hows"

Translocating at-risk native species such as kākahi was noted by some as an action of last resort, if *Corbicula* came to dominate an ecosystem, as it is possible that a translocation will do more harm than good, therefore it is best to be risk averse (see MacNeil, 2021 for a risk assessment of freshwater translocations in Aotearoa New Zealand). It would be important to do a Risk Assessment on the site one is translocating to, to understand the risk of *Corbicula* establishing there.

Potential population control measures for *Corbicula,* as mentioned above, are largely non-specific. The possibility exists that native species can be removed in advance of deploying control measures, and then reintroduced when conditions become safe. There will be risks associated with reintroduction, although likely lower than an initial translocation (Germano *et al.,* 2015).

In the event translocation is decided as the correct course of action, decisions around site selection (both origin and destination) are needed. These decisions should be made by the Iwi and Hapu with tikanga over the sites, with appropriate assistance, if required, from biosecurity personnel. In iwi-led translocations, karakia (prayer) to the awa (river) creating space for the species in question to grow has been vital in ensuring successful translocation.

Releasing pheromone into the destination site has been used in the past to acclimate translocated native species, helping them adjust to the new site, as does Taki Ihirangaranga (sacred vibrations of sound), and understanding the whakapapa of the way for translocated species such as kākahi. It is also important to note the phases of lunar cycle, as there are certain times that are appropriate for translocations to occur.

Kākāpō provides examples of successfully managed translocation, including their recent reintroduction to the nearby Sanctuary Mountain Maungatautari, and the use of mātauranga to prepare and manage this. There was a process of asking, giving, and receiving to ensure compatible genetics. This was a long process requiring a lot of relationship building. The process can be accelerated in emergencies, but relationships are still important. Therefore, it is important to start this thought process now.

The vulnerability status of the kākahi (kāeo) from the DOC threat perspective provides information on whether a translocation for arking is appropriate (Grainger *et al.,* 2013; Grainger *et al.,* 2018).

- One kākahi species *Echyridella menziesii* (Gray, 1843) is 'At Risk, declining' and is found throughout Aotearoa New Zealand.
- *E. aucklandica* (Gray, 1843) 'Threatened, Nationally Vulnerable' (is distributed mainly Waikato northward, also with disjunct populations in Whanganui, Wairarapa and Hauroko (Sth Island)).
- There is one other (known) species of kākahi (*E. onekaka* (Fenwick & Marshall, 2006) 'Data Deficient') found in the northwest South Island.
- Different species of kākahi have different Conservation Statuses, as above, and 'Threatened' is a higher status of risk than 'At Risk'.
- Threat status of *E. onekaka* was 'Naturally Uncommon' in 2013 and was changed to 'Data Deficient' in 2018.

Anecdotally populations appear to be in decline in many places. For example, they appear to be declining in some shallow lakes (e.g., Lake Ohinewai (Waikato), Punahau, Lake Horowhenua (Fenwick and Clearwater 2018)), but stable and/or thriving in other lakes (e.g., Rotorua, some O Tu Whare Kai/Ashburton lakes (Burton *et al.,* 2022)). In streams both *E. menziesii* and *E. aucklandica* (in particular) may be declining and dying out due to habitat degradation and fish passage issues (native freshwater mussels require a fish host to complete their life cycle). *E. aucklandica* requires smelt *Retropinna retropinna* to complete its life cycle. Smelt are fish that are affected by barriers to fish passage (*e.g.,* culverts and weirs) as they are 'poor climbers' thus loss of these fish from inland waterways may be contributing to other habitat pressures that are causing freshwater mussels to decline (Grainger *et al.,* 2013; Grainger *et al.,* 2018). Generally, there is a lack of recruitment in freshwater mussel populations and in some cases, they are considered locally extinct. We have limited knowledge of kākahi populations in larger rivers, due to the technical and logistical difficulties of surveying them effectively.

Indications are that it might be time for a formal assessment of kākahi populations and their vulnerability status, however we need population survey data to update the Threat Status. A good example is Waikato Regional Council's recent report that documents 5 years of survey data and makes management recommendations including habitat and fish passage restoration (Melchior *et al*., 2023).

A wadeable river survey protocol is available (Catlin *et al*., 2017) and a nation-wide freshwater mussel conservation group has recently reconvened and plans to collaborate on survey protocol development (Catlin *et al.,* 2017).

Not all overseas experience with *Corbicula* suggests deleterious impacts. *Corbicula* may change the environment in ways that don't impact native species, however this is likely to be dependent on the density of the *Corbicula* population. The densities that *Corbicula* populations reach in the Waikato relative to those seen in other invaded areas will be critical to monitor to understand the impact on native species – but high densities would likely mean high impacts. In Ireland or in the UK no specific actions were undertaken to protect native species from *Corbicula* as there were no vulnerable species at the heavily infested sites.

It is hard to ascribe the loss of species to a single invasive when several invasive species often invade simultaneously. One study in France suggests there are impacts on native bivalve diversity and numbers, but sometimes, this may be due to a subsequent, more impactful invader (Mouthon *et al.,* 2010). Kākahi are likely to be outcompeted by *Corbicula* even though they are much larger, as *Corbicula* are very effective filter feeders, and have a high growth rate and a high reproductive rate (Geist *et al*., 2023). *Corbicula* can quickly recolonise an area after a disturbance (e.g., a flood, or a mass clam die-off) and will eventually outcompete slower growing native shellfish.

Population dynamics and age cohorts of both populations, especially in relation to each other, need to be understood. It is conceivable that at high densities *Corbicula* may use kākahi as a substrate. It was noted that Zebra or Quagga mussels are likely significantly worse threats to kākahi should they invade and establish because these species attach permanently to hard surfaces and grow (*Corbicula* do not attach permanently). Zebra and Quagga mussels both produce tough byssal threads (similar to the 'beard' of New Zealand's green-lipped mussels) and attach to a settlement surface. If they attach to a living mussel they foul the shell competing for space and food, inhibiting the native mussels ability to move, feed, reproduce and grow (i.e., causing shell deformities) and increasing mortality rates (Sousa et al. 2011).

Any detrimental effects on kākahi may be ecosystem/environment dependent, so the impact of *Corbicula* in the Waikato remains to be seen. Other invaded areas have seen improved water clarity as large populations of *Corbicula* effectively filter out phytoplankton. There is evidence they can change the plankton community itself and ultimately lake food webs, selectively feeding on some plankton species and rejecting others (Bolam *et al.,* 2019). How this affects native species is not known. It may increase aquatic plant growth which could be beneficial in some locations (e.g*.,* in shallow turbid lakes), and detrimental in others where pest aquatic plants already form large problematic weed beds

Biosecurity challenges when Arking:

- The requirement to quarantine kākahi to ensure *Corbicula* aren't co-translocated:
    - A fortnight quarantine at 15°C water temperature or higher to allow for depuration of gut contents is likely required, work is needed to evaluate how this works in relation to *Corbicula*, and if it is even necessary.
    - Supplementary feeding of kākahi while in quarantine is recommended, especially when large numbers of mussels are being held. This can be difficult to manage, but de-activated algae is a good option.
    - Kākahi also excrete large quantities of ammonia so it is critical to filter any recirculating water effectively (pre-primed biological filters - standard good practice aquaculture).
    - Kākahi have successfully been held in captivity for many months.
- In the past when translocating kākahi from Lake Wairarapa to Rotomahanga in Zealandia Te Māra a Tāne, ecosanctuary it was undertaken under a 26ZM3 DOC permit (McEwan, 2022).
- Translocation requires research to examine whether kākahi ingest juvenile *Corbicula*, as they eat algal filaments that are ~350 microns in length. Juvenile *Corbicula* are 250 microns in length and probably slightly smaller in shell 'height'. They may not be an attractive food item to kākahi which "taste" their food prior to ingesting, but if they end up coated in mucus and bacteria juvenile *Corbicula* could be incidentally eaten by kākahi.

- Important to understand the risk profile of the sites - both origin and destination, particularly with reference to future *Corbicula* invasion, as there is no point carrying out a translocation to a site that could itself be vulnerable to *Corbicula* invasion anytime in the future.
- Preferable to use sites where there is some modicum of control at the site and researchers can manage the environmental conditions.
- Frequent monitoring and adaptive management of sites is important, and the need to have a Plan B if things don't proceed as hoped with the translocated population (mark translocated individuals, monitor etc).
- Need to test the options for non-destructive sampling from kākahi to understand disease or parasite load, and how best to ensure translocated kākahi are free from all relevant diseases and parasites.
- All the logistics could be pre-tested and practiced so they are ready to go if required, for example if a translocation is needed to save a threatened population of a native species. Any processes developed will be useful for any future incursions.

External decontamination of Kākahi

Collecting and keeping kākahi in quarantine will allow trials of cleaning protocols for kākahi to prevent the movement of *Corbicula* juveniles that may be attached to their shells.

- Acetic acid has been used previously to disinfect kākahi.
- A suite of trials focussed on decontamination methods for small juveniles not visible to the naked eye would be very useful. They may prove to be easier to kill than those say, 3 mm length and larger (Davis *et al.,* 2015; Cahill *et al.,* 2021).
- Any toxicity trials that are conducted should aim for 100% kill within 5 minutes to support easy decontamination.
- Ideally test methods on zebra and quagga mussels and other high risk invasive bivalves to future proof the Check, Clean, Dry programme and develop a suite of effective tools. These species are not yet present in Aotearoa New Zealand
- Could use freshwater mussel husbandry protocols that are already available. The protocols are focussed on conservation of native species but could be modified for quarantining. Methods for external cleaning and handling needs to minimise stress to the mussels (Horton *et al.,* 2014; Patterson*,* 2018; Aldridge *et al.,* 2023).

9 Summary

9.1 *Corbicula* control

Corbicula has never been eradicated from an invaded location before, so eradicating from the Waikato River is extremely unlikely. The consensus was that suppression and containment in the Waikato River will minimise the likelihood of spread to the rest of Aotearoa New Zealand, as well as maintain a possibility of eradication at some stage in the future. As such, actions include;

- Continued surveillance to detect any newly established populations of *Corbicula* in places it is not currently known to be.
  - Alternate methods for surveillance could be trialled such as colonisation plates or hand dredges.
- Commence work on trials and research to develop and validate tools to kill *Corbicula* – this includes testing combinations of known tools to understand synergistic effects. Methods trialled in the Waikato can then be applied if *Corbicula* is detected outside the Waikato.
  - The best starting point would be benthic barriers – these could be trialled in conjunction with other treatment options such as
    - Temperature shock treatment (during drawdowns); or
    - Adding organic matter beneath rubber matting (*e.g.* Uwhi mats); or
    - Brine
- Contain *Corbicula* within the Waikato with strict and enforced movement controls (hold the line to contain in Waikato for now until more information and tools are developed).
  - Movement controls of people, equipment, sand/gravel extraction and water (tanker) transfers.
- Eradicate any newly discovered *Corbicula* populations outside the Waikato if the population structure, abundance and area of infestation suggests it is not well established.
- Work on suppression within the Waikato catchment with a long-term view based on a strategy of containment leading towards eradication as methods are developed.
  - Work to eliminate *Corbicula* in small sections - start upstream and work downstream.
  - Removing *Corbicula* reduces propagule pressure in the Waikato and nation-wide.
- It is worth doing a Cost Benefit Analysis (CBA) to assess the long-term control costs versus the costs of the impact of an uncontrolled *Corbicula* incursion which may help decide where to prioritise resources.
- If it is eventually found in multiple sites outside the Waikato, reassess long term management goals.

9.1.1 Tools/Infrastructure

The best tool to kill *Corbicula* is still hot water (≥ 45 °C for 5 minutes), but other tools and treatments are worth testing, especially in contained infrastructure. In these cases, several steps are necessary – preventing *Corbicula* entry, killing *Corbicula* in the system and removal of dead *Corbicula*. This will likely need to be to be done on a regular basis if it is not possible to prevent entry of juveniles. Each facility needs to develop its own context-specific SOPs pre-emptively to prepare, including considerations for any retrofits to intakes or other infrastructure. Changes in maintenance programmes and scheduling can also be planned. Preventing *Corbicula* entering infrastructure is best (*e.g.* sand filters), but cleaning using flushing with hot or high-pressure water, or chlorination treatments are the most practical methods for control once they are in a system. Subsequent removal of dead *Corbicula* is then required. The environmental impacts of hot water and chlorination discharges must be managed. It is possible to use UV systems at intakes (dependent on volume and intake structures) to minimise entry of live juveniles.

9.2 Communications programme

Continue to use and develop the Check, Clean, Dry programme. There needs to be a strong emphasis on good messaging and communication, targeting both the public and industry. A clear need was identified for specific messaging co-developed with each stakeholder group.

- Messaging needs to be multifactorial, via many different media avenues and very hard to miss.
- Signage needs to be visible from all sides and needs to hammer home that **ALL** steps of the Check, Clean, Dry process need to be followed (not just stop after “Check”) and that this needs to be part of the education.
- Make maximum use of all stakeholder groups (including Ambassador/Champions in iwi, community groups, sports groups etc) as well as education of children to provide “self-policing” and positive “peer pressure” to continue to spread the message over time.
    - Noting that positive reinforcement and building a critical mass of people enacting good biosecurity behaviour is better than a negative calling out of poor behaviour.
- Provide support and materials that are co-designed to help all iwi and community groups develop their own messaging programmes.
- The campaign will have to be revitalised from time to time to stop “cleaning fatigue”.
- Make use of clubs to provide cleaning facilities and practical ways to help the public take the actions required to stop the spread.
- The best tool for killing *Corbicula* is hot water – can we provide facilities for this to happen?
- Consider “pre-cleaned” certification for boat movement or restricting boats to one waterway (especially wakeboats) to manage the risk of further spread within Aotearoa New Zealand.
- Wakeboats are a major risk that needs to be managed – need to focus management of that risk at the border, as well as internally (internal ballast tanks are very difficult to fully drain and decontaminate).
- Enforcement and regulation are important to manage the risk of spread – even ambassadors can help with “non-official” enforcement in a similar manner to that which Honorary Fisheries Officers work. Another good example is the self-certification that is deployed at Te Arawa Lakes.

9.3 Translocations

Several possibilities exist to continue translocating elvers safely, by treating elvers in a manner that kills *Corbicula* but doesn’t harm the elver. It is worth considering trials to determine the best methods before the next elver transfers will occur. Options include;

- Virkon Aquatic (trials possible with Virkon S which is currently available).
- UV light.
- Saline solution.
- Acetic acid/vinegar.
- Iodine.
- Formalin.
- Treatments used in conjunction with each other.

It would help to understand when the juvenile *Corbicula* concentrations in water are highest.

Arking and translocating of kākahi (and/or other native species) should be considered on a case-by-case basis. Ensuring plans and protocols are ready are a useful investment in management of these native species.

- Decide appropriate destination locations based on environment, kākahi genetics, and Hapu knowledge at place.
- Ensure culturally appropriate preparation of both the origin and destination sites.
- Test destination location and populations to ensure its safe for the translocated species.

- Biosecurity precautions must be taken for translocation.
  - Quarantine facilities are available (*e.g.* University of Waikato and NIWA at Hamilton).
  - Potentially “wash” the outside of the kākahi to get rid of external pests.
  - Test for disease or manage the disease risk profile to ensure low risk.
- If possible, translocate kākahi or other species within the same catchment or river to protect the population while *Corbicula* suppression measures are trialled.

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