Lake Horowhenua – Pest Fish Monitoring 2018

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Executive summary

Lake Horowhenua is a small, shallow, coastal dune lake on the west coast of the North Island. It has several surface inflows as well as significant ground-water inflows. Lake water levels are maintained by a weir on the Hokio Stream, the sole outflow on the western side of the lake. The Hokio weir was installed in 1956, and currently creates a drop of approximately 1 m under normal flows. The presence of this weir is thought to have contributed to the decline in native fish populations within Lake Horowhenua as it restricts the movement of diadromous fish (i.e., species that migrate between freshwater and the sea to complete their life cycle) into the lake. To improve the biodiversity of the fish communities and ecological integrity of Lake Horowhenua, Horizons Regional Council installed a fish pass along the true right margin of Hokio Stream to allow the migration of fish past the weir and into the lake.

Currently, the population densities of key pest fish species (koi carp, goldfish and perch) are thought to be below the known threshold levels where they are likely to cause ecological disturbance. However, concerns were raised that the installation of a fish pass at the weir on Hokio Stream could exacerbate pest fish densities by enhancing movement of pest fish into Lake Horowhenua. In this regard, the resource consent (ATH-2015200301.00) required for installation of the fish pass at Hokio weir included conditions around developing a Pest Fish Monitoring Programme (PFMP) to ensure the abundance of pest fish species within Lake Horowhenua did not increase in density as a direct result of the pass.

To identify changes in the abundance, composition and size structure of pest fish species present in Lake Horowhenua, gill net surveys were carried out in April 2017, prior to the installation of the fish pass, and during April and May 2018, a year post-completion of the fish pass. To enable the calculation of populations estimates (as required under condition 13 of the consent), depletion fishing was undertaken, setting nets for three consecutive nights.

Across 2017 and 2018, the main fish species captured in the gill nets were perch (2,420) and goldfish (266), with lower numbers of mullet (30) and rainbow trout (2) recorded. The perch population was dominated by large adult fish ranging between 350 and 500 mm, whereas the goldfish population was dominated by fish between 150 and 200 mm.

Monitoring indicated that populations of the main pest fish species recorded in Lake Horowhenua (perch, goldfish and koi carp) are all below the threshold density of 50 kg ha^{-1} specified by condition 13 of resource consent ATH-2015200301.00. Based on the current population structure and biomass of perch and goldfish there is no evidence to suggest that the abundance of these species within Lake Horowhenua has increased since 2017 as a direct result of the fish pass installed at Hokio weir. Although koi carp are a difficult species to capture and all fishing methods will underestimate their abundance, the continued difficulty in capturing koi carp within Lake Horowhenua since 2013 suggests this species remains at densities below those known to cause adverse ecological impacts. It should also be noted that once resident in a lake, perch, goldfish and koi carp will readily breed and form self-sustaining populations. In this regard, changes in abundance and size structure can naturally occur independent of immigration into the system via the fish pass at Hokio weir.

Overall, based on the biology of perch, goldfish and koi carp, it is our opinion that the fish pass at Hokio weir will not significantly impact their population size and structure within Lake Horowhenua, and local factors associated with the lake (e.g., water quality, habitat, food availability) will be the main drivers of pest fish abundance.

1 Introduction

1.1 Lake Horowhenua fish community

Lake Horowhenua is a small (surface area 2.9 km^2), shallow (< 2 m deep), coastal dune lake on the west coast of the North Island (Gibbs and White 1994). Land use within the catchment consists predominantly of dry stock or dairy farming (43.3%), urban development (8.4%) and horticulture (4.9%) (Gibbs 2011). Lake Horowhenua is currently classed as hypertrophic with a mean Trophic Lake Index (TLI) for 2005-2009 of 6.3 (Verburg et al. 2010). This TLI indicates it is one of the most degraded lakes in New Zealand. Gibbs (2011) identified a number of factors that have contributed to the decline in water quality of Lake Horowhenua over the past 50 years. These included historical discharge of treated sewage effluent from the township of Levin, nutrient leaching and sediment accumulation from horticultural and agricultural land-use, stormwater discharges, collapse of the lake weed *Potamogeton crispus* and ecosystem disturbance by invasive pest fish (Gibbs 2011).

Before the 1908 Land Drainage Act, Lake Horowhenua was renowned for the quality of the eels (tuna), and the large seaward migration runs of pre-spawning adults (tuna heke) (Cunningham 1953; Chisnall 1999). In addition, Lake Horowhenua was known to contain populations of black flounder (*Rhombosolea retiaria*), grey mullet (*Mugil cephalus*), and whitebait (*Galaxias* spp.) (Cunningham et al. 1953; Gibbs 2011). Since the decline of water quality in Lake Horowhenua, and the invasion of pest fish species, fish community composition within the lake has changed. Shortfin eels are still dominant within the lake, with catch per unit effort (CPUE) ranging from 15.3 to 49.6 eels per fyke net (across different types of fyke nets) in 1999 (Chisnall 1999), and 89.2 eels per fyke net in 2013 (Tempero 2013). However, goldfish (*Carassius auratus*) and perch (*Perca fluviatilis*) are now abundant within Lake Horowhenua, with Tempero (2013) capturing over 300 fish of each species in April 2013 by boat electrofishing (9.9 ha fished). A gill net survey carried out in Lake Horowhenua during April 2017 also recorded 798 perch (across 10 nets; NIWA, unpublished data). Other fish species recorded in low numbers in the Tempero (2013) and NIWA (2017) surveys were; common smelt (*Retropinna retropinna*), common bully (*Gobiomorphus cotidianus*), inanga (*Galaxias maculatus*), grey mullet (*Mugil cephalus*), koi carp (*Cyprinus carpio*), rainbow trout (*Oncorhynchus mykiss*) and suspected koi-goldfish hybrids. Of interest was the two rainbow trout captured in 2017 (NIWA 2017), as this species has not been recorded in Lake Horowhenua for several decades.

Introduced freshwater fish species such as perch and koi carp have been implicated in the decline of New Zealand's aquatic ecosystems (Rowe 2007). In particular, perch are one of the highest risk invasive species identified in the Fish Risk Assessment Model (FRAM; Rowe and Wilding 2012). Perch are an undesirable exotic fish species as they directly influence zooplankton, macroinvertebrate and fish populations. In New Zealand, freshwater systems dominated by perch are typically depauperate in native fish species due to predation by this opportunistic piscivore. For example, in Lake Ototoa, since the introduction of perch in 2002, their increase in abundance is thought to be directly responsible for the near extinction of dwarf inanga (*Galaxias gracilis*) within the lake. Between 2003 and 2011, perch also reduced kōura abundance in Lake Ototoa by over 90%, and common bullies by over 80%. Ludgate and Closs (2003) also found that perch abundance has a significant negative impact on the abundance of common bullies in lentic water bodies. Further, perch have been associated with reductions in water quality through 'top-down' predatory effects on zooplankton (Rowe & Smith 2001; Rowe 2007; Smith & Lester 2007). Impacts on zooplankton are most pronounced when the population structure is dominated by juvenile fish (<120 mm; Smith & Lester 2007).

Koi carp are undesirable as they are omnivorous and feed at all trophic levels. Their diet includes phytoplankton, zooplankton, invertebrates, small fish, a diverse range of plants and other organic matter (Lammens & Hoogenboezm 1991; Osborne 2006). In New Zealand, and particularly the Waikato Region, koi carp have been implicated in the degradation of many freshwater ecosystems because of their feeding mechanisms. Koi have been described as vacuum cleaners, digging into, and ingesting sediments with unwanted material discarded via the gills. As a result, koi carp cause bioturbation of substrates and uproot aquatic plants, which in turn increases water turbidity and destroys fish and plant habitats (Crivelli 1983; Roberts et al. 1995). The direct and indirect effects of koi carp can potentially initiate a regime shift in lake systems from clear water with high macrophyte abundance, to eutrophic turbid water devoid of aquatic macrophytes. Catastrophic effects of koi carp occur when fish reach a critical density (100 kg ha^{-1} threshold; Scheffer et al. 2001; Zambrano et al. 2001; Chumchal et al. 2005) and are more common in shallow waterbodies (Meijer et al. 1999).

Although goldfish have also been identified as a potential problem species, little research has been carried out on the ecosystem effects driven by this species (Rowe 2007; Tempero 2013). Given goldfish can breed with koi carp and produce fertile offspring, their abundance within Lake Horowhenua is also of concern.

Currently, the population densities of koi carp, goldfish and perch are thought to be below the known threshold levels where they are likely to cause ecological disturbance (Tempero 2013). However, concerns were raised that the installation of a fish pass at the weir on Hokio Stream could exacerbate pest fish densities by enhancing movement of pest fish into Lake Horowhenua.

1.2 The Hokio weir fish pass

Lake Horowhenua has several surface inflows as well as significant ground-water inflows. Lake water levels are maintained by a weir on the Hokio Stream, the sole outflow on the western side of the lake (Gibbs 2011). The Hokio weir was installed in 1956, and currently creates a drop of approximately 1 m under normal flows (Figure 1-1).

Figure 1-1: The Hokio Stream weir under moderate to high flow.

The presence of this weir is thought to have contributed to the decline in native fish populations within Lake Horowhenua as it restricts the movement of diadromous fish (i.e., species that migrate between freshwater and the sea to complete their life cycle) into the lake. Baker (2014) recommended the installation of a fish pass at the Hokio weir, as this would be beneficial to biodiversity within Lake Horowhenua, improving the fish communities and ecological integrity of the lake ecosystem.

Between March and May 2017, Horizons Regional Council installed a fish pass along the true right margin of Hokio Stream to allow the migration of fish upstream of the weir. The fish pass consists of a rock lined channel with rocks cemented in position to create a series of pools along the base of the channel (Figure 1-2). Erosion control measures (matting and vegetation) have subsequently been undertaken along the true right bank of the fish pass, with rock and vegetation also used to prevent scouring and erosion at the fish pass inlet and outlet (Figure 1-2).

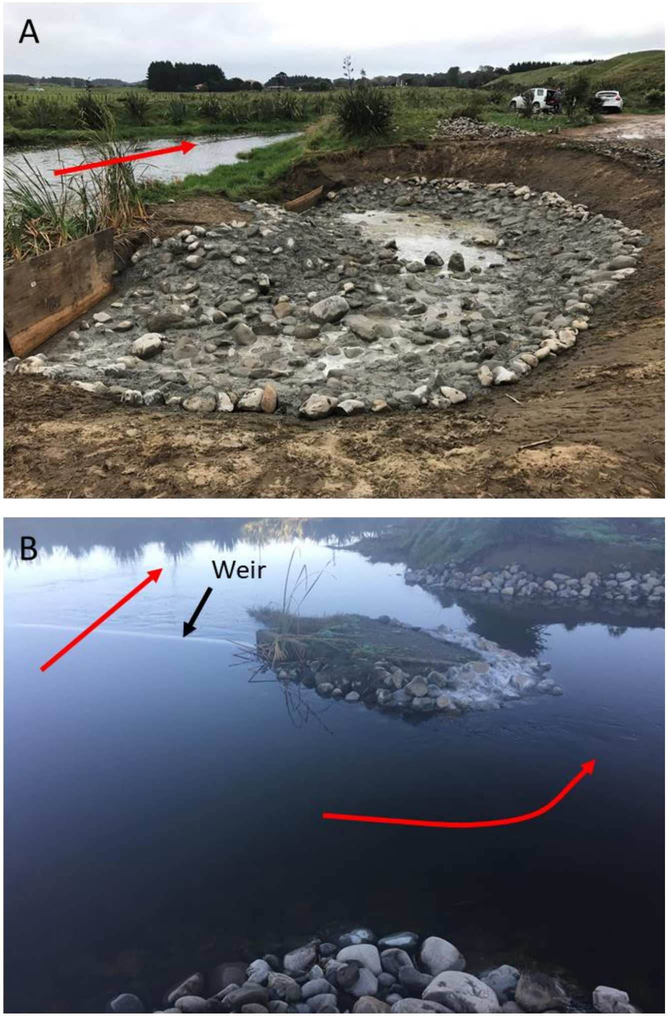

Figure 1-2: A, installation of the rock channel fish pass in March 2017; B, the fish pass under high flow in May 2017 The red arrows indicate the direction of flow in the Hokio Stream and in (B), into the fish pass.

The resource consent (ATH-2015200301.00) required for installation of the fish pass at Hokio weir included conditions around developing a Pest Fish Monitoring Programme (PFMP) to ensure the abundance of pest fish species within Lake Horowhenua did not increase in density as a direct result of the pass.

1.2.1 Consent conditions

Resource consent conditions (ATH-2015200301.00) relating to the PFMP:

6. The Consent Holder shall, in the 2018 calendar year, undertake a Pest Fish Monitoring Programme (PFMP) to assess pest fish numbers in Lake Horowhenua.
7. No less than 20 working days prior to the commencement of the pest fish monitoring, the Consent Holder shall provide the Manawatu-Wanganui Regional Council's Regulatory Manager with a Pest Fish Monitoring Programme (PFMP) prepared by a suitably qualified and experienced person(s).
8. The objective of the PFMP shall be to identify the number and type of pest fish present in Lake Horowhenua and assist in determining if monitoring of the fish pass, located adjacent to the Hokio Stream weir, is required to identify pest fish using the fish pass.
9. The PFMP shall include:
   a) Specific methodologies and protocols for sampling specified target pest fish species and how sampling protocols will be followed.
   b) Reporting procedures, including the reporting of the number of koi carp and hybrids per hectare of lake surface area.
10. The PFMP shall be certified in writing by the Manawatu Wanganui Regional Council in a technical certification capacity prior to the monitoring being undertaken.
11. The Consent Holder may commence the monitoring programme in accordance with the PFMP unless Manawatu-Wanganui Regional Council advises the Consent Holder in writing within 10 working days of receipt of the PFMP that it will not certify the plan on grounds it does not met the requirements of conditions 8 and 9 above.
12. Should Manawatu-Wanganui Regional Council refuse to certify the PFMP the Consent Holder shall submit a revised PFMP to Manawatu-Wanganui Regional Council for certification. The certification process shall follow the same procedure as outlined in conditions 6 to 11 of this consent.
13. If the number of koi carp and hybrids per hectare exceeds 50kg/Ha in the 2018 monitoring programme, the Consent Holder shall modify the PFMP to include:
    a. specific methodologies and protocols for the monitoring the number of pest fish using the fish pass
    b. protocols for establishing the trigger levels for the number of pest fish using the fish pass, and
    c. adaptive response programmes when established trigger levels of pest fish using the fish pass are exceeded.
14. The modified PFMP required by condition 13 shall follow the same certification procedure as outlined in conditions 6 to 11 of this consent.
15. The Consent Holder shall comply with the certified PFMP when pest fish monitoring is being undertaken.

To fulfil conditions 6 to 11 of resource consent ATH-2015200301.00, Horizons Regional Council contracted NIWA to undertake the 2018 pest fish monitoring in accordance with the PFMP detailed in Baker (2017).

2 Monitoring methodology

2.1 Background

The following monitoring programme was developed by Baker (2017) based on the results of previous exotic fish surveys within Lake Horowhenua (Tempero 2013; NIWA 2017) and utilising the most effective methodology for capturing the target species. The exotic fish species recorded in Lake Horowhenua are perch, goldfish, rainbow trout, koi carp, and potential koi-goldfish hybrids. Perch and goldfish are the most abundant species, with low numbers of all other exotics.

A caveat of the previous surveys is that the abundance of koi carp could be under-estimated. Koi carp are a difficult species to capture in gill nets, and the efficiency of the electrofishing boat can be reduced in turbid lakes with low visual clarity (Hicks et al. 2008). As six potential koi-goldfish hybrids were recorded by Tempero (2013) this suggests koi are numerous enough to breed with goldfish. However, only one koi carp was captured by Tempero (2013). Therefore, the catch efficiencies of koi carp may have been low in both gill nets and in the electrofishing boat survey.

Baker (2017) proposed using gill nets as the basis of the pest fish monitoring programme to examine the abundance of exotic fish species in Lake Horowhenua. This is because gill nets are more effective at capturing perch, the most abundant pest species present, and presently there is no method that is documented to have high capture efficiencies of koi carp in lakes with low visual clarity. Therefore, it is anticipated that both electrofishing and gill netting will underestimate the abundance of koi carp. Gill nets are also beneficial over electrofishing as they have higher efficiencies for capturing grey mullet and trout (Baker et al. 2011; NIWA 2017), three species of interest within the lake.

2.2 Methods

Following the methods set out in Baker (2017), 10 panel gill nets (25, 40, 55, 75 and 80 mm mesh in 10 m panels) were set within Lake Horowhenua on 17 April 2018 at the same locations as the NIWA 2017 survey (Figure 2-1) to identify the abundance, composition and size structure of pest fish species present in the lake. To determine populations estimates (as required under condition 13 of the consent), depletion fishing was planned, sampling the lake for three consecutive nights. However, because of strong winds over the sampling period, nets were only set for one night with the monitoring abandoned the following day. The winds also required net 7 to be repositioned east of the target location during the first night of fishing.

Once lake conditions settled, the monitoring was completed over the nights 1st, 2nd and 3rd May 2018. On each night, all 10 nets (Figure 2-1) were set between 3:20pm and 5:00pm (prior to dusk) and lifted the following morning between 8:10am and 10:30am.

After lifting, nets were brought back to shore and each fish was removed with the net number and panel they were captured in recorded. Each fish was identified to species and the total length (mm) and weight (g) measured.

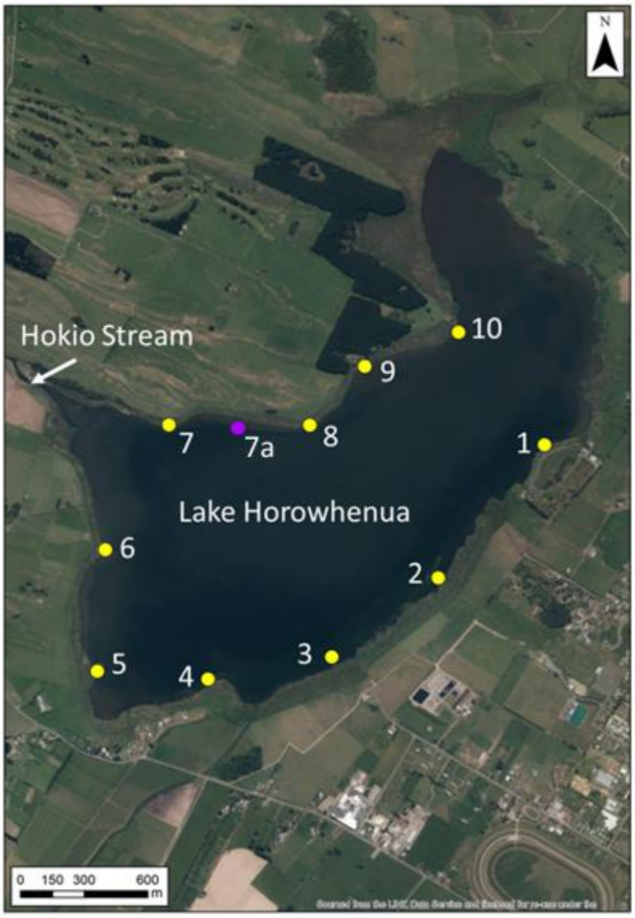

Figure 2-1: Location of the 10 gill net sites in Lake Horowhenua. Note: locations 1 through 10 were utilised on 11 April 2017 and 1, 2 & 3 May 2018. During the single night set on 17 April 2018, net 7 was moved to position 7a because of strong winds.

2.2.1 Biomass estimates

Population estimates for perch and goldfish (the only species captured in sufficient numbers for analysis) were carried out using the maximum likelihood equations of Zippin (1958). This method was chosen over Cowx (1953) as it provided an estimate of standard error around the population estimate.

Based on the population estimate, the biomass of each species was calculated by multiplying the mean weight of fish captured by the total number estimated in the lake. The density of each fish species in the lake was then calculated by dividing the population biomass by the surface area of Lake Horowhenua, to give the kilograms of fish per hectare of lake.

2.2.2 Population size and structure

To determine if the abundance or size of perch and the abundance of goldfish had significantly increased between 2017 and 2018, one-way analysis of variances (ANOVAs) were carried out. The ANOVAs compared catches from April 2017 with catches on the first night of fishing in April and May 2018. As only four goldfish were captured in 2017, a Kruskal-Wallis ANOVA was utilised for examining differences in fish size between the three surveys (using only the first night of fishing in May 2018). For both perch and goldfish, ANOVAs were also utilised to examine changes in fish size across the three nights of fishing in May 2018.

3 Results and discussion

Across 2017 and 2018, the main fish species captured in the gill nets were perch and goldfish, with lower numbers of mullet and rainbow trout recorded (Table 3-1). Too few mullet and trout were captured for analysis, and as the monitoring programme is targeting pest species, all subsequent analyses are focused on perch and goldfish.

Table 3-1: Total number of each fish species captured during the 2017 and 2018 gill net surveys in Lake Horowhenua.

	Survey date				
Species	**11 April 2017**	**17 April 2018**	**1 May 2018**	**2 May 2018**	**3 May 2018**
Perch	798	493	473	322	334
Goldfish	4	33	121	73	35
Grey mullet	17	6	3	2	2
Rainbow trout	2	0	0	0	0

3.1 Biomass estimates

The population biomass estimates for perch and goldfish are shown in Table 3-2. Although no koi carp or hybrids were captured in the survey, biomass estimates for both species are markedly lower than the 50 kg ha^{-1} specified by condition 13 of the resource consent. However, it should be noted that the threshold density of 50 kg ha^{-1} that has been stipulated for koi carp cannot be generalised to goldfish or perch.

Table 3-2: Population and biomass estimates for pest fish captured during the 2018 gill net surveys in Lake Horowhenua. Abbreviations: S.E. = standard error.

Species	**Population estimate (± S.E)**	**Mean weight (kg)**	**Total biomass (kg)**	**Biomass (kg ha^{-1}) (± S.E)**
Perch	2622 (387)	0.98	2566	8.85 (1.3)
Goldfish	273 (16)	0.06	17	0.06 (0.003)

Tempero (2013) also calculated population and biomass estimates for perch and goldfish during the April 2013 electrofishing survey of Lake Horowhenua. Tempero (2013) provided a population estimate for goldfish of 2691 ± 2486 (95% Confidence Interval, CI) and a biomass estimate of 2.14 kg ha^{-1} ± 1.98 kg ha^{-1} (95% CI). For perch a population estimate of 3915 ± 2846 (95% CI) was reported, with a biomass estimate of 11.96 kg ha^{-1} ± 8.70 kg ha^{-1} (95% CI). However, the error limits are unacceptably wide for the population and biomass estimates of Tempero (2013) to be of any value, and Cowx (1983) suggests the estimates should be rejected under such circumstances. In comparison, the population estimates provided in the 2018 survey for both perch and goldfish have error limits an order of magnitude lower than the estimate itself, which provides more confidence in the calculated biomass estimates.

Although only one koi carp was captured by Tempero (2013) and koi were not captured in the gill net surveys during 2017 and 2018, this is more likely to reflect the methods underestimating their abundance, rather than their absence from Lake Horowhenua. However, if koi carp were at densities higher than 50 kg ha^{-1} it is likely that both electrofishing and gill netting would reliably capture some individuals of this species. This notion is supported by the invasive fish control programme undertaken in Lake Ohinewai, also a shallow turbid lake where koi were reliably captured using these methods, especially at high densities. Through installation of a one-way gate and repeat boat electrofishing, the koi carp population was successfully reduced from its 2011 estimate of 374 kg ha^{-1} to 14 kg ha^{-1} in 2014 (Tempero and Hicks 2017). Therefore, it is likely that koi carp are also below the threshold density of 50 kg ha^{-1} specified by condition 13 of the resource consent.

3.2 Population size and structure

3.2.1 Perch

There was no significant difference in the mean number of perch captured between April 2017, and the first night of fishing during April and May 2018 (Figure 3-1). There was, however, significant differences in the size of perch captured between years, with significantly larger fish caught in both April and May 2018 compared to April 2017 ($P<0.001$; Figure 3-2).

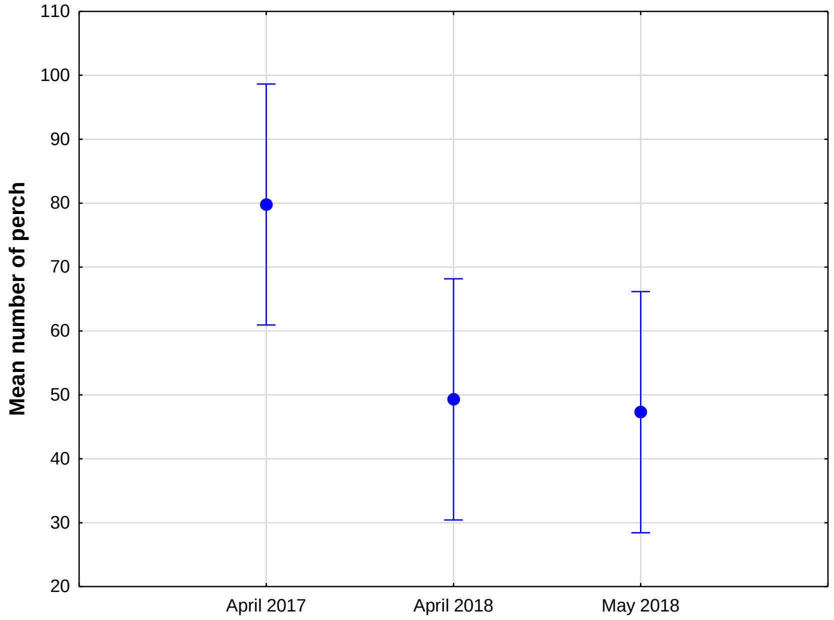

Figure 3-1: Mean number of perch captured across 10 gill nets during the April 2017, and April and May 2018 surveys of Lake Horowhenua. Note: data for May 2018 represents the first night of fishing only.

Across the three nights of fishing in May 2018, no significant difference was identified in the size of perch captured. As such, data for all fishing nights in 2018 were pooled to examine the size structure of perch between 2017 and 2018 (Figure 3-3). In 2017, the perch population was dominated by large adult fish with a smaller secondary age class of maturing fish (150 - 250 mm) present. Surveys in 2018 caught fewer fish less than 250 mm, with an increase in the dominance of large adults between 350 and 500 mm (Figure 3-3). These changes in the size structure of captured perch most likely reflect growth of the population between 2017 and 2018. Tempero (2013) also recorded a population structure of perch dominated by large adult fish, with a smaller cohort of juvenile fish (50 – 150 mm).

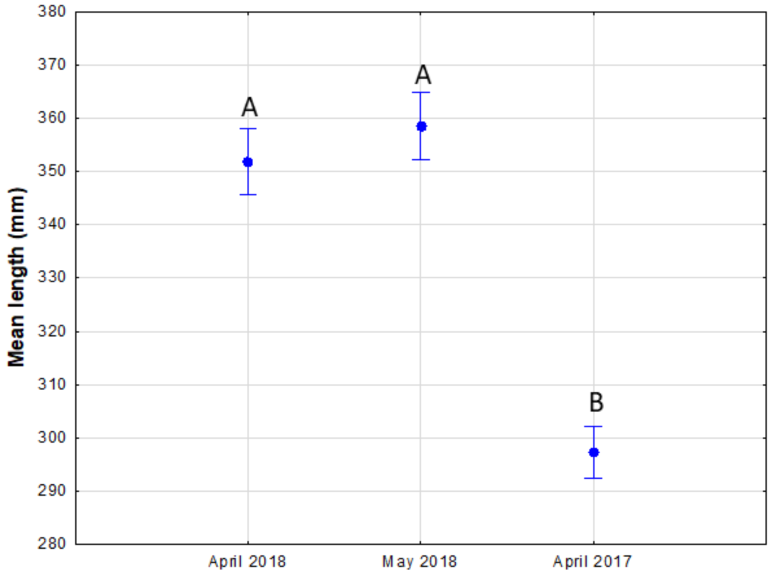

Figure 3-2: Mean length (mm; TL) of perch captured across 10 gill nets during the April 2017, and April and May 2018 surveys of Lake Horowhenua. Error bars represent ± 95% Confidence Intervals. Significant differences between surveys are indicated by different letters. Note: data for May 2018 represents the first night of fishing only.

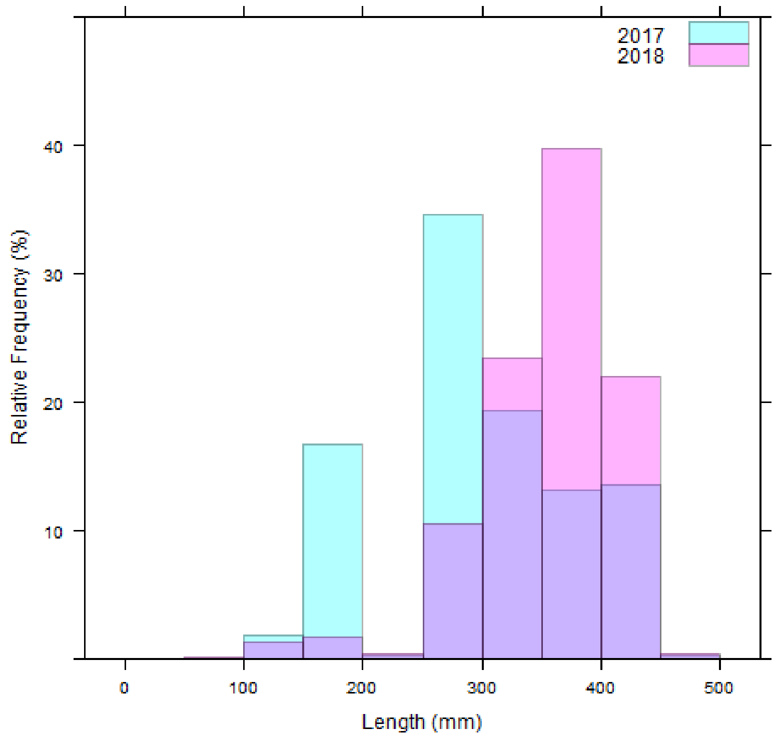

Figure 3-3: Size frequency of perch captured during all nights of the April 2017, and April and May 2018 surveys of Lake Horowhenua. N=798 for 2017 and 1623 for 2018. Note: areas shaded purple represent the overlap of lengths between years.

Based on the survey of Tempero (2013) and data from 2017 and 2018, the population structure of perch appears stable and does not appear problematic for water quality in Lake Horowhenua. Reductions in water quality associated with overgrazing of zooplankton occur when the population structure of perch is dominated by juvenile fish (<120 mm; Smith & Lester 2007). However, given the dominance of perch in Lake Horowhenua and their ability to decimate native fish species, further monitoring of their abundance and size structure is recommended to prevent perch densities or changes in population structure reaching levels where impacts on Lake Horowhenua are evident.

Given that there was no significant increase in catch rates between 2017 and 2018, these changes in fish size are likely to reflect the growth of the resident perch population in Lake Horowhenua, and do not indicate that the fish pass installed at the Hokio weir has resulted in an influx of perch to the lake.

3.2.2 Goldfish

There was a significant increase in the number of goldfish captured between April 2017 and 2018, and May 2018 ($P<0.001$; Figure 3-4). The significant increase in goldfish numbers recorded in May 2018 is likely to reflect different environmental conditions and the inherent variability associated with sampling fish populations rather than absolute changes in fish densities. This is because, without manually stocking the lake, the goldfish population within Lake Horowhenua could not triple in abundance within the two-week period between the April and May 2018 surveys.

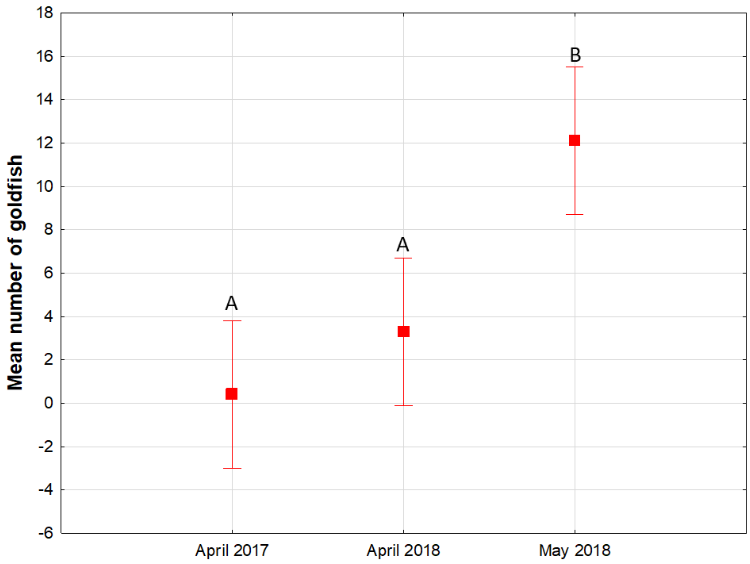

Figure 3-4: Mean number of goldfish captured across 10 gill nets during the April 2017, and April and May 2018 surveys of Lake Horowhenua. Error bars represent ± 95% Confidence Intervals. Significant differences between surveys are indicated by different letters. Note: data for May 2018 represents the first night of fishing only.

The marked difference in goldfish catch rates between the April 2018 and May 2018 (a two-week period) highlights the variability that can be associated with sampling fish populations and reinforces the importance of sampling at the same time across years. In three Canterbury streams, sampling at five weekly intervals across 18 months, Crow and Jellyman (2014) found that population estimates for resident fish species showed high temporal variation between months of the year. Therefore, for repeat surveys, sampling in the same month will provide a more accurate representation of the fish community at the survey site.

There was no significant difference in the size of goldfish captured between 2017 and 2018, however, a caveat of this analysis is that only four goldfish were captured in 2017. Across the three nights of fishing in May 2018, and the single fishing night in April 2018, no significant difference in the size of goldfish captured was identified. As such, data for all fishing nights in 2018 were pooled to examine the size structure of the goldfish population within Lake Horowhenua (Figure 3-5).

The goldfish population was dominated by fish ranging from 150 – 200 mm (Figure 3-5). In 2013, Tempero (2013) also found small goldfish were dominant in Lake Horowhenua, with most fish captured ranging from 76 – 125 mm. Tempero (2013) also captured low numbers of large adult goldfish between 300 and 375 mm, with 39 of the 325 fish captured weighing in excess of 1kg. In contrast, only one fish in 2017 and one fish in 2018 were larger than 250 mm.

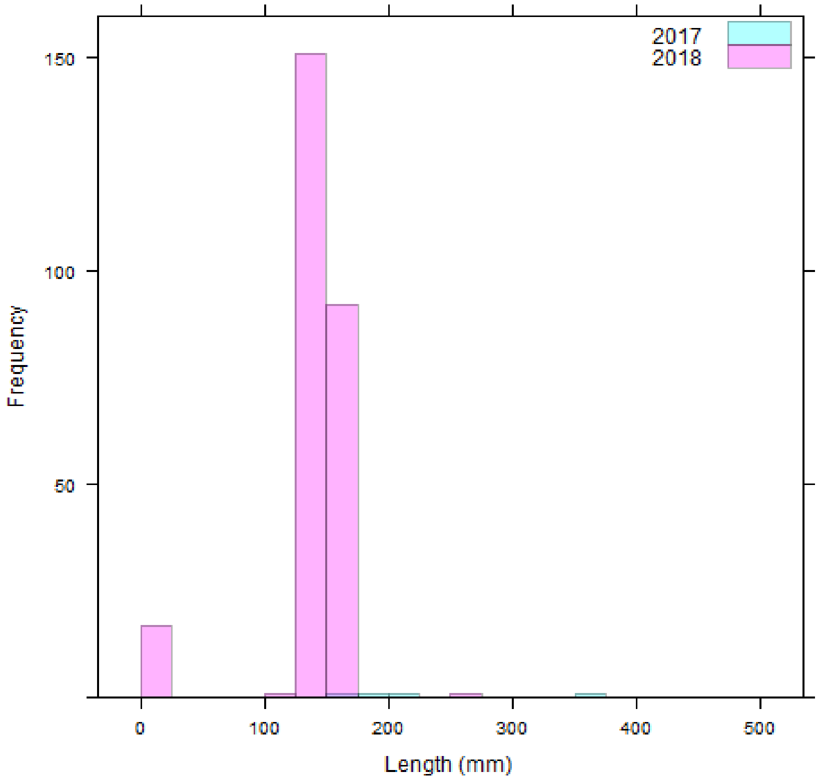

Figure 3-5: Size frequency of goldfish captured during all nights of the April 2017, and April and May 2018 surveys of Lake Horowhenua. N=4 for 2017 and 262 for 2018. Note: areas shaded purple represent the overlap of lengths between years.

The effects of goldfish on aquatic ecosystems are largely unknown. Goldfish may grow up to 450 mm reaching 3 kg, however, they generally only reach 200 mm weighing between 100–300 g (Lorenzoni et al. 2007). Therefore, the population structure recorded in Lake Horowhenua, dominated by fish between 100 and 200 mm, is not unusual in lake systems and has also been recorded within other shallow lakes such as Lake Ohinewai (Tempero and Hicks 2017) and Lake Waahi (Ratana and Baker 2015). Given the similar population structure, and low biomass recorded for goldfish across the Tempero (2013) and the 2017 and 2018 surveys, there is no indication that the fish pass on the Hoiko weir has resulted in an influx of goldfish to Lake Horowhenua.

4 Conclusions

In summary, monitoring in Lake Horowhenua carried out in 2013 (Tempero 2013), 2017 and 2018 indicates that populations of the main pest fish species recorded in the lake (perch, goldfish and koi carp) are all below the threshold density of 50 kg ha^{-1} specified by condition 13 of resource consent ATH-2015200301.00. Based on the current population structure and biomass of perch and goldfish there is no evidence to suggest that the abundance of these species within Lake Horowhenua has increased since 2017 as a direct result of the fish pass installed at Hokio weir. Although koi carp are a difficult species to capture and all fishing methods will underestimate their abundance, the continued difficulty in capturing koi carp within Lake Horowhenua suggests this species remains at low densities, and below those known to cause adverse ecological impacts on lentic waterbodies.

It should also be noted that once resident in a lake, perch, goldfish and koi carp will readily breed and form self-sustaining populations. In this regard, changes in abundance and size structure can naturally occur independent of immigration into the system via the fish pass at Hokio weir. Based on the biology of these three species, it is our opinion that the fish pass at Hokio weir will not significantly impact the population size of perch, goldfish or koi carp within Lake Horowhenua. Local factors associated with the lake (e.g., water quality, habitat, food availability) will be the main drivers of pest fish abundance.

5 References

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