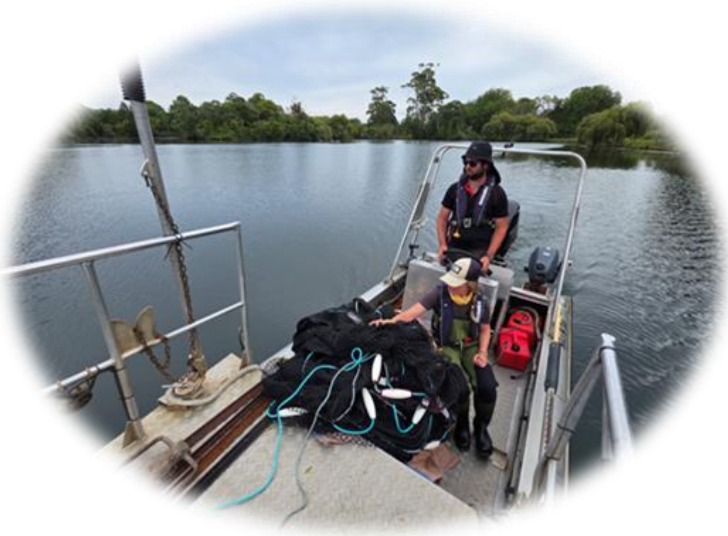
Pest Fish Removal by Boat Electrofishing

Western Springs Lake - Te Wai Orea

February 2026



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Cover images: Koi carp captured from Western Springs. The University of Waikato's electrofishing boat deploying a block net at Western Springs.

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Executive Summary

Invasive exotic fish species were removed from Western Springs Lake Te Wai Orea by boat electrofishing in February 2026. Over five days, a total of 372 fish (252 goldfish, 43 koi carp, 77 brown bullhead catfish) totalling 509.6 kg were removed from the lake. These were the only exotic species captured or observed. Eels were abundant in the lake, and three smaller native fish were also captured (īnanga, common smelt, common bully). Due to targeted fishing effort in areas frequented by fish rather than employing a randomised sampling method, and varying electrofishing pulsator settings to target particular species, a reduction in catch per unit effort (CPUE) was not observed for the two less common species (carp and catfish). However, a reduction in CPUE was observed for goldfish, and analysis of goldfish catch data by the Leslie plot method estimated 78% removal of this species from the lake. Goldfish catch rate declined from a peak of 18.7 fish per hour on day one to three fish per hour by day five. Most goldfish and catfish were captured in weedy habitat in Pumphouse Bay at the south-eastern end of the lake. Goldfish and koi carp were also associated with marginal beds of papyrus sedge (*Cyperus papyrus*) and also occurred in shallow bays on the western side of the lake. Few fish were captured or observed in devegetated central areas of the lake.

All three invasive species have detrimental impacts on water quality. The removal of a substantial proportion of the total pest fish biomass in Western Springs Lake will therefore likely have positive effects on water clarity. Further fish removal is recommended to maintain pressure on the adult fish population.

Introduction

Western Springs Lake – Te Wai Orea (36.866° S, 174.725° E) is a small (approximately 5.7 ha), shallow (mean depth 1.73 m), permanent, freshwater, spring-fed lake within the Auckland urban area, situated between the suburbs of Westmere, Grey Lynn and Point Chevalier (Johnstone 1972). The lake was created as a water supply reservoir for Auckland City in 1875 (MOTAT 2026) and is fed by a large inflow spring draining the Three Kings volcanic aquifer (Te Tatua-a-Riukiuta) formed by basaltic lava flows arising from volcanic activity approximately 28 kya (Lindsay et al. 2011). Western Springs served as a municipal water supply for Auckland City from 1877 to 1928 (MOTAT 2026).

The limnology of the lake was first studied in 1967/1968 by Johnstone (1972) for the purpose of investigating a method to control excessive growth of macrophytes in the lake. The lake at that time was extensively dominated by floating *Salvinia molesta* (formerly *Salvinia hertzogii*) sudd and submerged macrophytes, primarily *Elodea densa* (formerly *Egeria densa*) and *Elodea canadensis*. The lake was described as highly eutrophic and Johnstone (1972) concluded that extensive removal of macrophytes would result in massive algal growth. Measurements of nutrient concentrations in influent spring water by Johnstone in 1967/1968 were around 0.5 mg/L for nitrate. Recent monitoring of groundwater quality by Auckland Council shows a substantial increase with average values for nitrate in water of the Three Kings aquifer at around 4 mg/L indicating a significant increase in groundwater nutrient concentrations over the past half century. The lake is now described as supertrophic with a Trophic Lake Index (TLI) value of 5.5 (Auckland Council 2020). Challenges to improving lake water quality identified in the Te Wai Orea park development plan were:

Catchment issues

- Nutrients
- *E. coli*

Lake issues

- algal/cyanobacterial blooms
- avian botulism
- anaerobic sediment
- pest fish
- *E. coli*

Introductions of exotic fish to Western Springs Lake Te Wai Orea

Known introductions of exotic fish species to Western Springs Lake include the release of 128 Eurasian perch (*Perca fluviatilis*) between 1964 and 1966, 188 rudd (*Scardinius erythrophthalmus*) in 1970/1971, and 120 tench (*Tinca tinca*) in 1971 by Stewart Smith. Additionally, 3 large and 1001 small grass carp (*Ctenopharyngodon idella*) were released in 1996 to control aquatic macrophytes.

A pest fish removal operation undertaken by New Zealand Waterways Restoration Ltd in August and September of 2019 using a variety of different net types removed a total of 464.2 kg of pest fish comprising 63 koi carp (*Cyprinus rubrofuscus*; 269.8 kg), 143 bullhead catfish (*Ameiurus nebulosis*;156.5 kg), and 46 goldfish (*Carassius auratus*; 37.9 kg). Three species of eels (*Anguilla dieffenbachii*, *Anguilla australis*, *Anguilla reinhardtii*) were captured in fyke nets and one Crans bully (*Gobiomorphus basalis*) but no other fish species were recorded (Pullan 2019a, 2019b). Given the fishing effort and the variety of nets deployed in the 2019 removal, it would be expected that rudd, tench or perch, and possibly grass carp, would have been captured were they still present in the lake at that time. These species are therefore assumed to be extinct in the lake.

This report presents the results of a further removal of pest fish from Western Springs Lake Te Wai Orea commissioned by Auckland Council using boat electrofishing.

Methods

Lake preparation and fished area

Boat electrofishing was undertaken from 09/02/26 to 13/02/26 at Western Springs Lake Te Wai Orea, Western Springs, Auckland. The University of Waikato's electrofishing boat is a custom built 4.5 m aluminium pontoon boat with twin forward facing anodes and a 5 kilowatt Smith Root GPP5.0 electrofishing pulsator unit. Specific electrical conductivity measured at the main inflow spring was 212 µS/cm (water temperature 17.2°C) and fishing was undertaken using 60 PPS DC current at 20 to 40% of the low range (50-500 V) setting on the pulsator unit.

On the morning of 09/02/26, the operations team from Healthy Waters and Flood Resilience, Auckland Council, opened gates on the two weir outlets of Western Springs Lake to lower the lake level by approximately 70 cm to facilitate boat electrofishing. The lake reached its lowest level by 11/02/26 and the gates were then closed to allow the lake to refill. All fishing was restricted to the main body and navigable arms of the lake and no attempts were made to fish either of the two non-navigable connected lake arms that could potentially act as fish refugia (Fig. 1). Other wetland or shallow pond areas to the west of the main lake and one small pond (sometimes referred to as the filter pond) to the north which do not appear to allow fish passage to the main lake were also not fished.

Fish capture and disposal

Electrofishing technique varied by location and target species. In some cases, tracks across the lake used continuously applied current to see what turned up or short bursts of current were applied during these tracks. Eels were encountered throughout the lake. When an eel was observed to be impacted by the current, the current was immediately turned off to allow the eel to escape. In such cases the eels immediately bolted away once they were released from the immobilising effect of the current. In the case of koi carp and goldfish, these fish were often observed to swim away as the boat, without applied current, approached. In these circumstances they were followed and chased down until they were within the effective range of the electrofishing field when the current was then applied to immobilise or stimulate induced electroconvulsive swimming towards the anodes. Fish were collected using long handled pole nets and kept onboard in 60 L bins filled with lake water. Fish were subsequently transported to a shore station where University or Auckland Council staff humanely euthanised fish by stunning. Fish were measured for total length (goldfish and catfish) or fork length (koi carp) and individually weighed.

Attempts were made to install block nets (100 m length x 4 m drop x 45 mm stretched mesh) across the lake in three locations to section the lake but these did not work as anticipated because the leadlines were insufficiently weighted. A small mesh (25 mm stretched mesh) monofilament gill net with a heavily weighted lead line (chain) was also installed across the outlet of the main springs under the bridge (Fig. 2) in an attempt to block fish passage between the springs and the main lake but this failed due to collecting plant debris and the net being forced beneath the surface by the flow of water from the springs.

Fish were taken by a commercial contractor (Ecogas Ltd) for processing into biogas and fertiliser by anaerobic digestion.

Figure 1. Navigable areas of Western Springs Lake (red outline). White filled areas denote non-navigable lake arms allowing possible refuge for fish.

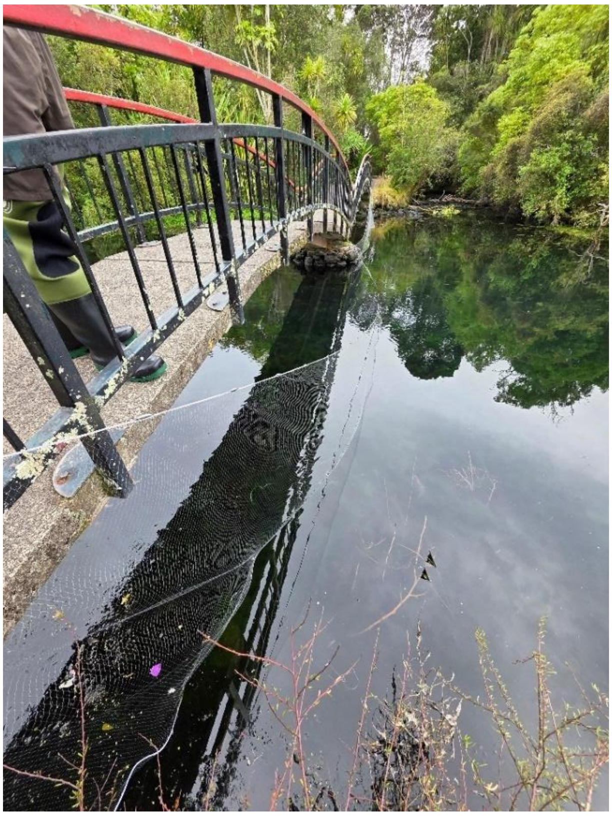


Figure 2. Fine mesh (13 mm) monofilament gill net strung beneath the springs bridge to block fish passage.

Results

Total electrofishing time over the week amounted to approximately 25 hours. A total of 372 fish were captured, comprising 43 koi carp (233.2 kg), 252 goldfish (254.3 kg) and 77 bullhead catfish (22.1 kg). Total weight of fish removed was 509.6 kg. A sample of the fish removed is shown in Fig. 3.

Length frequency distributions of fish are shown in Fig. 5 and compared to fish captured by the previous removal effort using a variety of nets in 2019 (Pullan 2019a, 2019b).

Koi carp

Koi carp captured by boat electrofishing were larger on average (583 mm average fork length) than those captured in 2019 (524 mm average fork length). It is possible that this size discrepancy reflects a size bias determined by the mesh sizes of the nets used in 2019, although it must be noted that some larger specimens (up to 70 cm) were caught in nets. It is more likely that the larger fish captured in 2026 (Fig. 4) are from the same cohort of koi as those in 2019 that have grown in the intervening years. These fish are likely getting quite old as New Zealand koi carp were found to reach 600 mm fork length by age 10 by Tempero (2004). It is possible that the smaller koi (<350 mm) recorded by Council staff processing fish from the current survey may have been incorrectly identified and were actually large, orange-black mottled goldfish.

Figure 3. Bins of captured pest fish, primarily goldfish.

Figure 4. A large (8.9 kg) koi carp captured in Pumphouse Bay.

Bullhead Catfish

Catfish captured by nets in 2019 were substantially larger on average (406 mm average fork length) than those caught by electrofishing (266 mm average fork length). Based on the findings of Patchell (1977) for catfish from the Waikato Region, the fish caught in 2026 would represent approximately three-year-old fish and therefore would have been recruited to the population after the 2019 removal. Once again, this difference in average size could be due to mesh size bias because no fish smaller than 270 mm were caught in nets in 2019. However, very few larger catfish were caught in the current removal which may suggest that the netting removed a substantial proportion of larger catfish from the lake in 2019. However, catfish are relatively short-lived fish. Patchel (1977) recorded a maximum age of 7+ in the Waikato Region for a specimen of 455 mm total length. Therefore, the influence of other factors, such as competition, on the size of catfish caught in 2026 cannot be ruled out.

Almost all catfish (>95%) were captured from submerged macrophyte habitat in Pumphouse Bay. Barnes & Hicks (2003) found that catfish in Lake Taupo were primarily associated with weedy habitat.

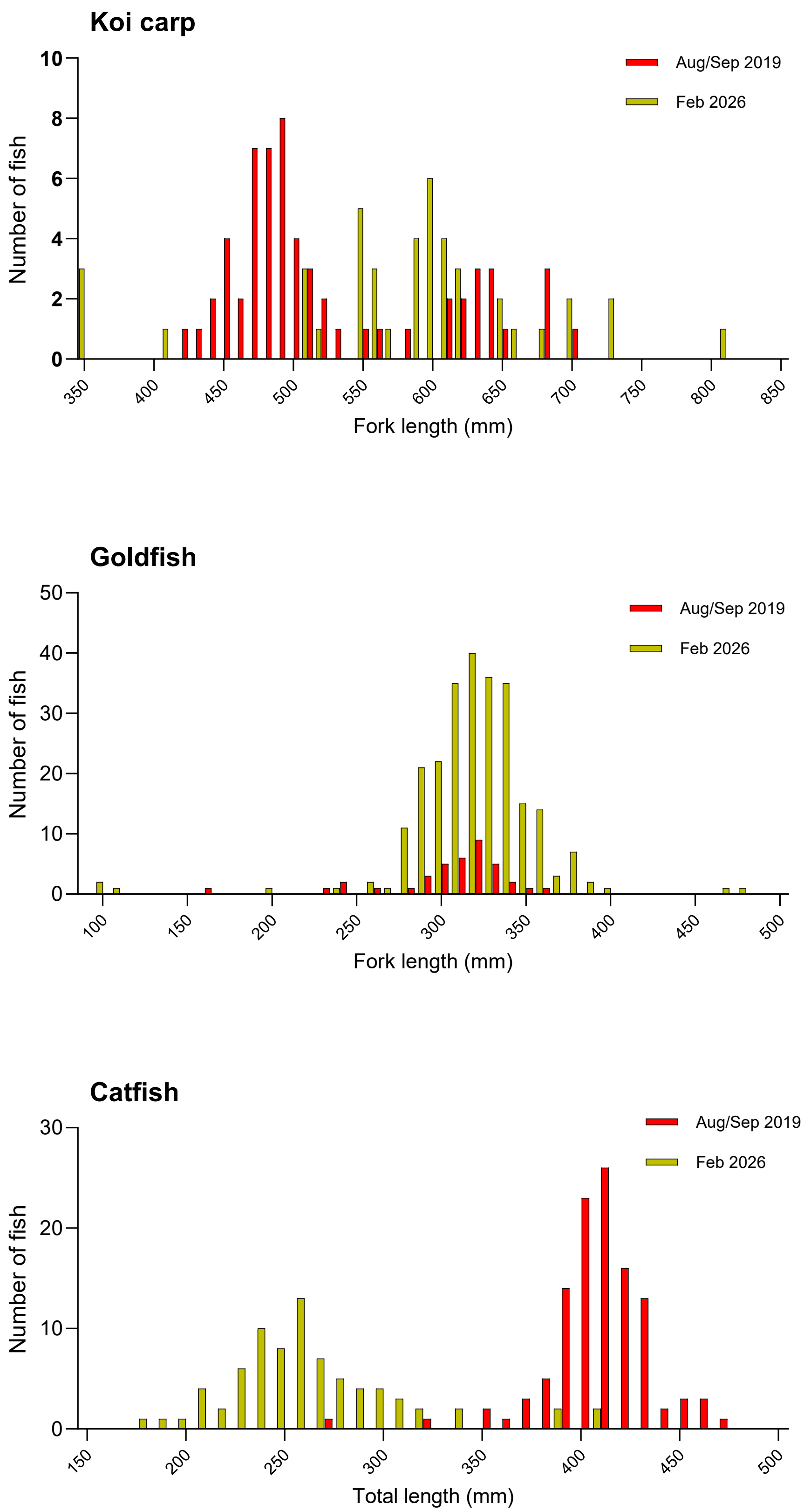


Figure 5. Length frequency distributions of fish captured by netting in Aug/Sep 2019 and boat electrofishing in Feb 2026.

Goldfish

Goldfish captured by boat electrofishing were on average slightly larger (321 mm average fork length) than those caught in 2019 (304 mm average fork length). Of the 2 larger fish (>450 mm) recorded by Council processing staff, one was later identified as a koi/goldfish hybrid and the other is also likely to be a hybrid because goldfish rarely reach this size. The maximum recorded length for goldfish is 48 cm (Fishbase 2026). A study of wild goldfish in Western Australia recorded a maximum size of 411 mm in an eight-year-old fish (Morgan & Beatty 2007) and wild goldfish from a lake in Italy reached a maximum size of 406 mm by age eight (Lorenzoni et al. 2007). Morgan & Beatty found that goldfish reach approximately 177 mm total length by their first year whereas Italian goldfish were slightly smaller (~140 mm) at the same age (Lorenzoni et al. 2007). Wild goldfish may reach a total length of around 350 mm by age six but growth thereafter slows considerably (Lorenzoni et al. 2007).

Goldfish were primarily concentrated in Pumphouse Bay (area A, Fig 6; Fig. 7), where large schools were observed swimming at the surface in the early part of the week. No schools of fish were observed by the end of the week. Goldfish were also relatively abundant in areas B, C and D (Fig. 6). Only three small goldfish (<150 mm total length, age 0+) were captured although some small fish were observed in shallow water in area D but could not be captured. Concentrations of fish were generally in areas where there were extensive beds of submerged macrophytes or around fringing emergent vegetation, primarily beds of papyrus sedge (*Cyperus papyrus*). Goldfish are benthic generalists/herbivores and this habitat provides greater feeding opportunities than areas of the lake devoid of plants.

Native fish species

Eels were abundant in the lake but we did not capture any to confirm the species. Pullan (2019a) reported catching all three New Zealand species (shortfin, longfin and Australian spotted or longfin eel). We did observe a large spotted eel in Pumphouse Bay which may have been the Australian species. In addition to eels, we observed small numbers of large īnanga (*Galaxias maculatus*), common smelt (*Retropinna retropinna*) and common bully (*Gobiomorphus cotidianus*).

Other exotic species

No other exotic fish species were collected or observed during the current fish removal, confirming the observation from the removal in 2019 that other species introduced to the lake (Eurasian perch, tench, rudd and grass carp) are almost certainly extinct.

Red-eared slider turtles are known to be present in the lake and one juvenile (approximately 100 mm carapace length) was observed swimming in area C (Figure 6) but was not able to be captured.

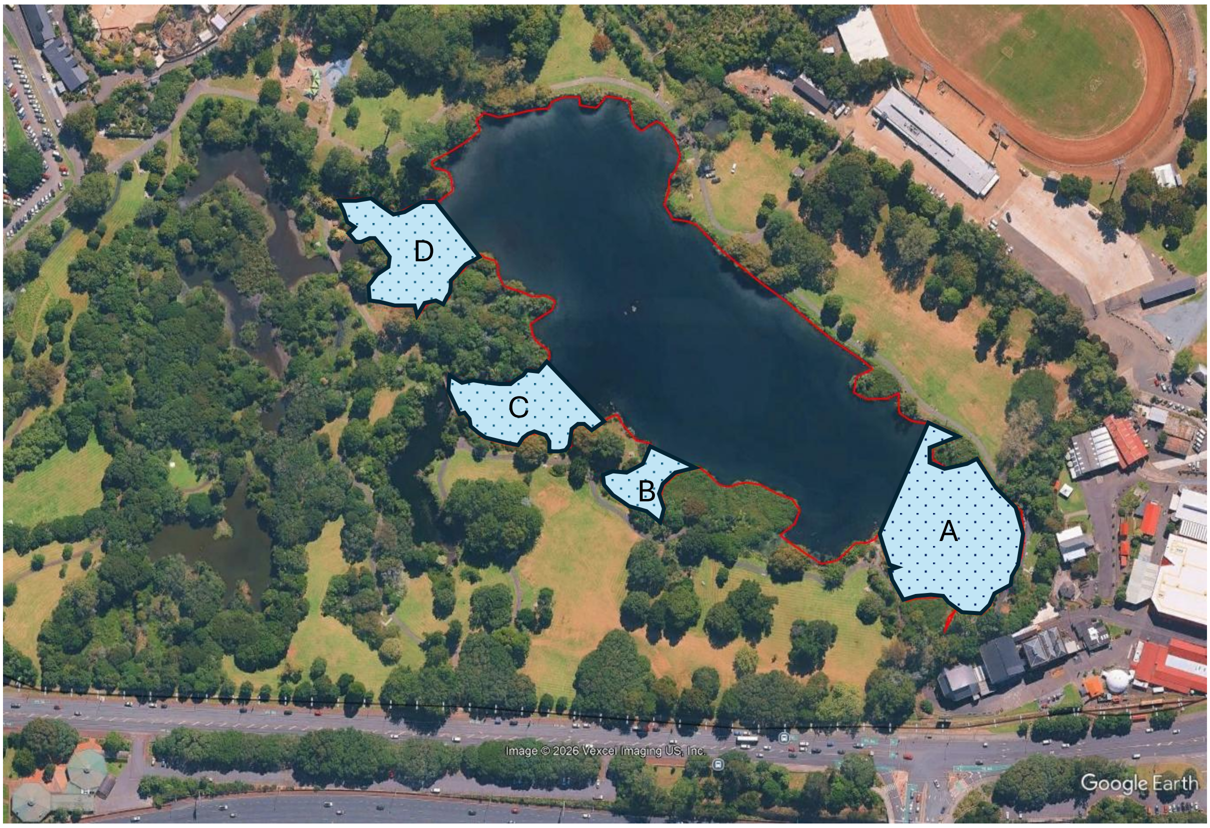


Figure 6. Western Springs Lake. Areas A to D showed high concentrations of goldfish and koi carp

Figure 7. A typical large goldfish captured in Pumphouse Bay.

Discussion

Removal of slightly more than half a tonne of pest fish likely constitutes a major proportion of the pest fish biomass in the lake. The boat electrofishing effort was targeted to maximise catch by concentrating efforts in areas of the lake where fish were observed to be present, rather than using a randomised spatial fishing pattern. Therefore, for the two less abundant species (koi and catfish), no observed reduction in catch was recorded although catch rate of koi did decline after the second day of fishing (Fig. 8a). In comparison, the catch rate of goldfish exhibited a progressive decline in catch per unit effort (CPUE) throughout the week ($r^2 = 0.848$, Fig. 8b). Based on the predictions of the Leslie plot analysis, the predicted total number of goldfish in the lake was 324 fish. The total catch of 252 fish therefore constitutes 78% of the estimated population. However, 95% confidence intervals for the x-axis intercept of the Leslie plot range from 246 to 855 fish.

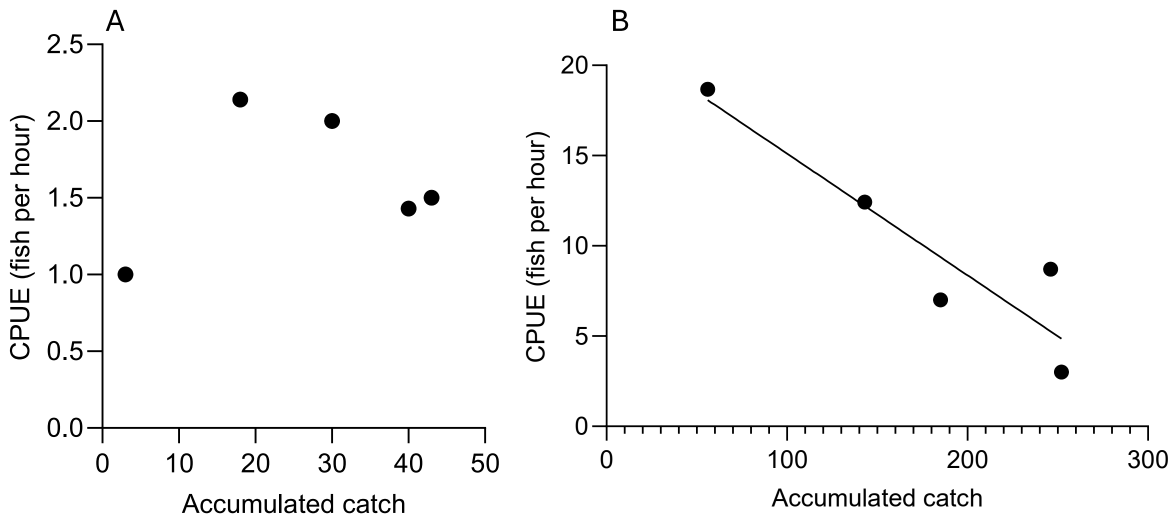
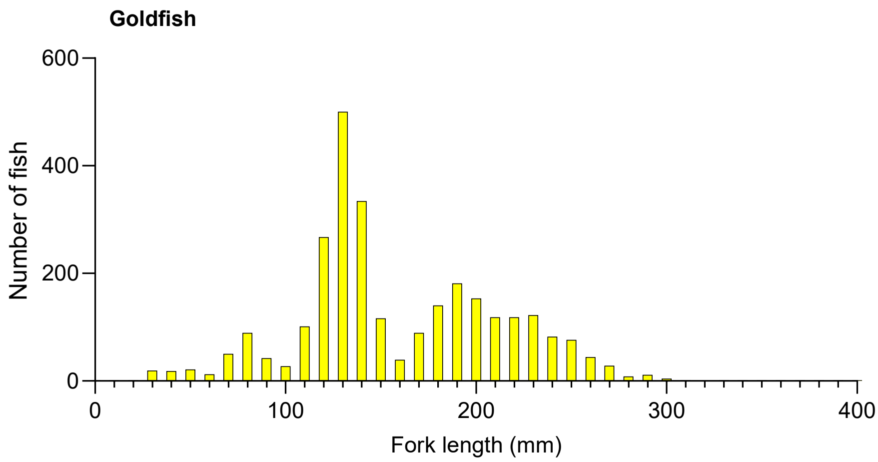


Figure 8. Leslie plots for accumulated catches of A. koi carp and B. goldfish.

It is unusual for fish populations to be so uniform in size. Although some fishing methods such as gill netting are highly size selective, this is not the case for boat electrofishing where capture efficiency is more determined by the visibility of the fish and the mesh size of the dip nets used (4 mm in this case). Figure 9 shows the size frequency of goldfish and catfish captured by the electrofishing boat in Lake Mangahia, Waikato, in 2010. Like Western Springs, Lake Mangahia is shallow with a dense marginal fringe of emergent sedges and an exotic fish population dominated by goldfish and bullhead catfish. The extensive size range and clearly apparent age cohorts observed in the Lake Mangahia catch data suggest that if smaller fish were abundant in Western Springs then they would have been caught.



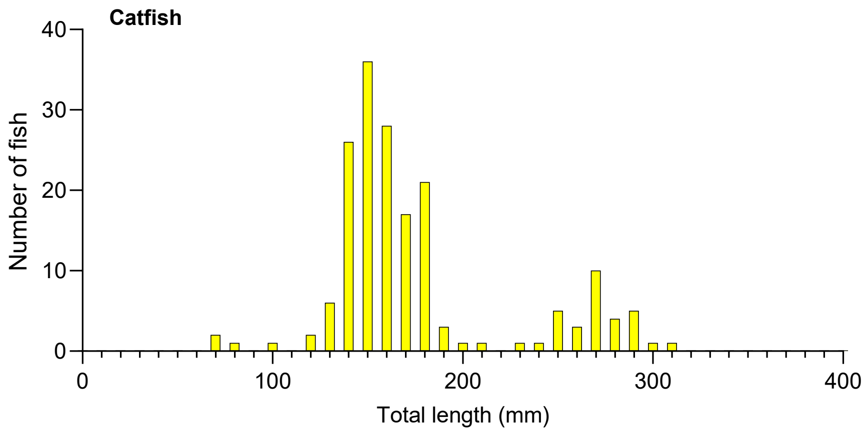


Figure 9. Size frequency of goldfish and brown bullhead catfish captured by boat electrofishing in Lake Mangahia, April 2010.

One possible reason for the apparent absence of juvenile goldfish and catfish in Western Springs is that they were present but occupying habitat inaccessible to the electrofishing boat. However, because the goldfish population in the lake is dominated by highly coloured fish it would be expected that significant numbers of juveniles in shallow littoral zones would be obvious. Another possibility is substantial predation pressure on juveniles by piscivorous predators such as eels and shags. In addition to the three eel (*Anguilla*) species mentioned earlier, all of which become piscivorous as large adults, four species of shag/cormorant have been recorded at Western Springs (great shag, *Phalacrocorax carbo*; pied shag, *Phalacrocorax varius*; little black shag, *Phalacrocorax sulcirestris*; little pied shag, *Microcarbo melanoleucos*).

Removal of a substantial proportion of the total exotic fish biomass will increase resource availability for the juveniles of all three pest fish species. Therefore, continued effort should be made to maintain fishing pressure on adults to limit breeding and the significant recruitment of juveniles. Further removals by boat electrofishing could be undertaken to apply further pressure on the three species present to both reduce the total fish population and to limit their potential impacts on water quality. Both goldfish and carp are known to negatively impact water quality in lakes, even at relatively low biomass (Richardson et al. 1995; Matsuzaki et al. 2009). Although there do not appear to be any specific studies of the impact of brown bullhead catfish on water quality, a study of the closely related black bullhead catfish (*Ameiurus melas*) found significant increases in turbidity, nutrients and chlorophyll a in a controlled mesocosm experiment (Fischer et al. 2013). Removal of a large proportion of the total adult biomass of all these species could therefore improve water clarity and increase predation pressure on juveniles from visually feeding piscivores such as shags.

Recommendations

We recommend repeat electrofishing is carried out prior to spawning.

Targeting these species in early September prior to spawning will help to remove as many adults as possible, especially as they aggregate leading up to spawning. We recommend up to 2 days of intensive boat electrofishing during this period, focusing primarily in the known areas for fish aggregation – Pumphouse Bay and the western embayments, because these areas seem to be preferred habitat for goldfish which have been shown to display strong affiliation to preferred areas for residency and spawning (Boston et al. 2024).

We do not recommend lowering of the lake during any subsequent removal efforts.

Because the lake is generally shallow throughout, the effective field of the electrofishing boat will be adequate to raise fish from the bottom in all areas of the lake. Furthermore, the lowering of the lake made shallow margins inaccessible or non-navigable due to exposure of logs and rocks. It was thought that lowering the level of the lake would dewater the marginal *Cyperus* beds so that they could not be utilised as refuge habitat for fish but this was not the case because they extend into relatively deep water. Concerns were also raised that lowering the lake level might increase the incidence of avian botulism by granting greater access to anaerobic lake sediments by waterfowl. Although there was no observed increase in cases of avian botulism after this removal operation it is thought that lowering the lake during future removals is unnecessary. Triggers for outbreaks of avian botulism are complex with outbreaks sometimes correlated with lower lake levels (Lafrancois et al. 2011) but also with high precipitation depositing excess allochthonous organic material into lakes and wetlands stimulating anaerobic conditions (Barras & Kadlec 2000).

We recommend that ongoing water quality monitoring be prioritised.

MOTAT has recently commissioned a water quality monitoring system on the outlet of Te Wai Orea that reports temperature, conductivity, pH, turbidity and dissolved oxygen. Ongoing support for this system will be invaluable in monitoring any changes in lake water quality that may be associated with removals of pest fish and with understanding other environmental factors that contribute to lake water quality.

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Appendix A: Fish captured from Western Springs Lake Te Wai Orea in February 2026.

Koi carp		**Goldfish**		**Brown bullhead catfish**	
Length (mm)	Weight (kg)	Length (mm)	Weight (kg)	Length (mm)	Weight (kg)
340	1.2	95	0.02	180	0.09
340	0.94	95	0.06	190	0.09
350	0.96	110	0.044	200	0.08
410	1.82	195	0.19	210	0.15
510	3.3	240	0.34	210	0.12
510	3.03	260	0.64	210	0.13
510	3.54	260	0.49	210	0.16
520	3.332	270	0.576	220	0.162
550	4.45	280	0.68	220	0.17
550	3.64	280	0.62	230	0.18
550	3.67	280	0.56	230	0.21
550	4.86	280	0.64	230	0.14
550	3.66	280	0.62	230	0.12
560	3.9	280	0.55	230	0.2
560	5.55	280	0.58	230	0.17
560	4.35	280	0.57	240	0.18
570	5.53	280	0.67	240	0.17
586	6.2	280	0.65	240	0.19
590	5.45	280	0.83	240	0.2
590	4.71	282	0.8	240	0.17
590	5	289	0.68	240	0.21
600	4.55	290	0.7	240	0.2
600	5.73	290	0.65	240	0.19
600	5.9	290	0.7	240	0.2
600	6.2	290	0.68	240	0.18
600	6.5	290	0.65	249	0.2
600	6.06	290	0.67	250	0.19
610	6.7	290	0.86	250	0.22
610	6.33	290	0.64	250	0.22
610	5.8	290	0.65	250	0.21
610	5.1	290	0.626	250	0.21
620	5.13	290	0.684	250	0.25
620	5.97	290	0.612	250	0.26
620	5.6	290	0.712	260	0.26
645	6.23	290	0.69	260	0.22
650	6.47	290	0.58	260	0.238
660	6.32	290	0.69	260	0.25
680	8.6	290	0.71	260	0.25
700	8.9	290	0.66	260	0.22

700	9.8	290	0.72	260	0.24
730	8.9	294	0.7	260	0.23
730	8.84	296	0.75	260	0.25
810	14.48	300	0.72	260	0.17
		300	0.886	260	0.26
		300	0.79	260	0.34
		300	0.79	260	0.27
		300	0.744	265	0.188
		300	0.79	270	0.26
		300	0.7	270	0.36
		300	0.63	270	0.31
		300	0.68	270	0.28
		300	0.68	270	0.25
		300	0.99	270	0.39
		300	0.48	271	0.27
		300	0.86	271	0.259
		300	0.93	274	0.29
		300	0.96	280	0.29
		300	1.02	280	0.31
		300	0.82	290	0.37
		300	0.69	290	0.42
		300	0.68	290	0.35
		300	0.68	290	0.38
		305	0.71	295	0.35
		305	0.78	300	0.37
		310	1.08	300	0.37
		310	0.86	300	0.37
		310	0.97	310	0.43
		310	0.96	310	0.39
		310	0.84	310	0.38
		310	1.01	319	0.412
		310	1.02	320	0.43
		310	0.7	340	0.53
		310	1	340	0.46
		310	1.026	385	0.73
		310	0.76	390	0.96
		310	0.734	405	0.9
		310	0.99	410	1.04
		310	1.06		
		310	0.95		
		310	0.81		
		310	0.93		
		310	0.74		
		310	0.82		
		310	0.896		

310	0.79
310	0.81
310	0.85
310	1.02
310	0.77
310	0.92
310	0.78
310	0.73
310	1
310	1.04
310	0.77
310	0.83
310	0.69
315	0.8
315	0.832
315	0.781
316	0.95
318	0.89
320	1
320	0.96
320	0.91
320	0.78
320	0.79
320	0.96
320	0.9
320	0.968
320	0.714
320	0.71
320	0.96
320	0.93
320	0.79
320	0.94
320	1.03
320	1.1
320	1.03
320	1.03
320	1
320	0.85
320	0.95
320	0.87
320	0.97
320	1.12
320	1.09
320	1.04
320	1.16

320	1.08
320	1.23
320	1.16
320	1
320	0.91
320	1.02
320	0.81
320	0.96
325	0.9
327	1.08
327	0.98
329	1
330	0.98
330	1.26
330	0.96
330	1.33
330	1.2
330	1.23
330	1.15
330	1.02
330	0.75
330	1.076
330	0.988
330	1.09
330	0.94
330	1.02
330	0.96
330	0.94
330	1.28
330	1.04
330	1.05
330	1.23
330	1.21
330	1.18
330	0.95
330	1.24
330	1.07
330	1.13
330	1.18
330	1.06
330	1.09
330	1.19
330	1
330	1.13
332	1.08

338	1.25
339	1.13
339	1.24
340	1.25
340	1.34
340	1.26
340	1.16
340	1.18
340	1.16
340	1.38
340	0.89
340	1.1
340	1.2
340	1.08
340	1.39
340	1.05
340	1
340	1.29
340	1.42
340	1.2
340	1.12
340	0.89
340	1.3
340	1.2
340	1.18
340	1.32
340	1.3
340	1.35
340	1.36
340	1.16
340	1.2
340	1.12
340	1.05
340	1.1
341	1.19
349	1.51
350	1.5
350	1.3
350	1.1
350	1.044
350	0.98
350	1.57
350	1.37
350	1.37
350	1.38

350	1.39
350	1.49
350	1.5
350	1.46
355	1.36
355	1.5
357	1.51
358	1.44
360	1.13
360	1.33
360	1.46
360	1.62
360	1.53
360	1.31
360	1.37
360	1.89
360	1.68
360	1.3
365	1.77
370	1.57
370	1.51
379	1.7
380	1.93
380	0.97
380	1.3
380	1.6
380	1.89
380	1.98
383	1.6
389	0.7
400	1.35
470	1.5
480	2.5