Kākahi in Cashmere Stream: Distribution and Current State of the Population

June 2020

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EXECUTIVE SUMMARY

This report describes results of a survey of freshwater mussels, or kākahi (*Echyridella menziesi)*, undertaken in February 2020 in Cashmere Stream. The purpose of the survey was to determine whether kākahi are in the upper reaches of the stream, where stream realignment and restoration is proposed, and to compare the population to a baseline survey in 2007. A rapid survey revealed kākahi at eight of the 15 sites sampled. No kākahi were found in the upper reaches of the stream, where stream realignment and restoration is proposed, which is consistent with findings from the 2007 survey. A total of 101 live kākahi were detected during quantitative sampling at eight sites. Mean kākahi density declined with distance upstream from the Ōpawaho/Heathcote River, from a maximum of 12.4 kākahi per m² at Site 1 to 0.4 per m² at Site 8. Kākahi densities were higher in 2020 than in 2007 and we found a greater proportion of small individuals in 2020, indicating a younger population. The presence of numerous younger kākahi indicates reasonable recruitment and suggests that the population is viable. Restoration activities in the upper reaches of Cashmere Stream may provide habitat that is more suitable and stable for kākahi in the long term. Colonisation of restored reaches by kākahi will be a slow process, although the rate of colonisation could be enhanced by translocating kākahi from other locations. Any translocation would require appropriate planning and approvals, with follow-up monitoring of the population.

1. INTRODUCTION

Three species of native freshwater mussel (kākahi) occur in New Zealand. *Echyridella menziesi* is the only kākahi species found in Christchurch streams and it has an 'At Risk – Declining' conservation status (Grainger *et al.* 2018). A previous survey of kākahi in Cashmere Stream revealed kākahi distributed throughout the lower reaches of the stream, towards its confluence with the Ōpawaho/Heathcote River (Burdon & McMurtrie 2009). Kākahi are uncommon in Christchurch waterways, so the population in Cashmere Stream is of considerable local value.

The upper reaches of Cashmere Stream were historically artificially straightened, to improve land drainage in an area that was once an extensive wetland. Christchurch City Council (CCC) and Environment Canterbury have worked with the Cashmere Stream Care Group to restore natural form and enhance habitat in the headwaters of the stream, upstream of Sutherlands Road. CCC is now looking to restore sections of the stream further downstream.

This report describes the results of a survey of the Cashmere Stream kākahi population undertaken in February 2020. The purpose of the survey was to determine whether kākahi are in the upper reaches of the stream, where restoration and channel realignment is proposed, and to compare the state of the kākahi population to the previous 2007 survey reported in Burdon & McMurtrie (2009).

2. METHODS

2.1. Sampling Sites and Survey Dates

All sampling sites were located within a c. 4.2 km reach of Cashmere Stream (Figure 1), which is a spring-fed tributary of the Heathcote River. The sampling sites extended from the Heathcote River/Cashmere Stream confluence upstream to Sutherlands Road. Study sites were selected to match locations previously sampled by Burdon & McMurtrie (2009). Of the 58 study sites of Burdon & McMurtrie (2009), 15 were selected, five from each of the "Lower", "Mid", and "Upper" reaches (denoted by the coloured sections in Figure 1). Within each reach, the five sites were randomly selected. A short section of the stream between 9 and 23 Waiau Street was intentionally excluded from sampling, to avoid confounding effects caused by recent bank works and mussel salvage in that area. The survey was conducted from 10 to 12 February 2020.

2.2. Field Methods

A two-tier approach to sampling was adapted from Catlin et al. (2017). This involved an initial rapid survey for kākahi at each site, followed by more intensive, quantitative sampling at sites where kākahi were found during the rapid survey. This sampling approach was the most cost-effective way of addressing the survey's dual purposes: determining whether kākahi were present in the upper reaches of Cashmere Stream and comparing the state of the population to the previous study.

Figure 1. Locations of survey sites in Cashmere Stream. Extents of the Lower, Mid, and Upper reaches are shown. LINZ mapping data are licensed for reuse under CC BY 4.0.

For the rapid survey, two surveyors carried out a 15-minute visual search at each site. The substrate was examined for kākahi using an underwater viewer, focussing on areas with greater habitat potential (e.g., undercut banks and woody debris), and moving in an upstream direction (Figure 2). At sites with high turbidity (Sites 4, 5, and 6), a combination of visual and hand searches was carried out. The time taken to find the first kākahi was recorded, along with its GPS location (taken from the stream bank). Rapid habitat assessments were undertaken using the methods of Clapcott (2015). The rapid habitat assessment involves assigning 10 habitat parameters with a score from 1 to 10, with higher scores for better quality habitat. The habitat parameters include measures of fine sediment cover, habitat diversity and abundance, and riparian width and shade. Representative site photographs were also taken at each rapid survey site.

Figure 2. Surveyors conducting a rapid survey for kākahi using underwater viewers.

Quantitative sampling involved searching for kākahi in five quadrats located along five transects at each site. The most downstream transect at each site was located where the first kākahi had been detected during the rapid survey, with each of the remaining four transects spaced 10 m apart upstream, over a total distance of 40 m. Quadrats were placed across the entire width of each transect, with one quadrat near each bank, one in the centre, and the remaining two quadrats spaced evenly between the bank and stream centre. Quadrats were 0.1 m^2 Surber samplers, with a 500 µm mesh. A visual and hand search was conducted within each quadrat, with the hand search extending approximately 20 cm into softer sediments. The contents of the Surber net were checked following completion of each hand search, although no kākahi were found in the net on any occasion.

For quantitative sampling, it was noted whether each kākahi had been detected by visual or hand search methods, and whether it was emerged or buried. Each kākahi was then removed from the stream and shell length, width, and depth were measured using digital Vernier callipers. Percent shell erosion was also estimated, using the condition categories of Catlin et al. (2017). Kākahi were then carefully returned to the stream bed, with the shell hinge pointing down into the substrate.

At each transect stream width and maximum water depth were measured, as well as percent shading (using a spherical densiometer). In addition, percent bed cover of the following habitat features was estimated visually over 10 m of river length extending upstream from each transect: wood, macrophytes and substrate composition. Substrate composition was comprised of the following classes (based on a modified Wentworth Scale): clay (<0.004 mm), silt (0.004–0.06 mm), sand (0.06–2 mm), small gravel (2–16 mm), large gravel (16–64 mm), cobble (64–256 mm), boulder (>256 mm), artificial, or bedrock.

Additional habitat parameters recorded at the quadrat level included: flow character (riffle, run, pool, backwater), stream position (outside bend, inside bend, straight), dominant habitat (macrophyte, wood, other organic, bankfoot, undercut bank, root mat, sand bar), and dominant substrate class (clay, silt, sand, small gravel, large gravel, cobble, boulder, bedrock).

2.3. Data analysis

All field data were entered into MS Excel spreadsheets and provided to CCC, along with site photographs. Rapid habitat assessment data were plotted, but not analysed statistically, due to the lack of replication in the data and the overall similarity of habitat conditions amongst the sampling sites. General habitat conditions are described in the results section.

Kākahi density was calculated from the mean of the total kākahi count per transect. Thus, the contents of each 0.1 m² quadrat was summed for each transect, giving a total area of 0.5 m² sampled per transect. The total area sampled per site was 2.5 m² (five 0.1 m² quadrats across five transects). This is the same total area sampled per site as Burdon & McMurtrie (2009). However, they used ten 0.25 m² quadrats randomly placed throughout a sampling site. In addition, Burdon & McMurtrie (2009) calculated density using a method for systematic sampling, from Strayer et al. (2003). Their method of density calculation was not appropriate for our sampling design. Therefore, to directly compare results between the two studies, we recalculated kākahi density for the Burdon & McMurtrie (2009) data using the mean of kākahi counts from the ten quadrats at each site.

The spatial distribution of kākahi was examined using linear regression, to test whether kākahi density declined significantly as a function of distance from the Cashmere Stream/Heathcote River confluence. Due to the heteroscedastic nature of the calculated kākahi densities, confirmed by a Breush-Pagan test, a Theil-Sen regression was run. This nonparametric method calculates a slope between all combinations of observations and selects the median slope. Consequently, the method is robust to outliers and heteroscedasticity.

A generalised linear mixed-effects model (GLMM) was run to determine if there was a significant difference in kākahi densities between studies. For this model the distribution family was set to Poisson, which is standard for count data containing many zero observations (Crawley 2013). The GLMM incorporated “site” as a random term, to control for spatial associations with kākahi density.

To assess population structure, kākahi age was calculated using the following formula developed by Ogilvie (1993):

$$Y = -7.7839 + 0.8812X - 0.0178X^2 + 0.00014X^3$$

Where Y is mussel age in years and X is shell length. This method of age estimation is consistent with the methodology of Burdon & McMurtrie (2009). Using the calculated ages, a two-sample exact permutation test was run to determine if the mean age of kākahi differed between the two studies. This test made no assumption about the underlying distribution of the data, which was important given that the age data was not normally distributed. This test incorporated all kākahi observations, from all sites, for both studies.

A linear regression was run to determine if age classes increased or decreased over the length of the stream. Due to the heteroscedastic nature of the data, a Theil-Sen regression was again implemented. This test calculated the relationship between kākahi age and distance to the Cashmere Stream/Heathcote River confluence.

Density plots were calculated for the 2007 and 2020 kākahi observations, using kernel density estimation. Density plots smooth the distribution by taking an average of neighbouring values. The values are then reported as a percentage of the total sum of observations, such that the area under each line is equal to 1.0 (100%).

All maps were created in QGIS v.3.10.3 (QGIS Development Team, 2016), and statistical analyses run in R v.3.6.3 (R Development Core Team, 2013).

3. RESULTS

3.1. Habitat Overview

The Lower reach of Cashmere Stream mostly follows a natural, meandering course, whereas the Mid and Upper reaches are more clearly unnatural and artificially straight (Figure 1). Low bunds line the banks on the upper reaches of the stream, which are evidence of many years of weed and sediment removal and dumping on the banks. Shading from riparian vegetation is patchy, with the greatest shade typically occurring within CCC reserves (e.g., Site 1) and the least shade in rural land in the upper reaches. Stream banks are typically steep and comprised of natural earth in the upper reaches and along CCC reserves, but artificial banks made of wood or concrete are common adjacent to residential properties. Bed cover with fine sediment (<2 mm diameter) is high at all sites. Rapid habitat assessment scores were low overall and varied across a narrow range, from a minimum of 47% at Sites 2 and 4 to a maximum of 63% at Sites 6 and 7. See Figure 3 and Figure 4 for representative site photographs.

Figure 3: Representative site photographs from the Lower reach sampled.

Figure 4: Representative photographs from the Mid (left) and Upper (right) reaches sampled.

3.2. Underwater Observations

Kākahi were found associated with both stony and fine sediments (Figure 5), and they were often amongst accumulations of woody debris (Figure 6). However, no kākahi were found amongst very fine, loosely-packed sediments associated with macrophyte beds, despite plenty of hand searching. Four kōura, or freshwater crayfish (*Paranephrops zealandicus*), were observed at Site 14 in the Upper reach sampled (Figure 7). Numerous potential kōura burrows were also observed, which were small cavities, less than 10 cm wide, at the base of the stream bank.

Figure 5: Kākahi amongst finer sediments (left) and coarser, stony sediment (right). Arrows indicate the location of kākahi in the image to the right.

Figure 6: Examples of kākahi associated with woody debris and sparse macrophytes.

Figure 7: Kōura near a burrow (left) and close up (right).

3.3. Kākahi Distribution

Kākahi were found during rapid surveys at Sites 1 to 8 and none were found at Sites 9 to 15. Kākahi were located within the first five minutes of searching at Sites 1 to 7, with a maximum search distance of 18 m (measured by GPS). At Site 8, a single kākahi was found in the fifteenth minute of the rapid survey, after a search length of 40 m. The remaining sites yielded no kākahi during the 15-minute rapid search, despite an average search length of 82 m. The search lengths for Sites 9 to 15 totalled 574 m, which represents approximately 34% of the total length of this section of Cashmere Stream (Figure 8). Our findings on kākahi distribution are consistent with those of Burdon & McMurtrie (2009), who also recorded no kākahi from sampling sites equivalent to our Sites 9 to 15.

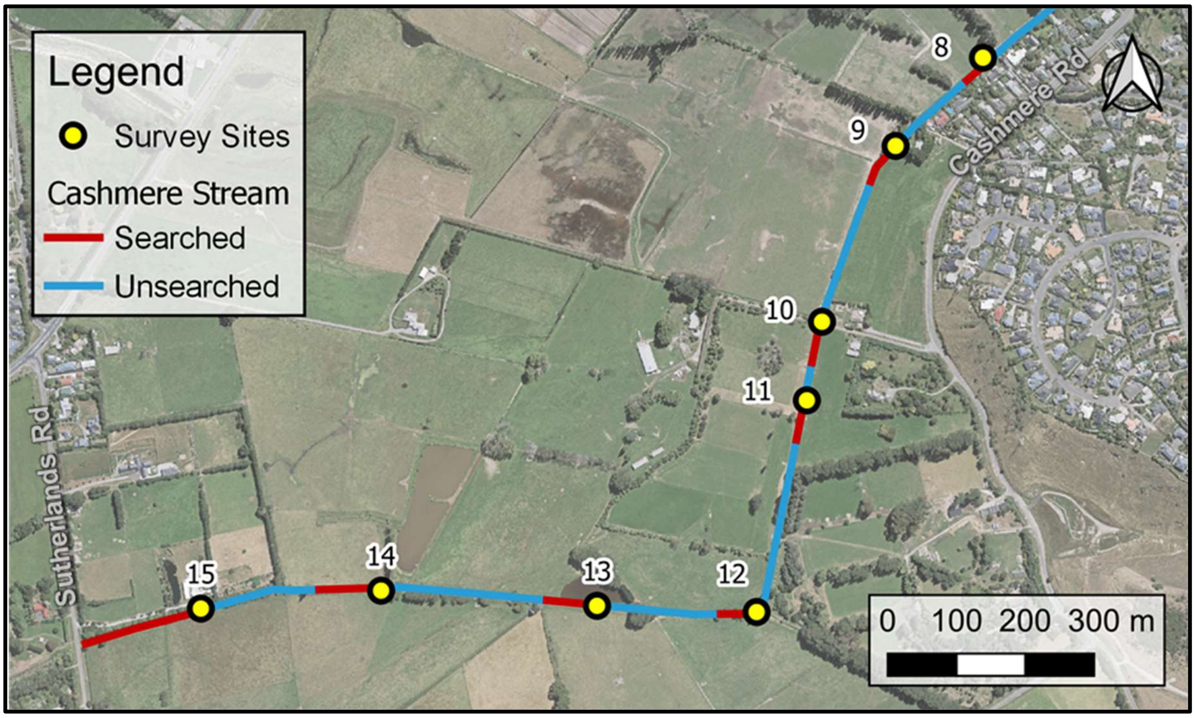

Figure 8. The search lengths of the 15-minute rapid surveys for Sites 8–15.

3.4. Kākahi Density

A total of 101 live kākahi were recovered during quantitative sampling during the current study, plus a single dead individual. All kākahi were captured within the Lower and Mid reaches of Cashmere Stream, from Sites 1 to 8. Kākahi density in the current study was highly variable among sites, with the highest mean density at Site 1, with 12.4 kākahi per m^2, and the lowest at Site 8, with 0.4 per m^2 (Figure 9). Kākahi densities were also highly variable among transects within sites, indicated by the large error bars in Figure 9. Densities were especially variable among transects at Site 1, with 26 of the total 35 kākahi recovered (87%) at this site found in just two transects.

Mean kākahi density was greater in the current study at every site compared to the 2007 survey of Burdon & McMurtrie (2009). A GLMM confirmed that the density was significantly higher in 2020 when compared to 2007, while controlling for site ($p<0.001$). Interestingly, no kākahi were found at Site 1 in the earlier survey, whereas we found the highest kākahi density at Site 1.

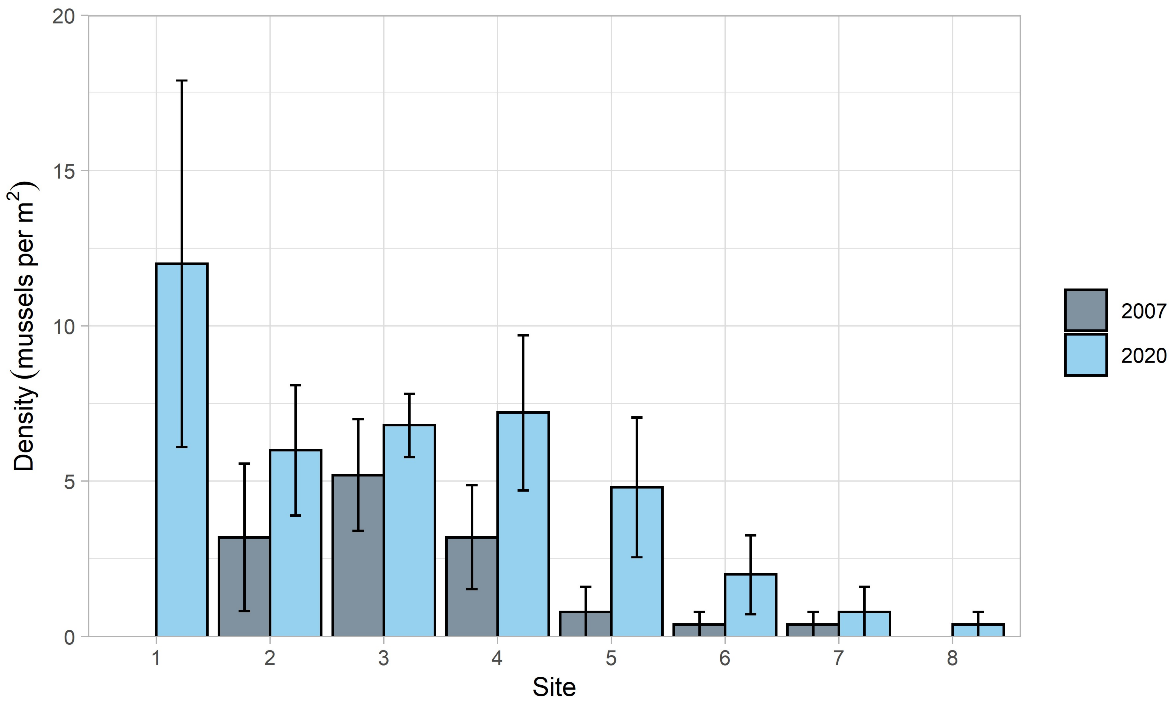

Figure 9. Mean (±1 SE) kākahi density at each sampling site in 2007 and 2020. Kākahi were not recovered from sites 9–15 in either study.

Kākahi density declined significantly ($r^2 = 0.79$, $p = 0.014$) with increasing distance from the Cashmere Stream/Heathcote River confluence, following the equation:

$$Y = -0.00424X + 9.09205$$

Where Y is the site mean kākahi density (per m^2) and X is the site distance (m) from the Cashmere Stream/Heathcote River confluence. No kākahi were found beyond Site 8, approximately 2,250 m upstream of the confluence (Figure 10).

Due to the small number of sampling sites and low numbers of observed kākahi, it was not possible to statistically examine kākahi distributions and their associations with habitat characteristics. Rapid habitat assessment scores were quite homogenous in terms of most of their instream and riparian habitat features, even when sites were separated by the presence or absence of kākahi (Figure 11). However, sites where kākahi were present generally scored higher in the categories of ‘Bank vegetation’, ‘Invertebrate habitat diversity’, and ‘Riparian shade’.

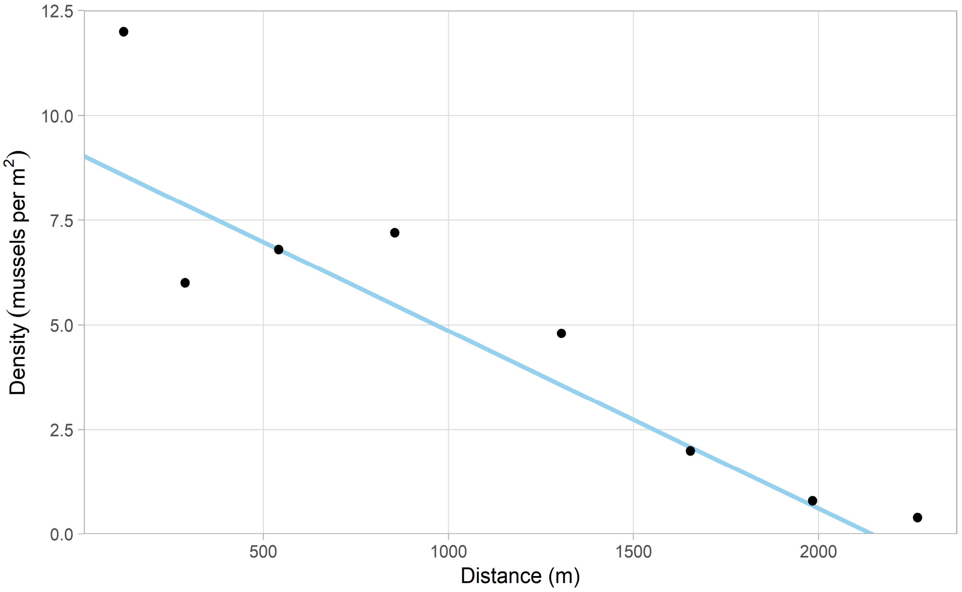

Figure 10. The relationship between kākahi density and distance from the Cashmere Stream / Heathcote River confluence. Also included is the calculated Theil-Sen regression line ($R^2 = 0.79$, $p = 0.014$).

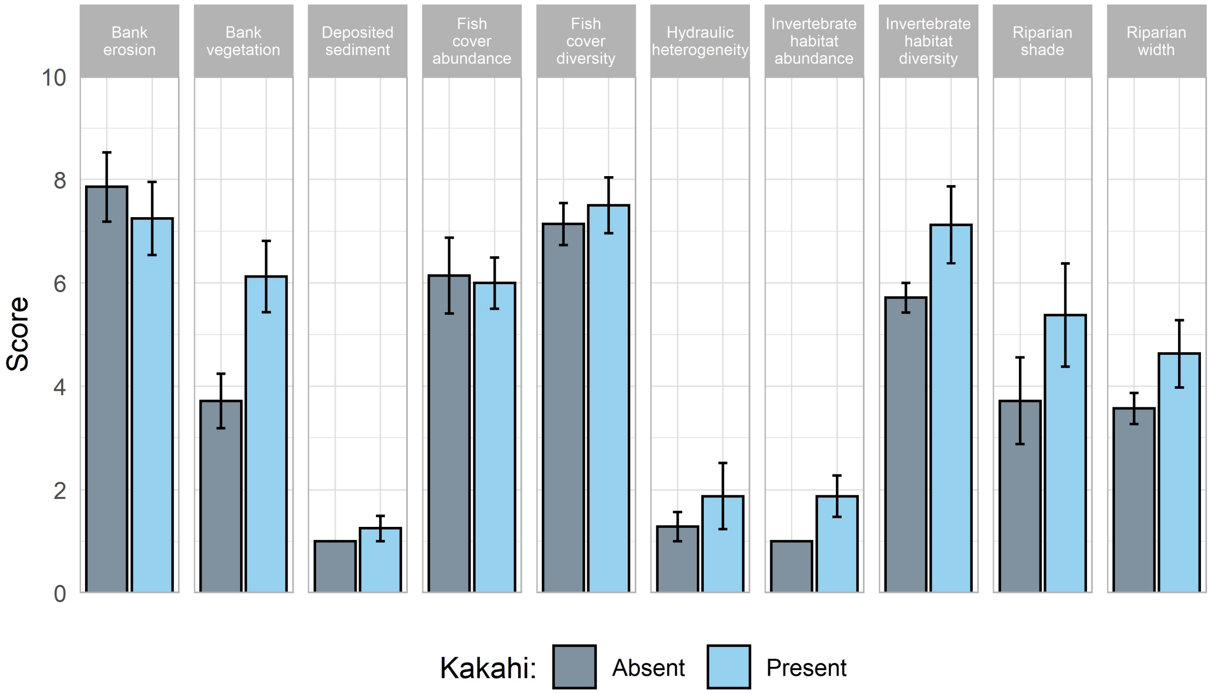

Figure 11. Results of the rapid habitat assessments categorised by sites where kākahi were either: present (Sites 1–8) or not present (Sites 9–15). Data are means (±1 SE).

3.5. Population Structure

Recovered kākahi ranged in length from 42–102 mm, with a mean length of 75 mm (Table 1). Corresponding age estimates ranged between 8–45 years, with a mean of 20 years. When compared to the 2007 survey of Burdon & McMurtrie (2009), we found a similar, albeit slightly wider, range of sizes and calculated ages (Table 1).

Table 1. Summary statistics for kākahi length and age, including all individuals from this study compared to the 2007 survey of Burdon & McMurtrie (2009). Age was calculated using the formula of Ogilvie (1993).

	Mean	Median	Minimum	Maximum	Standard Deviation
Length (mm)					
2007	86	89	46	101	9
2020	75	73	42	102	14
Age (years)					
2007	27	28	9	44	7
2020	20	16	8	45	9

In 2007, kākahi ages were bimodally distributed, dominated by individuals in the age classes 28–32 years, with individuals between 20–24 years of age also common (Figure 12). In 2020, the population was generally younger, being dominated by kākahi between 12–18 years old, although the population was again bimodally distributed, with kākahi between 28–32 years old also common (Figure 12).

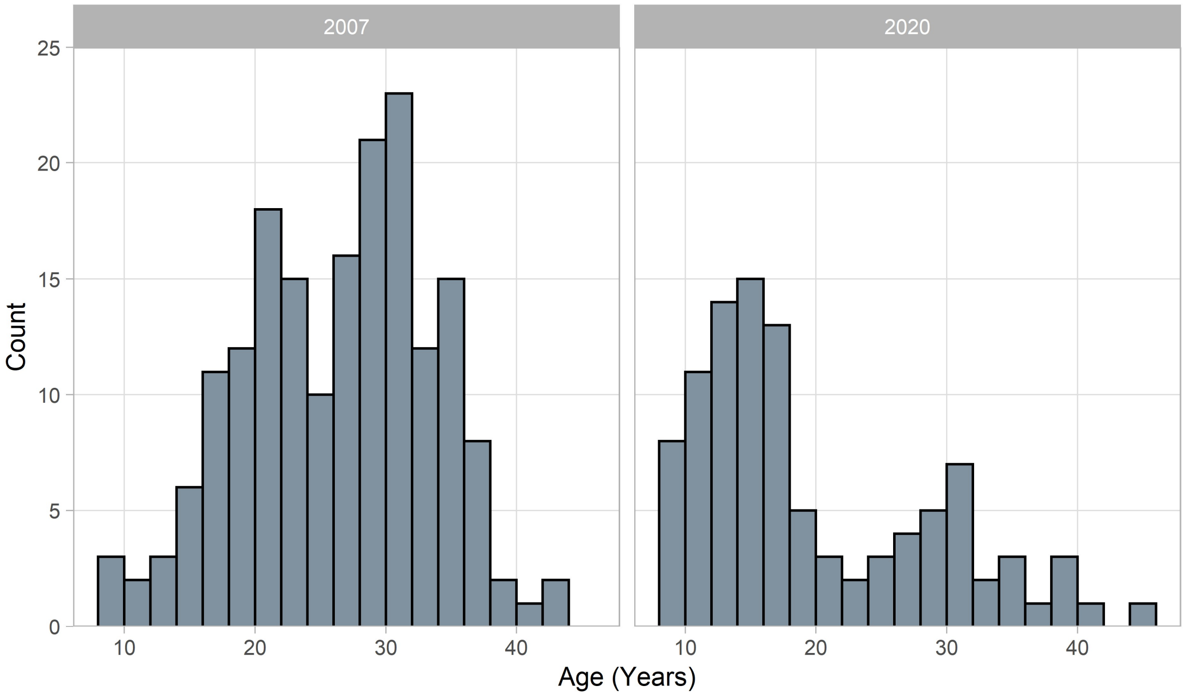

Figure 12. Histograms showing kākahi age class structure from 2007 (left) and 2020 (right). Kākahi from all sites were included for each study year.

The age distribution of kākahi was greatly skewed towards younger mussels (<20 years) in the current study, while the 2007 population was more heavily skewed towards older (>20 years) kākahi (Figure 13). The exact two-sample permutation test confirmed a significant difference (T = 24812, p<0.001) between mean age of kākahi in the current study (mean age = 19.6 years) and in the 2007 study (mean age = 26.3 years). This result is driven partially by the large number of young kākahi found at Site 1 in the current study, whereas no individuals were detected at this site in 2007, but this trend was also consistent across the other comparison sites.

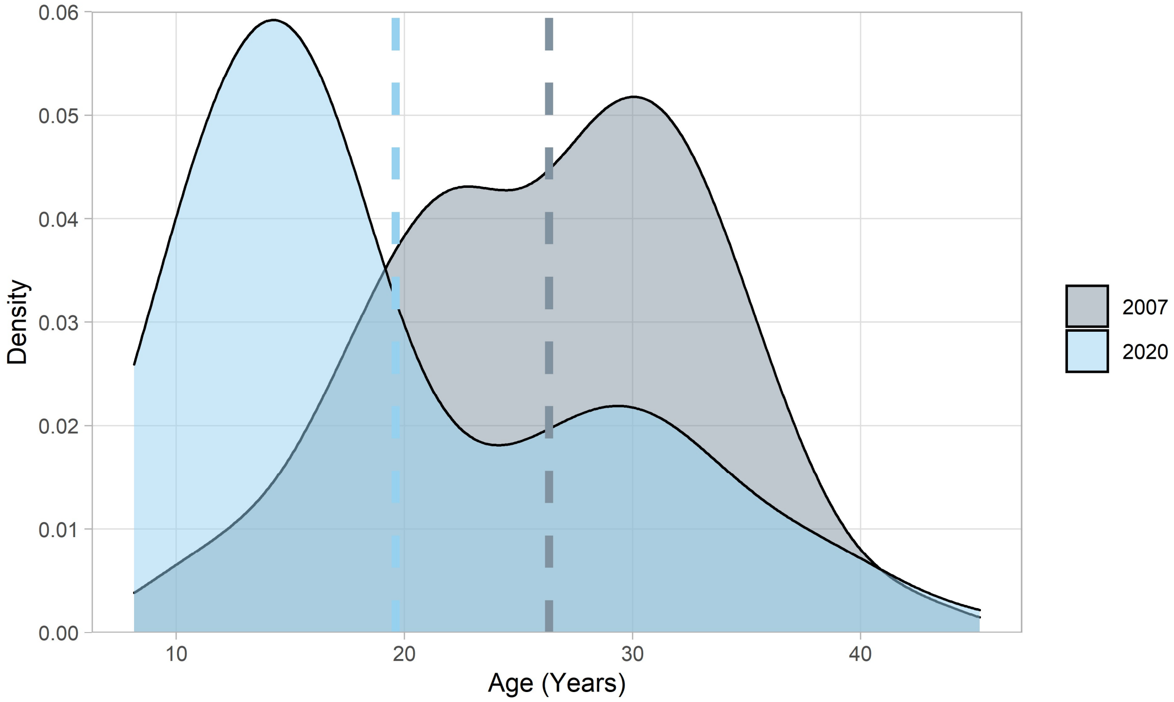

Figure 13. Density plots for the 2007 and 2020 kākahi observations. Mean age for each sampling year is indicated by the vertical dashed line of corresponding colour to the key at the right.

Site-wise comparison of age distributions showed that kākahi were consistently younger in the current study, when compared to the 2007 study. A distinct shift in age distribution was also observed in the current study. The downstream sites were dominated by younger kākahi, with older kākahi increasing in dominance in an upstream direction. While the dominance of age classes varied among sites, most age classes were still represented at all the sites, except for kākahi >c. 35 years old at Sites 1 and 2. Theil-Sen regression analysis confirmed that there was a significant positive relationship between kākahi age and distance to the Cashmere Stream/Heathcote River confluence (p<0.001), although the correlation coefficient was weak ($r^2 = 0.18$), reflecting considerable scatter in the data (Figure 15).

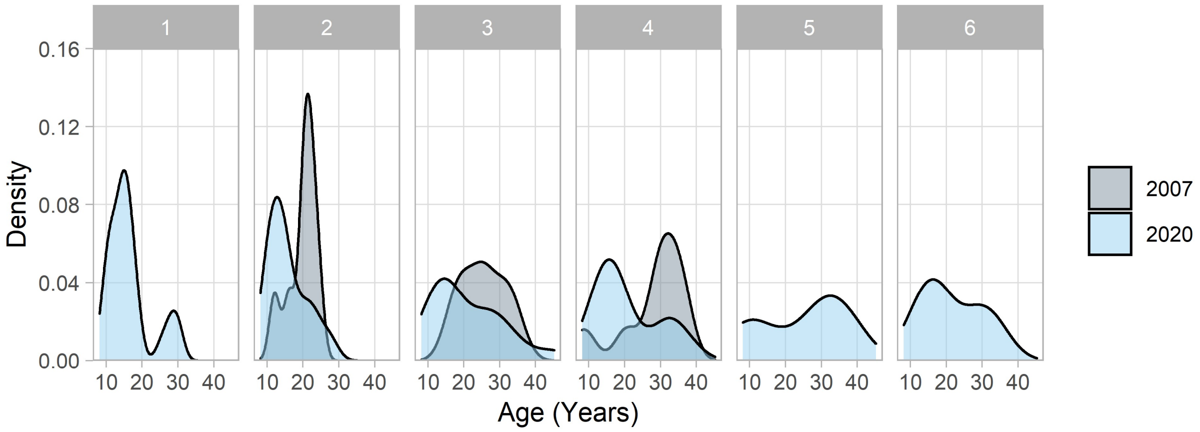

Figure 14. Density plots for kākahi found at different sites in 2007 and 2020. Site labels are across the top of the plots. For this figure, only sites with five or more kākahi were included (min N=5, max N=31, median N=13).

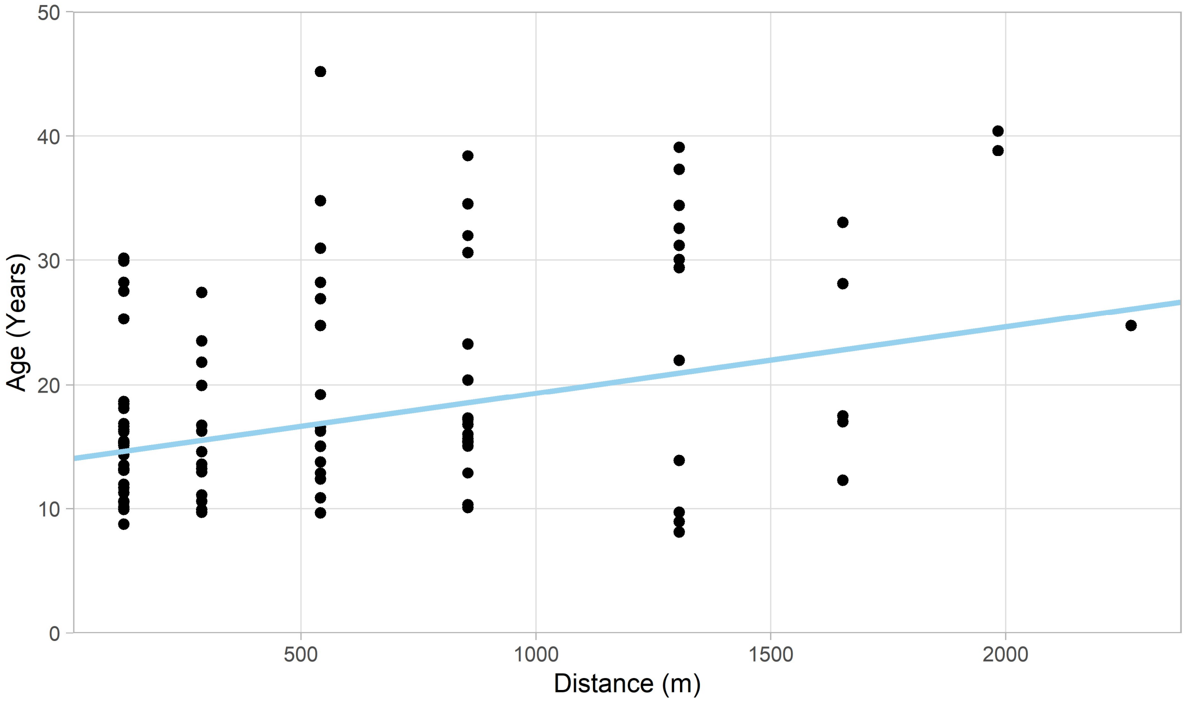

Figure 15. The relationship between distance from the Cashmere Stream/Heathcote River confluence and kākahi age, including all kākahi captured in the current study. Theil-Sen estimated slope indicated by the solid line (r^2 = 0.18, $p<0.001$)

Shell erosion was low overall and was minimal at the most downstream sites (Figure 16, Figure 17). At Sites 1 and 2, 84% and 60% of kākahi had zero shell erosion, respectively (Figure 17). The remaining kākahi at these sites had less than 25% erosion. Shell erosion generally increased in an upstream direction, with kākahi at Sites 3–6 all having greater than 25% shell erosion. However, caution should be taken when interpreting these results, due to the low number of observations, especially at Sites 6–8.

Figure 16: Examples of kākahi with minimal shell erosion (left) and relatively high levels of erosion (right).

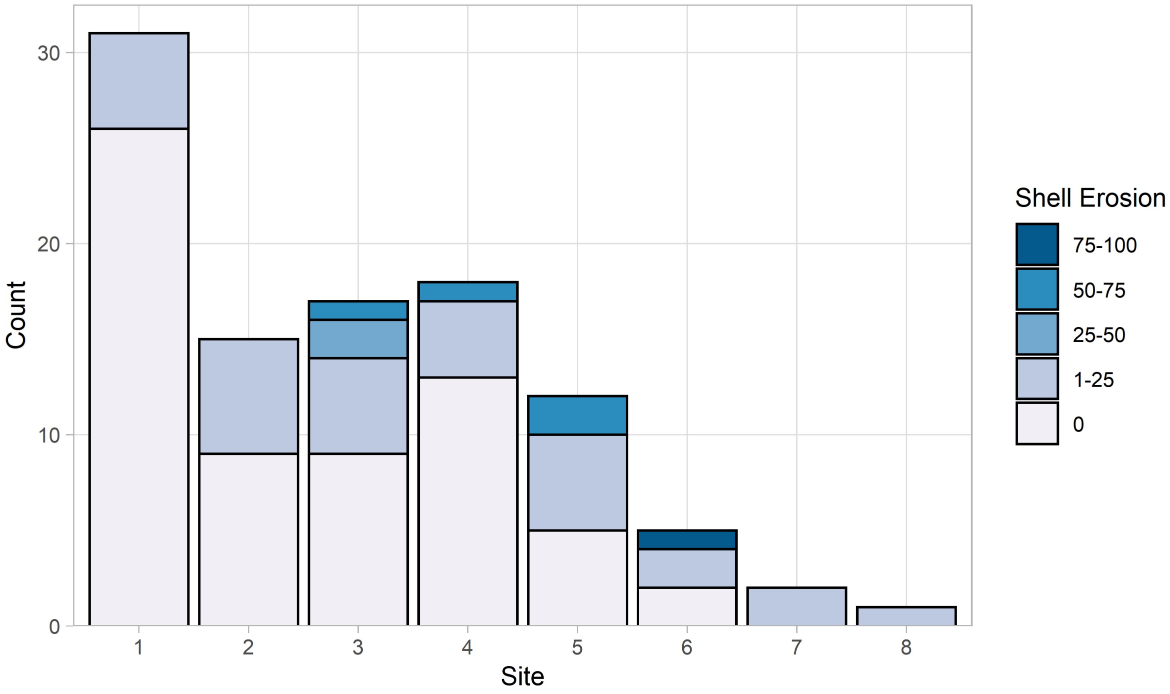

Figure 17. Percent shell erosion for all kākahi sampled in the current study.

4. DISCUSSION

Results from this survey indicate that the kākahi population in Cashmere Stream is stable or improving, relative to the 2007 baseline survey (Burdon and McMurtrie 2009). Kākahi densities appear to have increased, although the spatial range of the population has remained consistent. Thus, the current range of the kākahi population remains limited to the Lower and Mid sections of Cashmere Stream (Figure 1). Despite extensive surveys in the Upper section of Cashmere Stream (34% of the waterway was searched from Site 9 to Sutherlands Road), no kākahi were discovered. It is therefore very unlikely that kākahi are present within the Upper section of Cashmere Stream, where habitat restoration and channel realignment is proposed.

Restoration activities in the upstream reaches may result in some additional fine sediment entering Cashmere Stream, even with sediment controls in place. This could be associated with increased turbidity and fine sediment deposition in downstream reaches where kākahi are present. However, Cashmere Stream has suffered from relatively high and prolonged levels of turbidity for at least the last 15 years (James and McMurtrie 2010). For example, median turbidity was 10 NTU at Worsley Road in 2018 (Marshall and Noakes 2019), indicating the stream was visibly turbid most of the time. It is clearly preferable to avoid further worsening turbidity in Cashmere Stream. However, relatively small and temporary increases in turbidity that are associated with restoration construction activities are unlikely to affect a population that is acclimated to turbid conditions.

Kākahi densities in Cashmere Stream ranged from 0.4 (Site 8) to 12.4 (Site 1) kākahi per m², with a mean of 5 kākahi per m² across all sites where kākahi were detected. In the Waikato region, kākahi densities of 1.58, 0.29, and 1.62 per m² were reported in Pakoka River, Ohautira Stream, and Mangapapa Stream, respectively (Hanrahan 2019). Walker *et al.* (2001) reported a mean density of 6 kākahi per m² across 12 New Zealand lake populations. Densities of 40 to 55 kākahi per m² were recorded during a baseline dive survey of the lower Styx River, in northern Christchurch (Instream Consulting 2018). Overall, the Cashmere Stream kākahi population appears to have similar densities to those recorded elsewhere in the country, except for the lower Styx River population, which is exceptionally dense.

Substantial local disturbances have occurred since the 2007 baseline kākahi survey in Cashmere Stream, including the Canterbury earthquakes (2010–11), the Port Hills fires (2017), and ongoing weed clearance and residential development within the catchment. Despite these disturbances, recruitment is occurring and the kākahi population is persisting. Consistent with the findings of Burdon & McMurtrie (2009), kākahi densities declined upstream of the Cashmere Stream/Heathcote River confluence in a linear fashion, with the upstream extent of the population being approximately 2.3 km from the confluence. However, over this extent, kākahi density has increased significantly since 2007. This result may be due to sampling error (related to the patchiness of the population), differences in sampling methodology between studies, or it may represent a true increase in the abundance of kākahi in the system. Potential reasons for greater kākahi densities being recorded in 2020 are explored in the following paragraphs.

Both the 2007 baseline study and the current study found the population to be spatially highly patchy, with large variance between the densities of kākahi between quadrats and transects at each site. This patchiness was highlighted during a kākahi salvage operation in 2017, undertaken by Aquatic Ecology Limited prior to replacement of a wooden retaining wall. They recovered 1,345 kākahi within an approximately 27 m² search area of Cashmere Stream, equating to a density of 50 kākahi per m² (Winsome Marshall, Aquatic Ecology Limited, Pers.

Comm.). This is far higher than the mean kākahi density at any sites during our study, where mean density was greatest at Site 1, with 12.4 kākahi per m². Patchy or clumped populations are inherently difficult to sample, due to the natural variance between observations introducing large error terms into statistical models. However, compared to the 2007 baseline survey, kākahi density was consistently higher across all study sites, and the GLMM confirmed this increase to be highly statistically significant. Thus, the measured increase in kākahi density is unlikely due to chance sampling of high-density areas.

Differences in sampling design may have also influenced the kākahi density estimates. The 2007 baseline survey employed a systematic design with multiple random starts (Strayer *et al.* 2003), while the current study used a rapid survey, followed by a systematic transect-based survey. The main concern with the latter is that there is a bias for finding kākahi, as the transect survey was initiated from the point at which a kākahi was found during the rapid survey. This approach, while being more efficient at detecting kākahi, may increase the chance of kākahi being found in quadrats during the systematic transect survey. While it is not possible to precisely calculate the effect of this bias on the data, sampling bias does not fully explain the difference in kākahi densities between the two studies. At Sites 1–7 kākahi were detected rapidly, within five minutes of searching and in less than 18 m. Therefore, in the absence of a rapid search, much of the same area would have been covered by the transects. In addition, despite differences in sampling methods, both studies sampled a total of 2.5 m² of stream bed at each site, giving a similar overall likelihood of encountering an individual kākahi at each site.

Beyond the potential effects of sampling error and bias, the measured change in kākahi density between sampling years likely has an ecological basis. This is supported by population structure data from the current study. The calculated mean age of kākahi in the 2020 survey was 19.6 years, compared to 26.3 years in the 2007 study. In a study of the European freshwater pearl mussel (*Margaritifera margaritifera*), Hastie & Cosgrove (2002) suggested that population viability occurs when at least 25% of the population is younger than 20 years old, as that indicates sufficient recruitment is occurring. We found age classes of 8–18 years dominated the population and 60% of the sampled individuals were under the age of 20. Given that well over 25% of the population was estimated to be under the age of 20 years in the present study, this suggests that the Cashmere Stream population is viable and there is sufficient recruitment.

Current research on kākahi by Channell Thoms, a University of Canterbury PhD candidate, indicates that the formula developed by Ogilvie (1993) may overestimate the age of kākahi in Cashmere Stream. Based on mark-recapture measurements from 50 individuals in Cashmere Stream, mean annual growth rates were 4.3 mm with a maximum growth rate of 13.2 mm (Channell Thoms, Pers. Comm.). In comparison, growth rates for similar-sized kākahi predicted by the Ogilvie (1993) formula are approximately 1-2 mm per year. Growth rates in Cashmere Stream appear to be high compared to rates measured in other Canterbury waterbodies, which may be due to high calcium levels in Cashmere Stream (Channell Thoms, Pers. Comm.). If the Ogilvie (1993) formula overestimates the age of 20-year-old individuals by as little as 1.5 years, the population sampled by Burdon & McMurtrie (2009) would have comprised greater than 25% of individuals under 20 years old. By the measure of Hastie & Cosgrove (2002) this would deem the population sampled in 2007 viable, which is consistent with our findings.

Despite the current population being much younger than the 2007 population, no juvenile kākahi less than 42 mm were detected, with the youngest individual having a calculated age of eight years. A lack of juvenile kākahi has been reported by numerous studies elsewhere in New Zealand (Grimmond 1968; James 1985; Roper and Hickey 1994). This has led to a suggestion that the juveniles may occur in different habitats to those of the adults, undergoing migration as they develop (Phillips *et al.* 2007). While this is an appealing hypothesis, it lacks supporting data, because until recently kākahi reproduction has been poorly studied in New Zealand. However, graduate research projects currently underway at Canterbury and Waikato universities will lead to improved understanding of kākahi reproduction and ecology.

Due to the low number of observed kākahi and the highly patchy nature of their distribution, it is not possible to relate the observed population patterns discussed above to habitat features or other influences in Cashmere Stream. Furthermore, despite some positive indicators of population health, including a relatively younger and more abundant population compared to the 2007 baseline study, it is difficult to predict the future direction of the population. Ongoing monitoring and research will be required to determine if recruitment is ongoing, and if a failure to detect juvenile kākahi relates to patterns of habitat or reproduction.

The current extent of kākahi in Cashmere Stream corresponds roughly to the extent of natural channel form, with kākahi absent from the straightened upper reaches. This was also noted in the 2007 survey report (Burdon & McMurtrie, 2009), where it was suggested that frequent mechanical disturbance and sediment removal limits the kākahi population in the upstream reaches. Restoration activities proposed in the upper reaches of the stream provide the opportunity to enhance channel form, while the creation of major stormwater treatment facilities may also reduce sources of fine sediment. The implication of this is that the upper reaches of Cashmere Stream may provide habitat that becomes more suitable and stable for kākahi.

Increasing the length of waterway suitable for kākahi colonisation in Cashmere Stream would help ensure the population's viability. If left to natural processes, the kākahi population may slowly extend its spatial range into the upper reaches of Cashmere Stream. However, the rate of colonisation could be enhanced via translocation of kākahi from nearby populations, such as the Styx River. Translocation of kākahi to new environments was historically common and translocation has recently been undertaken at several locations in New Zealand (McEwan *et al.* 2020). Any kākahi translocation would preferably be undertaken with local iwi, and it would require prior approval from the Department of Conservation. Careful follow-up monitoring of any translocated population would be essential.

5. ACKNOWLEDGEMENTS

Thank you to Katie Noakes and Andrew Chinn from CCC, who provided funding for this study. Thanks also goes to EOS Ecology, who undertook the original baseline study and for providing the raw data from the 2007 study to CCC. While we used the EOS Ecology data, Instream is responsible for any subsequent data manipulation and interpretation. A special thanks goes to the Cashmere Stream Care Group, who have worked tirelessly over many years to protect and improve the ecology of Cashmere Stream.

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