

**Boat electrofishing survey of the lower Waikato River
and its tributaries**

CBER Contract Report 39

Client report prepared for
Environment Waikato

by

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THE UNIVERSITY OF
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Executive summary

We conducted the first electrofishing boat survey of the lower Waikato River and its tributaries between 8 and 15 February 2005. We caught 2,915 fish comprising seven introduced and six native fish species in 5.63 km of fished length from a total of 27 sites. Assuming that the bow-mounted anodes caught fish within a 1 m radius, the width fished was 4 m, and the total area fished was 22,520 m² or 2.252 ha.

Common smelt were the most numerous species caught (mean density 9.3 fish 100 m⁻²), followed by koi carp (mean density 1.7 fish 100 m⁻²) and goldfish (mean density 1.4 fish 100 m⁻²). Relatively few longfin eels, trout, bullies, and torrentfish were caught. In addition, three koi carp-goldfish hybrids were caught.

Koi carp comprised 285 kg, or 69% (range 0-97% per site) of the 410 kg of fish caught. The majority of koi carp were caught in Zones 2-4, where they occurred in all habitats except mid-channel sand bars. Koi carp biomasses up to 124 g m⁻² were associated with willow fringed and macrophyte beds. Biomass is a more accurate reflection of the potential ecological impact of koi carp than their density.

Adult trout were found only in the confluence habitats of Zone 1; all were brown trout except for one rainbow trout caught at LW007. Grey mullet comprised the greatest biomass of any native fish species, and shortfin eels, though widespread, did not comprise a high biomass. Only one torrentfish was found; this small juvenile (36 mm TL) was caught on a mid-channel bar at Mercer (site LW035).

Koi carp size increased with distance downstream, suggesting that the upper zones were more important for rearing than the lower river. The mean biomass for koi carp for all sites was 16 g m⁻², but previous results suggest that 21-73% of the total population estimate is caught on the first removal, depending on water visibility. As we fished over the area at each site only once, the estimates in this survey represent a minimum abundance, and true population sizes are likely to be 1.4-4.8 times greater. Of ecological concern for the Waikato region is the dominance of the fish biomass by introduced koi carp, which have a deleterious impact on aquatic habitats.

The fish data have been entered into NIWA's New Zealand Freshwater Fish Database as card numbers 25,836 to 25862.

1. Introduction

Environment Waikato contracted the Centre for Biodiversity and Ecology Research (CBER) to fish the lower Waikato River and its tributaries between the Karapiro Dam and Mercer by boat electrofishing. For this survey, the river was divided into four zones bounded by (from upstream to downstream) the Karapiro Dam, Hamilton, Ngaruawahia, Rangiriri, and Tuakau (Fig. 1). The fishing effort was apportioned approximately equally between each of the zones. We attempted to fish littoral areas, macrophyte beds, willow fringes, and tributary junctions (confluences) within each of these zones.

2. Methods

We used a 4.5-m long electrofishing boat with a 5-kilowatt gas-powered pulsator (GPP, model 5.0, Smith-Root Inc, Vancouver, Washington, USA) powered by a 6-kilowatt custom-wound generator. Two anode poles, each with an array of six droppers, create the fishing field at the bow, with the boat hull acting as the cathode.

We fished 27 sites on the lower Waikato River and its tributaries between 8 and 15 February 2005 (Table 1; Fig. 1). Electrical conductivity was measured with a YSI 3200 conductivity meter. Specific conductivity, i.e., standardised to 25°C, ranged from 156 to 256 $\mu\text{S cm}^{-1}$, so all sites were fished with the GPP set to low range (50-500 V direct current) and a frequency of 60 pulses per second. We adjusted the percent of range setting of the GPP to between 40 and 70% to give an applied current of 3-4 A root mean square. We assumed from past experience that an effective fishing field was developed to a depth of 2-3 m, and about 2 m either side of the centre line of the boat. We thus assumed that the boat fished a transect about 4 m wide, which was generally consistent with the behavioural reactions of fish at the water surface. This assumption was used to calculate area fished from the linear distance measured with the global positioning system.

The fish data have been entered into NIWA's New Zealand Freshwater Fish Database as card numbers 25,836 to 25862 (Table 1).

3. Results

Specific conductivities were moderate in the main channel (about 160 $\mu\text{S cm}^{-1}$), but were greater in some tributaries (up to 256 $\mu\text{S cm}^{-1}$ in the Opuatia Stream; Table 2). Water temperatures ranged from 18.5 to 25.7°C (Table 2); the highest temperature was measured at site LW026, downstream of the Huntly Power Station on the true left bank, at 1030 h NZST on 14 February 2005.

Table 1. Locations of sites fished 8-15 February 2005 in the lower Waikato River. NZFFDB, card number of the fishing record in NIWA's New Zealand Freshwater Fish Database.

Site code	NZFFDB	Location	Tributary name	Habitat type	NZ map grid	
					Easting	Northing
Zone 1						
LW006	25836	Main channel		Rock face	2731872.8	6363064.5
LW007	25837	Confluence	Unnamed tributary	Littoral shelf	2730721.0	6363181.0
LW008	25838	Confluence	Unnamed tributary	Cove/backwater	2730208.0	6363770.3
LW009	25839	Main channel		Willow fringe	2729509.8	6364091.7
LW010	25840	Confluence	Mangaonua Stream	Willow fringe	2714801.6	6374212.1
LW011	25841	Main channel		Littoral shelf	2714445.7	6374592.3
LW012	25842	Main channel		Willow fringe	2713750.6	6374938.6
LW014	25843	Main channel		Macrophyte bed	2713154.4	6374727.4
Zone 2						
LW015	25844	Main channel		Macrophyte bed	2705726.6	6386092.7
LW016	25845	Main channel		Willow fringe	2705758.6	6385720.6
LW019	25846	Side channel	Lake D outlet	Macrophyte bed	2704371.2	6387357.1
LW020	25847	Main channel		Macrophyte bed	2703826.6	6387422.2
LW021	25848	Main channel		Willow fringe	2702208.8	6388936.0
LW022	25849	Confluence	Waipa River	Willow fringe	2698902.6	6389921.8
Zone 3						
LW023	25850	Confluence	Mangawara Stream	Littoral shelf	2703407.5	6396821.6
LW024	25851	Main channel		Willow fringe	2701167.4	6398165.3
LW025	25852	Side channel		Willow fringe	2700785.7	6406013.2
LW026	25853	Side channel		Macrophyte bed	2700724.0	6405709.2
LW027	25854	Main channel		Willow fringe	2700875.5	6405387.3
LW028	25855	Main channel		Sand bar	2700621.9	6404600.2
Zone 4						
LW029	25856	Confluence	Whangape Stream	Macrophyte bed	2694188.5	6417198.5
LW030	25857	Confluence	Opuatia Stream	Macrophyte bed	2692456.2	6419294.5
LW031	25858	Side channel		Littoral shelf	2693170.2	6430662.7
LW032	25859	Main channel		Willow fringe	2693197.7	6430000.0
LW033	25860	Confluence	Whangamarino River	Willow fringe	2693117.4	6432151.5
LW034	25861	Main channel		Willow fringe	2692528.2	6431976.7
LW035	25862	Main channel		Sand bar	2692862.5	6431305.1

Water at the sites fished in the main river channel in Zone 1 (Karapiro Dam to Hamilton City) were 3-6 m deep. The river was constrained between steep banks, and was relatively fast flowing (e.g., Fig. 2). Development of littoral zones was poor in this section as the channel was steep sided. Willow fringes were limited to the lower end of Zone 1, and a few 3-6 m beds of the aquatic macrophytes hornwort (*Ceratophyllum demersum*) and egeria (*Egeria densa*) were seen. In Zone 2 (Hamilton City to Ngaruawahia), the river was wider than in Zone 1 and sandy littoral zones were extensive; most had well-developed macrophyte beds in 0.5-1.5 m of water. Willow fringes were extensive (Fig. 3). In Zone 3 (Ngaruawahia to Rangiriri), the river was wider still and shallower than in Zone 2, with occasional mid-channel bars. Macrophyte beds were well developed in the extensive littoral areas. In Zone 4 (Rangiriri to Tuakau),

willow fringes were extensive but the river was deeper at the sides, and littoral areas had only patchy macrophyte beds. In places, artificial groynes encouraged willow establishment into the river channel (Fig. 4).

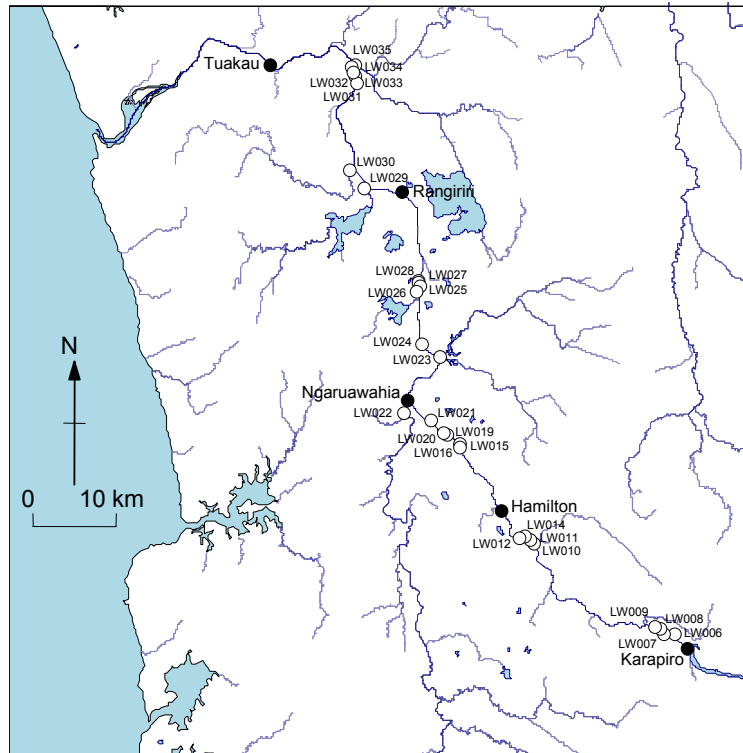


Figure 1. Sites fished in the lower Waikato River between 8 and 15 February 2005. ○, fished sites; ● locations of zones breaks. Source: Fish Database Helper (Jowett 2005). Site codes correspond to the GPS points in Table 1.



Figure 2. The main channel of the Waikato River in Zone 1 at LW007. Photo: Brendan Hicks.



Figure 3. The willow-fringed main channel of the Waikato River in Zone 2 at LW016 downstream of the Pukete boat ramp, Hamilton City. Photo: Brendan Hicks.



Figure 4. Willow groyne (to the left) extending into the channel of Zone 4 at site LW032. Photo: Brendan Hicks.

We caught 2,915 fish comprising seven introduced and six native fish species at 27 sites in 5.63 km of fished length of the lower Waikato River between 8 and 15 February 2005 (Table 3). Common smelt were the most numerous species, followed by goldfish. Relatively few longfin eels, trout, bullies, and torrentfish were caught. Koi carp were common, and in addition, three koi carp-goldfish hybrids were caught. Koi carp comprised 285 kg, or 69% of the 408 kg of fish caught (Table 4). The majority of carp were caught in Zones 2-4, where they occurred in all habitats except mid-channel sand bars. Biomasses up to 124 g m⁻² were associated with willow fringed and macrophyte beds (Table 5). We also observed pock-marked soft sediment in shallow water in the side channel at LW019 that is likely to have been the result of koi carp foraging (Fig. 5).

Adult trout were found only in the confluence habitats of Zone 1; all were brown trout except for one rainbow trout caught at LW007. Goldfish were found at most sites that had koi carp, but comprised on average only one quarter of the biomass of koi carp (Table 5). Grey mullet (Fig. 6) comprised the greatest biomass of any native fish species, and shortfin eels, though widespread, did not comprise a high biomass. Only one torrentfish was found; this small juvenile (36 mm TL) was caught on a mid-channel bar at Mercer (site LW035).



Figure 5. Pock-marked soft sediment in shallow water in the side channel at LW019 that is likely to be the result of koi carp foraging. Photo: Brendan Hicks.

Table 2. Sites and physical conditions in the lower Waikato River between 8 and 15 February 2005.

Site code	Date	Macrophytes	Bank and substrate	Specific conductivity ($\mu\text{S cm}^{-1}$)	Water temperature ($^{\circ}\text{C}$)	Distance fished (m)	Fishing time (mins)	Water depth (m)
Zone 1								
LW006	8-Feb	<i>Persicaria</i>	Steep silt edge, privet, toetoe	157.3	22.2	105	11	0.4-1.5
LW007	8-Feb	None	Rockface, littoral boulders	158.5	22.1	52	8	0.3-4.5
LW008	8-Feb	Hornwort	Willow, privet, fuchsia, coprosma	156.5	22.3	210	16	0.3-1.3
LW009	8-Feb	Hornwort	Poplar, conifer, willow, privet	155.7	22.6	76	10	2.0-4.5
LW010	9-Feb	None	Willow, rock & mud sides	241.0	18.5	100	4	0.2-0.9
LW011	9-Feb	None	Sand, wood	159.5	22.1	151	18	0.4-1.5
LW012	9-Feb	<i>Egeria</i>	Silt, wood	159.2	22.3	108	22	0.5-1.2
LW014	9-Feb	<i>Egeria</i>	Silt, gravel	159.4	22.4	230	17	0.5-1.5
Zone 2								
LW015	9-Feb	<i>Egeria</i> , hornwort	Silt	166.8	23.2	206	20	0.5-1.5
LW016	9-Feb	Hornwort, <i>Egeria</i>	Willow	166.8	23.2	141	10	3.5
LW019	11-Feb	<i>Egeria</i> , hornwort	Silt, wood, willows	166.8	22.4	151	17	0.3-1.0
LW020	11-Feb	Hornwort, <i>Egeria</i>	Silt	167.2	22.3	327	17	0.4-1.5
LW021	11-Feb	<i>Egeria</i> , hornwort	Silt, wood	166.0	23.3	130	13	0.4-1.5
LW022	11-Feb	None	Willow, wood	136.8	24	216	19	1.5-5
Zone 3								
LW023	11-Feb	Parrot's feather, hornwort, <i>Egeria</i>	Willow, wood, silt	211.5	25.1	222	29	1.5-4.0
LW024	11-Feb	Hornwort, <i>Egeria</i> , parrot's feather	Willow, pasture, polygonum	165.0	23.1	74	16	0-1.2
LW025	14-Feb	<i>Ludwigia</i> , hornwort, <i>Egeria</i> , parrot's feather	Wood, silt	164.4	25.7	294	27	0.3-0.6
LW026	14-Feb	<i>Egeria</i> , hornwort, <i>Ludwigia</i>	Silt	164.4	25.7	310	14	0.4-0.8
LW027	14-Feb	Hornwort, <i>Egeria</i>	Wood	166.1	22.5	186	15	0.4-2.2
LW028	14-Feb	None	Silt	165.8	25.6	261	10	0.4-0.6
Zone 4								
LW029	14-Feb	Hornwort	Silt	232.4	23.7	523	31	0.2-8.8
LW030	14-Feb	Parrot's feather, hornwort	Silt	255.5	25.2	294	24	0.2-2.5
LW031	15-Feb	Hornwort	Silt, wood	164.5	22.7	451	31	0.4-1.0
LW032	15-Feb	Hornwort, <i>Ludwigia</i> , water parsnip	Silt, wood, roots	164.4	23	164	21	1.0-2.5
LW033	15-Feb	<i>Ludwigia</i> , <i>Glyceria maxima</i>	Silt, wood, roots	163.6	24.7	138	0	0.3-2.5
LW034	15-Feb	Hornwort	Wood, roots, silt	164.4	23.6	144	34	0.3-2.5
LW035	15-Feb	None	Sand, fine gravel	164.0	23.6	361	8	0.3-0.6

Table 3. Density of fish caught in the lower Waikato River between 8 and 15 February 2005.

Bold values are non-zero.

Density of fish per site (number 100 m ⁻²)																	
Site	Brown trout	Rainbow trout	Common bully	Catfish	Gambusia	Goldfish	Inanga	Koi carp	Koi-goldfish hybrid	Longfin eel	Grey mullet	Rainbow trout	Rudd	Shortfin eel	Common smelt	Torrentfish	Sum
Zone 1																	
LW006	0.0	0.0	0.2	0.0	0.2	0.0	0.7	0.2	0.0	0.0	0.5	0.0	0.0	0.0	12.4	0.0	14.3
LW007	2.4	0.5	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.5	0.0	0.5	17.8	0.0	22.1
LW008	0.1	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.1	0.0	0.0	0.2	5.4	0.0	7.1
LW009	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	1.3	0.0	0.0	1.6	15.1	0.0	18.4
LW010	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	18.0	0.0	19.0
LW011	0.0	0.0	1.2	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	3.0	14.2	0.0	18.6
LW012	0.0	0.0	0.2	0.0	0.0	0.0	1.6	2.8	0.0	0.0	0.5	0.0	0.0	3.2	20.3	0.0	28.6
LW014	0.0	0.0	0.0	0.0	0.0	0.1	0.4	2.5	0.0	0.0	0.0	0.0	1.8	1.5	5.5	0.0	12.0
Mean	0.4	0.1	0.2	0.0	0.0	0.0	0.6	0.7	0.0	0.0	0.3	0.1	0.2	1.3	13.6	0.0	17.5
Zone 2																	
LW015	0.0	0.0	1.3	0.0	0.0	1.7	2.2	6.8	0.0	0.0	0.0	0.0	0.1	1.9	2.3	0.0	16.4
LW016	0.0	0.0	0.4	0.0	0.0	0.5	0.5	0.4	0.0	0.0	0.0	0.0	0.2	0.5	13.4	0.0	15.9
LW019	0.0	0.0	0.7	0.0	0.0	1.5	1.5	2.3	0.0	0.0	0.8	0.0	4.3	1.5	4.6	0.0	17.2
LW020	0.0	0.0	2.7	0.0	0.5	1.9	1.7	1.3	0.0	0.0	0.0	0.0	2.0	0.8	12.1	0.0	23.0
LW021	0.0	0.0	0.2	0.0	0.0	3.7	0.6	6.3	0.0	0.0	0.6	0.0	0.0	0.8	11.7	0.0	23.8
LW022	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.3	0.0	0.0	0.6
Mean	0.0	0.0	0.9	0.0	0.1	1.5	1.1	2.9	0.0	0.0	0.3	0.0	1.1	1.0	7.4	0.0	16.2
Zone 3																	
LW023	0.0	0.0	0.1	0.0	0.8	8.2	0.1	2.1	0.0	0.0	0.0	0.0	1.5	0.2	1.4	0.0	14.4
LW024	0.0	0.0	0.3	0.0	0.7	1.0	0.7	10.1	0.0	0.0	0.0	0.0	0.0	2.7	9.1	0.0	24.6
LW025	0.0	0.0	0.2	0.2	0.7	3.6	0.2	1.8	0.0	0.0	0.3	0.0	0.6	0.7	1.4	0.0	9.5
LW026	0.0	0.0	0.7	0.0	0.3	1.7	0.1	0.4	0.2	0.0	0.0	0.0	0.0	0.7	0.6	0.0	4.8
LW027	0.0	0.0	0.8	0.0	0.0	0.0	0.8	1.6	0.0	0.0	0.0	0.0	0.0	0.0	22.2	0.0	25.4
LW028	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.1	1.9	0.0	2.2
Mean	0.0	0.0	0.4	0.0	0.4	2.4	0.3	2.7	0.0	0.0	0.1	0.0	0.3	0.7	6.1	0.0	13.5
Zone 4																	
LW029	0.0	0.0	0.0	0.1	0.1	2.4	0.0	0.7	0.0	0.0	0.1	0.0	0.0	0.6	2.5	0.0	6.7
LW030	0.0	0.0	0.2	0.1	1.0	6.0	0.1	1.8	0.0	0.0	0.0	0.0	0.1	0.3	0.6	0.0	10.2
LW031	0.0	0.0	0.4	0.0	0.1	0.0	0.4	0.4	0.0	0.0	0.3	0.0	0.0	1.9	10.9	0.0	14.3
LW032	0.0	0.0	0.5	0.0	0.0	0.0	0.3	0.9	0.0	0.0	0.8	0.0	0.0	0.5	31.2	0.0	34.1
LW033	0.0	0.0	0.0	0.0	1.4	5.1	0.2	2.5	0.0	0.0	0.4	0.0	0.0	0.7	0.4	0.0	10.7
LW034	0.0	0.0	0.0	0.7	0.0	0.2	0.2	1.4	0.0	0.0	0.7	0.0	0.2	0.9	15.0	0.0	19.1
LW035	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.1	1.1
Mean	0.0	0.0	0.2	0.1	0.4	1.9	0.2	1.2	0.0	0.0	0.3	0.0	0.0	0.7	9.8	0.0	14.9

Table 4. Weight of fish caught in the lower Waikato River between 8 and 15 February 2005.

Numbers in bold are non-zero.

Site	Fresh weight per site (kg)														Sum of weight	
	Brown trout	Rainbow trout	Common bully	Carfish	Gambusia	Goldfish	Inanga	Koi carp	Koi-goldfish hybrid	Longfin eel	Grey mullet	Rudd	Shortfin eel	Common smelt		Torrenfish
Zone 1																
LW006	0.000	0.000	0.001	0.000	0.000	0.000	0.004	2.363	0.000	0.000	1.029	0.000	0.000	0.087	0.000	3.5
LW007	9.991	1.047	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.192	0.082	0.000	11.3
LW008	2.109	0.000	0.000	0.000	0.000	0.000	0.013	0.000	0.000	0.000	0.693	0.000	2.460	0.114	0.000	5.4
LW009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	4.270	0.000	0.000	3.204	0.000	2.314	0.105	0.000	9.9
LW010	3.192	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.392	0.133	0.000	3.7
LW011	0.000	0.000	0.019	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.000	0.000	2.108	0.205	0.000	2.3
LW012	0.000	0.000	0.002	0.000	0.000	0.000	0.010	2.387	0.000	0.000	1.833	0.000	1.500	0.160	0.000	5.9
LW014	0.000	0.000	0.000	0.000	0.000	0.179	0.004	5.957	0.000	0.000	0.000	0.310	1.617	0.099	0.000	8.2
Mean	1.9	0.1	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.8	0.0	1.3	0.1	0.0	6.3
Zone 2																
LW015	0.000	0.000	0.037	0.000	0.000	2.042	0.034	15.660	0.000	0.000	0.000	0.009	1.711	0.028	0.000	19.5
LW016	0.000	0.000	0.006	0.000	0.000	0.461	0.004	0.182	0.000	0.000	0.000	0.220	0.792	0.101	0.000	1.8
LW019	0.000	0.000	0.008	0.000	0.000	1.036	0.011	4.120	0.000	0.000	2.992	1.957	1.106	0.093	0.000	11.3
LW020	0.000	0.000	0.095	0.000	0.008	2.298	0.050	7.438	0.000	0.000	0.000	1.263	0.724	0.247	0.000	12.1
LW021	0.000	0.000	0.004	0.000	0.000	2.582	0.007	29.521	0.000	0.000	2.377	0.000	0.436	0.068	0.000	35.0
LW022	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.364	0.000	0.377	0.000	0.000	0.7
Mean	0.0	0.0	0.0	0.0	0.0	1.4	0.0	9.5	0.0	0.0	1.0	0.6	0.9	0.1	0.0	13.4
Zone 3																
LW023	0.000	0.000	0.002	0.000	0.002	4.041	0.002	34.883	0.000	0.000	0.000	1.770	0.152	0.021	0.000	40.9
LW024	0.000	0.000	0.002	0.000	0.000	0.010	0.004	36.621	0.000	0.000	0.000	0.000	0.921	0.030	0.000	37.6
LW025	0.000	0.000	0.002	0.514	0.003	3.884	0.001	17.009	0.000	0.000	3.367	0.585	1.073	0.017	0.000	26.5
LW026	0.000	0.000	0.012	0.000	0.003	2.291	0.003	3.670	1.929	0.000	0.000	0.000	0.782	0.007	0.000	8.7
LW027	0.000	0.000	0.008	0.000	0.000	0.000	0.014	3.258	0.000	0.000	0.000	0.000	0.000	0.149	0.000	3.4
LW028	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.337	0.000	0.001	0.024	0.000	0.4
Mean	0.0	0.0	0.0	0.1	0.0	1.7	0.0	15.9	0.3	0.0	0.6	0.4	0.5	0.0	0.0	19.6
Zone 4																
LW029	0.000	0.000	0.011	0.540	0.002	5.579	0.000	26.444	0.858	0.283	2.612	0.139	1.858	0.146	0.000	38.5
LW030	0.000	0.000	0.005	0.186	0.004	7.181	0.003	28.422	0.000	0.000	0.000	0.658	0.472	0.017	0.000	36.9
LW031	0.000	0.000	0.022	0.000	0.001	0.000	0.010	10.474	0.000	0.000	2.414	0.000	3.951	0.274	0.000	17.1
LW032	0.000	0.000	0.027	0.000	0.000	0.000	0.003	11.711	0.000	0.000	5.046	0.000	0.491	0.344	0.000	17.6
LW033	0.000	0.000	0.000	0.000	0.001	2.131	0.001	21.170	0.000	0.000	2.322	0.000	0.262	0.003	0.000	25.9
LW034	0.000	0.000	0.000	0.915	0.000	0.263	0.004	17.105	0.000	0.000	3.717	0.216	1.115	0.094	0.000	23.4
LW035	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.030	0.001	0.000	0.0
Mean	0.0	0.0	0.0	0.2	0.0	2.2	0.0	16.5	0.1	0.0	2.3	0.1	1.2	0.1	0.0	22.8

Table 5. Biomass per unit area of the most abundant fish species caught in the lower Waikato River between 8 and 15 February 2005.

Numbers in bold are non-zero.

Site	Location	Habitat type	Biomass (g fresh weight m ⁻²)								Sum all species	Koi carp biomass as a proportion of total (%)
			Brown trout	Rainbow trout	Catfish	Goldfish	Koi carp	Grey mullet	Rudd	Shortfin eel		
Zone 1												
LW006	Main channel	Rock face	0.0	0.0	0.0	0.0	5.6	2.5	0.0	0.0	8.3	68
LW007	Confluence	Littoral shelf	48.0	5.0	0.0	0.0	0.0	0.0	0.0	0.9	54.4	0
LW008	Confluence	Cove/backwater	2.5	0.0	0.0	0.0	0.0	0.8	0.0	2.9	6.4	0
LW009	Main channel	Willow fringe	0.0	0.0	0.0	0.0	14.0	10.5	0.0	7.6	32.5	43
LW010	Confluence	Willow fringe	8.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	9.3	0
LW011	Main channel	Littoral shelf	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5	3.9	0
LW012	Main channel	Willow fringe	0.0	0.0	0.0	0.0	5.5	4.2	0.0	3.5	13.6	40
LW014	Main channel	Macrophyte bed	0.0	0.0	0.0	0.2	6.5	0.0	0.3	1.8	8.9	73
Mean			7.3	0.6	0.0	0.0	4.0	2.3	0.0	2.6	17.2	28.0
Zone 2												
LW015	Main channel	Macrophyte bed	0.0	0.0	0.0	2.5	19.0	0.0	0.0	2.1	23.7	80
LW016	Main channel	Willow fringe	0.0	0.0	0.0	0.8	0.3	0.0	0.4	1.4	3.1	10
LW019	Side channel	Macrophyte bed	0.0	0.0	0.0	1.7	6.8	4.9	3.2	1.8	18.7	36
LW020	Main channel	Macrophyte bed	0.0	0.0	0.0	1.8	5.7	0.0	1.0	0.6	9.3	61
LW021	Main channel	Willow fringe	0.0	0.0	0.0	5.0	56.8	4.6	0.0	0.8	67.3	84
LW022	Main channel	Willow fringe	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.4	0.9	0
Mean			0.0	0.0	0.0	2.0	14.8	1.7	0.8	1.2	20.5	45.4
Zone 3												
LW023	Confluence	Littoral shelf	0.0	0.0	0.0	4.6	39.3	0.0	2.0	0.2	46.0	85
LW024	Main channel	Willow fringe	0.0	0.0	0.0	0.0	123.6	0.0	0.0	3.1	126.9	97
LW025	Side channel	Willow fringe	0.0	0.0	0.4	3.3	14.5	2.9	0.5	0.9	22.5	64
LW026	Side channel	Macrophyte bed	0.0	0.0	0.0	1.8	3.0	0.0	0.0	0.6	7.0	42
LW027	Main channel	Willow fringe	0.0	0.0	0.0	0.0	4.4	0.0	0.0	0.0	4.6	95
LW028	Main channel	Sand bar	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.3	0
Mean			0.0	0.0	0.1	1.6	30.8	0.5	0.4	0.8	34.6	64.0
Zone 4												
LW029	Confluence	Macrophyte bed	0.0	0.0	0.3	2.7	12.6	1.2	0.1	0.9	18.4	69
LW030	Confluence	Macrophyte bed	0.0	0.0	0.2	6.1	24.2	0.0	0.6	0.4	31.4	77
LW031	Side channel	Littoral shelf	0.0	0.0	0.0	0.0	5.8	1.3	0.0	2.2	9.6	61
LW032	Main channel	Willow fringe	0.0	0.0	0.0	0.0	17.8	7.7	0.0	0.7	26.9	66
LW033	Confluence	Willow fringe	0.0	0.0	0.0	3.8	38.3	4.2	0.0	0.5	46.8	82
LW034	Main channel	Willow fringe	0.0	0.0	1.6	0.5	29.8	6.5	0.4	1.9	40.8	73
LW035	Main channel	Sand bar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Mean			0.0	0.0	0.3	1.9	18.3	3.0	0.1	0.9	24.8	61.0



Figure 6. Grey mullet (432 mm fork length) caught at site LW032. Photo: Brendan Hicks.

Koi carp attained their greatest biomass in willow fringes compared to macrophyte bed and other habitats (Table 6). Small koi carp were most common near macrophytes, whereas larger koi carp occurred near willows. Goldfish, rudd, common bullies, and inanga, in contrast, were abundant near macrophytes, whereas shortfin eels had similar biomasses in all habitats. The few koi-goldfish hybrids caught were only found near macrophytes.

Koi carp were generally large in Zone 4 (e.g., Fig. 7), and mean length for each zone increased from upstream to down stream (Fig. 8). The geometric mean weight of all koi carp caught was 892 g ($N = 317$), but koi carp were heavier in Zone 4 (mean weight 1624 g) than in Zone 1 (mean weight 405 g; ANOVA $P << 0.001$). The length frequency distribution showed that there were two distinct size classes of koi carp in the lower Waikato River (Fig. 9). There were more small koi carp in Zone 2 than in other zones, suggesting that more koi carp were rearing here. As koi were largely absent from the upper parts of Zone 1, this means that the Hamilton to Ngaruawahia section had the largest proportion of rearing koi carp.

Table 6. Biomass of fish associated with macrophyte beds, willow fringes, and other habitats in the in the lower Waikato River between 8 and 15 February 2005.

Species	Mean biomass (g m ⁻²)			Kruskal-Wallis <i>P</i>
	Macrophyte	Willow	Other	
Koi carp	11.10	25.41	6.34	0.090
Goldfish	2.39	1.12	0.57	0.016
Shortfin eel	1.16	1.83	1.21	0.725
Grey mullet	0.88	3.41	0.62	0.126
Rudd	0.74	0.11	0.25	0.018
Koi-goldfish hybrid	0.28	0.00	0.00	0.051
Brown bullhead catfish	0.06	0.17	0.00	0.344
Longfin eel	0.02	0.00	0.00	0.240
Brown trout	0.00	0.67	6.32	0.297
Rainbow trout	0.00	0.00	0.63	0.305
Common bully	0.021	0.007	0.006	0.167
Common smelt	0.082	0.197	0.162	0.412
Inanga	0.015	0.008	0.005	0.635
Sum of all species	16.8	32.9	16.1	0.300
Percent koi carp	62.6	54.6	26.7	0.139



Figure 7. Koi carp caught at Mercer (site LW031; Zone 4). Photo: Brendan Hicks.

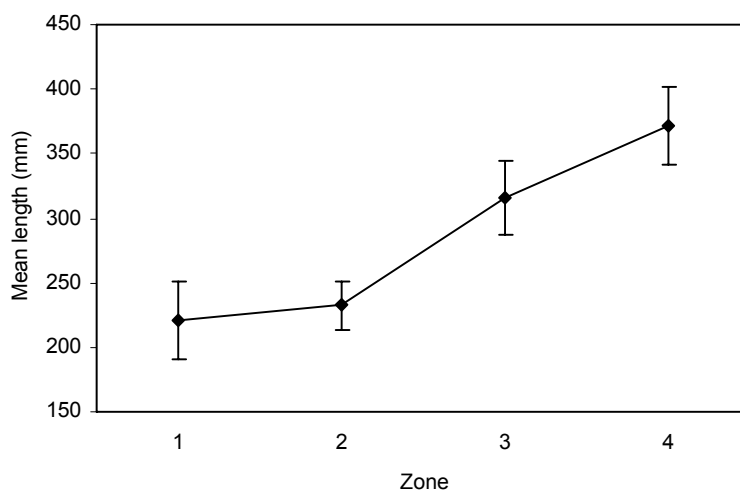


Figure 8. Mean length of koi carp in each of four zones of the Waikato River.

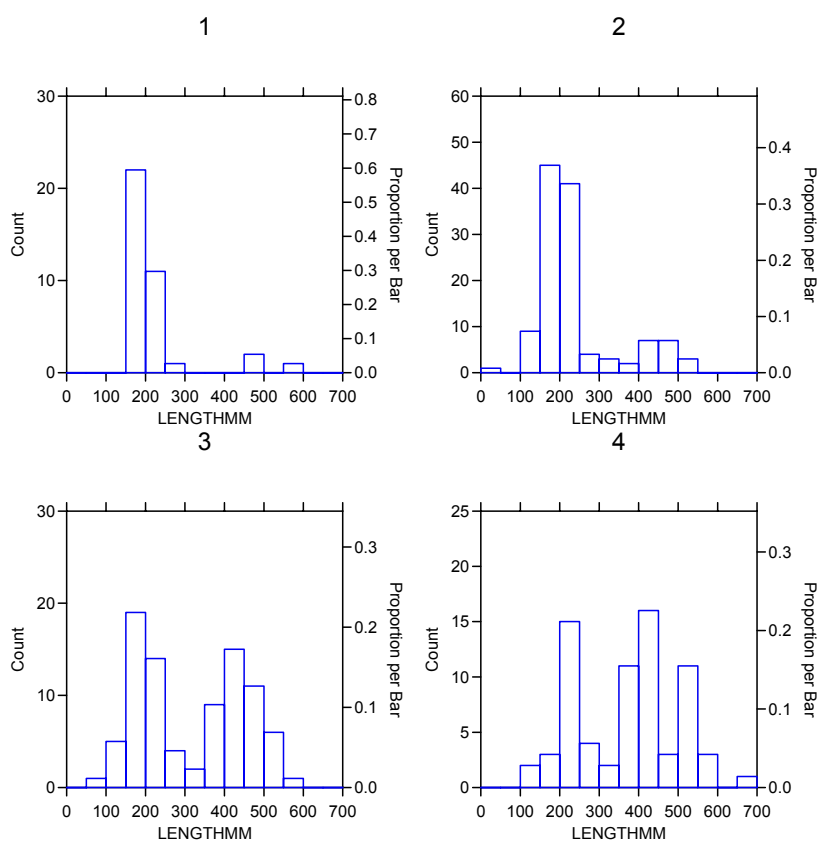


Figure 9. Length frequency of koi carp caught in four zones of the lower Waikato River between 8 and 15 February 2005.

Zone 1, $N = 37$; Zone 2, $N = 122$; Zone 3, $N = 87$; Zone 4, $N = 71$;

4. Conclusions

Boat electrofishing caught a diverse range of native and introduced fish with a large size range (from a 36-mm juvenile torrentfish to a 548 mm koi carp weighing 5.5 kg). Common smelt, koi carp, grey mullet, goldfish, shortfin eels, and inanga were widely caught. Common smelt were on average 20 times more numerous than inanga at sites where both occurred together.

Biomass is a more accurate reflection of the potential ecological impact of koi carp than their density. Koi carp dominated the biomass at sites where they occurred, but grey mullet biomass approached that of koi carp at some sites. The mean biomass of koi carp for all sites was 16 g m^{-2} , but previous results suggest that 21-73% of the total population estimate is caught on the first removal, depending on water visibility (Hicks, unpubl. data). As we fished over the area at each site only once, the estimates in this survey represent a minimum abundance, and true population sizes would be 1.4-4.8 times greater.

The two size classes of the koi carp in this study corresponded to 1-3 year olds (100-300 mm FL) and 4-7 year olds (325-600 mm FL; Tempero 2004), so did not appear to reflect distinct year classes.

Previous fishing with the electrofishing boat in the North Island, in similar conductivities and habitats and with similar machine settings, has caught a full size range eels, smelt, bullies, grey mullet, rudd, brown bullhead catfish, perch, tench, goldfish, and koi carp (Hicks, unpubl. data). The moderate conductivities of the lower Waikato River allowed efficient power transfer from the water to the fish as the range of conductivities was about the same as the presumed conductivity of the fish. Goldfish have effective conductivities of about $100\text{-}160 \mu\text{S cm}^{-1}$ (Kolz and Reynolds 1989).

This survey demonstrates the ability of boat electrofishing to catch a broad cross section of fish species under conditions where conventional netting techniques would be challenging or impossible. The wide range of fish sizes caught suggests that sampling was representative of the size ranges available for cyprinids (koi carp, goldfish, and rudd), and probably also for grey mullet, inanga, and common smelt. Common bullies, gambusia, and torrentfish, however, were probably not caught in representative numbers. Of ecological concern for the Waikato region is the dominance of the fish biomass by introduced koi carp, which have a deleterious impact on aquatic habitats (Roberts & Ebner 1997).

5. Acknowledgements

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