Boat electrofishing survey of Lake Ngaroto

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Client report prepared for the Waipa District Council

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Executive summary

Lake Ngaroto, a 130-ha hypertrophic lake located near Te Awamutu, has previously been found to contain a diverse fish fauna of both native and introduced fish (Hicks et al. 2001). Native fish in the lake are common bullies (*Gobiomorphus cotidianus*), shortfin eels (*Anguilla australis*), longfin eels (*Anguilla dieffenbachii*) and common smelt (*Retropinna retropinna*). Introduced species include goldfish (*Carassius auratus*), brown bullhead catfish (*Ameiurus nebulosus*), rudd (*Scardinius erythrophthalmus*), gambusia (*Gambusia affinis*) and koi carp (*Cyprinus carpio*), with some koi carp/goldfish hybrids.

As part of the ongoing research of the invasive fish research programme, run by the Centre for Biodiversity and Ecology Research (CBER), current baseline values for species abundance and indigenous biodiversity need to be established for at least 5 Waikato lakes over 5 ha in size, with Lake Ngaroto selected as a candidate. On 2 February 2009, we conducted twelve 10-min (nominal) fishing shots comprising eleven shoreline shots and one mid-lake shot with the electrofishing boat. Water quality of Lake Ngaroto had not improved since the previous survey in 2001 (unpublished Environment Waikato data) as high levels of suspended solids (0.411 mg mL^{-1}), low Secchi depths (0.4 m compared to 0.59 m in 2001), high levels of both N and P (similar to levels seen in 2001) and high levels of chlorophyll *a* (33.3 µg L^{-1}) were observed.

193 fish (31.6 kg biomass) were caught in 2,443 lineal m (0.9772 ha) including two native and six introduced species. The native fish community sampled by boat electrofishing in Lake Ngaroto was less diverse compared to a previous fyke net study (Hicks et al. 2001), as no common smelt or longfin eels were captured, whereas the introduced fish community was more diverse. In 2001, brown bullhead catfish were the most abundant species and goldfish, koi and gambusia were in low densities, whereas in 2009 low numbers of catfish and higher numbers of goldfish, koi and gambusia were found. These differences can largely be attributed to differences in sampling methods. Fyke nets are biased towards catfish and eels whereas boat electrofishing is biased towards koi and goldfish. Goldfish were the most abundant species caught by boat electrofishing with an average density of 0.55 fish 100 m^{-2}. Rudd and gambusia were also relatively abundant with average densities of 0.38 and 0.34 fish 100 m^{-2}. Goldfish, rudd and gambusia were most abundant, but fish biomass was dominated by koi carp and shortfin eels, with biomasses of 2.03 g m^{-2} and 0.56 g m^{-2} respectively. Almost 60% of the total biomass was koi carp (18.4 kg), compared to rudd (4% of total biomass), goldfish (7%) and gambusia (<0.1%) were lower. Shortfin eels comprised 15% of the total biomass. Although the average biomass of koi carp caught by the electrofishing boat in Lake Ngaroto (2.03 g m^{-2}) is much lower than in the main channel of the Waikato River between Hamilton City and Rangiriri (14.8 to 30.8 g m^{-2}; Hicks et al. 2005), it is still of ecological concern as they would have a deleterious impact on the aquatic habitat of the lake (Roberts & Ebner, 1997).

The total benthivorous fish biomass (60-90 kg ha^{-1}) is between 50 and 150 kg ha^{-1}, suggesting a moderate prospect for water quality improvement if these fish are removed.

1. Introduction

Lake Ngaroto has a diverse fish fauna of both native and introduced fish. In 1977, the fish present in the lake consisted of goldfish (*Carassius auratus*), common bullies (*Gobiomorphus cotidianus*), brown bullhead catfish (*Ameiurus nebulosus*) and eels (Chapman & Boubée, 1977). Hicks et al. (2001) caught 4,317 fish with a combination of fyke nets, gill nets and beach seining in seven sites around Lake Ngaroto between 21 and 29 August, 2001. The most abundant fish species during this time period were brown bullhead catfish, rudd (*Scardinius erythrophthalmus*), and shortfinned eels (*Anguilla australis*). A few goldfish, longfinned eels (*Anguilla dieffenbachii*), common bullies, one common smelt (*Retropinna retropinna*), one gambusia (*Gambusia affinis*) and one koi carp (*Cyprinus carpio*) were also captured in their midwinter sampling.

As part of the ongoing research of the invasive fish research programme, run by the Centre for Biodiversity and Ecology Research (CBER), current baseline values for species abundance and indigenous biodiversity need to be established for at least 5 Waikato lakes over 5 ha in size. This information is necessary for future work on estimating the response of pest fish to different control measures, and the response of lake trophic state and indigenous fish biodiversity to pest fish removal. One objective of the freshwater restoration OBI programme is to remove pest fish from 5 lakes in the Waikato area of over 5 ha in area. The costs of removal, reductions of pest fish biomass and recovery of indigenous biodiversity need to be quantified. Lake Ngaroto may be a candidate for this project as it is over 5 ha and there are currently a range of monitoring programmes and lake restoration activities that have been operating. The objectives of the report are to establish current estimates of invasive and native fish abundance in Lake Ngaroto prior to any mass harvest of pest fish which may occur in the near future.

2. Methods

Electric fishing was undertaken using a 4.5-m long, custom-made electric fishing boat. The boat has a rigid aluminium pontoon hull with a 2-m beam, and is equipped with a 5-kw gas-powered pulsator (GPP, model 5.0, Smith-Root Inc, Vancouver, Washington, USA) which is powered by a 6-kilowatt custom-wound generator. Two anode poles, each with an array of six electrode droppers, created the fishing field at the bow, with the boat hull acting as the cathode.

Electrical conductivity and temperature were measured with a YSI 3200 conductivity meter. The measured conductivity was then used to calculate the settings on the GPP which resulted in the lake being fished with the GPP set to low range (50-500 V direct current) and a frequency of 60 pulses per second. We adjusted the GPP to 50% of range to give an applied current of 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 with an approximate width of 4 m, 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 boat's global positioning system. Water clarity was measured using a Secchi disc, where the clarity is determined by the depth the Secchi disc reaches before it can no longer be seen.

On 2 February 2009, we conducted 12 fishing shots of about 10 min (ranging from 8.9-12.5 min) comprising eleven shoreline shots (all trails except Trail 4) and one mid-lake shot (Trail 4) between 10:00 and 14:30 h NZ Daylight Saving Time (Figure 1). All introduced fish were removed and humanely killed, whereas all native fish were counted, measured for length and weight, and returned to the lake.

3. Study Site

Lake Ngaroto is the largest of the Waipa peat lakes. It is located 19 km south of Hamilton City and 8 km north-west of Te Awamutu (NZMG E 2711300, NZMG N 6358500). The lake has a surface area of approximately 108 ha, an average depth of less than 2 m, and a maximum depth of 4 m (Boubée, 1977; Lowe & Green, 1987).

Lake Ngaroto has been detrimentally affected by agricultural development in its catchment (Lowe & Green, 1987; Selby & Lowe, 1992). The lake has poor water quality and is classed as a hypertrophic lake. Water quality monitoring of Lake Ngaroto by Environment Waikato between 1995 and 2001 found very high levels of nutrients (average nutrient levels of 118 mg P m^{-3} and 1900 mg N m^{-3}), toxic cyanobacterial blooms during summer months, low water clarity (average Secchi depth of 0.59 m) and high levels of suspended sediment (Environment Waikato, unpublished data). No submerged aquatic vegetation was recorded in the last vegetation survey in 2003 by the National Institute of Water and Atmospheric Research (Edwards et al., 2007).

Restoration projects were started in 1995 by the Waipa District Council and included the creation of areas of land around the lake which could be fenced and planted. The whole lake shore has now been fenced and a significant amount of planting has occurred. Other restoration activities include the construction of a weir on the main outflow to regulate water levels, building sediment and nutrient traps on the main inflows and weed control through spraying and competition with planted native species.

The marginal vegetation of boat electrofishing sites located along the shoreline of Lake Ngaroto varied between sites dominated by pasture (Figure 2) to sites containing *Carex* species, raupo (*Typha orientalis*) and willows (Table 1; Figure 3).

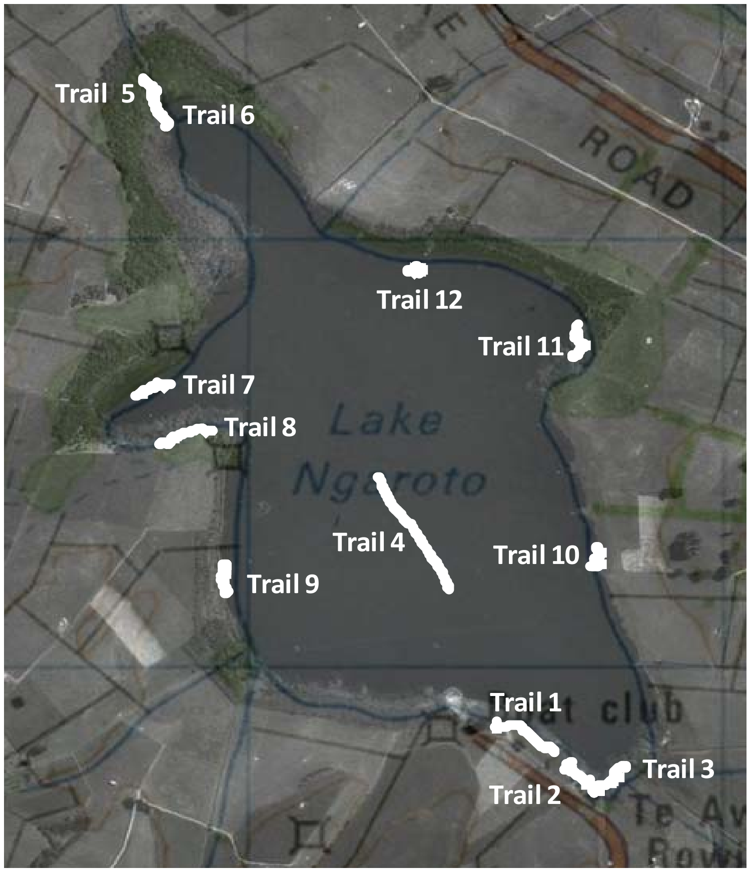

Figure 1. A topographical view of Lake Ngaroto and the locations of the twelve electrofishing trails.

Figure 2. Photo of site dominated by pasture along the shoreline of Lake Ngaroto. Photo: Brendan Hicks.

Figure 3. Photo of site containing mixture of raupo and willows. Photo: Brendan Hicks.

Table 1. Physical characterisics of sites boat electrofished in Lake Ngaroto on 2 February 2009.

Trail	Time fished (min)	Distance fished (m)	Area fished (m^2)	Habitat	Bank	Water depth (m)
1	10.5	198	794	Shoreline	Grass	0.3-0.7
2	10.1	163	653	Shoreline	Grass	0.7
3	11	205	820	Shoreline	Grass	0.3-0.8
4	10.1	312	1248	Mid lake	none	3.1-3.3
5	10	194	777	Shoreline	Willow, raupo, *Carex* spp.	0.4-1.0
6	9.9	160	641	Shoreline	Willow, raupo, *Carex* spp.	0.4-1.0
7	10.1	183	734	Shoreline	Willow	0.4-0.9
8	10.2	217	870	Shoreline	Willow, raupo	0.9-1.3
9	12.5	200	799	Shoreline	Willow, raupo	0.6-1.1
10	9.3	193	770	Shoreline	Willow, raupo, grass	0.4-0.8
11	10.2	201	802	Shoreline	Raupo, willow	0.4-0.8
12	8.9	217	867	Shoreline	Raupo	0.6-1.1

4. Results

Water temperature recorded at the start of fishing was 23.9°C, and electrical conductivity was 169.9 µS cm^{-1} ambient and 173.3 µS cm^{-1} specific. The water clarity was low with a Secchi disc reading of 0.40 m and the amount of total solids in the water was 0.411 mg mL^{-1}. Nutrient samples taken from the centre of the lake showed high nitrogen (1200 mg total N m^{-3}) and phosphorus levels (130 mg total P m^{-3}). Chlorophyll *a* was measured to be 33.3 µg L^{-1}. We also observed that numerous raupo plants along the shoreline were uprooted (Figure 4).

Figure 4. Example of uprooted raupo along the shoreline of Lake Ngaroto on 2 February 2009. Photo: Brendan Hicks.

We caught 193 fish in Lake Ngaroto comprising a biomass of 31.6 kg in 2,443 lineal m fished (0.9772 ha). The fish community comprised six introduced species (koi carp, goldfish, gambusia, brown bullhead catfish, rudd and koi-goldfish hybrid) and two native species (shortfin eel, common bully). Goldfish were the most abundant species caught as they were found at all of the sites (with the exception of trail 4) and had an average density of 0.55 fish 100 m^{-2} (Tables 2 and 3). Rudd and gambusia were also quite abundant with average densities of 0.38 and 0.34 fish 100 m^{-2}, although the number of gambusia, eels and catfish were almost certainly underestimated. This is because numerous small eels were entangled in vegetation, right at the water's edge, gambusia were less affected by the electric field than the larger species and catfish are difficult to catch in low clarity water as they tend not to float to surface once stunned. Boat electrofishing was much more successful in the edge habitat than in the mid-lake habitat as no fish were caught mid-lake (Table 2). All species with the exception of common bully and koi/goldfish hybrids displayed the highest abundance in trail 9 on a shoreline dominated by willows and raupo.

Despite goldfish, rudd and gambusia being the most abundant species, fish biomass was dominated by koi carp and shortfin eels with biomasses of 2.03 g m^{-2} and 0.56 g m^{-2}, respectively (Tables 4 and 5). Approximately 60% of the total biomass was found to be koi carp (18.4 kg), whereas rudd (4% of total biomass), goldfish (7%) and gambusia (<0.1%) were all much lower. Shortfin eels comprised 15% of the total biomass which was mainly from the large individuals found at Trails 1 and 2.

Table 2. Number of fish caught in Lake Ngaroto on 2 February 2009. Gambusia and shortfin eels were underestimated. Trail 4 is mid-lake, and all others are littoral samples.

	Number of fish								
Trail	Shortfin eels	Common bully	Rudd	Koi	Koi/Goldfish Hybrids	Catfish	Goldfish	Gambusia	Total
1	2	15	4	1	1	0	2	4	29
2	1	2	6	5	0	0	4	9	27
3	0	2	1	0	1	0	4	0	8
4	0	0	0	0	0	0	0	0	0
5	0	0	3	1	0	0	3	0	7
6	5	0	3	3	1	1	1	8	22
7	3	1	0	0	1	0	8	0	13
8	0	0	0	1	0	1	2	0	4
9	7	2	7	5	0	3	13	8	45
10	1	0	5	2	0	0	1	0	9
11	2	0	3	3	0	1	4	0	13
12	0	0	2	2	0	2	10	0	16
Total	21	22	34	23	4	8	52	29	193
Average	2	2	3	2	0	1	4	2	16

Table 3. Densities of fish species caught in Lake Ngaroto on 2 February 2009. Gambusia and shortfin eels were underestimated. Trail 4 is mid-lake, and all others are littoral samples.

	Fish density (fish 100 m^{-2})								
Trail	Shortfin eel	Common bully	Rudd	Koi	Koi/Goldfish Hybrid	Catfish	Goldfish	Gambusia	Total
1	0.25	1.89	0.51	0.13	0.13	0.00	0.25	0.51	3.66
2	0.15	0.31	0.92	0.77	0.00	0.00	0.61	1.38	4.14
3	0.00	0.24	0.12	0.00	0.12	0.00	0.49	0.00	0.98
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.39	0.13	0.00	0.00	0.39	0.00	0.90
6	0.78	0.00	0.47	0.47	0.16	0.16	0.16	1.25	3.44
7	0.41	0.14	0.00	0.00	0.14	0.00	1.09	0.00	1.78
8	0.00	0.00	0.00	0.12	0.00	0.12	0.23	0.00	0.46
9	0.88	0.25	0.88	0.63	0.00	0.38	1.63	1.00	5.63
10	0.13	0.00	0.65	0.26	0.00	0.00	0.13	0.00	1.17
11	0.25	0.00	0.37	0.37	0.00	0.12	0.50	0.00	1.62
12	0.00	0.00	0.23	0.23	0.00	0.23	1.15	0.00	1.84
Average	0.24	0.24	0.38	0.26	0.05	0.08	0.55	0.34	2.13

Table 4. Biomasses of fish species caught in Lake Ngaroto on 2 February 2009. Gambusia and shortfin eels were underestimated. Trail 4 is mid-lake, and all others are littoral samples.

	Fish biomass (g)								
Trail	Shortfin eel	Common bully	Rudd	Koi	Koi/Goldfish Hybrid	Catfish	Goldfish	Gambusia	Total
1	1276	13	150	1018	1552	0	2	2	4013
2	1320	1	171	957	0	0	134	4	2587
3	0	5	24	0	680	0	88	0	797
4	0	0	0	0	0	0	0	0	0
5	0	0	76	505	0	0	266	0	847
6	694	0	53	3595	746	73	3	1	5165
7	249	1	0	0	650	0	781	0	1681
8	0	0	0	255	0	56	126	0	437
9	538	1	198	3009	0	623	107	2	4478
10	357	0	149	3815	0	0	121	0	4442
11	418	0	257	3605	0	203	124	0	4607
12	0	0	67	1619	0	549	319	0	2554
Total	4852	21	1145	18378	3628	1504	2071	9	31608
Average	404	2	95	1532	302	125	173	1	2634

Table 5. Areal biomasses of fish species caught in Lake Ngaroto on 2 February 2009. Gambusia and shortfin eels were underestimated. Trail 4 is mid-lake, and all others are littoral samples.

	Areal fish biomass (g m^{-2})								
Trail	Shortfin eel	Common bully	Rudd	Koi	Koi/Goldfish Hybrid	Catfish	Goldfish	Gambusia	Total
1	1.61	0.02	0.19	1.29	1.96	0.00	0.00	0.00	5.07
2	2.02	0.00	0.26	1.47	0.00	0.00	0.21	0.01	3.97
3	0.00	0.01	0.03	0.00	0.83	0.00	0.11	0.00	0.97
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.10	0.65	0.00	0.00	0.34	0.00	1.09
6	1.08	0.00	0.08	5.62	1.17	0.11	0.00	0.00	8.07
7	0.34	0.00	0.00	0.00	0.89	0.00	1.07	0.00	2.30
8	0.00	0.00	0.00	0.29	0.00	0.06	0.15	0.00	0.50
9	0.67	0.00	0.25	3.76	0.00	0.78	0.13	0.00	5.60
10	0.46	0.00	0.19	4.94	0.00	0.00	0.16	0.00	5.75
11	0.52	0.00	0.32	4.48	0.00	0.25	0.15	0.00	5.73
12	0.00	0.00	0.08	1.87	0.00	0.63	0.37	0.00	2.94
Average	0.56	0.00	0.12	2.03	0.40	0.15	0.22	0.00	3.50

There was a large range in the sizes of goldfish caught ranging from 34 to 231 mm. The length-frequency distribution (Figure 4) shows that at least four different size classes of goldfish are present. Recruitment and survivorship of juvenile goldfish is occurring successfully as there was an abundance of juveniles. Rudd ranged from 98 to 202 mm and at least two size classes were present, although the majority of these fish were one-year olds (Figure 5). There was also a wide range of size classes of koi carp ranging from 60 to 470 mm (Figure 6). Recruitment and survivorship of koi carp is successfully occurring with relatively similar numbers in all size classes. Figure 7 shows that there was also a wide size range of shortfin eels (245 to 838 mm total length). The number of small eels is most likely an underestimate of the true population density as capture probability by the electrofishing boat is lower than other fish species such as koi carp.

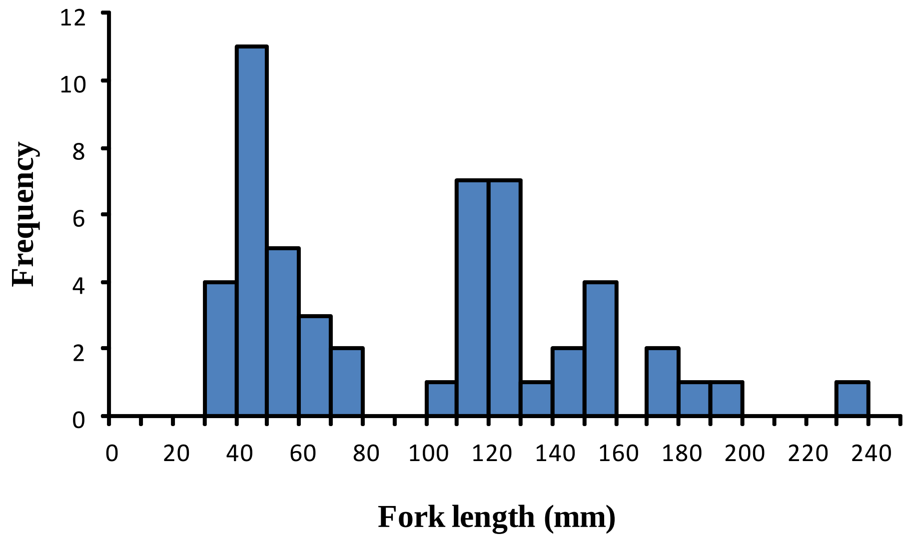

Figure 5. Length-frequency distribution of goldfish caught by boat electrofishing on Lake Ngaroto on 2 February 2009. *N* = 52.

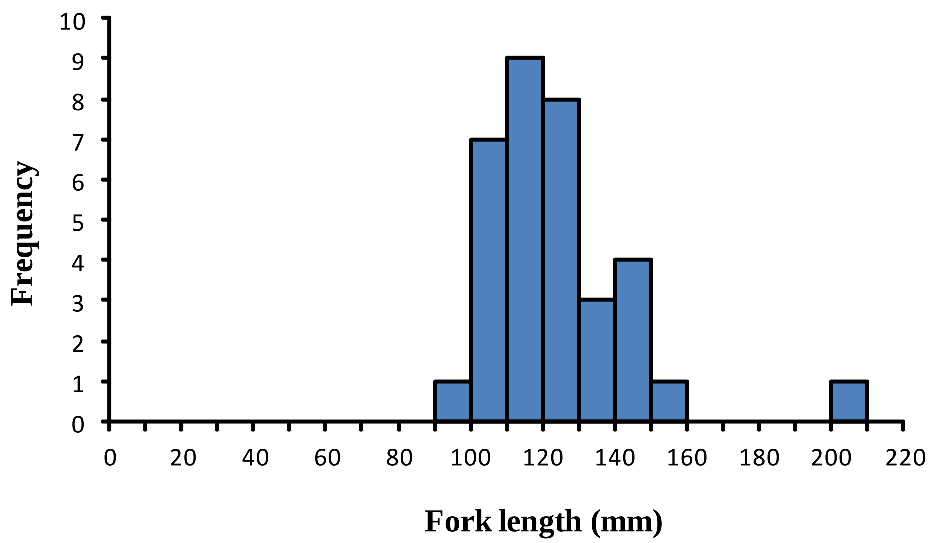

Figure 6. Length-frequency distribution of rudd caught by boat electrofishing on Lake Ngaroto on 2 February 2009. *N* = 34.

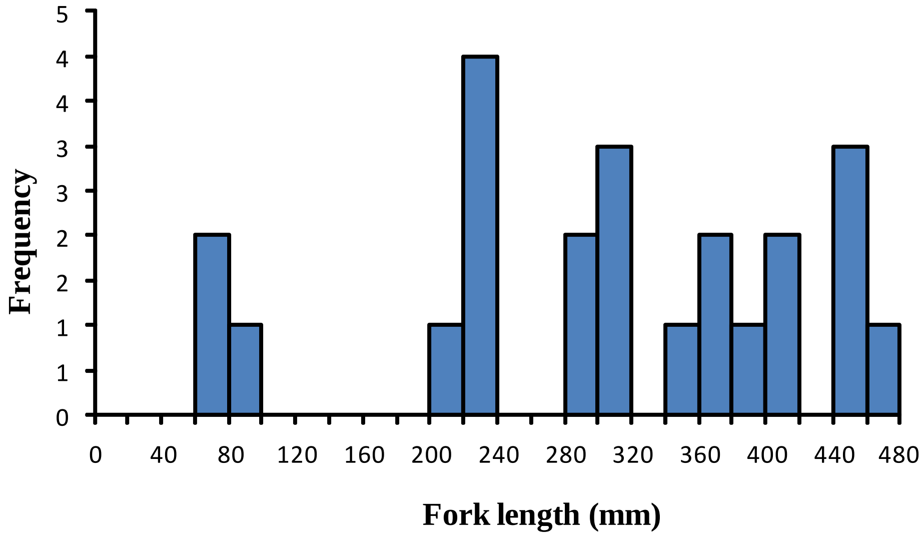

Figure 7. Length-frequency distribution of koi carp caught by boat electrofishing on Lake Ngaroto on 2 February 2009. *N* = 23.

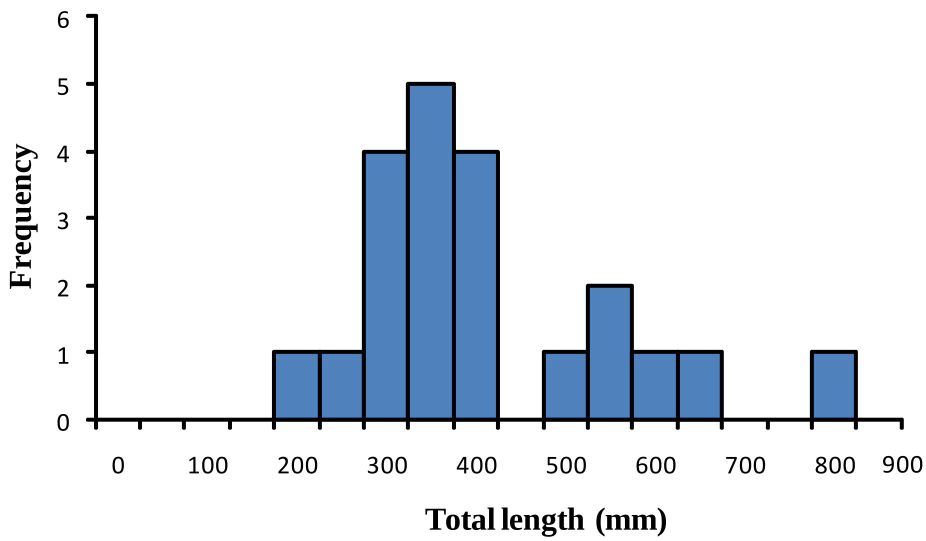

Figure 8. Length-frequency distribution of shortfin eel caught by boat electrofishing on Lake Ngaroto on 2 February 2009. *N* = 21.

We are beginning to learn about the biases of boat electrofishing compared to netting. In Lake Ngaroto in 2001, catfish dominated fyke net catches (mean 63 fish net^{-1} 24 h^{-1}) and rudd dominated gill net catches (mean catch rate 52 fish 100 m^{-1} net 24 h^{-1}; Hicks et al. 2001). Goldfish were rare in fyke nets (2 caught in 70 net sets), only slightly more abundant in gill nets (mean 5.6 fish 100 m^{-1} net 24 h^{-1}). Boat electrofishing in the current study, on the other hand, caught mostly goldfish (0.55 fish 100 m^{-2}; Table 4) and relatively few catfish (0.08 fish 100 m^{-2}; Table 4).

A comparison of boat electrofishing and fyke netting in nearby Lake Mangahia, a 10-ha peat lake, 10 km to the north of Lake Ngaroto, showed a clear bias of boat electrofishing towards goldfish and fyke netting was biased towards catfish and eels (Table 6).

Table 6. Mean catch per unit effort in Lake Mangahia from fyke netting on 25 Aug 2009 (10 nets set overnight) and boat electrofishing on 4 February 2009 (10 ten-minute shots covering 3,673 m^2 in total).

Species	Fyke netting		Boat electrofishing	
	Fish net^{-1} $night^{-1}$	kg net^{-1} $night^{-1}$	Density (number 100 m^{-2})	Biomass (g m^{-2})
Catfish	39.8	8.4	0.82	1.76
Shortfin eel	8.2	5.2	0.67	2.49
Longfin eel	3.3	5.2	0.06	0.76
Goldfish	1.8	0.6	13.72	7.88
Rudd	0.2	0.1	0.00	0.00
Common bully	0	0.0	0.11	<0.01
Gambusia	0	0.0	0.38	<0.01
Total	53.3	19.4	15.74	12.90

5. Conclusions

A few previous studies (Chapman & Boubée, 1977; Hicks et al. 2001) have shown that Lake Ngaroto contains a diverse fish fauna of both native (common bully, shortfin eel, longfin eel and common smelt) and introduced fish species (goldfish, catfish, rudd, gambusia and koi carp). The native fish community present in Lake Ngaroto on 2 February 2009 was less diverse compared to what was found in 2001 as no common smelt or longfinned eels were captured, but the introduced fish community was more diverse with the addition of the koi/goldfish hybrids. Hicks et al. (2001) found that brown bullhead catfish were the most abundant species, comprising over 70% of the total catch. In the current survey, catfish comprised less than 5% of the total catch, but this was most likely because of differences in capture methods. Boat electrofishing is biased towards goldfish, and koi carp if they are present, whereas fyke nets are biased towards catfish and eels (Table 6).

All the introduced fish species found in Lake Ngaroto in 2001 (Hicks et al., 2001) were still present in 2009. Comparisons between densities of introduced fish species in 2001 and 2009 cannot be made as different sampling methods were utilised. The high productivity of Lake Ngaroto may be reflected by the presence of introduced fish species such as goldfish, koi carp, koi/goldfish hybrid and catfish which all prefer highly productive habitats, and are very tolerant to poor water quality. The excretion and bioturbation of koi carp during feeding in bottom sediments has been shown to increase rates of nutrient cycling (Crivelli, 1983; Roberts et al., 1995; Zambrano et al., 1999; Barton et al., 2000; Zambrano et al., 2001). Species such as goldfish and catfish have a similar feeding mechanism to koi carp and thus could also be contributing to nutrient cycling.

Despite goldfish, rudd and gambusia being the most abundant species captured by the electrofishing boat in 2009, fish biomass was dominated by koi carp, which comprised of over 60% of the areal biomass. Biomass is a more accurate reflection of the potential ecological impact of koi carp than their density. Although the average biomass of koi carp caught by the electrofishing boat in Lake Ngaroto (20.3 kg ha^{-1}) is much lower than that found in the main channel of the Waikato River between Hamilton City and Rangiriri (148 to 308 kg ha^{-1}; Hicks et al. 2005), it is still of ecological concern as they would have a deleterious impact on the aquatic habitat of the lake (Roberts & Ebner, 1997).

There is a well established population of goldfish in Lake Ngaroto with successful recruitment and survivorship of juveniles occurring, which can be seen by the presence of at least four size classes. The size-frequency of shortfin eels captured during this survey is very similar to the 2001 survey with the eels ranging between 200 and 850 mm with a modal size of approximately 400 mm. There was a wide size range of koi carp ranging from 60 to 470 mm suggesting that successful recruitment is occurring in the lake.

The captured biomass of introduced benthivorous fish (29 kg ha^{-1}) probably represents a total benthivorous fish biomass of 60-90 kg ha^{-1} using the correction factor of Hicks et al. (2006). This is between 50 and 150 kg ha^{-1}, which Hosper and Meier (1993) suggest gives a moderate prospect of water quality improvement if these fish are removed.

6. Acknowledgements

We gratefully acknowledge the assistance in the field from Dudley Bell, Warrick Powrie and Kerry Barker from the University of Waikato. This study was funded by FRST contract UOWX0505.

7. References

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