Kākahi (Freshwater Mussel) Monitoring in Christchurch 2023

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Prepared for:
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EXECUTIVE SUMMARY

This report describes results of surveys for kākahi – freshwater mussels (*Echyridella menziesii*) in Christchurch city waterways in autumn 2023. Twenty locations were searched for kākahi in the Pūharakekenui – Styx River catchment, using a combination of rapid search and eDNA sampling methods. Quantitative sampling occurred at one site in Cashmere Stream, in Worsleys Reserve, at a location previously sampled in 2021.

Kākahi were found at three of the 20 sites sampled in the Pūharakekenui catchment, including two sites on the Pūharakekenui River and one site on Kā Pūhahi – Kaputone Creek. Kākahi densities were low at all sites, with one kākahi found at two of the sites and three kākahi found at the other site. All kākahi were detected during the rapid survey, with kākahi eDNA only detected at one of the three sites. The lack of eDNA detection likely reflects the combination of low kākahi densities and lack of replication of eDNA samplers. A single kanakana – lamprey (*Geotria australis*) was observed during kākahi sampling in Kā Pūtahi Creek. This is the first reported occurrence of both kanakana and kākahi from Kā Pūtahi Creek.

The Cashmere Stream kākahi population showed no change in density, distribution, or size structure between 2021 and 2023 sampling occasions. Small changes to the sampling methods in 2023 were associated with reduced sampling error and greater ability to detect changes in kākahi density over time. The persistence of high-density patches, or beds, of kākahi between sampling years is similar to observations reported overseas, but is a new observation for New Zealand freshwater mussels.

Recommendations include the following: further searches for kākahi and kanakana in Kā Pūtahi Creek; continued monitoring of kākahi in Cashmere Stream; further rapid surveys for kākahi in the Huritini – Halswell River catchment; and eDNA sampling for kākahi in spring/summer with replicate samples.

1. INTRODUCTION

Kākahi (*Echyridella menziesii*) is a native freshwater mussel that is an At Risk species of cultural significance (Grainger et al. 2018; McEwan et al. 2020). Kākahi may be impacted by a range of human activities, and urban populations are exposed to multiple pressures (e.g., water pollution, channel realignment, and sediment removal). It is therefore important to monitor the state of known kākahi populations and to delineate their geographical extent via surveys in locations where kākahi searches have not previously occurred. In recognition of this, kākahi monitoring has recently been added to Christchurch City Council's (Council) Environmental Monitoring Programme (EMP) attached to their Comprehensive Stormwater Network Discharge Consent (CSNDC, consent number CRC231955).

A previous monitoring report for Christchurch City Council identified a lack of kākahi survey data in the upper Pūharakekenui – Styx River catchment, upstream of Marshland Road (Instream Consulting 2021). The same report also described results of a quantitative survey of kākahi in Cashmere Stream, where kākahi are abundant, and recommended that the survey be repeated in 2023. This report describes results of a survey for kākahi in the upper Pūharakekenui catchment and quantitative monitoring in Cashmere Stream in 2023.

2. METHODS

2.1. Pūharakekenui Catchment

Kākahi sampling involved rapid surveys and use of eDNA samplers at 20 locations within the Pūharakekenui catchment (Figure 1, Table 1). Sites were selected to provide good spatial coverage and focussed on locations that had not been sampled before. In addition, sites were selected to be located near Council ecological monitoring sites where possible, and accessibility was also considered. Six sites were on the mainstem of the river, five were on the largest tributary, Kā Pūtahi – Kaputone Creek, and the remaining sites were on another eight, smaller tributaries. Fieldwork commenced in March 2023, starting with sites where there was minimal macrophyte cover, and hence greatest search efficiency. The last sites were sampled in early May 2023, when it became clear that there would be no macrophyte removal by maintenance crews at those sites, within an appropriate timeframe.

The rapid kākahi surveys followed the methods described by Instream Consulting (2021). This involved a total 30-minute timed search effort, achieved either by two people searching for 15 minutes or one person searching for 30 minutes. The search involved visually observing the full width of stream bed through a bathyscope (for wadeable sites) or using snorkel and mask (for non-wadeable sites), moving in an upstream direction. Surveys were carried out at baseflow and, when possible, shortly after macrophyte removal, to enhance search efficiency. Any factors identified by surveyors that may impact search efficiency were recorded (e.g., high macrophyte cover or elevated turbidity). Once a kākahi was located, the position was recorded via GPS, and the elapsed search time was noted. The search then resumed for any remaining time left in the search. All kākahi observed over the 30-minute search were counted. Using this method resulted in a semi-quantitative measure of kākahi abundance (i.e., number of kākahi per 30-minute search).

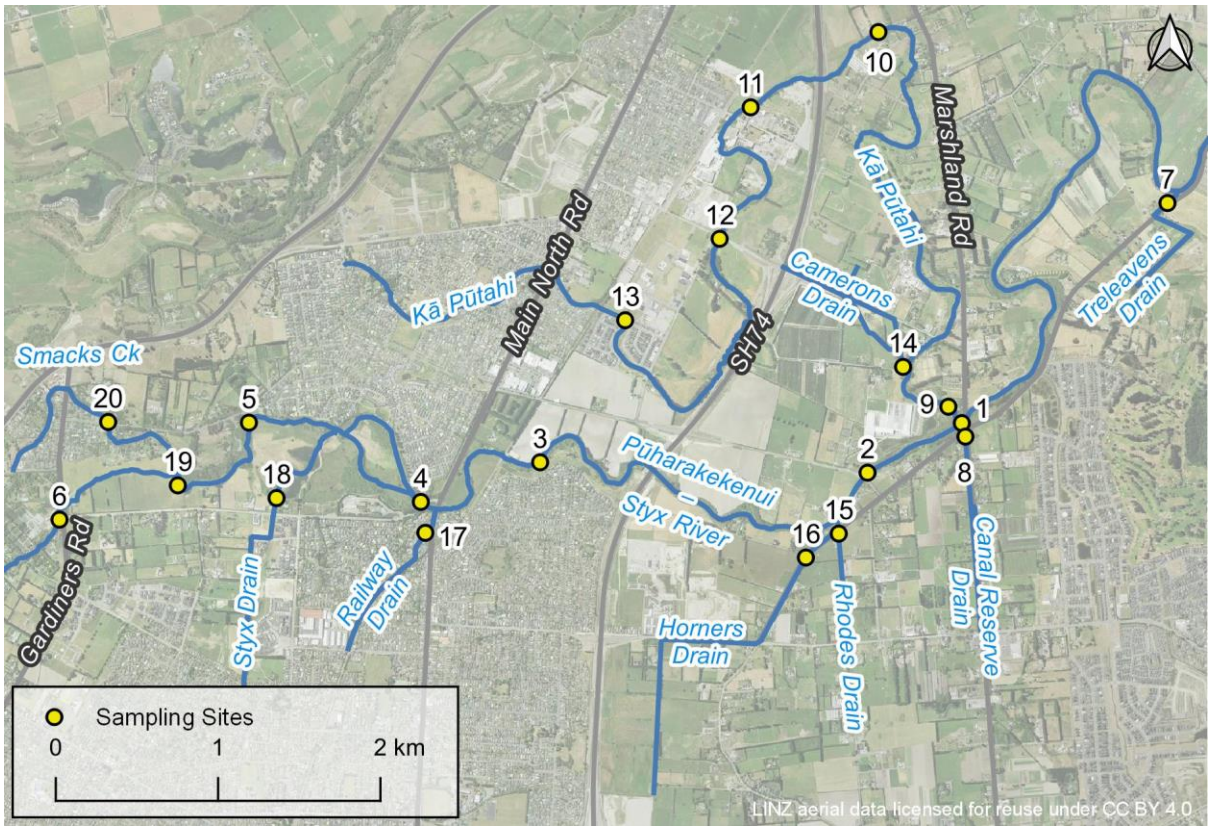

Figure 1: Kākahi rapid survey locations in the Pūharakekenui – Styx River catchment in 2023.

A single passive eDNA sampler was deployed at each of the 20 rapid survey sites. While the manufacturer currently recommends six replicates per site, a single sampler was used to lower costs, allowing for greater spatial coverage. Lower replication increases the risk of false negatives (i.e., failing to detect taxa), however, increased replication can become prohibitively expensive due to analysis costs. Therefore, while using one sampler allows for a greater number of sites to be sampled, negative results should be interpreted with caution. Each sampler consisted of a sampling filter attached to a peg mount that was deployed at the sampling site, in flowing water, as per the manufacturer's instructions (Wilderlab, Wellington). The peg sampler was attached to a waratah-type steel post at deeper sites. Each sampler was left in place for a minimum of 24 hours, before being retrieved. Upon retrieval, the sampler was lifted from the water, the filter was extracted and placed in a preservative solution, and relevant metadata was recorded. All samples were then sent to Wilderlab for analysis.

A rapid habitat assessment (Clapcott 2015) was also undertaken at each site. The resultant habitat quality score, ranging from a minimum of 10 to a maximum of 100, was tabulated for each site.

2.2. Cashmere Stream

The Cashmere Stream quantitative monitoring site is in Worsleys Reserve, immediately south (upstream) of Cashmere Road. Sampling methods were the same as those described previously by Instream (2021), as summarised in the CSNDC EMP, and paraphrased in the following paragraphs. Several small changes were made to the methods, largely following the

recommendations of Instream (2021), to improve sampling precision and efficiency. The changes are outlined at the end of this section.

Sampling was undertaken during baseflow conditions in April 2023, the same month sampling occurred in 2021. The survey was not timed to avoid macrophyte removal, as macrophyte cover is low at this location, due to high levels of shade from surrounding trees. Macrophyte removal was occurring further upstream, which increased turbidity, but clarity was still sufficient that search efficiency was not appreciably affected.

Sampling involved systematic sampling with multiple random starts using 0.25 m^2 quadrats placed at predetermined locations. To confirm the sampling reach was in the same location as 2021, a tape measure was run out along the stream bank from a datum[1] to the downstream extent of the sampling reach. The locations of the first three quadrats were selected at random from within a small starting area, using a random number generator. Each of these quadrats represented the beginning of a repeated sampling unit called a 'chain', with each chain located 3 m apart. Quadrats were then sampled at 3 m intervals from the initial three quadrats, in all directions, filling the entirety of the sampling area. The predetermined quadrat locations were found in the field by running a tape along the full length of the survey area and a tape across the waterway. A total of 200 quadrats were sampled over the same 100 m stream length sampled in 2021.

All kākahi observed within each quadrat were placed in a 5 mm mesh sieve. Where the bed consisted of fines <2 mm diameter (which was most of the site), sediment was extracted by hand to a depth of approximately 10 centimetres and put through the sieve. The total number of live kākahi and dead/empty kākahi shells were recorded per quadrat.

The length of each live kākahi was also recorded before it was returned hinge down to the location it was collected from. The lengths of all kākahi were measured in 2021. For the 2023 survey, we did not measure lengths of all kākahi, due to higher number of quadrats and therefore higher anticipated kākahi numbers than in 2021. Instead, we measured a minimum of 300 kākahi. Once 300 had been measured, all kākahi were measured for the remainder of the transect, to avoid any sampling bias. A total of 326 kākahi were measured on that basis. An additional two kākahi were measured after this number was reached, as they were the smallest two kākahi seen while sampling in 2023 and they were not in the first 326 measured. We only used the first 326 kākahi for calculating summary statistics and data plotting. The additional smallest kākahi measurement was only used when reporting the minimum size for 2023.

Habitat measurements included: wetted width at 10 equidistant transects; depth and velocity at five points across the waterway at five equidistant transects; percent shade (using a spherical densiometer), macrophyte cover, and composition, and fine sediment cover at five equidistant transects; and substrate composition, by measuring 10 particles at each of five equidistant transects, giving a total of 50 particles.

[1] The downstream end of the sampling reach was 61 m upstream from the south side of the Cashmere Road bridge, measured along the true left bank.

Changes to the 2021 methods:

- The total number of quadrats sampled was increased from 156 in 2021 to 200 in 2023, to increase sampling precision.
- Sampling only occurred in the central 6 m of the channel (between 1 m and 7 m from the true left bank). This was to increase sampling precision, because 2021 monitoring found no kākahi along the edges.
- Quadrat sampling density increased from every 4 m in 2021 to every 3 m in 2023. This was done to ensure at least two quadrats per chain were sampled across the stream width, providing greater lateral coverage.
- All kākahi were measured in 2021, but only 326 kākahi were measured in 2023, to improve sampling efficiency. Three hundred kākahi were considered sufficient to characterise the size/population structure and compare amongst years.

2.3. Mapping and Data Analysis

Results of rapid kākahi surveys and eDNA sampling in the Pūharakekenui catchment were collated with an existing database of kākahi distribution in Christchurch city, and then mapped. All existing survey data was from the year 2019 or later. All mapping was done using QGIS (QGIS Development Team 2016). All other statistical analysis and plotting was done using R (R Core Team 2013).

Included with the eDNA results were sequence counts, indicating the number of times a DNA sequence particular to a given taxon was detected in a sample. Wilderlab suggests that low sequence counts collected from a small number of replicates should be considered a tentative detection (Wilderlab 2022), and we followed that advice. While our eDNA sampling was focussed on detecting kākahi, we also summarised eDNA detections for kēkēwai – freshwater crayfish (*Paranephrops zealandicus*), which have an At Risk conservation status (Grainger et al. 2018), and for freshwater fish species with an At Risk or Threatened conservation status (Dunn et al. 2018).

At the Cashmere Stream monitoring site, kākahi densities and shell lengths were compared statistically between years by running permutation tests. Parametric tests were not appropriate as kākahi densities and shell lengths were not normally distributed. Due to the non-normality of the data, confidence intervals were calculated around kākahi density estimates via bootstrapping, based on 100,000 simulations. In addition, spatial interpolation (Akima R Package; Akima 1978) was used to compare the spatial distribution of kākahi between years. This method allows for the prediction of values (i.e., kākahi density), among irregularly distributed points with known values (i.e., sampled quadrats). Using these values, heatmaps of the quantitative survey reach were produced using 2021 and 2023 data.

3. RESULTS AND DISCUSSION

3.1. Pūharakekenui Catchment

All the waterways surveyed have a stable, spring-fed source of flow, but they differ greatly in size and degree of habitat modification. The Pūharakekenui River and Kā Pūtahi Creek are the largest of the waterways sampled (Table 1). They both follow a natural, meandering course, have natural banks (at least at the survey sites), and have varying degrees of channel

shading from riparian trees. Smacks Creek (Sites 19 and 20) and Railway Drain (Site 17) had the most natural form and developed riparian vegetation of the tributary sites sampled. The most modified waterways were timber-lined, and typically were poorly shaded. There were six timber-lined sites, including Sites 7,8, 14–16, and most of the length of Site 18 (a 5 m length with natural banks was also searched at the downstream end of the reach). See Figure 2 for representative site photographs.

Figure 2: Representative photographs of the range of habitats surveyed in the Pūharakekenui catchment.

Habitat quality scores ranged from a low of 41 at Site 7 (Treleavens Drain) and Site 14 (Camerons Drain) to a maximum of 90 at Site 20 (Smacks Creek; Table 1)). For context, habitat quality scores of 26–50 indicate 'fair' habitat quality, scores of 51-75 are 'good', and 73–100 are 'excellent' (Clapcott et al. 2020). Thus, most sites fell into the 'good' category, only four tributary locations might be considered 'fair' (Sites 7, 8, 13, and 14), and four sites had excellent scores; Sites 4 and 5 on the Pūharekekenui River, plus Site 17 (Railway Drain) and Site 20 (Smacks Creek). Most sites were dominated by homogenous run habitat and fine bed sediments, which reduced their overall habitat scores.

Table 1: Rapid survey and eDNA sampling locations. Asterisks (*) mark sites where kākahi were found.

Site	Waterway	Easting (NZTM)	Northing (NZTM)	Mean width (m)	Mean depth (m)	Survey length (m)	Habitat quality score (%)
1*	Pūharakekenui River	1572327	5187745	9.5	1.5	122	57
2*	Pūharakekenui River	1571746	5187440	11.0	1.3	95	64
3	Pūharakekenui River	1569729	5187504	4.5	1.8	96	64
4	Pūharakekenui River	1568994	5187260	4.5	0.5	102	85
5	Pūharakekenui River	1567935	5187748	4.3	0.8	100	77
6	Pūharakekenui River	1566768	5187151	2.8	0.9	91	66
7	Treleavens Drain	1573594	5189099	1.4	0.4	38	41
8	Canal Reserve Drain	1572349	5187662	0.9	0.3	74	45
9	Kā Pūtahi Creek	1572244	5187846	5.0	1.2	139	60
10*	Kā Pūtahi Creek	1571813	5190151	3.5	0.5	77	67
11	Kā Pūtahi Creek	1571026	5189688	9.5	1.5	84	56
12	Kā Pūtahi Creek	1570835	5188879	5.0	0.3	107	52
13	Kā Pūtahi Creek	1570253	5188378	1.7	0.3	237	50
14	Camerons Drain	1571965	5188091	0.9	0.3	269	41
15	Rhodes Drain	1571569	5187065	1.5	0.7	79	56
16	Horners Drain	1571366	5186918	2.6	0.4	86	59
17	Railway Drain	1569022	5187070	2.6	0.1	151	81
18	Styx Drain	1568105	5187284	1.8	0.6	126	53
19	Smacks Creek	1567497	5187362	4.4	0.4	83	53
20	Smacks Creek	1567068	5187752	2.2	0.4	108	90

Kākahi were observed at three sites during the rapid surveys: Sites 1 and 2, the two most downstream sites on the Pūharakekenui River (Figure 3), and Site 10, Kā Pūtahi Creek at Ouruhia Reserve (Figure 4). Densities were low at all three sites, with a single kākahi observed at Sites 1 and 10, and three kākahi observed at Site 2. The kākahi at Site 2 were all found under the Radcliffe Road bridge. An additional, incidental observation was a single kanakana – lamprey (*Geotria australis*) observed while snorkelling at Site 11 in Kā Pūtahi Creek. The kanakana was a juvenile in the brilliant blue macrophthalmia life stage, indicating it was ready to commence its migration from freshwater to the sea. Observing kanakana at any location is of ecological significance, because they have a Threatened – Nationally Vulnerable conservation status (Dunn et al. 2018).

There was no strong association between the presence of kākahi and habitat conditions, with Sites 1, 2, and 10 all having habitat quality scores ranging from 57 to 67. The kākahi at Sites 1 and 2 were associated with fine sediment, which was the dominant substrate, while the kākahi at Site 10 was amongst coarser gravels and small cobbles (Figure 4), which was the dominant substrate at that location. However, it was notable that the three kākahi found at Site 2 were all located underneath a bridge. We have previously observed that kākahi are disproportionately found around road culverts, bridges, and other solid structures in waterways, where they are protected from physical disturbance. In spring-fed waterways such

as those sampled here, there is minimal bed disturbance by floods, so the major physical disturbance likely occurs during weed and sediment removal associated with waterway maintenance.

Figure 3:. Site 1 (left) and Site 2 (right) on the Pūharakekenui River, where kākahi were observed.

Figure 4: Site 10, Kā Pūtahi Creek at Ouruhia Reserve (left), where a single kākahi was observed (right)

Kākahi were only detected at one location using the eDNA passive samplers. That was Site 1, where kākahi were also detected during the rapid survey (Table 2). The lack of kākahi detection at any other sites suggests that kākahi are absent, present in low densities, or that there was insufficient sample replication to detect the low amount of kākahi DNA present. Six replicates are recommended by Wilderlab, based on their research looking at species accumulation curves for stream invertebrate and freshwater fish communities. However, the number of eDNA sample replicates required for detection varies amongst species, and a species' detection will be affected by its rate of DNA shedding, dilution, and their abundance. Detection of rare freshwater mussel species using eDNA may be enhanced during spawning and glochidia release periods, when there is more genetic material released into the water column (Wacker et al. 2019; Schmidt et al. 2021). Recent research indicates that peak kākahi spawning and glochidia release occurs over spring/summer (Melchior 2021). Therefore,

spring/summer is likely the optimal period for detecting kākahi DNA, particularly when there is no existing data on their presence, or when previous sampling suggests kākahi are present in low densities. In summary, to optimise the likelihood of eDNA detection of kākahi, we recommend taking replicate samples and sampling during spring/summer.

Kākahi had not been detected previously at any of the three sites we found them. Kākahi have previously been observed in the Pūharakekenui River from the Marshland Road bridge downstream, but not upstream (Figure 5). The most upstream location we observed kākahi was at the Site 2 at Radcliffe Road, approximately 700 m upstream from Marshland Road. Further searching may detect kākahi elsewhere in the Pūharakekenui River, as they are typically very patchily distributed. However, based on the data collected to date, kākahi densities in the upper river are much lower than those observed downstream of Marshland Road (Instream Consulting 2021).

Table 2: eDNA sequence counts for At Risk and Threatened invertebrates and fish at each site.

Site	Kākahi (At Risk)	Kēkēwai (At Risk)	Tuna Kūwharuwharu (At Risk)	Īnanga (At Risk)	Kanakana (Threatened)
1	472	0	314	545	0
2	0	0	36	285	0
3	0	1,111	392	22	0
4	0	323	823	40	0
5	0	744	837	0	0
6	0	0	130	0	0
7	0	0	0	0	0
8	0	0	537	26	25
9	0	0	0	13	0
10	0	0	32	29	0
11	0	0	0	246	0
12	0	0	11	163	0
13	0	0	0	84	0
14	0	0	362	0	0
15	0	0	1,785	8	0
16	0	0	554	82	0
17	0	0	0	0	0
18	0	0	219	0	0
19	0	0	328	0	0
20	0	0	3,749	0	0

Note: Conservation status is from Grainger et al. (2018) for invertebrates and Dunn et al. (2018) for fish.

The kākahi and kanakana records are firsts for the Kā Pūtahi catchment, with neither species noted in previous monitoring reports (Eldon and Taylor 1990; Instream Consulting 2018) or recorded in the New Zealand Freshwater Fish Database. The presence of kanakana macrophthalmia indicates kanakana are not only present, but also spawning in the catchment.

Further survey work for kākahi and kanakana is recommended in the Kā Pūtahi catchment, due to their threat status. Given the cryptic nature of these species, we recommend that sampling involves a combination of electric fishing (for kanakana), visual searches (wading and snorkel), and use of replicate eDNA samplers for kākahi and pheromone traps for kanakana. Pheromone traps have proven effective for detecting kanakana in the wider Pūharakekenui catchment (Baker et al. 2019).

Other notable species detections from eDNA were Threatened (Nationally Vulnerable) kanakana at Site 8 (Canal Reserve Drain), At Risk (Declining) kēkēwai at three sites, and At Risk (Declining) īnanga (*Galaxias maculatus*) and tuna kūwharuwharu – longfin eel (*Anguilla dieffenbachii*) at 12 and 15 sites, respectively (Table 2). Widespread detection of tuna kūwharuwharu DNA reflects the prevalence of this species in the catchment, consistent with previous reports (Eldon and Taylor 1990; Instream Consulting 2018). Īnanga had a more widespread distribution indicated by the eDNA results than reported previously using more conventional sampling methods (Eldon and Taylor 1990; Instream Consulting 2018). This reflects the fact that electric fishing has been the dominant method of fish sampling in the catchment, and electric fishing is inefficient at detecting īnanga compared to other methods, including trapping (Joy et al. 2013). The three sites where kēkēwai DNA was detected were within, or downstream, of Styx Mill Conservation Reserve, where kēkēwai have previously been detected by electric fishing (Instream Consulting 2018). The detection of kanakana eDNA in Canal Reserve Drain was expected, as Canal Reserve Drain supports significant spawning habitat for kanakana (Baker et al. 2019).

The current study has improved our understanding of the spatial extent of kākahi in the Pūharakekenui catchment. These survey methods may be deployed in other catchments in Christchurch where kākahi are known to be present, but where their extent within the catchment is poorly delineated. A previous city-wide survey of kākahi (Instream Consulting 2021) identified the Huritini – Halswell River catchment as a priority for further kākahi surveys. We suggest using a combination of rapid surveys and deployment of replicate eDNA samplers to search for kākahi in the Huritini catchment.

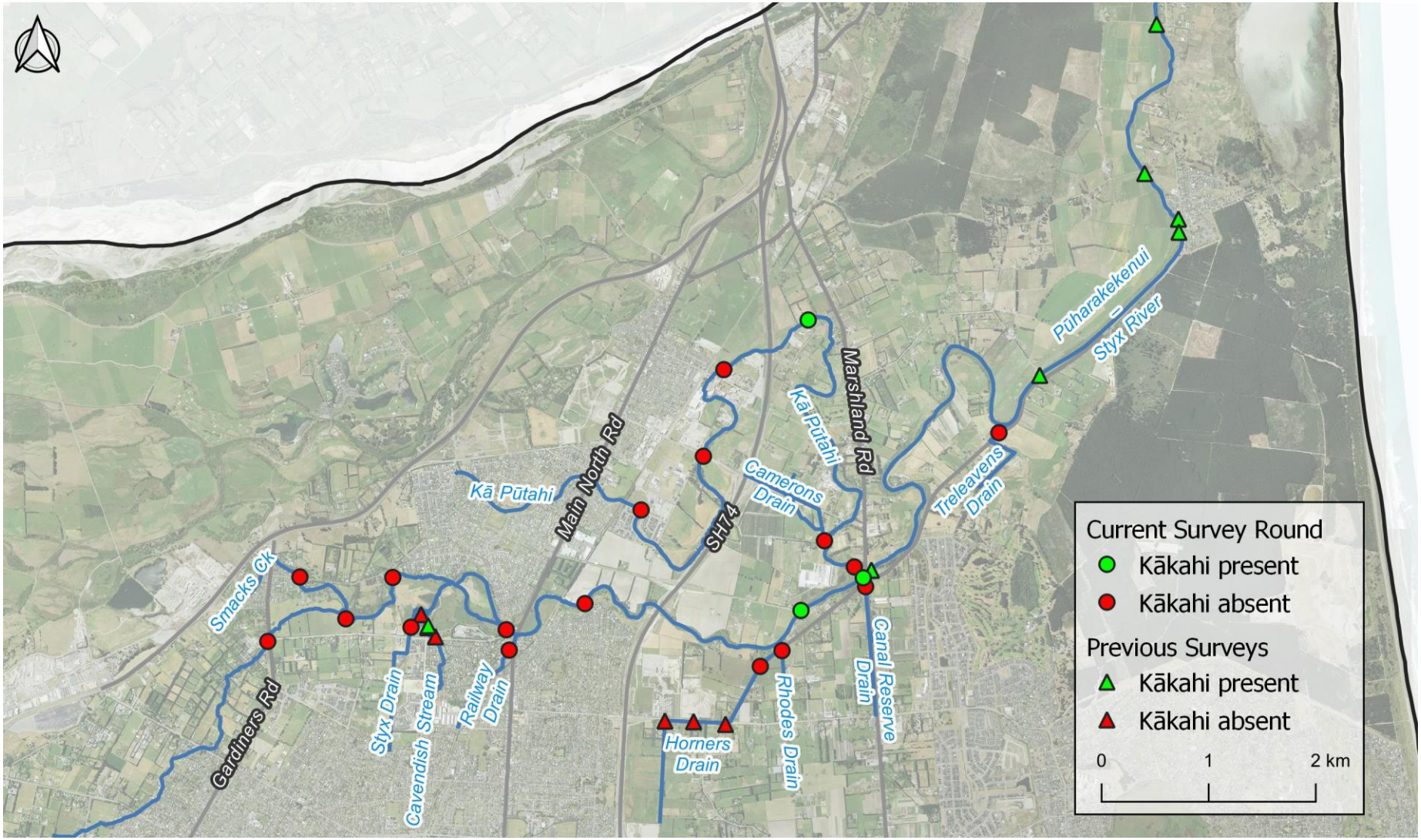

Figure 5: Location and results of current (2023) and collated previous surveys in the Pūharakekenui – Styx River catchment. Some points have been slightly offset for visibility.

3.2. Cashmere Stream

Higher rainfall over summer 2022/23 was associated with higher baseflow sampling conditions in 2023 than in 2021, with greater water depths and slightly swifter velocities observed (Table 3). Stream shading from riparian trees remained high and macrophyte cover remained correspondingly low (<5% cover). Similarly, the substrate remained dominated by fine sediment (<2 mmm diameter). Some large logs were present within the survey reach, which were not recorded during the 2021 survey. Overall, physical habitat conditions were very similar between sampling years, except for higher water levels in 2023 (Table 3).

Table 3: Select habitat parameters for each sampling year in Cashmere Stream. Data are site means.

Year	Shade (%)	Width (m)	Depth (m)	Velocity (m/s)	Substrate Size (mm)
2021	79	7.5	0.19	0.08	1
2023	81	8.7	0.34	0.15	7

A total of 740 live kākahi were collected from 200 quadrats in 2023. This equated to a mean (± 1 standard error) density of 15 ± 2 kākahi per m². This compares to a mean of 18 ± 3 kākahi per m² in 2021 (Table 4). Although mean density was slightly lower in 2023, this difference was not statistically significant (P=0.40). Sampling precision (the ratio of standard error to mean) declined (i.e., improved) from 19% in 2021 to 13% in 2023. This improved precision reflected the combination of increased sampling effort and avoidance of edge habitat lacking kākahi. Greater precision will enhance the ability to detect changes in density over time, due to reduced error around the estimated mean.

Table 4: The total number of kākahi recorded, respective sampling efforts, and estimated kākahi densities each year at the Cashmere Stream quantitative survey site. Confidence Intervals (C.I. = 90%) around density estimates included.

Year	Kākahi Sampled	No. of Quadrats	Total Area Sampled (m²)	Mean Density (per m²)	90% Confidence Intervals	Standard Error / Mean (%)
2021	701	156	39	18	12–24	19
2023	740	200	50	15	12–18	13

The patchy distribution of kākahi in Cashmere Stream is illustrated by the heatmap in Figure 6. The heatmap shows two distinct higher density patches, one at around 20 m and another at around 90–100 m along the sampling reach, with lower density patches scattered between them. The heatmap shows a very similar pattern between the two sampling years, indicating persistence of the high-density patches over time. Overseas studies have found that these dense patches, or beds, of freshwater mussels can persist in the same location for many decades (Sansom et al. 2018). We are unaware of any studies of kākahi in New Zealand rivers

that have monitored their spatial distribution over time, at a resolution comparable to this study. It is therefore unknown how long the observed patches or beds of kākahi will persist over time.

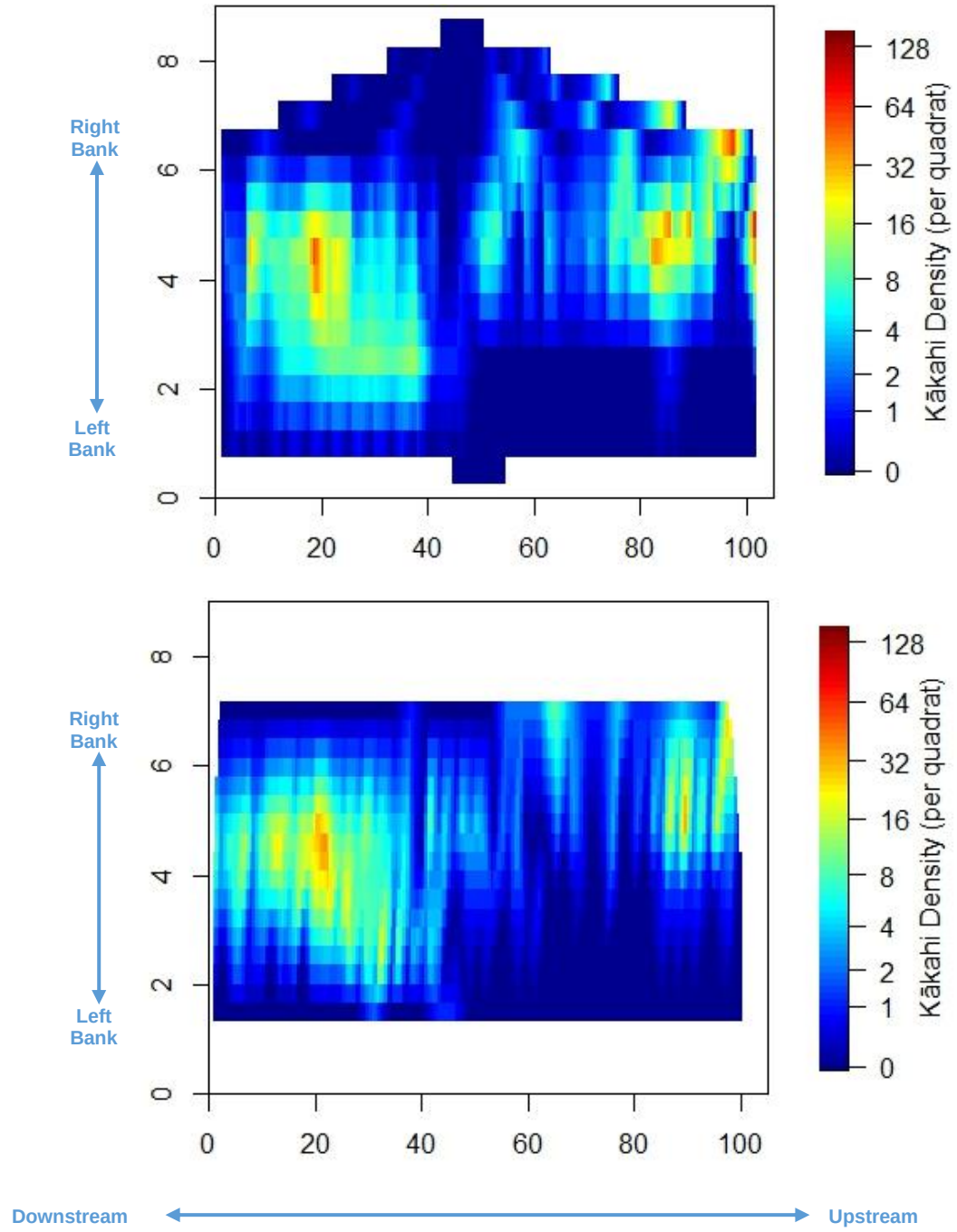

Figure 6: Heatmaps of kākahi density in Cashmere Stream in 2021 (top) and 2023 (bottom). Axis units are meters. Note that the colour ramp is a log scale.

The distribution of shell lengths was similar between sampling years, with a large peak around 70–75 mm and a smaller peak around 90 mm (Figure 7). There was no significant difference in mean shell length (P=0.68), with a mean length of 75 mm recorded both years. All summary statistics for shell length were similar between sampling years (Table 5), indicating no marked change in population structure.

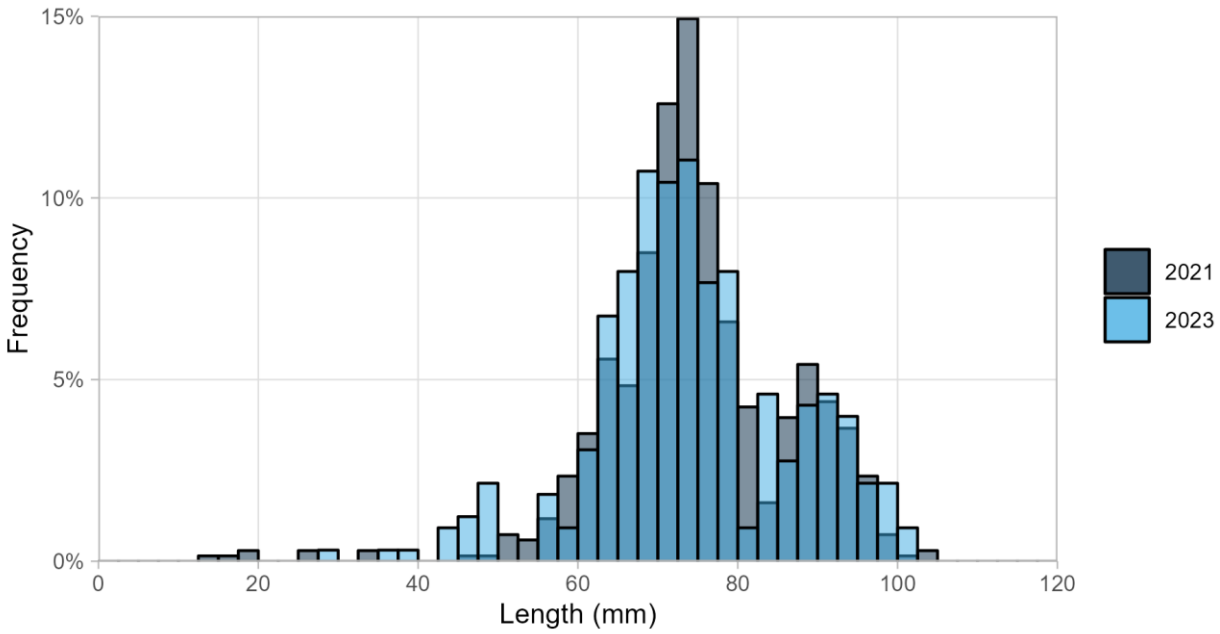

Figure 7: The distribution of kākahi shell lengths in Cashmere Stream in 2021 and 2023. Overlapping data between monitoring years is indicated by a darker shade of blue.

Table 5: Summary statistics of kākahi lengths recorded in Cashmere Stream in 2021 and 2023.

Year	Mean (mm)	Median (mm)	Minimum (mm)	Maximum (mm)	Standard Deviation (mm)
2021	75	74	14	104	12
2023	75	73	21	102	12

4. CONCLUSIONS AND RECOMMENDATIONS

Kākahi were detected at three of the 20 sampling locations in the Pūharakekenui River catchment. All three locations were new records for kākahi, including two in the mainstem of the Pūharakekenui River, and one location in Kā Pūtahi Creek. While kākahi had previously been found further downstream in the Pūharakekenui River, there were no previous records for Kā Pūtahi Creek, the river's main tributary. Rapid searches were more successful at detecting kākahi than the eDNA method, but more eDNA detections may have occurred if sampling had been timed during spawning and glochidia release (spring/summer) and with sample replication.

The Cashmere Stream kākahi population showed no change in density, distribution, or size structure between 2021 and 2023 sampling occasions. Small changes to the sampling methods in 2023 were associated with reduced sampling error and greater ability to detect changes in kākahi density over time. The stability of high-density patches, or beds, of kākahi between sampling years is similar to observations reported overseas, and is a new observation for New Zealand freshwater mussels.

Based on the results discussed above, we recommend the following:

- **Further searches for kanakana and kākahi in Kā Pūtahi Creek.** This is warranted, given that neither species had been detected within the catchment until this survey. Sampling should include a combination of electric fishing (for kanakana), visual searches (wading and snorkel), and use of replicate eDNA samplers for kākahi and pheromone traps for kanakana.
- **Continue monitoring kākahi in Cashmere Stream.** The slightly revised methods have improved sampling precision, so should be used in future monitoring. We recommend monitoring every two years, at least during the current period of rapid landuse change within the catchment.
- **Further rapid surveys in the Huritini – Halswell River catchment.** As noted by Instream Consulting (2021), further surveys are recommended following macrophyte removal, to confirm that kākahi are absent in this catchment, within the Christchurch district. We suggest the survey should comprise a combination of rapid search and eDNA methods. This can be timed for the next round of 5-yearly ecology monitoring, in 2026.
- **eDNA sampling for kākahi in spring/summer with replicate samples.** Sample during spring/summer to coincide with peak spawning and glochidia release, when there would be more kākahi DNA in the environment. It is currently uncertain how many replicates are required to adequately reduce error rates around kākahi detection in flowing waters. Until this information is available, it would be prudent to use the manufacturer's default recommendation of six replicate samples.

5. REFERENCES

Akima H. 1978. A Method of Bivariate Interpolation and Smooth Surface Fitting for Irregularly Distributed Data Points. ACM Transactions on Mathematical Software (TOMS). 4(2):148–159. https://doi.org/10.1145/355780.355786

Baker C, White E, Wadhwa S, Stewart M. 2019. Lamprey pheromones in the Styx River catchment. Report prepared for Environment Canterbury by NIWA; Client Report 2019140HN, June 2019.

Clapcott J. 2015. National rapid habitat assessment protocol development for streams and rivers. Cawthron Institute Report 2649, prepared for Northland Regional Council, January 2015.

Clapcott J, Casanovas P, Doehring K. 2020. Indicators of freshwater quality based on deposited sediment and rapid habitat assessment. Prepared for Ministry for the Environment Cawthron Report No 3402, February 2020.

Dunn NR, Allibone RM, Closs GP, Crow SK, David BO, Goodman JM, Griffiths M, Jack DC, Ling N, Waters JM, Rolfe JR. 2018. Conservation status of New Zealand freshwater fishes, 2017. New Zealand Threat Classification Series 24.:11.

Eldon GA, Taylor MJ. 1990. Fisheries survey of the Styx River, summer 1990. Report prepared by the Freshwater Fisheries Centre, MAF Fisheries, for Christchurch City Council New Zealand Freshwater Fisheries Report No 120, September 1990.

Grainger N, Harding J, Drinnan T, Collier K, Smith B, Death R, Makan T, Rolfe J. 2018. Conservation status of New Zealand freshwater invertebrates, 2018. Department of Conservation New Zealand Threat Classification Series 28.

Instream Consulting. 2018. Styx River catchment aquatic ecology 2018. Prepared for Christchurch City Council, August 2018.

Instream Consulting. 2021. Kākahi (freshwater mussel) monitoring in Christchurch City. Report prepared for Christchurch City Council, December 2021.

Joy M, David B, Lake M. 2013. New Zealand freshwater fish sampling protocols. Part 1 - Wadeable rivers and streams. Palmerston North: The Ecology Group - Institute of Natural Resources, Massey University.

McEwan AJ, Dobson-Waitere AR, Shima JS. 2020. Comparing traditional and modern methods of kākahi translocation: implications for ecological restoration. New Zealand Journal of Marine and Freshwater Research. 54(1):102–114.

Melchior M. 2021. Partitioning along reproductive niche dimensions in sympatric New Zealand freshwater bivalve species. Unpublished PhD thesis. University of Waikato, Hamilton, New Zealand.

QGIS Development Team. 2016. QGIS geographic information system. Open source geospatial Foundation project.

R Core Team. 2013. R: A language and environment for statistical computing.

Sansom BJ, Bennett SJ, Atkinson JF, Vaughn CC. 2018. Long-term persistence of freshwater mussel beds in labile river channels. Freshwater Biology. 63(11):1469–1481. https://doi.org/10.1111/fwb.13175

Schmidt BC, Spear SF, Tomi A, Jachowski CMB. 2021. Evaluating the efficacy of

environmental DNA (eDNA) to detect an endangered freshwater mussel Lasmigona decorata (Bivalvia:Unionidae). Freshwater Science. 40(2):354–367. https://doi.org/10.1086/714411

Wacker S, Fossøy F, Larsen BM, Brandsegg H, Sivertsgård R, Karlsson S. 2019. Downstream transport and seasonal variation in freshwater pearl mussel (Margaritifera margaritifera) eDNA concentration. Environmental DNA. 1(1):64–73. https://doi.org/10.1002/edn3.10

Wilderlab. 2022. Interpreting eDNA results. Wilderlab eDNA data interpretation guide, August 2022 V 126.:1–2.