Boat electrofishing survey of the lower Waikanae River, Ratanui Lagoon, and Lake Waitawa

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by

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Executive summary

We conducted the first electrofishing boat survey of the lower Waikanae River, Ratanui Lagoon, and Lake Waitawa on 11-12 July 2006. We caught five introduced and five native fish species in 4.74 km of fished length from a total of nine 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 16,200 m^2 or 1.62 ha.

We landed a total of 125 fish comprising five introduced and five native fish species at the nine fished sites (Table 3). Shortfin eels were the most numerous species but are mostly not included in this total. We did not bring eels on board because of the handling time this involved, except for two sites 263 and 264 where densities were 1.19 fish 100 m^{-2}, which is a moderate density of eels compared to previous boat electrofishing one-pass estimates. Perch, tench, and rudd were found at most sites in Lake Waitawa. Goldfish had a much more restricted distribution, and were caught at only one site. Four adult brown trout were caught in the lower Waikanae River. Because of their large size, adult brown trout and tench comprised a significant part of the fish biomass where they occurred.

No koi carp were caught, probably because of a combination of low density and low water temperature. Water temperature at the time of fishing (10.2-10.5 ºC in Lake Waitawa) may have influenced the susceptibility of koi carp to electrofishing. Common carp are known to seek winter refuge in deep water at temperatures below 11ºC. Electrofishing is limited to the upper 3 m of the water column and would be ineffective if koi carp were in the deeper sections of Lake Waitawa. Common carp (the European race of koi carp, *Cyprinus carpio*) are also less active during periods of low water. Inactivity reduces the probability of encountering fish and lowers catch rates. The optimal period for sampling koi carp begins as the water warms in spring, when koi carp move into the littoral shallows to spawn and are therefore highly visible. Common carp in Australia begin to spawn when water temperatures reach 15ºC and koi carp have been observed spawning in New Zealand in Lake Waikare as early as 11 September in a water temperature 15.3ºC. However, it is encouraging that no small koi carp were caught because this is evidence that breeding is not occurring in Lake Waitawa or Ratanui Lagoon, where koi carp are known to occur (Ian Cooksley, DOC, pers. comm.).

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 of eels, smelt, bullies, grey mullet, rudd, brown bullhead catfish, perch, tench, goldfish, and koi carp. Thus we believe that these results reflect an accurate picture of fish abundance in the Waikanae area but we acknowledge that fishing in spring or summer in higher water temperatures is likely to increase the likelihood of catching koi carp.

The fish data have been entered into NIWA's New Zealand Freshwater Fish Database as card numbers 15190 to 15198.

1. Introduction

Boat electrofishing can give reliable estimates of fish density (Basler and Schramm 2006). The Department of Conservation, Wellington Conservancy, contracted the Centre for Biodiversity and Ecology Research (CBER) to fish the lower Waikanae River, one of the Ratanui Lagoons, and Lake Waitawa. The purpose was to produce a comprehensive overview of the invasive fish populations of all sites, and to catch the koi carp that had been seen in the Ratanui Lagoons and Lake Waitawa.

2. Methods

We used a 4.5-m long electrofishing boat with a 5-kilowatt petrol-powered pulsator (Model GPP 5.0, Smith-Root Inc, Vancouver, Washington, USA) powered by a 6-kilowatt custom-wound Honda 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 three sites on the lower Waikanae River and its tributaries and six sites in Lake Waitawa on 11-12 July 2006 (Table 1; Fig. 1). The Ratanui Lagoons (Fig. 2) drain into the Waikanae River, and Lake Waitawa drains into the Waitohu Stream. Electrical conductivity was measured with a YSI 3200 conductivity meter. Ambient conductivity, i.e., not standardised for temperature, ranged from 76 to 312 $\mu S\ cm^{-1}$ (Table 2), so the GPP settings had to be adjusted for each location in order to achieve an applied current of 2-4 A root mean square. For conductivities of 170-312 $\mu S\ cm^{-1}$, we set the GPP to low range (50-500 V direct current) and a frequency of 60 pulses per second. We fished the Ratanui Lagoon using 30% of low range, and Lake Waitawa using 60% of range. For the lower Waikanae River (ambient conductivity 76 $\mu S\ cm^{-1}$), we fished with the GPP set to high range (50-1000 V direct current) and 60pps, and we used 40% of range. Relative abundance was ranked as a = abundant (>10), c = common (6-10), o = occasional (2-5), r = rare (1)

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. We fished from 140 m to 1.28 km at each site (466-4,109 m^2; Table 1). Water clarity was measured with a black disc viewed horizontally (Davies-Colley 1988).

The fish data have been entered into NIWA's New Zealand Freshwater Fish Database as card numbers 15190 to 15198 (Table 1). Because eels, smelt, and bullies were not the target of the fishing, their numbers were generally estimated only qualitatively.

Table 1. Sites fished 11-12 July 2006 in the lower Waikanae River and nearby locations, showing locations as New Zealand map grid (NZMG) references. Card numbers of the fishing record are shown for NIWA's New Zealand Freshwater Fish Database (NZFFDB).

Site	ID	Date	FFDB card	NZMG easting	NZMG northing	Distance fished (m)	Area fished (m^2)	Elapsed fishing time (mins)
Ratanui Lagoon	260	11-Jul-06	15190	2679666	6033028	1,283	3,179	43
Lower Waikanae River	261	11-Jul-06	15191	2679746	6034840	205	815	15
El Rancho Drain & upstream Waikanae River	262	11-Jul-06	15192	2680296	6034838	233	762	15
Lake Waitawa, shore south of camp	263	11-Jul-06	15193	2693531	6051269	326	1,096	27
Lake Waitawa, far shore south of camp	264	11-Jul-06	15194	2693656	6051209	552	2,023	29
Lake Waitawa, west shore	265	11-Jul-06	15195	2693100	6051330	140	466	12
Lake Waitawa, northern arm	266	12-Jul-06	15196	2693701	6051738	687	2,718	52
Lake Waitawa, far eastern arm	267	12-Jul-06	15197	2693767	6051578	1,058	4,109	51
Lake Waitawa, west shore	268	12-Jul-06	15198	2693187	6051389	255	1,007	28
Total						4,739	16,175	272

Table 2. Conductivity, temperature, water clarity (black disc), and water depth in the lower Waikanae River, Ratanui Lagoon, and Lake Waitawa 11-12 July 2006.

Site	ID	Ambient conductivity (μS cm^{-1})	Specific conductivity (μS cm^{-1})	Water temperature (^oC)	Black disc (m)	Depth (m)
Ratanui Lagoon	260	312	410	12.6	0.58	0.5-2.7
Lower Waikanae River	261	76	104	11.3	0.60	0.2-0.75
El Rancho Drain & upstream Waikanae River	262	76	104	11.3	0.60	0.2-1.3
Lake Waitawa, shore south of camp	263	170	237	10.2	0.63	0.2-2.0
Lake Waitawa, far shore south of camp	264	170	237	10.2	0.63	0.5-2.0
Lake Waitawa, west shore	265	170	237	10.2	0.63	0.8-1.8
Lake Waitawa, northern arm	266	171	237	10.5	0.63	0.4-2.0
Lake Waitawa, far eastern arm	267	171	237	10.5	0.63	0.4-2.0
Lake Waitawa, west shore	268	171	237	10.5	0.63	0.8-1.8

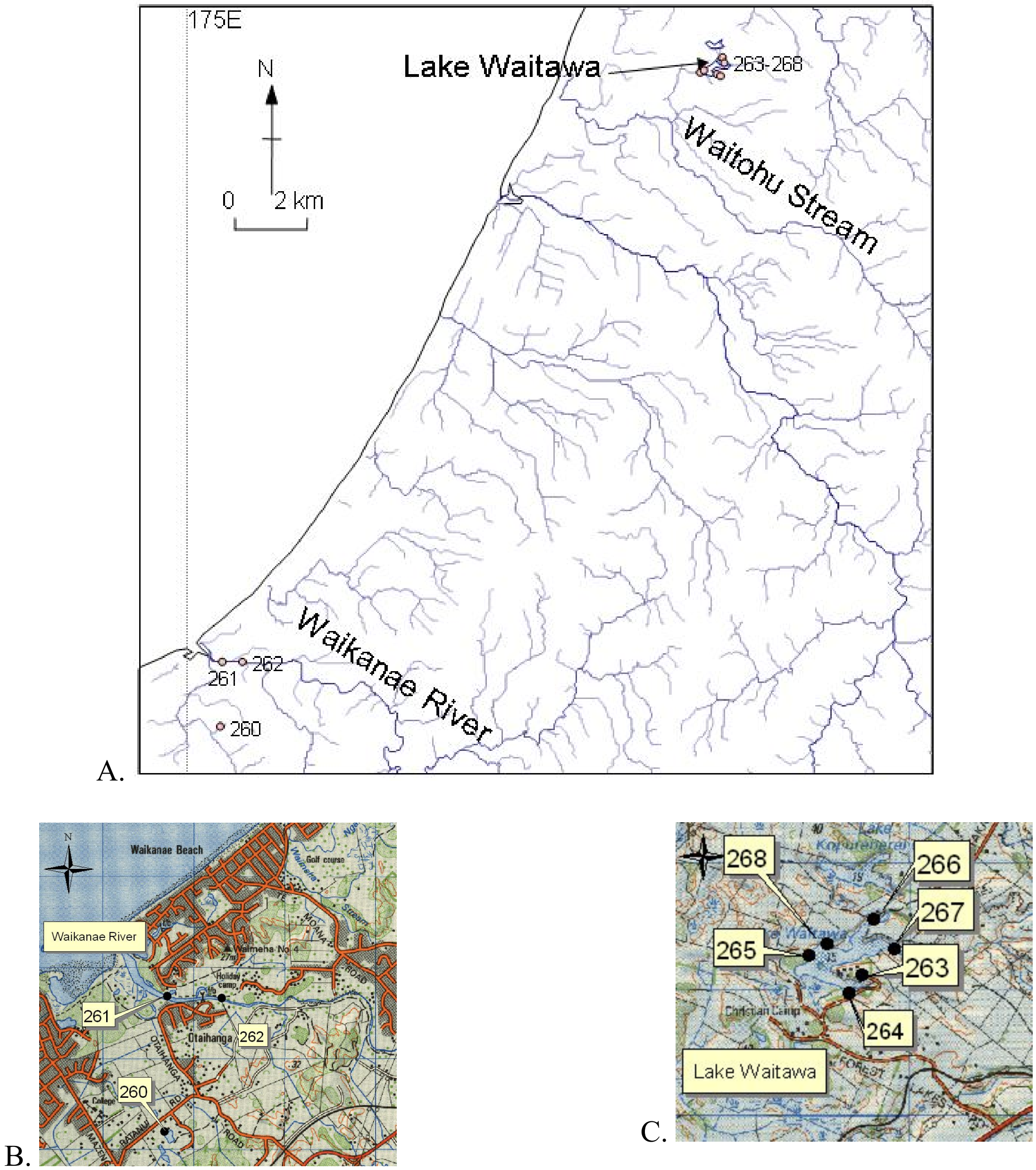


Figure 1. Sites fished in the lower Waikanae River 11-12 July 2006. (A) Regional map, (B) site 260 on the Ratanui Lagoons and 261-262 on the Waikanae River, and (C) sites 263-264 on Lake Waitawa. Site codes correspond to the GPS points and ID column in Tables 1-4.

3. Results

Specific conductivities (standardised to 25°C) were low in the main channel of the Waikanae River (104 µS cm^{-1}), but were higher in Lake Waitawa (237 µS cm^{-1}) and in the Ratanui Lagoon (410 µS cm^{-1}; Table 1). Water temperatures ranged from 10.2 to 12.6°C. The lower Waikanae River and El Rancho Drain were within the tidally influenced reach, and were fished at about mid-tide on an out-going tide.

We caught five introduced and five native fish species in 4.74 km of fished length from a total of nine 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 16,200 m^2 or 1.62 ha. We landed a total of 125 fish comprising five introduced and five native fish species at the nine fished sites (Table 3). Shortfin eels were the most numerous species but are mostly not included in this total. We did not bring eels on board because of the handling time this involved, except for sites 263 and 264 where we attempted catch all the eels that we saw. Perch (Fig. 3), tench (Fig. 4), and rudd were found at most sites in Lake Waitawa. Goldfish had a much more restricted distribution, and were caught at only one site. Four adult brown trout (Fig. 5) were caught in the lower Waikanae River.

Table 3. Number of fish caught by single-pass boat electrofishing in the lower Waikanae River, Ratanui Lagoon, and Lake Waitawa 11-12 July 2006. a, abundant; c, common; o, occasional; –, none found. (Totals do not include eels, common smelt, and bullies where they are ranked a, c, or o).

Site	ID	Shortfin eel	Bullies	Common smelt	Brown trout	Flounder	Goldfish	Perch	Rudd	Tench	Yelloweyed mullet	Total
Ratanui Lagoon	260	a	c	1	–	–	–	–	–	–	–	1
Lower Waikanae River	261	o	o	–	–	1	–	–	–	–	–	1
El Rancho Drain & upstream Waikanae River	262	c	1	a	4	1	–	–	–	–	5	11
Lake Waitawa, shore south of camp	263	13	c	–	–	–	5	6	1	4	–	29
Lake Waitawa, far shore south of camp	264	24	–	–	–	–	–	10	2	1	–	37
Lake Waitawa, west shore	265	a	–	–	–	–	–	2	–	–	–	2
Lake Waitawa, northern arm	266	a	o	–	–	–	–	5	5	3	–	13
Lake Waitawa, far eastern arm	267	a	1	–	–	–	–	12	3	3	–	19
Lake Waitawa, west shore	268	a	–	–	–	–	–	11	1	–	–	12
Total		37	2	1	4	2	5	46	12	11	5	125

Table 4. Density of fish caught by single-pass boat electrofishing in the lower Waikanae River, Ratanui Lagoon, and Lake Waitawa 11-12 July 2006.

Site	ID	Fish density (number/100 m^2)										
		Shortfin eel	Bullies	Common smelt	Brown trout	Flounder	Goldfish	Perch	Rudd	Tench	Yelloweyed mullet	Total
Ratanui Lagoon	260	a	c	0.03	–	–	–	–	–	–	–	0.03
Lower Waikanae River	261	o	o	–	–	0.12	–	–	–	–	–	0.12
El Rancho Drain & upstream Waikanae River	262	c	0.13	a	0.52	0.13	–	–	–	–	0.66	1.44
Lake Waitawa, shore south of camp	263	1.19	c	–	–	–	0.46	0.55	0.09	0.36	–	2.65
Lake Waitawa, far shore south of camp	264	1.19	–	–	–	–	–	0.49	0.1	0.05	–	1.83
Lake Waitawa, west shore	265	a	–	–	–	–	–	0.43	–	–	–	0.43
Lake Waitawa, northern arm	266	a	o	–	–	–	–	0.18	0.18	0.11	–	0.48
Lake Waitawa, far eastern arm	267	a	0.02	–	–	–	–	0.29	0.07	0.07	–	0.46
Lake Waitawa, west shore	268	a	–	–	–	–	–	1.09	0.1	–	–	1.19

Eels were numerous but relatively small (mean weight 80-125 g) in Lake Waitawa (Table 5). This is less than the legal minimum harvestable size (220 g), but shows that recruitment is occurring. Tench were relatively large (mean weight 603-1081 g). Rudd caught were mostly small juveniles, showing that that boat electrofishing was effective in catching small juveniles, and that we would have caught juvenile koi carp if they had been present.

Table 5. Mean weight of fish caught by boat electrofishing in the lower Waikanae River, Ratanui Lagoon, and Lake Waitawa 11-12 July 2006.

Site	ID	Mean weight (g)						
		Shortfin eel	Brown trout	Goldfish	Perch	Rudd	Tench	Yelloweyed mullet
Ratanui Lagoon	260	–	–	–	–	–	–	–
Lower Waikanae River	261	–	–	–	–	–	–	–
El Rancho Drain & upstream Waikanae	262	–	2124	–	–	–	–	130
Lake Waitawa, shore south of camp	263	125	–	353	275	12	603	–
Lake Waitawa, far shore south of camp	264	80	–	–	273	<1	740	–
Lake Waitawa, west shore	265	–	–	–	531	–	–	–
Lake Waitawa, northern arm	266	–	–	–	263	6	1081	–
Lake Waitawa, far eastern arm	267	–	–	–	407	10	852	–
Lake Waitawa, west shore	268	–	–	–	328	1	–	–

Figure 2. University of Waikato's electrofishing boat fishing the Ratanui Lagoon.

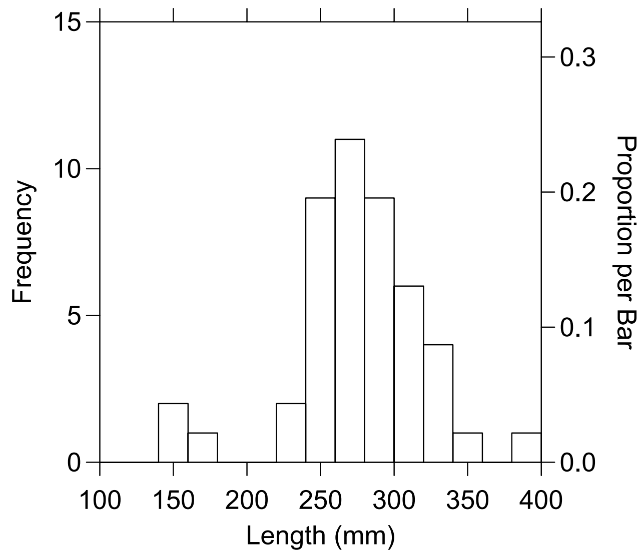
Figure 3. Perch from Lake Waitawa.

Figure 4. Tench from Lake Waitawa.

Figure 5. Brown trout from the lower Waikanae River.

We caught two sizes classes of both perch and shortfin eels (Fig. 6). Relatively few small fish of both species were caught.

A. Perch ($N = 46$)



B. Shortfin eels ($N = 37$)

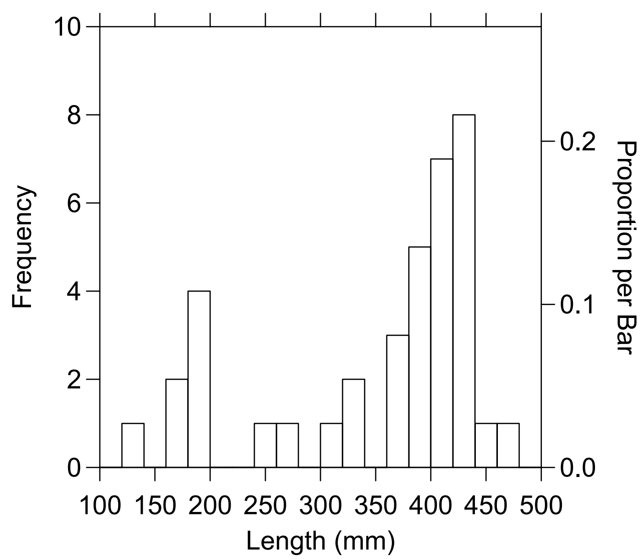


Figure 6. Length frequency of (A) perch and (B) shortfin eels caught by boat electrofishing in Lake Waitawa.

Introduced fish comprised most of the biomass at sites other than Ratanui Lagoon (Table 6). Shortfin eels accounted for 20-40% of the fish biomass at the two Lake Waitawa sites where they were quantitatively fished. Because of their large size, adult brown trout and tench contributed significantly to biomass where they occurred.

Table 6. Fish biomass caught by single-pass boat electrofishing in the lower Waikanae River, Ratanui Lagoon, and Lake Waitawa 11-12 July 2006. a, abundant; c, common; o, occasional; –, none found. (Totals do not include eels, common smelt, and bullies where they are ranked a, c, or o).

Site	ID	Fish biomass (g/m^2)						
		Shortfin eel	Brown trout	Goldfish	Perch	Tench	Yelloweyed mullet	Total
Ratanui Lagoon	260	a	–	–	–	–	–	0
Lower Waikanae River	261	o	–	–	–	–	–	–
El Rancho Drain & upstream Waikanae River	262	c	11.2	–	–	–	0.85	12.0
Lake Waitawa, shore south of camp	263	1.49	–	1.61	1.51	2.2	–	6.8
Lake Waitawa, far shore south of camp	264	0.95	–	–	1.35	0.37	–	2.7
Lake Waitawa, west shore	265	a	–	–	2.28	–	–	2.3
Lake Waitawa, northern arm	266	a	–	–	0.48	1.19	–	1.7
Lake Waitawa, far eastern arm	267	a	–	–	1.19	0.62	–	1.8
Lake Waitawa, west shore	268	a	–	–	3.58	–	–	3.6

4. Conclusions

Boat electrofishing caught a diverse range of native and introduced fish with a large size range (from a 33-mm juvenile rudd to a 550 mm brown trout). Perch, shortfin eels, bullies, rudd, and tench were widely caught. Flounder, common smelt, and yelloweye mullet were all caught in the lower Waikanae River; one common smelt that was caught in the Ratanui Lagoon, showing that they had restricted access to this site. At any given site, one pass of boat electrofishing catches one half to one sixth of the fish present (Hicks et al. in press).

Goldfish occurred at only one site in Lake Waitawa, and no koi carp were caught, probably because of a combination of low density and low water temperature. Spring or summer would probably have been a better time to fish for koi carp. However, it is encouraging that no small koi carp were caught because this is evidence that breeding is not occurring in Lake Waitawa or Ratanui Lagoon, where koi carp are known to occur (Ian Cooksley, DOC, pers. comm.). Koi carp in New Zealand can have 300,000 per female (Tempero et al. in press).

Water temperature at the time of fishing (10.2-10.5ºC in Lake Waitawa) may have influenced the susceptibility of koi carp to electrofishing. Common carp are known to seek winter refuge in deep water at temperatures below 11ºC (McCrimmon 1968). Electrofishing is limited to the upper 3 m of the water column and would be ineffective if koi carp were in the deeper sections of Lake Waitawa. Common carp (the European race of koi carp) are also less active during periods of low water temperatures (Brown et al. 2001). Inactivity reduces the probability of encountering fish and lowers catch rates (Crivelli 1981). The optimal period for sampling koi carp begins as the water warms in spring, when koi carp move into the littoral shallows to spawn and are therefore highly visible. Common carp in Australia begin to spawn when water temperatures reach 15ºC (Stuart and Jones 2002) and koi carp have been observed spawning in New Zealand in Lake Waikare as early as 11 September in a water temperature 15.3ºC (Hicks unpubl. data).

The moderate conductivities of the surveyed sites 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, for instance, have effective conductivities of about 100-160 µS cm^{-1} (Kolz and Reynolds 1989). More recent work confirms and widens this range slightly (72–204 µS/cm) for a range (Kolz 2006). When water has similar electrical conductivity, power transfer to fish is at its most efficient. Ambient conductivities in this survey were close to optimal. 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 of eels, smelt, bullies, grey mullet, rudd, brown bullhead catfish, perch, tench, goldfish, and koi carp (Hicks et al. 2005). Thus we believe that these results reflect an accurate picture of fish abundance in the Waikanae area, but we acknowledge that fishing in spring or summer in higher water temperatures might increase the likelihood of catching koi carp.

5. Acknowledgements

We gratefully acknowledge assistance the field from Nadine Gibbs, Amber McEwan, Clint Purches, Ian Cooksley of the Department of Conservation. The survey was funded by the Department of Conservation, Wellington Conservancy. Special thanks to Amber McEwan for her photos.

6. References

Basler, M. C., and H. L. Schramm. 2006. Evaluation of electrofishing and fyke netting for collecting black carp in small ponds. *Transactions of the American Fisheries Society 135*:277-280.

Brown, R. S., G. Power, and S. Beltaoa. 2001. Winter movements and habitat use of riverine brown trout, white sucker and common carp in relation to flooding and ice break-up. *Journal of Fish Biology* 59(5):1126-1141.

Crivelli, A. J. 1981. The biology of the common carp, Cyprinus carpio L. in the Camargue, southern France. *Journal of Fish Biology* 18(3):271-290.

Davies-Colley, R. J. 1988. Measuring water clarity with a black disk. *Limnology and Oceanography 33(4, part 1)*:616-623.

Hicks, B. J., N. Ling, M. W. Osborne, D. G. Bell, and C. A. Ring. 2005. Boat electrofishing survey of the lower Waikato River and its tributaries. *CBER Contract Report No. 39*. Client report prepared for Environment Waikato. Centre for Biodiversity and Ecology Research, Department of Biological Sciences, The University of Waikato, Hamilton.

Hicks, B. J., M. W. Osborne, and N. Ling. In press. Quantitative estimates of fish abundance from boat electrofishing. Proceedings, Australian Society for Fish Biology annual conference, Darwin, NT, 11-15 July 2005.

Kolz, A. L. 2006. Electrical conductivity as applied to electrofishing. *Transactions of the American Fisheries Society 135*: 509-518.

Kolz, A. L., and J. B. Reynolds. 1989. Determination of power threshold response curves. U.S. Fish and Wildlife Service, *Fish and Wildlife Technical Report 22*: 15-24.

McCrimmon, H. R. 1968. Carp in Canada. Fisheries Research Board of Canada (Bulletin 165).

Stuart, I., and M. Jones. 2002. Ecology and management of common carp in the Barmah-Millewa forest: final report of the point source management of carp project to Agriculture, Fisheries and Forestry Australia. Arthur Ryhlah Institute for Environmental Research, Heidelberg, Victoria.

Tempero, G. W., N. Ling, B. J. Hicks, and M. W. Osborne. In press. Age composition, growth, and reproduction of koi (*Cyprinus carpio*) in the lower Waikato region, *New Zealand. New Zealand Journal of Marine and Freshwater Research*.

Appendix 1. Lengths and weights of fish caught in the Ratanui Lagoon, lower Waikanae River, and Lake Waitawa by boat electrofishing.

Species	Length (mm)	Weight (g)	ln(length)	ln(weight)	Weight method
Ratanui Lagoon, 11 July 2006					
Shortfinned eels					
Common bullies					
Lower Waikanae River, 11 July 2006, ID 262					
Bully	45				
Flounder	40				
Brown trout	550	2124	6.31	7.66	calculated
Brown trout	550	2124	6.31	7.66	calculated
Brown trout	550	2124	6.31	7.66	calculated
Brown trout	550	2124	6.31	7.66	calculated
Yelloweyed mullet	220	130	5.39	4.87	calculated
Yelloweyed mullet	220	130	5.39	4.87	calculated
Yelloweyed mullet	220	130	5.39	4.87	calculated
Yelloweyed mullet	220	130	5.39	4.87	calculated
Yelloweyed mullet	220	130	5.39	4.87	calculated
Lake Waitawa, Shore south of camp, 11 July 2006, ID 263					
Perch	255	258	5.54	5.55	
Perch	270	310	5.60	5.74	
Perch	277	306	5.62	5.72	
Perch	260	281	5.56	5.64	
Perch	264	276	5.58	5.62	
Perch	255	220	5.54	5.39	
Goldfish	295	742	5.69	6.61	
Goldfish	190	180	5.25	5.19	
Goldfish	213	223	5.36	5.41	
Goldfish	244	406	5.50	6.01	
Goldfish	205	212	5.32	5.36	
Tench	334	624	5.81	6.44	
Tench	335	626	5.81	6.44	
Tench	300	374	5.70	5.92	
Tench	380	787	5.94	6.67	
Rudd	93	12	4.53	2.48	
Shortfin eel	430	151	6.06	5.02	calculated
Shortfin eel	420	140	6.04	4.94	calculated
Shortfin eel	380	101	5.94	4.61	calculated
Shortfin eel	370	92	5.91	4.52	calculated
Shortfin eel	385	105	5.95	4.65	calculated
Shortfin eel	423	143	6.05	4.96	calculated
Shortfin eel	410	129	6.02	4.86	calculated
Shortfin eel	468	199	6.15	5.30	calculated
Shortfin eel	423	143	6.05	4.96	calculated
Shortfin eel	333	65	5.81	4.18	calculated
Shortfin eel	430	151	6.06	5.02	calculated
Shortfin eel	406	125	6.01	4.83	calculated
Shortfin eel	362	86	5.89	4.45	calculated

Appendix 1 (continued).

Species	Length (mm)	Weight (g)	ln(length)	ln(weight)	Weight method
Lake Waitawa, Far shore south of camp, 11 July 2006, ID 264					
Tench	360	740	5.89	6.61	
Perch	290	330	5.67	5.80	
Perch	255	254	5.54	5.54	
Perch	310	399	5.74	5.99	
Perch	270	333	5.60	5.81	
Perch	283	351	5.65	5.86	
Perch	280	367	5.63	5.91	
Perch	280	333	5.63	5.81	
Perch	244	250	5.50	5.52	
Perch	157	57	5.06	4.04	
Perch	160	56	5.08	4.03	
Shortfin eel	395	114	5.98	4.74	calculated
Shortfin eel	410	129	6.02	4.86	calculated
Shortfin eel	400	119	5.99	4.78	calculated
Shortfin eel	428	149	6.06	5.00	calculated
Shortfin eel	385	105	5.95	4.65	calculated
Shortfin eel	436	158	6.08	5.06	calculated
Shortfin eel	411	130	6.02	4.87	calculated
Shortfin eel	404	123	6.00	4.81	calculated
Shortfin eel	459	187	6.13	5.23	calculated
Shortfin eel	388	108	5.96	4.68	calculated
Shortfin eel	335	67	5.81	4.20	calculated
Shortfin eel	400	119	5.99	4.78	calculated
Shortfin eel	300	46	5.70	3.84	calculated
Shortfin eel	366	89	5.90	4.49	calculated
Shortfin eel	279	37	5.63	3.60	calculated
Shortfin eel	435	157	6.08	5.06	calculated
Shortfin eel	250	25	5.52	3.24	calculated
Shortfin eel	193	11	5.26	2.39	calculated
Shortfin eel	195	11	5.27	2.42	calculated
Shortfin eel	174	8	5.16	2.05	calculated
Shortfin eel	183	9	5.21	2.21	calculated
Shortfin eel	179	9	5.19	2.14	calculated
Shortfin eel	192	11	5.26	2.37	calculated
Shortfin eel	134	3	4.90	1.19	calculated
Rudd	12	0.013	2.48	-4.37	calculated
Rudd	15	0.027	2.71	-3.62	calculated
Lake Waitawa, west shore, 11 July 2006, ID 265					
Perch	285	403	5.65	6.00	
Perch	355	660	5.87	6.49	calculated

Appendix 1 (continued).

Species	Length (mm)	Weight (g)	ln(length)	ln(weight)	Weight method
Lake Waitawa, northern arm, 12 July 2006, ID 266					
Rudd	106	19	4.66	2.94	
Rudd	67	4.132	4.20	1.42	calculated
Rudd	72	5.264	4.28	1.66	calculated
Rudd	33	0.381	3.50	-0.96	calculated
Rudd	36	0.511	3.58	-0.67	calculated
Tench	431	1160	6.07	7.06	
Tench	324	575	5.78	6.35	
Perch	276	343	5.62	5.84	
Perch	256	232	5.55	5.45	
Perch	268	278	5.59	5.63	
Perch	261	290	5.56	5.67	
Perch	228	173	5.43	5.15	
Tench	450	1509	6.11	7.32	
Lake Waitawa, far eastern arm, 12 July 2006, ID 267					
Tench	347	704	5.85	6.56	
Tench	439	1263	6.08	7.14	
Tench	340	588	5.83	6.38	
Perch	305	403	5.72	6.00	
Perch	315	420	5.75	6.04	
Perch	305	404	5.72	6.00	
Perch	325	476	5.78	6.17	
Perch	279	330	5.63	5.80	
Perch	334	550	5.81	6.31	
Perch	332	514	5.81	6.24	
Perch	320	450	5.77	6.11	
Perch	287	377	5.66	5.93	
Perch	270	303	5.60	5.71	
Perch	310	432	5.74	6.07	
Perch	250	226	5.52	5.42	
Rudd	100	12	4.61	2.48	
Rudd	93	12	4.53	2.52	calculated
Rudd	70	5	4.25	1.57	calculated
Lake Waitawa, west shore, 12 July 2006, ID 268					
Perch	389	865	5.96	6.76	calculated
Perch	254	244	5.54	5.50	calculated
Perch	280	326	5.63	5.79	calculated
Perch	278	319	5.63	5.77	calculated
Perch	258	256	5.55	5.55	calculated
Perch	235	194	5.46	5.27	calculated
Perch	304	416	5.72	6.03	calculated
Perch	293	373	5.68	5.92	calculated
Perch	288	355	5.66	5.87	calculated
Perch	240	207	5.48	5.33	calculated
Perch	146	47	4.98	3.86	calculated
Rudd	45	1.44	3.81	0.37	calculated