Lake Rotonuiaha

Kākahi Assessment

June 2022

AOTEAROA LAKES

CITIZEN SCIENCE FOR OUR LAKES

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1 Executive Summary

Lake Rotonuiaha was surveyed on the 4th and 5th of June 2022, the surveys focused on identifying suitable kākahi (freshwater mussel) habitat, obtaining quantitative information on the kākahi population, assessing key impacts and setting up baseline kākahi monitoring sites.

The bathymetry and littoral habitat assessments indicate that there is limited habitat availability across the lake, this is largely due to extensive invasive hornwort (*Ceratophyllum demersum*) growth. Hornwort has an almost 100 % cover across the littoral margins of the lake and extends to depths past 14 m. Only four areas suitable for kākahi bed establishment were identified, two of which were surveyed (Site 1 & Site 2).

A total of 519 live Echyridella menziesii were counted across all the transects, 109 from Site 1 and 410 from Site 2. The resulting density across both sites (total survey area of 198 m^2) was 2.62 kākahi per square meter. Site 2 had a higher density of kākahi (3.79/m^2) than Site 1 (1.21/m^2), this is likely due to habitat quality and availability.

Majority of the live kākahi were found between 1.5 – 6 m deep in areas just below the crest of the sloping lakebed approximately 4 – 6 m from the shore. These areas are shallow enough within the epilimnion to avoid persistent anoxia and increased sedimentation but deep enough to avoid exposure during low lake levels while still being in the zone with the highest algal growth.

The size class distribution across both sites was heavily skewed toward adults, 81.7 % of the total count was larger than 61 mm in length and 13.7 % was between 51 – 60 mm. Less than 5 % of the total count was smaller than 51 mm and only 2 live individuals across all transects were found in the 21 – 30 mm size class (one was 28 mm, and the other was 30 mm). No live mussels or dead shells were found smaller 28 mm.

The overall shell condition across both sites was light to medium surface wear across 25 – 50 % of the shell with no obvious deformations associated with parasitic infections.

The results are indicative of an aging kākahi population with limited to no recruitment. The live individuals appear to be in good health and the principal impacts are thought to be habitat loss, alteration to water quality and sediment properties as well as possible intermediate host limitations. The extensive hornwort growth is considered a priority issue.

2 Introduction

Lake Rotonuiaha is the largest in a cluster of three lakes known as the Putere Lakes, located near the Waiau River in Wairoa (Hawke's Bay). The lake is directly feed by two inflowing streams; one on the western bank that drains out of Lake Rotoroa and another on the eastern bank that drains from the main stem of the Waiau River. Lake Rotonuiaha is a 43.8-hectare monomictic lake that has a maximum depth of 29.2 m and is located amongst steep hill terrain with highly erodible soils. The surrounding catchment land cover largely consists of high production exotic grassland (LCDB v5.0 - Manaaki Whenua Landcare Research, 2020) and is dominated by pastoral land use activities. As a result, the lake has been subject to persistent nutrient and sediment loading. Regular surface water quality monitoring is currently being undertaken by Ngāti Pāhauwera and an analysis of the data is part of the wider Putere Lakes project.

Little is known about the in-lake biodiversity of Lake Rotonuiaha, recent macrophyte surveys have been completed (Burton, 2017) and Hawke's Bay regional council have historic records of rainbow trout, smelt, crans bullies, longfin eels, shortfin eels and banded kokopu. No data on kākahi (freshwater mussels) in this lake could be found. Verbal recollections of kākahi were noted by mana whenua. The purpose of this assessment was to identify suitable kākahi habitat, carry out a quantitative survey and establish baseline monitoring sites. As part of the assessment, information on kākahi habitat quality, general condition and impacts was also gathered.

Freshwater mussels are one of the most imperiled organisms on Earth and populations are declining globally with majority of species considered at risk or threatened, including three species endemic to New Zealand. *Echyridella menziesii* is classified as at-risk declining, *Echyridella aucklandica* is considered nationally vulnerable, and *Echyridella onekaka* is naturally uncommon (Grainger et al., 2018; Catlin et al., 2017; Grainger et al., 2014). These species are often geographically isolated and can only be found in a few locations.

Global freshwater mussel population decline has been attributed to the loss of habitat associated with eutrophication and sedimentation as well as general pollution (Catlin et al., 2017). The loss of native intermediate host fish (dwarf inanga and bullies) through predation from invasive species is also a significant contributor to their reduction in numbers (McDowall, 2002; McDowall, 2011). Unlike their marine counterparts, freshwater mussels cannot anchor themselves to a substrate. Instead, they bury themselves into the sediment which makes them vulnerable to increased sedimentation that can result from erosion in the catchment as well as from excessive organic matter like algal blooms. These species are filter feeders as adults so fine silt can clog their gills and suffocates them leading to widespread mortality (Phillips, 2007).

Mussels are an important part of a lake ecosystem; as biofilters and bioturbators they filter out nutrients, algae, bacteria, and fine organic material which helps purify the water (Collier et al., 2016). They have an average filtration capacity of 1 liter per mussel per hour (Walker et al., 2001) but rates of 1.6 to 1.8 liters/hour/g have been recorded (Phillips, 2007) and if present in large enough numbers, they can filter the entire volume of a small lake within days. They also oxygenate the sediment by moving it around which decreases anoxia and stems sediment nutrient remobilization. Aside from their ecological importance, these mussels are considered taonga and were once a valuable food source for many Māori. The shells were used as a utensil for cutting umbilical cords, flax and hair.

Adults can live to over 50 years and have an average life expectancy of 20 – 25 years (Grimmond, 1968). They are hardy animals which means that residual adults are not reflective of viable, self-sustaining populations (Rainforth, 2008; McEwan, 2022). Mature adults can reach sizes over 100 mm in length but typically range from 60 – 84 mm.

Their life cycle is complicated and differs from marine mussel species. They typically spawn during summer when females lay eggs into a space above their gills and the males ejaculate sperm directly into the water (Phillips, 2007). The females suck sperm laden water into their gills where it fertilizes the eggs. The larvae develop into glochidia while in the mantel of the female until spring when they are released into the water (McEwan, 2022). The glochidia attach to the pectoral fins, mouth and head of native galaxiids and bullies, these fish transport the glochidia until they drop off and mature further (Clearwater et al., 2014). There is little information around how they mature and migrate through the final parts of their life cycles however there has been research on key extent limiting factors.

Bed establishment tends to be influenced largely by substrate type and stability (James, 1985; James et al., 1998; Cyr et al., 2017), they prefer soft sand and mud so that they can easily bury themselves, but fine silt can clog their gills. Large beds are typically found on gentle sloping lake beds with an even bathymetric gradient (Phillips, 2007; Cyr et al., 2017). The upper bed extent can be limited by fluctuations in water level, temperature and wave action, the lower bed extent is heavily influenced by macrophyte establishment and water quality (particularly in stratified systems) (James, 1985; Burlakova & Karatayev, 2007; Cyr et al., 2017). Dissolved oxygen is also considered a major limiting factor for the lower bed extent, James et al., 1998 suggests dissolved oxygen concentrations above 5mg/L is likely to be the threshold for long term bed viability.

This report will discuss the results from the kākahi surveys done on the 4th and 5th of June 2022 and outline specific recommendations.

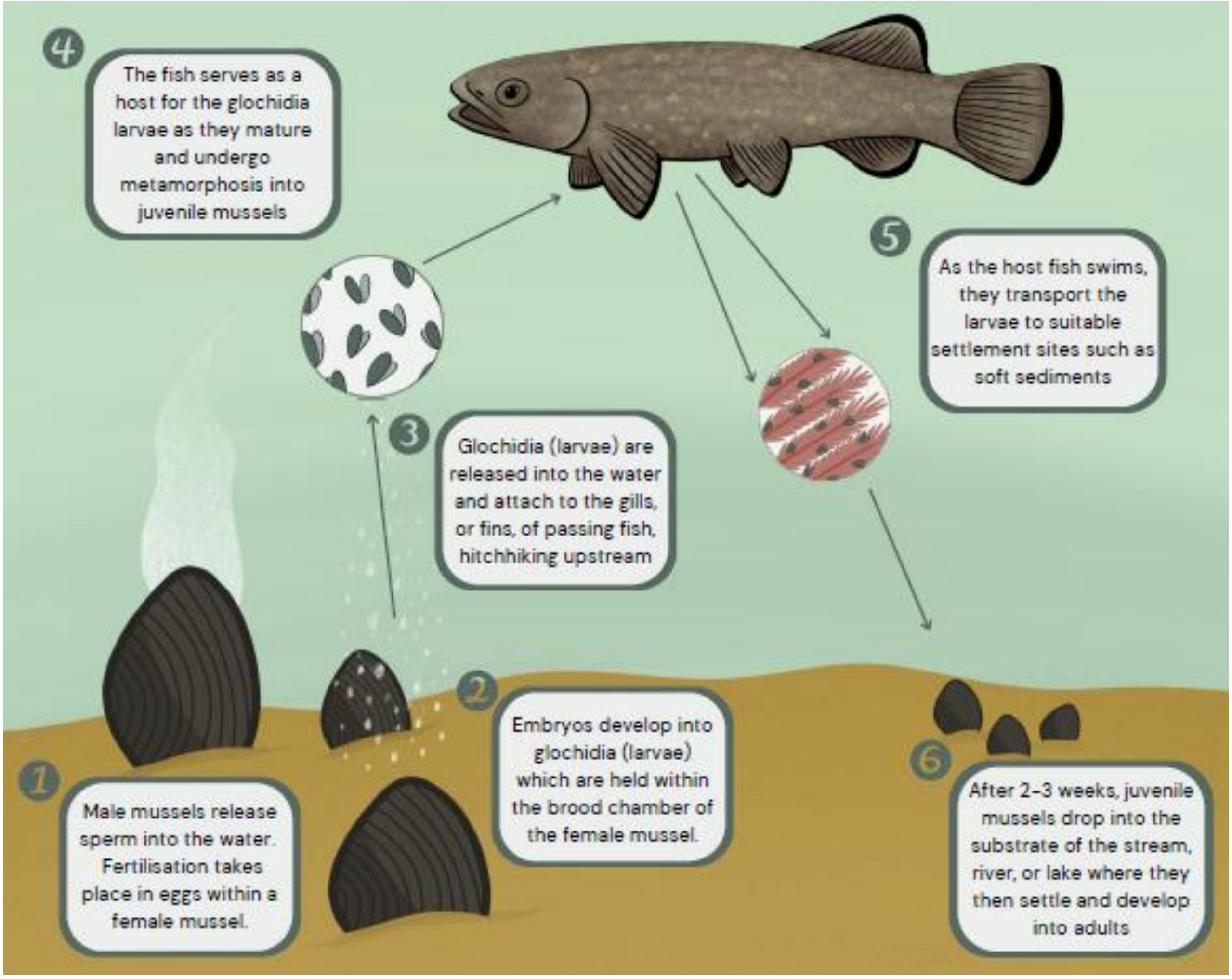

Figure 1: Illustration of the kākahi life cycle

3 Methods

All survey work was conducted on the 4th and 5th of June 2022. Day one entailed a visual and bathymetric assessment of the lake, selection of survey sites and a quantitative kākahi survey. Day two focused on quantitative kākahi surveys and monitoring programme set up.

A combination of bathymetry, visual inspections, and historical records (provided by Ngāti Pāhauwera) was used to select survey sites.

The entire lake edge was inspected using a handheld bathyscope at the same time as the bathymetric survey. Bathymetric data was collected and viewed in real time using a Deeper Smart Sonar CHIRP 2. Areas of interest were subsequently identified based on bathymetric slope, macrophyte cover, substrate characteristics, kākahi sightings (past & present) and riparian characteristics.

Two areas were ultimately surveyed as part of this assessment (Figure 2). These sites are on opposite sides of the lake and provide both spatial and habitat type representation.

Figure 2: Map of survey sites & transects (*green marker - Site 1 transect 1, blue marker - Site 1 transect 2, red marker - Site 2 transect 1, purple marker - Site 2 transect 2, yellow marker - Site 2 transect 3*)

The approximate area with the highest kākahi density in each site was marked out by divers. Two transects were laid representatively across the marked-out area, a third transect was surveyed at Sites 2 along the edge of the dense hornwort (*Ceratophyllum demersum*) bed that bordered the site (Figure 2). This transect was placed to monitor the effects of encroaching hornwort on kākahi numbers and track the rate of hornwort expansion across the site.

Each transect was laid perpendicular to shore and extended from the surface to the maximum depth kākahi were seen. Divers searched a 3 m width along each transect for kākahi, the search area was excavated to 15 cm to uncover buried individuals.

Each live kākahi found was counted, measured across the longest axis, and placed into size classes, dead individuals were counted but not measured. The depth and distance along the transect where kākahi were found was noted. A minimum of 10% of all live individuals counted per site were used to assess shell condition as per Mc Ewan 2015 protocol, random individuals were inspected along each transect ensuring an even distribution across depth and transect distance.

All kākahi measurements were done in water and each individual was gently placed back where it was found, this reduces the overall stress to the mussel. Care was taken to ensure that the kākahi were placed upright in the sediment with their siphons facing upward, this allows them to quickly resume filtering without the need to expend energy while reorientating themselves (McEwan, 2022).

The following metadata was collected at each site; upper & lower kākahi bed extent, establishment pattern, substrate characteristics, macrophyte growth/extent, fauna sightings and general signs of impacts.

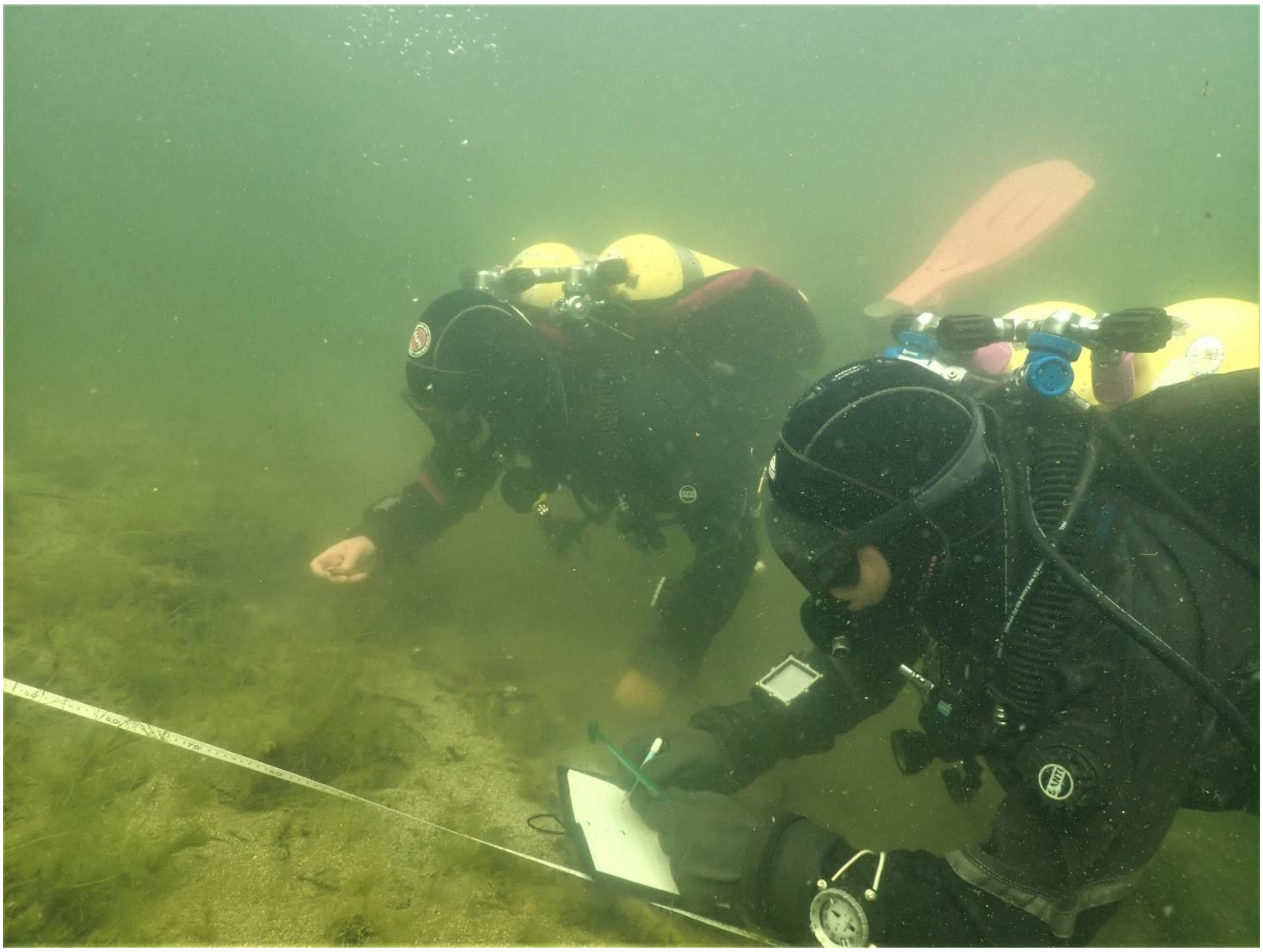

Image 1: Divers surveying kākahi along a transect

4 Results

The surveys were done on the 4th and 5th of June 2022. The weather on both days was largely clear with periods of light rain and cloud cover. Heavy rain had occurred in the week preceding the surveys.

All kākahi observed in Sites 1 and 2 were *Echyridella menziesii*, this is the most common and widespread species in the North Island.

Refer to Appendix A for site/transect GPS coordinates and Appendix B for raw kākahi survey data.

4.1 Site 1 - Description

Site 1 was identified by Kuki Green (Ngāti Pāhauwera) on the 4th of June 2022 as an area known for historic kākahi populations and was surveyed on the same day. This area is located at the mouth of an unnamed stream that flows from Lake Rotoroa into Lake

Rotonuiaha (Figure 2 & 3). The river was flowing strongly at the time of the survey and was discharging sediment laden water into the lake. The river mouth is bordered by well-established riparian vegetation.

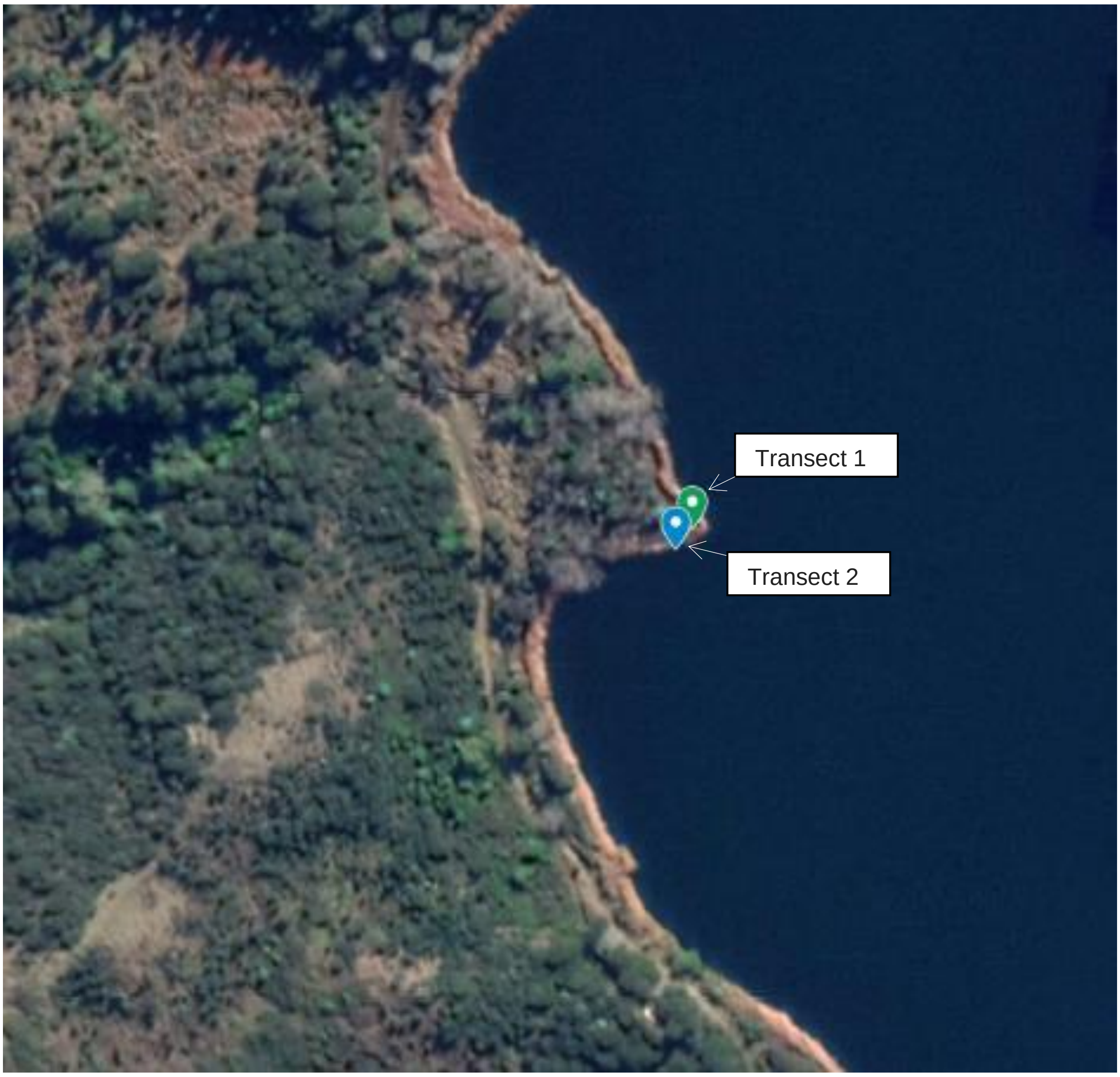

Figure 3: Site 1 map & transect locations

The lakebed sloped steeply from the river mouth down to a maximum depth of 14 m. The survey area was a V shaped clearing on the lakebed that extended southeast out from the river mouth into the lake. The sides of the V shaped clearing were bordered by dense hornwort (*Ceratophyllum demersum*) beds (Image 2).

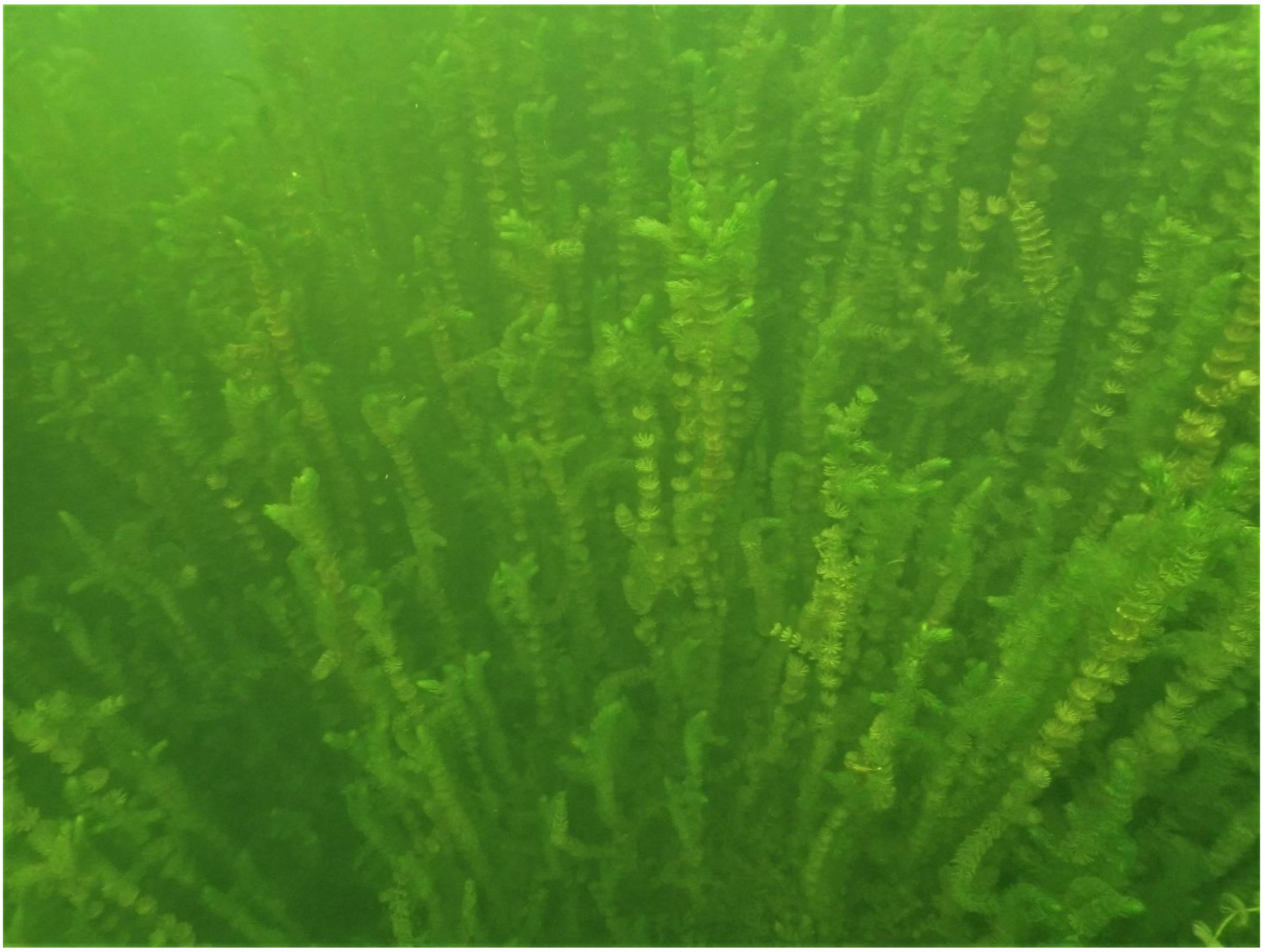

Image 2: Tall hornwort beds bordering Site 1

The centre of the clearing was almost completely devoid of vegetation down to 4 m deep, presumably due to flow and sediment deposition. Past 4 m the lakebed was covered by dense hornwort beds, the sides of the clearing had hornwort from the surface down to 12 m. Majority of the hornwort past 8 m was dead and coated with a layer of fine slit (Image 3), majority of which likely stems from sediment laden discharge.

The area between 8 – 10 m appears to be a deposition zone and had large amounts of sediment, dead hornwort, leaf litter and other organic debris, there were signs of persistent anoxia throughout this zone (Image 3 & 4).

No thermal stratification was observed and the temperature across the depth profile was 13°C (± 0.5). There was minimal light penetration past 3 m deep however, horizontal visual clarity in the wider survey area was approximately 2 m on the surface (visibility reduced to 0.5 m directly in front of the river mouth due to strong flows and sediment discharge) and deteriorated to almost zero past 10 m (Image 3 & 4).

Image 3: Lakebed at 8 - 10 m with dead hornwort and leaf litter coated with fine slit, the hazy appearance is due to sulphide precipitate in the water column

Image 4: Anoxic sediment and decomposing hornwort along the deeper contours (8 - 10 m)

There was a thin sulphide layer at 5 m that cleared up at 8 m, the visibility was remarkably clear between 8 – 10 m (approx. 6 – 10 m). A thick opaque sulphide layer was seen throughout the deeper contours from 10 – 14 m, the formation of these layers may be a result of the decomposition of large amounts of organic material on the lakebed (Image 3).

The top of the V shaped clearing, around the river mouth, consisted of a thick layer of soft silt, past 2 m down the steep slope the substrate changed to well sorted medium to large grain sizes with patches of soft silt. The lower extent of the clearing (4 m) had a thick buildup of fine sediment against the edge of the hornwort bed. Large patches of benthic algal growth were seen along the mid – deep (5 – 10 m) sections of the site. The lack of benthic algal growth along the shallower sections is likely due to the scouring effect of sediment laden flow exiting the river mouth.

No native macrophytes were seen within the wider survey area, only invasive hornwort and small stands of *Potamogeton crispus* occupied the wider site (Image 5). Three bullies (suspected common or crans) (Image 6) and a school of common smelt (*Retropinna retropinna*) were seen in the shallows (2 – 4 m). Four short fin eels (*Anguilla australis*) were seen at 7 – 10 m amongst the thick hornwort beds (between the two sulphide layers) (Image 7). They exhibited lethargic behaviour and were often buried in the thick beds of dead hornwort, presumably this behaviour is in response to the colder temperatures (Graynoth & Jellyman, 2002).

Image 5: Stand of *Potamogeton crispus*

Image 6: Bully species

Image 7: Short fin eel (*Anguilla australis*) amongst the thick hornwort bed

4.2 Site 1 – Kākahi Survey

The only section of Site 1 that had kākahi was the V shaped clearing in front of the river mouth. The center of the clearing had limited kākahi numbers, presumably due to strong flows. The areas of the highest kākahi densities were along the edges of the V shaped clearing. These areas had no hornwort and good flow but was out of the direct flow. The kākahi formed a band, perpendicular to the shore, along the shallower section of these areas. The bed pattern changed from a band to a patch type distribution past 5 m deep. No kākahi were seen past a depth of 10 m.

Transect 1 was 15 m long and laid perpendicular to shore along the true left of the V shaped clearing (Figure 3). It extended from the surface at the river mouth down to 10 m deep.

A total of 43 live *Echyridella menziesii* were counted along Transect 1, resulting in a density of 0.96 live kākahi per square meter. No dead kākahi were found with intact shells, shell fragments were seen sparsely spread across the deeper sections of the transect (> 5 m).

No kākahi were found between 8- 10 m and only 4.7 % of the total count was between 6 – 8 m deep, 69.8 % was found between 2 – 6 m deep and 25.6 % between 0 – 2 m. The highest density of kākahi along this transect was found between 2 – 6 m deep.

Majority of the kākahi (44.2 %) were larger than 70 mm, 30.2 % were in the 61 – 70 mm size class and 23.3 % in the 51 – 60 mm size class. Only one individual was found in the 41 – 50 mm size class and no kākahi were found in the smaller size classes.

The shell condition of individuals along Transect 1 ranged from light wear across 25 – 50 % of the shell to heavily worn and eroded shells. The average shell condition was light surface wear across 25 – 50 % of the shell (McEwan, 2015).

Transect 2 was 15 m long and laid perpendicular to shore along the true right of the V shaped clearing (Figure 3). It extended from the surface at the river mouth down to 10 m deep.

A total of 66 *Echyridella menziesii* were counted along Transect 2, resulting in a density of 1.47 live kākahi per square meter. Similarly to Transect 1, no dead kākahi were found with intact shells and fragments were seen sparsely spread across the deeper sections of the transect (> 5 m).

Three kākahi (4.5 % of the total count) were found between 8- 10 m deep, 25.8 % of the total count was between 6 – 8 m, 15.2 % was found between 4 – 6 m, 37.9 % was found between 2 – 4 m and 16.7 % between 0 – 2 m. Unlike the band formation in Transect 1, kākahi along Transect 2 established beds in a patch formation. As a result, the areas with the highest densities were split across two different depth contours; the first patch was between 2 – 4 m deep and the second patch between 6 – 8 m deep.

Majority of the kākahi (43.9 %) were in the 61 – 70 mm size class followed by 33.3 % in the >70 mm size class, 22.7 % were in the 51 – 60mm size class and no individuals were found in any of the smaller size classes.

The shell condition was similar to Transect 1 and ranged from light wear across 25 – 50 % of the shell to heavily worn and eroded shells. The average shell condition was light surface wear across 25 – 50 % of the shell (McEwan, 2015).

A total of 109 live *Echyridella menziesii* were counted across Site 1, resulting in a site density of 1.21 live individuals per square meter. Majority (76 %) of the individuals were larger than 61 mm (38.5 % of the total site count in the 61 – 70 mm size class and 37.6 % in the >70 mm size class), only 22.9 % of the total site count was in the 51 – 60 mm size class and only 1 individual was found in the 41 – 50 mm size class. No smaller kākahi were found across the site.

Most (35.8 %) of the kākahi across Site 1 were found between 2 – 4 m deep followed closely by 23.9 % found between 4 – 6 m and 20.2 % between 0 – 2 m. Only 20.2 % of the total site count was found deeper than 6 m (17.4 % between 6 – 8 m and 2.8 % between 8 – 10 m).

Kākahi beds along Transect 1 appeared to be in a band formation, the kākahi bed is not clearly divided into section but rather forms as a continuous band across a specific area/depth contour. This is evident by the relatively even distribution of individuals from 0 – 6 m deep. In contrast the kākahi along Transect 2 appeared to establish in patch like beds, individuals are unevenly distributed across a wide area with patches of high numbers in between areas with little to no kākahi. Distinct patches were identified between 2 – 4 m deep and 6 – 8 m deep.

Transect 1 had more kākahi along the 0 – 2 m depth contour compared to Transect 2, this is likely a result of the environment type. The area around 0 – 1.5 m deep at the top of Transect 1 was flat and out of the main channel, the reduced flow and substrate characteristics may be preferred environmental conditions. The same depth contour on Transect 2 was steeper and nearer to the center channel so the flow was noticeably higher. Transect 2 had more kākahi along the 6 – 10 m depth contour than Transect 1, this could be a result of the patch bed formation. The lower depths (8 – 10 m) of Transect 1 was covered by dense hornwort beds which may explain why so few kākahi were found at these depths.

The upper extent of kākahi appears to be limited by flow and wave action in some areas but kākahi were sighted in the river mouth and further upstream. The lower extent was clearly limited by dense hornwort growth, no individuals were seen in areas with dense growth despite actively searching for them amongst the live and dead hornwort. The 2 – 4 m depth contour likely had the highest kākahi numbers as it is just below the strong surface flows exiting the river mouth but above the hornwort and sulfide layers. kākahi will avoid persistent anoxic conditions and will move out of areas with a dissolved oxygen concentration of 5 mg/L or less (James et al., 1998). The dense hornwort and sulphide layers create anoxic conditions that would limit the lower depth extent of kākahi bed establishment. They also appear to prefer areas 1 -2 m deep just below the crest of a sloping lakebed where the substrate still has a thin surficial layer of soft silt, the exact reasons are unknown but could be due to a combination of food availability, flow and substrate conditions (Phillips et al., 2007). Surveys in other North Island lakes have also reported on this potential kākahi habitat preference (Hussain, 2020; Hussain 2021).

The overall shell condition for Site 1 was light to medium surface wear across 25 – 50 % of the shell. Some individuals were covered with a thin layer of epiphyton, but it did not appear to be hindering filtering activity. No obvious deformations associated with parasitic infections were noted at Site 1.

Image 8: Photos of kākahi from Site 1, left image - adult kākahi along the deeper edge of Transect 2; Right image - aggregate of adult kākahi in the shallow water near the start of Transect 1

Image 9: Close up of filtering kākahi amongst the leaf litter on Transect 2

4.3 Site 2 – Description

Site 2 was identified during the littoral mapping and was surveyed of the 5th of June 2022. This area is located along the eastern bank of a bay on the southern end of Lake Rotonuiaha (Figure 2 & 4).

Three flowing overland flow paths were draining into the site from the surrounding steep sloped paddock. The inflowing discharge ran clear with no visible signs of suspended matter (organic & inorganic).

The lakebed formed a 4 m wide flat band along the edge of the bank that gently sloped down to a maximum depth of 6 m. The survey area was a semi-circle shaped clearing that extended west from the shore into the lake. The sides and lower extent of the clearing were bordered by dense hornwort (*Ceratophyllum demersum*) beds with stands of *Elodea canadensis* along the deeper contours (2.4 m) (Image 10).

Despite the encroaching hornwort, the clearing had a good representation of native macrophytes. Small clumps of *Chara australis* were seen in the shallows (1 – 2 m), *Ruppia polycarpa, Potamogeton cheesemanii, Nitella leonhardii* and *Nitella sp. aff. Cristata* was seen across the entire site (Image 11). The Nitella species formed dense clumps along the deeper sections (2.4 m) of the clearing against the edge of the hornwort/Elodea beds, these sections also had small stands of *Potamogeton crispus*. *Chara globularis* and *Nitella* *leonhardii* was seen growing amongst the deeper Elodea clumps (Image 12). Small stems of hornwort were also seen throughout the site and were forming clumps in some areas, the edges of the clearing had sections of hornwort clumps that have almost joined together to form a continuous bed (Image 13).

Figure 4: Site 2 map & transect locations

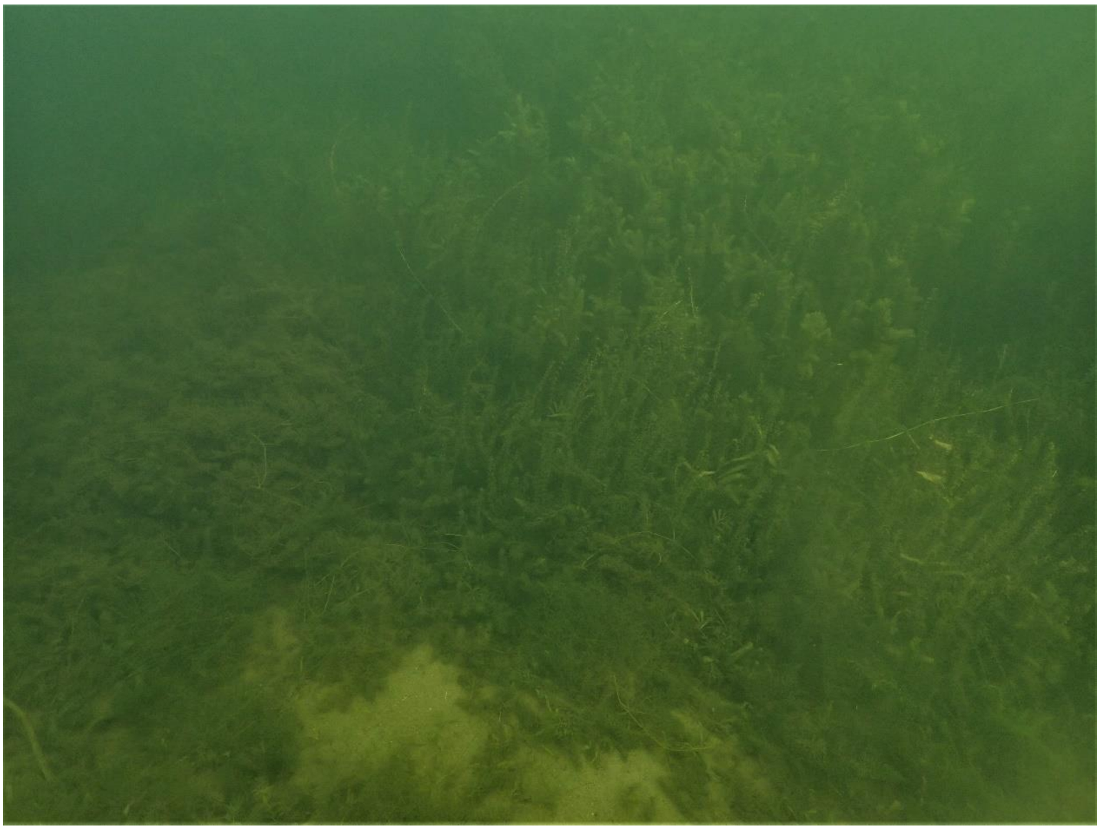

Image 10: Side and lower extent of Site 2 bordered by dense hornwort (*Ceratophyllum demersum*) and *Elodea canadensis*

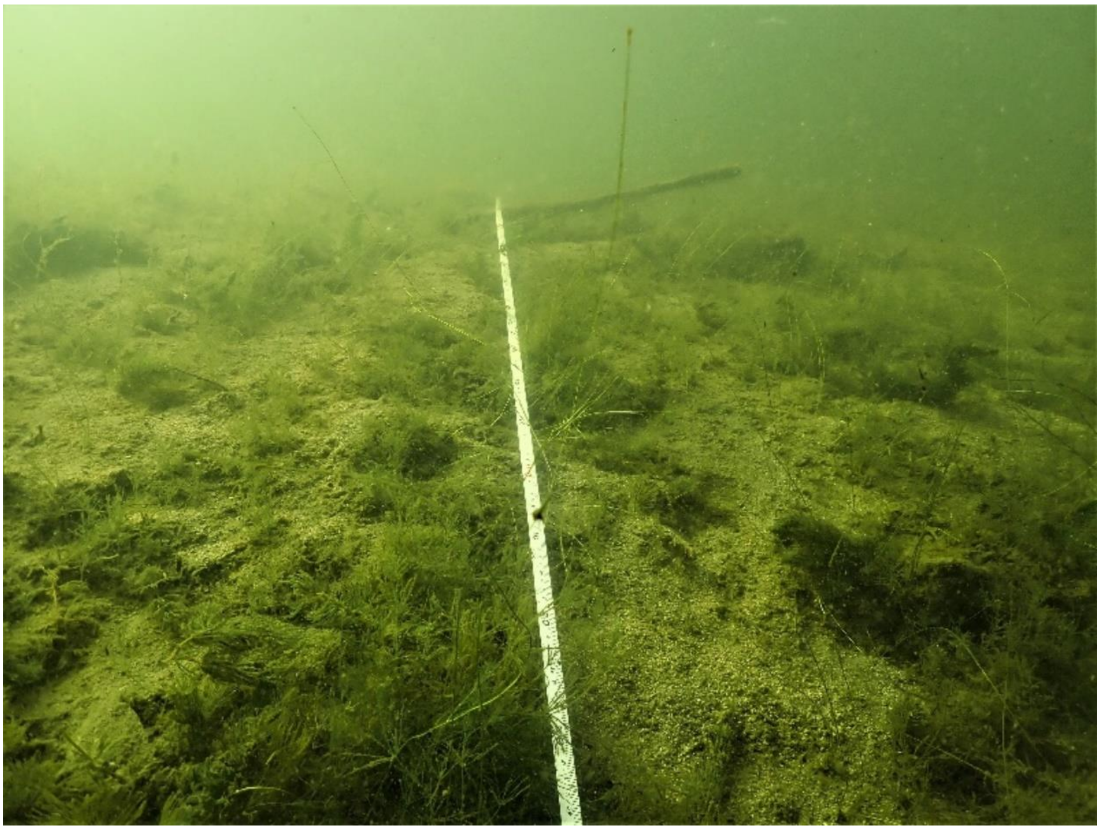

Image 11: Transect 2 - representative photo of the lakebed across site 2 showing stems & clumps of native macrophytes and hornworth

Image 12: Chara & Nitella species growing amongst the stands of Elodea

Image 13: Hornwort encroaching into the kākahi beds at Site 2, ***Left image – clumps of hornwort forming a bed in the middle of the kākahi survey area (Transect 3); Right image – dense hornwort beds along the sides of Transect 3, encroaching into the main kākahi bed area***

On the surface, the banks had a thin strip of riparian vegetation that was infested by pest species. The deeply undercut banks were collapsing in places and there were large tree branches and woody debris scattered across the flat area (2 – 6 m from shore) adjacent to the bank. Leaf litter was present across most of the site and the substrate largely consisted of medium to large grain sizes with gravel along the flat areas adjacent to the bank. A thin surficial layer of benthic algal growth was seen in sections of the site and there were no signs of persistent anoxia.

Two additional clearings were found on either side of the survey area but had very few kākahi. This could be due to the distinctly different substrate; these clearings were had an undulating clay like lakebed with sections of thick silt.

No thermal stratification was observed and the temperature across the depth profile was 13°C (± 0.5). Horizontal visual clarity in the wider survey area was approximately 5 m. Bullies (suspected common or crans) were the only fish sighted during the survey.

4.4 Site 2 – Kākahi Survey

The only area within the wider site that had kākahi was the semi-circle shaped clearing in between the three overland flow paths. The clearing was visually inspected to determine the area with the highest number of kākahi. The chosen survey areas were shallow (0.5 – 2.4 m) and had no established hornwort beds (small stems and clumps were seen throughout the area). The kākahi were uniformed distributed across the clearing with no clear patch formation. No kākahi were seen past 2.4 m deep (12 m from shore), this is where the dense hornwort growth along the lower bed extent began.

Transect 1 was 12 m long and laid perpendicular to shore just below the first overland flow path (Figure 4). It extended from the shore (0.5 m) down to 2.4 m deep.

A total of 76 live *Echyridella menziesii* were counted along Transect 1, resulting in a density of 2.11 live kākahi per square meter. Thirteen dead kākahi were found with intact shells, shell fragments were seen sparsely spread across the site.

Majority of the kākahi (69.7 %) were found between 4 – 10 m away from shore. The lowest density of kākahi along this transect was found near the bank and against the hornwort beds (5.3 and 9.2 % respectively).

Majority of the kākahi (52.6 %) were larger than 70 mm, 31.6 % were in the 61 – 70 mm size class, both the 51 – 60 mm and 41 – 50 mm size classes had 6.6 % of the total count and one individual was found in the 31 – 40 mm and 21 – 30 mm size classes. No smaller kākahi were found.

The shell condition of individuals along Transect 1 ranged from light wear across 25 – 50 % of the shell to moderate ware across 50 – 75 % of the shell. The average shell condition was light surface wear across 25 – 50 % of the shell (McEwan, 2015).

Transect 2 was 12 m long and laid perpendicular to shore 10 m south of Transect 1 near the outlet of the second overland flow path (Figure 4). It extended from the shore (0.5 m) down to 2.4 m deep.

A total of 221 live *Echyridella menziesii* were counted along Transect 2, resulting in a density of 6.14 live kākahi per square meter. Forty-eight dead kākahi were found with intact shells, shell fragments were seen sparsely spread across the site.

Majority of the kākahi (73.8 %) were found between 4 – 8 m away from shore. The lowest density of kākahi along this transect was found within 4 m of the hornwort beds (9 % of the total count). In contrast to Transect 1, 17.2 % of the total count was found in the shallows (0.5 m) against the shore (0 – 2 m from the bank).

Majority of the kākahi (54.3 %) were larger than 70 mm, 29.9 % were in the 61 – 70 mm size class, 10.9 % were in the 51 – 60 mm size class and 4.5 % were in the 41 – 50 mm size class. Only 1 individual was found in the 31 – 40 mm size class and no smaller kākahi were found.

The shell condition of individuals along Transect 1 ranged from light wear across 25 – 50 % of the shell to moderate ware across 50 – 75 % of the shell. The average shell condition was light surface wear across 25 – 50 % of the shell (McEwan, 2015).

Transect 3 was 12 m long and laid perpendicular to shore near the outlet of the fastest flowing overland flow path, south of Transect 2 (Figure 4). It extended from the shore (0.5 m) down to 2.4 m deep. There was a thick band of hornwort that separated this transect from transects 1 & 2. Transect 3 was laid through a narrow clearing with high kākahi numbers, surrounded by hornwort beds on three sides (no hornwort had established along the shallow upper extent of the clearing, but small stems were seen across the area). This made it an ideal site for assessing the effects of hornwort establishment on kākahi numbers. As the hornwort encroaches further into the kākahi bed the displacement effect can be monitored, very few studies have looked at this and this site presents a good opportunity to better understand the rate and scale of effects caused by hornwort on kākahi.

A total of 113 live *Echyridella menziesii* were counted along Transect 3, resulting in a density of 3.14 live kākahi per square meter. Twenty-one dead kākahi were found with intact shells, shell fragments were seen sparsely spread across the site.

Majority of the kākahi (47.8 %) were found between 4 – 6 m away from shore, 38.1 % were found from 0 – 4 m away from shore and the remaining 14.2 % near the edge of the hornwort beds along the lower extent of the clearing (8 – 12 m from shore at a depth of 2.4 m).

Majority of the kākahi (40.7 %) were larger than 70 mm followed closely by 39.8 % in the 61 – 70 mm size class, 15.0 % were in the 51 – 60 mm size class and 3.5 % were in the 41 – 50 mm size class. Only 1 individual was found in the 31 – 40 mm size class and no smaller kākahi were found.

The shell condition of individuals along Transect 3 ranged from light wear across 25 – 50 % of the shell to moderate ware across 50 – 75 % of the shell. The average shell condition was light surface wear across 25 – 50 % of the shell (McEwan, 2015).

There was no clear difference in bed pattern between the three transects however, there appeared to be a preference for the areas between 4 – 6 m from shore. This area is halfway between the shore and the start of the hornwort beds and is just below the crest of the steeper sloping section of the site, this preference was also seen in Site 1.

This is a relatively even distribution of individuals along the middle portion of the site with numbers reducing as you reach the upper and lower extent of the beds. The lower numbers seen along the shore are likely a result turbulent conditions, elevated temperatures and potential exposure to predators (rats are known to swim into the shallow water along lake margins and forage for kākahi). The likely limiting factor for the lower extent is the dense hornwort growth. Like Site 1, no kākahi were found with the dense hornwort bordering the survey area.

Transect 2 had the most amount of kākahi followed by Transect 3 and Transect 1. Transect 2 was in the middle of the survey area and was the furthest away from the hornwort beds that boarded either side of the site. It's possible that this transect was the least effected by dissolved oxygen fluctuations, overnight dissolved oxygen sags around the dense hornwort could have caused kākahi to move to the center of the site. That being said, Transect 1 was only 10 m away from Transect 2 so was only marginally closer to the hornwort beds. The kākahi along Transects 3 were closely surrounded by dense hornwort yet it had the second highest number of kākahi. This may be due to the lack of recoloration options, being bordered on three sides and confined to a narrow clearing, limits the ability of kākahi to escape adverse conditions.

The overall shell condition for Site 2 was light to medium surface wear across 25 – 50 % of the shell (Image 14). Some of the larger individuals (> 60 mm) had thick clumps of epiphyton on their shells but it did not appear to be hindering filtering activity (Image 15). No obvious deformations associated with parasitic infections were noted at Site 2.

Image 14: Adult kākahi with representative shell conditions seen across Site 2

Image 15: Large filtering kākahi covered with epiphyton

4.5 Survey Summary

A total of 519 live Echyridella menziesii were counted across all the transects, 109 from Site 1 and 410 from Site 2. The resulting density across both sites (total survey area of 198 m^2) was 2.62 kākahi per square meter. Site 2 had a higher density of kākahi (3.79/m^2) than Site 1 (1.21/m^2), this is likely due to habitat quality and availability.

Site 1 was a deep, steep sloped area with high flows and sedimentation bordered by dense hornwort growth and covered by organic debris. These conditions are not conducive to dense kākahi bed establishment. In contrast, Site 2 was shallow, flat and had the preferred substrate characteristics. This site was also bordered by invasive macrophyte growth however the kākahi bed area had a lower amount of organic debris and no signs of persistent anoxia. There was less flow at Site 2, but the shallow nature of the site promotes well mixed oxygenated conditions all year round. Site 1 is deeper and would experience thermal stratification during summer with persistent anoxia in the hypolimnion.

No dead kākahi with intact shells were found at Site 1, it is assumed that the high flow in this area would sweep dead shells down the steep sloped lakebed toward the deeper sections of the lake. These areas a deposition zones and the shells would quickly become buried under fine sediment, organic debris and a thick blanket of dead hornwort. Eighty-two dead kākahi with intact shells were found at Site 2 which is 13.6 % of the total kākahi count (live and dead individuals) across the site. This was expected from a low energy environment with a gentle bathymetric slope.

Majority of the live kākahi were found between 1.5 – 6 m deep in areas just below the crest of the sloping lakebed approximately 4 – 6 m from the shore. These areas are high enough within the epilimnion to avoid persistent anoxia and increased sedimentation but deep enough to avoid exposure during low lake levels while still being in the zone with the highest algal growth.

The size class distribution across both sites was heavily skewed toward adults, 81.7 % of the total count was larger than 61 mm in length and 13.7 % was between 51 – 60 mm. Less than 5 % of the total count was smaller than 51 mm and only 2 live individuals across all transects were found in the 21 – 30 mm size class (one was 28 mm, and the other was 30 mm). No live mussels or dead shells were found smaller 28 mm.

The overall shell condition across both sites was light to medium surface wear across 25 – 50 % of the shell with no obvious deformations associated with parasitic infections.

5 Discussion

There is no reference condition for kākahi in Lake Rotonuiaha and very little is known about their natural state in lakes across the Hawke's Bay region. Kākahi data from other North Island lakes can be used to contextualise the Lake Rotonuiaha survey data and gain an understanding of the current population state.

The bathymetry and littoral habitat assessments indicate that there is limited habitat availability across the entire lake, this is largely due to extensive hornwort growth. Hornwort has an almost 100 % cover across the littoral margins of the lake and extends to depths past 14 m. Only four areas suitable for kākahi bed establishment were identified, two of which were surveyed (Site 1 & Site 2), one was along the blind end of the bay south of Site 2 and the fourth area was along the western margin of the bay where we launched the boat (Figure 5). These areas were devoid of dense hornwort growth and have the appropriate substrate and bathymetric slope characteristics. Limited habitat availability is recognised as a key issue across New Zealand lakes and in the case of Lake Rotonuiaha, it has likely contributed to the low kākahi numbers and constrained bed establishment.

Kākahi have been known to occur in large continuous bands along the littoral margins of North Island lakes (Happy, 2006; Cry et al., 2017; Hussain, 2020; Burton et al., 2022) and this may have been the case in Lake Rotonuiaha. The kākahi bed pattern at Site 2 reflects this continuous band formation and there are signs that this bed would have historically extended for hundreds of metres. All three transects surveyed at Site 2 were once part of the same bed but the encroaching hornwort has separated Transect 3 from the main bed area, this bed fragmentation was also seen in the area immediately north of Site 2 and along the blind end of the bay south of Site 2 (Image 13).

The displacement of freshwater bivalves from the littoral zone by invasive macrophyte growth is common (James, 1985; Burlakova & Karatayev, 2007) and has contributed to the fragmented bed establishment and isolation of beds in discrete locations seen in Lake Rotonuiaha.

The aggregated kākahi density across both survey sites was 2.62 live individuals per square meter. This is an extremely low number considering dense beds exceeding 600 live individuals per square meter have been reported in New Zealand lakes (James, 1985; James, 1987; Weatherhead & James, 2001). Several surveys in the Rotorua lakes recorded average densities of 43 – 322 live individuals per square meter (Happy, 2006) with maximums reaching 550 per square meter (Wells & Clayton, 1996), similar numbers were seen by Roper & Hickey (1994) in the Waikato region.

Recent surveys from two Auckland lakes have reported similarly low densities, Lake Rototoa had an aggregated density of 7.2 live individuals per square meter across 4 sites (Hussain, 2020) and Lake Tomorata had 14 live individuals per square meter across 2 sites (Hussain, 2021). These lakes have a similar range of impacts to Lake Rotonuiaha, they have a high biomass of invasive species, loss of habitat as well as increased eutrophication and sedimentation.

The size class distribution across both sites was heavily skewed toward the larger size classes, 81.7 % of the total count was larger than 61 mm in length and only 2 live individuals were found in the 21 – 30 mm size class (one was 28 mm, and the other was 30 mm). No live mussels or dead shells were found smaller 28 mm.

Figure 5: Location suitable for kākahi bed establishment – ***red polygons indicate mapped areas***

Image 16: 31 - 40 mm size class kākahi (approx. 5 years old), ***the colour variation is distinctly different to the 50 mm and larger individuals***

The transition from juvenile to reproductive adult kākahi is considered to occur at the 37 mm shell length size (S. Clearwater, DOC, pers. comm., 20/09/2021), this means that almost 99.8 % of the total count is considered as adult kākahi. A healthy population of kākahi would be expected to have a range of sizes from small (10 mm) to large (c. 100 mm) individuals (James, 2006). The limited size class representation and dominance of larger individuals is indicative of an aging population that has had no successful recruitment for some time. It is difficult to determine exactly how long this recruitment failure has been going on for but, considering the size of the individuals it is plausible that it has been ongoing for 5 – 10 years. This scenario has also been seen in several lakes across the country (Grimmond, 1968; James, 1985; Roper & Hickey, 1994; Hussain, 2020; Hussain, 2021).

The ongoing lack of juvenile size classes and low densities is concerning and does not bode well for the future sustainability of kākahi in Lake Rotonuiaha. This could be due to a variety of reasons with the most likely factors including habitat availability, deteriorating water quality, increased sedimentation, and declines in intermediate fish hosts. Nevertheless, we cannot rule out the possibility that recruitment is happening in areas other than where the main aggregations of adults, the inflowing river could still hold a source population for the lake.

Aside from physical displacement of kākahi, dense hornwort growth directly effects various aspects of the lake environment by modifying water currents and sediment characteristics, increasing water temperature as well as creating diurnal fluctuations in oxygen and pH (Hussain & Jones, 2022). These changes result in periods/areas of unfavorable environmental conditions for kākahi. Signs of persistent anoxia were noted throughout the dense hornwort and surrounding areas, masses of decomposing hornwort reduce dissolved oxygen and increase ammonia concentrations. Juvenile kākahi are extremely susceptible to ammonia with acute and chronic effects manifesting at trace levels (Clearwater et al., 2014). Kākahi have a dissolved oxygen threshold of 5 mg/L for long term viability and are sensitive to temperatures exceeding 19°C (James et al., 1998; Butterworth, 2008; Hussain & Jones, 2022). Oxygen depletion due to thermal stratification was attributed as the cause of a mussel die-off event in Lake Camp in Summer 2013 (Beech, 2013; Sutherland, 2013). Considering the likely extent of the anoxia, seasonal stratification and elevated temperatures seen in hornwort beds (Hussain & Jones, 2022), kākahi establishment in Lake Rotonuiaha is limited to a small portion of the lake.

Sediment type and stability is considered a key physical factor influencing the density of kākahi (James 1985, James et al. 1998, Cyr et al. 2017), with soft sediment, generally sand or silt required by kākahi for burial. Bathymetric slope, and an interplay with sediment stability, are also thought to be determinants of the depths at which kākahi density peaks (Cyr et al. 2017). Excessively deep, soft silt has been found to be unsuitable due to the potential for clogging of filtering mechanisms (James, 1985; James, 1987, Hussain, 2020; Hussain 2021), with potential for kākahi to sink and suffocate on low density substrates. This soft silty substrate type was commonly encountered in Lake Rotonuiaha at depths greater than 6 m. The inflowing river at Site 1 was discharging sediment laden water from Lake Rotoroa and the surrounding sub-catchment into Lake Rotonuiaha. There was evidence of increased sedimentation across the lake and the substrate gradually became softer with depth. Majority of the lake has some degree of riparian buffer, but the surrounding catchment is steeply sloped and sparsely planted making it prone to erosion and sediment discharge during high rainfall events. Based on the in-lake substrate assessments and likely depth of the anoxic hypolimnion, it is unlikely that kākahi beds would be able to establish deeper than 6 - 8 m in Lake Rotonuiaha.

The upper extent of the kākahi is thought to be governed by flow and wind/wave action. High energy environments like river outflows or shallow exposed margins are unlikely able to support bed establishment (James, 1985; Cyr et al. 2017). Predation by rats and pukekos are also known to limit the upper extent of kākahi beds, particularly along shallow wadable margins (Hussain, 2020; Hussain, 2021). The impact of terrestrial pests at Lake Rotonuiaha is unknown.

Cyanobacteria could be responsible, in part, for declining kākahi numbers. Lake Rotonuiaha does not have any algal data but, considering it is likely to be eutrophic it is possible that seasonal cyanobacteria blooms could form. Observations of low kākahi numbers despite the presence of apparently suitable habitat have been related to cyanobacteria (Anabaena) blooms (Sullivan et al., 2012; de Winton, 2013). Juvenile kākahi mortality increased when exposed to toxin concentrations typical of a severe cyanobacteria (Microcystis) bloom (Clearwater et al., 2012). Adult kākahi survival and reburial rates decreased significantly after exposure to microcystins (Clearwater et al. 2012).

Kākahi are expected to be more abundant in lakes with a higher trophic status due to greater planktonic food availability (Phillips et al., 2007). However, higher trophic levels (supertrophic and hypertrophic) can produce combinations of water quality and sediment conditions that prevent juvenile recruitment, and eventually becomes toxic to adult mussels.

Host availability could also be a contributing factor to the lack of recruitment. Common bullies and smelt were seen during the surveys, both species are known to be viable intermediate hosts but there is no population data for these fish in Lake Rotonuiaha. Both species were also sighted in Lake Rotoroa (Hussain & Jones, 2022) and it is assumed that the fish populations between the two lakes are linked via the river that connects them.

Pest fish could be a potential limiting factor. It is unknown if pest fish are present in the lake, with the last fish survey information collected in 1995. Pest fish often predate on, or out compete with native intermediate host species. Benthivorous pest species have also been known to predate on freshwater mussels overseas (Giles, Street & Wright, 1990).

The principal drivers behind the kākahi population collapse in Lake Rotonuiaha could be better understood through further targeted investigations.

6 Conclusion

Suitable kākahi habitat in Lake Rotonuiaha is extremely limited with only four potential locations identified, two of these were surveyed. The remaining littoral zone of the lake has been overrun by dense hornwort.

The kākahi survey results are indicative of a population collapse. The populace is heavily skewed to a mature community with 99.8 % of the counted individuals considered as adult. This aging population and limited size class representation indicates that little to no recent recruitment has successfully occurred. The principal drivers responsible for these results are likely habitat loss, deteriorating habitat quality, decreasing water quality and potential host fish limitations. Hornwort was assessed as being the most pressing impact to kākahi in the lake.

Immediate hornwort management needs to be undertaken where fragmented kākahi populations remain. Under the correct conditions hornwort can quickly overrun the remaining kākahi habitat. Hornwort is already showing signs of encroachment amongst the kākahi beds, with small sprigs and clumps emerging. The loss of further habitat may cause a reduction in genetic diversity and number of breeding adults. This would eventually lead to the extinction of kākahi from Lake Rotonuiaha.

Ongoing management of hornwort and water quality in both Lake Rotonuiaha and Lake Rotoroa needs to be undertaken due to their hydrological connectivity.

7 Invasive Macrophyte Management Considerations

There are a variety of management options that can be utilised for hornwort (*Ceratophyllum demersum*) and Elodea (*Elodea canadensis*) control. Macrophyte removal options are typically grouped into either chemical control (herbicides) or physical/manual removal. Each of these options have certain application limitations and their effectiveness varies depending on the site-specific conditions and constraints.

Herbicides such as Diquat and Endothall can be very effective but may cause adverse effects. These herbicides have been successfully used in New Zealand Lakes and the associated environmental concerns can be effectively managed. Both hornwort and Elodea are prone to fragmentation and cutting/disturbance of plant material produces propagules that can spread the incursion. This makes successful control via manual removal difficult.

Smothering invasive macrophytes using woven mats, hessian bags and tarpaulins have been used with some success elsewhere in New Zealand however it is not a suitable option for hornwort. Hornwort does not rely on typical roots for anchorage or nutrient absorption and can form floating mats, this will allow them to establish on/above the mats. If mats are used over the dense hornwort beds the disturbance will likely cause further dispersal of fragments, these fragments will settle on top of the mat and begin to grow. The subsequent removal of the mats will disturb the newly established hornwort and cause further dispersal. Smothering could be a viable option for Elodea in Lake Rotonuiaha. Unlike the extensive tall and floating hornwort beds the Elodea beds remain rooted in the sediment, are small and are confined to the shallow gently sloped margins. It is likely that a combination of manual removal, herbicides and strategic smothering will result in the best outcome.

Despite the impacts hornwort and Elodea are currently causing in the lake they are still performing key ecosystem functions like nutrient assimilation, habitat provision and regulation of in-water conditions. As a result, the management/control of these invasive macrophytes should be approached with caution and with consideration of the potential collateral effects. Staging the macrophyte removal to ensure some ecosystem functions remains at all times should be considered.

It is important to note while planning any macrophyte control strategies that studies suggest the removal of >30 % of the submerged macrophytes in a lake with high nutrient input was sufficient to trigger a regime shift to an alternative stable state with higher phytoplankton biomass (Thiemer, Schneider & Demars, 2021). One way to avoid this shift in trophic state is to restore native charophyte beds while invasive species are being controlled/removed.

Dense charophyte meadows can cause long-term immobilisation of nutrients (Hilt et al., 2006). Native charophytes are also able to deliver oxygen to the sediment and they do not die off in the same quantities as other macrophytes, this means they do not add to the oxygen depletion through decomposition and are able to maintain nutrient assimilation capacity year-round.

Several native macrophyte species were seen during the surveys and it is likely that there is still a viable seed bank in Lake Rotonuiaha. Restoring native charophyte beds should be considered as a key management objective. Studies suggest that 50 % is the optimal submerged macrophyte coverage for improvements in water quality in temperate shallow lakes (Zhang et al., 2021). Achieving this amount of cover may not be possible however even lower cover can create positive environmental effects.

8 Recommendations

1. **Invasive macrophyte management plan**
   The creation and implementation of a hornwort management plan with immediate focus on the areas with remaining live kākahi populations. A control plan should include management for both Lake Rotonuiaha and Rotoroa due to their hydrological connection.

2. **Detailed habitat delineation survey**
   The survey of available habitat space was undertaken using a bathymetry and a bathyscope. To determine if there are any fragmented kākahi beds across the lake, a detailed delineation survey including wading, snorkeling/diving the entire lake margin is recommended. This will help inform any other priority management areas.

3. **Juvenile kākahi survey.**
   Sieve representative substrate samples across Site 1 & 2 as well as locations suspected of suspected juvenile habitat. Sieving will uncover smaller juvenile individuals (< 10 mm). This data will provide a better understanding of the recruitment potential and failure points. It will also aid in identifying juvenile habitat, little is known about the habitat preferences for juveniles and finding these locations will allow for better species management/restoration plans.

4. **Glochidia survey.**
   Survey potential immediate hosts for parasitic glochidia should be undertaken in suspected breeding season (spring/summer). Glochidia numbers and encystment should be noted.

5. **Kākahi spawning condition survey.**

Assess spawning condition and brood pouch formation in representative numbers of adult kākahi from Site 1 & 2 during breeding season (spring/summer). This will provide insight into whether or not the adult population is spawning.

6. **Investigate interim kākahi conservation measures**

   Investigate options that could provide an interim solution to safeguard the kākahi population from further decline. Considering hornwort encroachment is likely the most pressing issue a potential interim measure could be fencing off Site 2 with shade cloth barriers to prevent further hornwort encroachment into the kākahi bed area. The barriers could be stocked with intermediate fish hosts during breeding season to ensure host availability during spawning. This and other potential options should be closely investigated to ensure they will not result in worse outcomes for kākahi.

7. **Stream survey**

   A stream walk survey of all inflows and outflows of the lake should be undertaken to identify any potential source populations of kākahi and fish barriers. Should kākahi be discovered, a quantitative survey should be done. This data will provide a better understanding of kākahi population sources and host availability.

8. **Detailed assessment of in-lake fauna**

   Biodiversity surveys, using eDNA, standard netting and underwater searching for cryptic species that are hard to detect using molecular methods, this will help fill knowledge gaps regarding in lake ecology. Knowing what fauna exists in the lake will improve our understanding of in-lake ecology and kākahi limiting factors.

9. **Catchment management options assessment**

   Investigate external nutrient/sediment loads and assess potential catchment management options aimed at reducing contaminant loading to the lake. Ensure future land use activities and the associated effects are considered.

10. **Riparian Restoration**

    Lake Rotonuiaha has varying riparian buffer widths and quality. A riparian restoration plan should be created with consideration of the surrounding land use, contours and land stability.

11. **Bathymetry and residence time**

    Bathymetry and residence time assessments will aid in establishing nutrient budgets (including translating external loads to in-lake loads), water balances and in-lake process models. It will also provide useful information for the invasive macrophyte management, knowing the depth, slope and location of macrophyte beds will guide the selection of the best methods.

12. **Floating wetlands**

    Floating wetlands can provide shading, decontamination (through biofilm production), and nutrient assimilation functions. The grown plants can be harvested and used for riparian planting elsewhere in the catchment. Baskets of bio balls can be attached to the bottom of the rafts to increase the surface area for beneficial bacteria and provide midwater refugia for zooplankton.

13. **Restore charophyte meadows**

    Restoring charophyte meadows will assist in maintaining lake health by absorbing nutrients, stabilising sediment and creating habitat for in-lake fauna. Restoration can be via natural regeneration (pending seed bank viability) or by cultivating seedings from the in-lake seed bank and replanting them. If there is no viable seed bank or the sediment condition no longer supports natural regeneration, interventions like RotoTurf could be used (natural fibres mats with seeds that are laid over the lakebed to accelerate macrophyte regeneration and sediment stabilisation).

14. **Restoration and management strategy**

    Create a restoration and management strategy that clearly discusses the expectations and project objectives. Include and operational section that outlines what interventions will be used, where they will be used and when they be used. A monitoring plan including methods and specific metrics aimed at assessing the effectiveness of the interventions as well as progress toward the project goals should be part of the strategy.

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10 Appendix A – Transect Coordinates

Site	Transect	Latitude	Longitude
Site 1	Transect 1	S 38°56.7885'	E 177°02.1640'
	Transect 2	S 38°56.7921'	E 177°02.1603'
Site 2	Transect 1	S 38°57.0088'	E 177°02.5727'
	Transect 2	S 38°57.0205'	E 177°02.5718'
	Transect 3	S 38°57.0297'	E 177°02.5849'

11 Appendix B – Kākahi Survey Data

Date	Site	Transect	Depth Contour	Dead	0-20mm	21–30mm	31–40mm	41–50mm	51–60mm	61–70mm	>70mm
04/06/22	1	1	0-2m					1	3	2	5
			2-4m						5	3	6
			4-6m						2	6	8
			6-8m							2	
			8-10m								
04/06/22	1	2	0-2m						3	4	4
			2-4m						6	12	7
			4-6m						2	4	4
			6-8m						4	7	6
			8-10m							2	1
Date	**Site**	**Transect**	**Transect Interval**	**Dead**	**0-20mm**	**21–30mm**	**31–40mm**	**41–50mm**	**51–60mm**	**61–70mm**	**>70mm**
05/06/22	2	1	0-2m							1	3
			2-4m						2	4	6
			4-6m	4		1		2	1	5	10
			6-8m	3			1	2	2	5	8
			8-10m	6				1		7	8
			10-12m							2	5
05/06/22	2	2	0-2m	2						24	14
			2-4m	8					8	12	37
			4-6m	10				4	10	10	30
			6-8m	11			1	1	3	16	31
			8-10m	7				2		2	6
			10-12m	10				3	3	2	2
05/06/22	2	3	0-2m	3					3	7	11
			2-4m	4				3	4	10	5
			4-6m	7			1	1	8	19	25
			6-8m	2					1	2	2
			8-10m	5						4	
			10-12m						1	3	3

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