Get out, stay out! Restoring a small New Zealand floodplain lake: removal and exclusion of carp

Adam J. Daniel[1,2], Dai K. Morgan[1,3], Nicholas Ling[1]

[1] School of Science, The University of Waikato, Private Bag 3105, Hamilton, New Zealand.

[2]Current address: Fish & Game New Zealand, Auckland Waikato Region, 156 Brymer Rd, RD9, Hamilton, New Zealand. (carpresearch@gmail.com)

[3]Current address: Department of Environment, Water and Natural Resources, 37 Dauncey Street, Kingscote SA 5223, Australia.

Introduction

Ornamental common carp (koi; *Cyprinus carpio* L.) were introduced to New Zealand in the 1960s for the aquarium trade and were subsequently released in farm ponds in the Waipa tributary catchment of the Waikato River, northern New Zealand. By 1983, eel fishermen were reporting catches of juvenile koi carp in the main Waikato River system (Pullan 1984). Koi carp have since expanded their range throughout the Waipa River system and the lower 152 km of the Waikato River downstream of the Karapiro hydroelectric dam. They have also been introduced to many other localities throughout the North Island (Figure 1).

The lower Waikato River floodplain contains many shallow lakes ranging in size from a few hectares to the 3400 ha Lake Waikare. The floodplain has been highly developed for pastoral agriculture, primarily dairy farming, resulting in extensive drainage and flood control measures to regulate river and lake levels. Most lakes have degraded water quality as a result of nutrient and sediment enrichment, and the additional impacts of pest fish such as carp, goldfish (*Carassius auratus*), brown bullhead catfish (*Ameiurus nebulosis*) and rudd (*Scardinius erythrophthalmus*) have generally resulted in the total collapse of submerged macrophytes and progression to a highly eutrophic state. Of all New Zealand lakes monitored regularly for water quality, around 25% of those categorised as supertrophic or hypertrophic are on the Waikato floodplain (Verburg et al 2010).

Study Site and Methods

Lake Ohinewai is a shallow (4.5 m depth), 16.8 ha lake on the Waikato River floodplain. The lake has a 331 ha primarily flat catchment dominated by intensive pastoral farming and minor residential development with several inlet drains. A single outlet drain leads to Lake Waikare via Lake Rotokawau (Figure 1) and passes through a circular 1400 mm diameter road culvert 930 metres from the lake outlet. Lake Ohinewai deteriorated from a stable oligotrophic state (macrophyte dominated) to a stable eutrophic (algal dominated) state during the early 1990s and currently lacks aquatic macrophytes. In 1981, 80% of the lake was covered in aquatic macrophytes and by 1991 none remained (Edwards et al 2005).

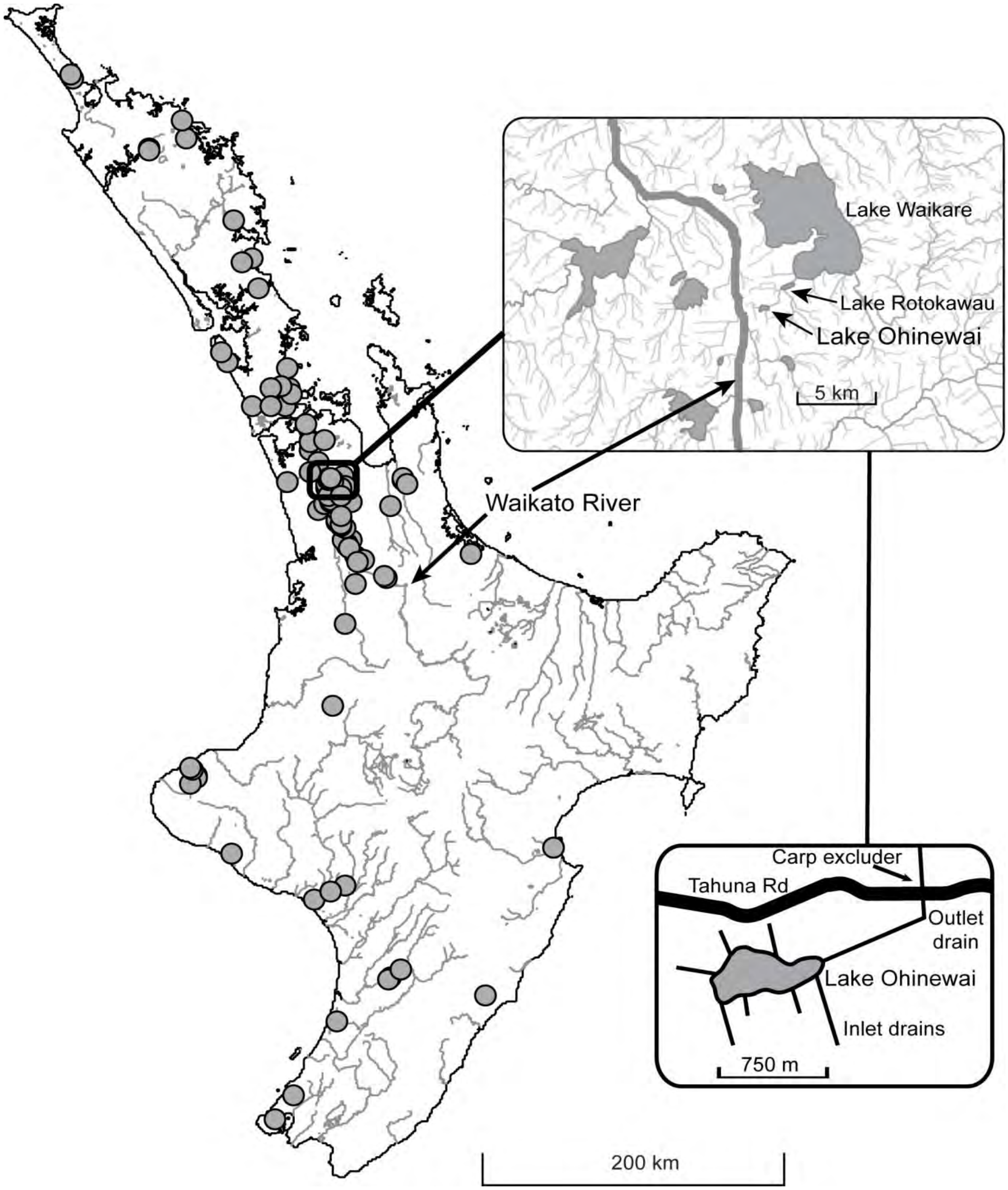

Figure 1. Distribution of ornamental common carp (koi) in New Zealand's North Island. Insets: Lakes and streams of the lower Waikato River floodplain and Lake Ohinewai drainage.

Fish were captured for marking and removal (24 January to 2 May 2011) using fyke nets, minnow traps, electrofishing, beach seining and baited traps. Bow fishing was trialled for fish removal in drains where other methods were not effective. Electrofishing was conducted using a total of 34 separate 20-min sampling periods (11 during marking and 23 during the removal phase) and concentrated on productive shallow-water habitat near the shore. Forty fyke nets were set from 17-19 January (marking) and 24-28 January (removal) for a total of 240 net nights. Fyke nets were cleared daily and sites were distributed evenly around the lake. Seining was conducted using a purpose built 100-m seine (40-mm mesh size) that was hand-pulled from the western shore of the lake. Baited and unbaited fish traps were used from 24 January until 2 May for a total of 85 net nights. Traps were placed in five locations but were limited to relatively shallow locations (>2 m) due to the wall height of the traps (2 m). All non-native fish were removed from the lake and donated to a fertiliser processor while native fish were released. Traps were set in various formations to determine the most productive configuration including baited and unbaited sets. Pen traps consisted of a 0.1-ha net enclosure with two one-way doors, two automatic feeders distributing chicken layer pellets, and two traps located on the outer corners of the pen.

Fish were marked using left pectoral fin clips (eels, rudd, goldfish and koi carp) or dorsal spine removal (brown bullhead catfish) and released on the western end of the lake (17-19 January 2011). To satisfy the assumptions of a Lincoln-Petersen mark recapture study (closed population) the fish population sampled at Lake Ohinewai was isolated using a temporary barrier in the drain consisting of 30-mm mesh netting. Population estimates were calculated using the Lincoln-Petersen method using the programme Mark-recapture (Jungck 2011). Biomass estimates calculated are for fish >75 mm due to the bias of sampling methods toward larger fish. Due to the length of the recapture operation (>90 days) fin clips became indistinguishable from fin injury due to fin regrowth by the end of the third month of removals. Accordingly, population estimates are based on data collected during the first three months of the removal operation (24 January to 31 March 2011).

Following the removal operation in 2011, a permanent adult pest fish barrier (Figure 2) was installed on the 1400 mm diameter culvert under Tahuna Road to block upstream movement of adult pest fish into Lake Ohinewai. Telemetry tracking of koi carp in the lower Waikato River and riverine lakes has suggested that up to 75% of koi carp will leave lakes at some point in their life history (Daniel et al 2011). The one-way fish barrier is designed to allow fish to leave the lake but not return. The barrier was designed with horizontal bars to allow debris <30 mm to pass through unobstructed and was hinged at the top to allow for easy cleaning in the case of blockage. The bar spacing of the one-way gate (Figure 3) installed in the barrier was based on the fish trap design of Thwaites et al (2010) and included a set of weighted swinging bars at the base of the trap that would allow adult carp and eels to push through the trap when moving downstream but not allow them to return. Although it is possible for juvenile pest fish to enter Lake Ohinewai it was deemed impractical to design a barrier capable of blocking all pest fish movement due to the potential impact on migratory native species. The bar spacing of 30 mm will likely allow native fish to pass through the barrier in both directions with the assumption that large adult eels will only be passing in the downstream direction (out of the lake).

In November 2011 and February 2012, a second mark recapture study was undertaken to assess the status of pest fish populations in the lake following installation of the one-way barrier.

Figure 2. Permanent fish barrier installed on downstream side of road culvert outlet to Lake Ohinewai showing around 60 adult koi carp attempting to pass the barrier.

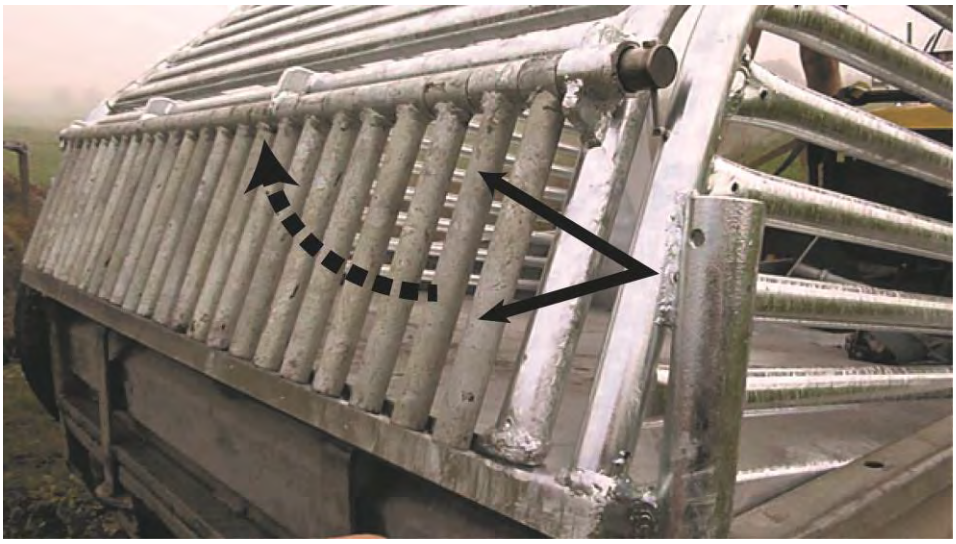

Figure 3. Detail of the permanent fish barrier. The weighted hinged bars (arrowed) swing upwards as indicated to allow adult fish to push through the trap when moving downstream to exit the lake but prevent upstream passage.

Results

The initial mark recapture effort in early 2011 removed 2.74 tonnes of exotic fish comprising koi carp (89.3%), goldfish (7.0%), brown bullhead catfish (3.3%), rudd (0.3%) and carp-goldfish hybrids (0.1%). Initial biomass estimates for these species at the start and end of this period are given in Table 1 along with biomass estimates determined in the fish removal the following summer. More than half of the carp biomass in the lake was removed during the initial fish removal, reducing the estimated biomass to below 100 kg/ha. However, initial estimates of carp biomass in the following summer were around 50 kg/ha indicating significant loss of carp biomass from the lake in the intervening period presumably resulting from downstream movement of carp through the one-way barrier.

Table 1. Mark-recapture estimates of exotic fish biomass (95% confidence limits in parentheses) in Lake Ohinewai prior to and following fish removals. The solid vertical line corresponds to installation of the permanent fish barrier on the lake outlet.

Species	*Estimation of fish biomass (kg/ha)*			
	February 2011	May 2011	November 2011	February 2012
Common carp	242 (185 – 299)	96 (39 – 153)	55 (31 – 85)	47 (18 – 69)
Goldfish	19 (0 -28)	7 (0 – 16)	17 (8 – 27)	16 (7 – 25)
Brown bullhead catfish	14 (12 – 17)	8 (5 – 10)	10 (8 – 12)	8 (6 – 11)

The lake outlet barrier seems to only have reduced the biomass of carp. Adult carp are known to undertake significant migrations between suitable feeding and spawning habitat as adults whereas the biomass of other exotic species in the lake remains unchanged. It is therefore inferred that the reduction in carp biomass occurred as a result of adult carp leaving the lake during winter. Subsequent fish surveys using boat electrofishing reveal some biomass recovery as indicated by relative catch per unit effort (CPUE) but carp biomass has not returned to original levels prior to the mass removal (Figure 4) whereas goldfish biomass has remained fairly constant. The biomass recovery of carp may be due to growth of juveniles.

Following carp removal there were promising signs of improving water quality with an average increase in Secchi depth (Figure 5) and a corresponding decrease in total suspended solids (data not shown).

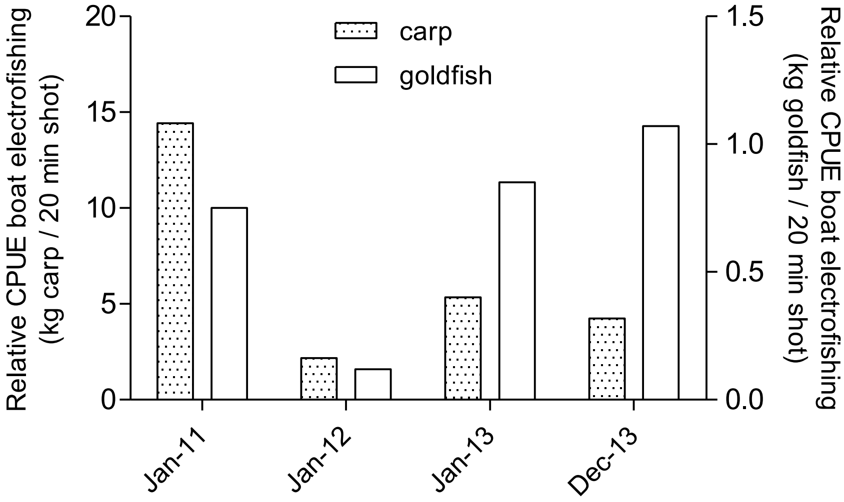

Figure 4. Relative catch per unit effort (CPUE) by boat electrofishing in Lake Ohinewai for common carp and goldfish since the start of the mass removal in January 2011.

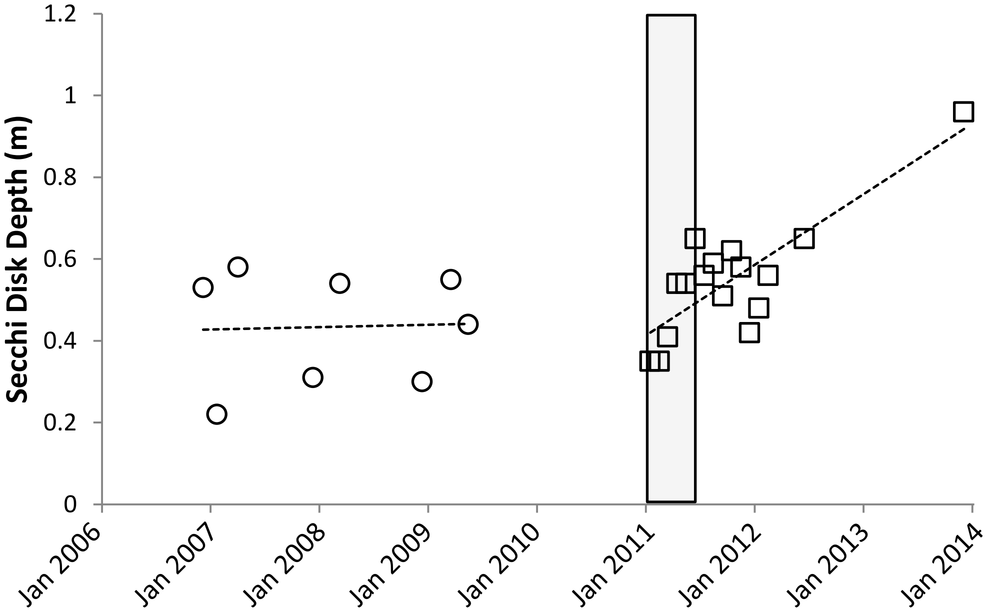

Figure 5. Secchi disk depth (m) in Lake Ohinewai. Open circles – historical data. Open squares – data obtained during and following pest fish removal (vertical bar).

Discussion

The purpose of this study was to reduce carp biomass in a shallow eutrophic lake to examine medium-term impacts on water quality from pest fish removal and to test the effectiveness of a cheap, simple exclusion device for adult carp. It is highly likely that the biomass of carp in this lake contributed to persistently poor water quality and the algal-dominated eutrophic state. Estimates of carp biomass thresholds that cause negative ecological effects vary. The review by Weber and Brown (2009) settled on a threshold of 450 kg/ha. However, many studies have measured ecological impacts at much lower fish biomass. Haas et al (2007) found that carp biomass of 120-130 kg/ha was sufficient to depress macroinvertebrate and plant biomass and Bajer et al (2009) determined that the ecological integrity of a shallow lake was compromised at a carp biomass of ~100 kg/ha.

Eradication of a population of carp from a water body is unlikely to be achieved using active fishing methods without resorting to options such as poisoning, and the costs required to reduce biomass by active fishing rise exponentially as fish biomass declines. In other words, it is much cheaper to fish a population biomass from 400 to 300 kg/h than it is to fish a population from 200 to 100 kg/ha. Cheap and effective devices that reduce fish biomass in passive ways are therefore highly cost effective if they can exploit particular fish behaviours such as migration. In this study, the installation of a simple barrier to allow adult carp to leave but not return to the lake appears to have achieved quite an effective reduction in fish biomass from ~ 100 kg/ha to ~50 kg/ha thereby removing some 850 kg of carp biomass from the lake. The cost of actively fishing the population with a wide range of active fishing methods including 40 fyke nets, multiple other large nets and traps, seining and electrofishing over several months that achieved a reduction in biomass from 250 to ~100 kg/ha was estimated at around 1288 person hours and in excess of $NZ40,000. The installation of the carp exclusion screen that achieved a further 50 kg/ha biomass reduction was therefore highly cost effective at around $NZ5000 and required relatively little maintenance at around 6 visits per year to clear it of debris and ensure that the hinged weighted bars were still moving freely. Such devices may be effective aids to reduce carp biomass if installed at locations which exploit the migratory movement of adult carp.

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