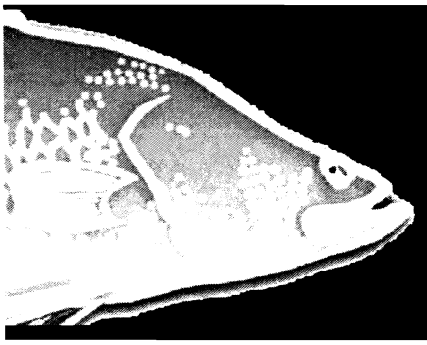

Quantitative estimates of fish abundance from boat electro-fishing

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Abstract

Multiple removals by boat electro-fishing were used to estimate fish populations in non-wadeable habitats in New Zealand lakes and rivers. Mean capture probability was 0.47±0.10 (± 95% CI) from 35 population estimates made with 2-7 successive removals. The relationship between the population estimate from the Zippin method (*Y*) and the number of fish caught in the first removal (*X*) was significant (adjusted r^2=0.84, P<0.001; Figure 2). The least-squares regression was $Y = 1.55\ X^{1.23}$. Mean density ± 95% confidence interval for 13 fishing occasions was 30±27 fish 100 m^{-2}. Mean biomass of fish for sites was 78±39 g m^{-2} (range 29 to 245 g m^{-2}). Koi carp comprised the largest proportion of the fish biomass wherever they were present. The high biomasses of koi carp estimated in these results (mean 56±33 g m^{-2}) suggest that they can reach problematic abundances in New Zealand. Biomass of spawning koi carp can exceed 400 g m^{-2}.

Introduction

Passive capture techniques such as gill and trap nets have been used to capture a wide variety of fish species in shallow New Zealand lakes (e.g. Hayes, 1989), but they have the limitation that the area sampled is generally unknown. Thus any inferences that can be made about fish abundance relate only to relative abundance and not to estimates of absolute abundance. The objective of our study was to make quantitative estimates of fish abundance in non-wadeable habitats with removal population estimates from boat electro-fishing. Further, we sought to establish the relationship between the first removal and the total population estimate.

Previous studies have used multiple-removal boat electro-fishing (e.g., Meador 2005), and Mitro and Zale (2000) compared first removals to multiple removal population estimates. Jowett and

Richardson (1996) used electro-fishing to compare first-removal catches to population estimates in wadeable streams and rivers. Bayley and Austen (2002) estimated capture efficiency from comparisons of boat electro-fishing and independent population estimates by a combination of toxicants, explosives, and draining. One study used multiple removal boat fishing to estimate fish biomass directly, without first calculating density (Thompson et al., 2002).

Methods

We fished with a 4.5-m long electro-fishing boat. The boat had a rigid aluminium pontoon hull with a 2-m beam, and was fitted with a 6-kilowatt Honda-powered custom-wound generator and a 5-kilowatt gas-powered pulsator (Smith-Root, Inc., model 5.0 GPP); two anode poles created the fishing field at the bow. The pulsator emitted pulses of direct current at a frequency of 60 pulses per second, and the power output was normally 2-4 amps root mean square. The two adjustable anode arrays each had 1-m long stainless steel rat tails that dangled in the water, and the boat hull itself acted as the cathode. We estimated the length and area fished with a boat-mounted global positioning system (Lowrance GlobalMap® 2400). We assumed from the reactions of fish that were observed to undergo forced swimming at the surface that the effective fishing width of the field was 4 m, and we used this width to estimate the area fished.

To estimate fish population size, we tallied the fish from each of 2-7 successive removals separately, fishing without replacement. We calculated the population size and capture probability for two removals using the Zippin method (e.g. Hicks 2003). For three removals or more, we used the programme CAPTURE (White et al., 1982). Length fished ranged from 53 to 987 m (mean 312 m), and area ranged from 212 to 3948 m^2 (mean 1578 m^2). The study sites were all located in the North Island of New Zealand (Figure 1).

Results

We caught five native and seven introduced fish species at the eight sites fished (Table 1). In general, we caught all species present at any site on the first removal, and species richness did not increase with subsequent removals. Mean capture probability calculated from 35 population estimates was 0.47±0.10 (± 95% CI). Capture probabilities varied with fish species; koi carp generally had the highest capture probabilities (generally >0.5).

The relationship between the population estimate from the Zippin method (Y) and the number of fish caught in the first removal (X) was significant (adjusted r^2=0.84, N=35, P<0.001; Fig. 2). The least-squares regression was

$$Y = 1.55\,X^{1.23} \quad \text{equation 1.}$$

Mean density ± 95% confidence interval for 13 fishing occasions was 30±27 fish 100 m^{-2}. Mean biomass of fish for sites was 78±39 g m^{-2} (range 29 to 245 g m^{-2}). Mean koi carp weight was 357-3657 g, which implies a non-spawning biomass range for koi carp of 13.4-163.5 g m^{-2} (mean 56±33 g m^{-2}).

Koi carp reached huge biomasses in the shallow lakes and wetlands of the Waikato region during spawning. In Lake Whangape in September 2003, we caught 24 koi carp in 696 m^2 of edge habitat in 11 mins. Total fish weight was 87 kg. Estimating total abundance from this single-pass removal with equation 1 suggests that the population estimate was 77 fish, or 11.1 fish 100 m^{-2}. As mean individual fish weight was 3645 g, this estimated density implies that the true biomass could be 403 g m^{-2}, or 4030 kg ha^{-1}.

Seasonal abundance of koi carp in the outlet of the Kimihia Wetland was low in October, probably as a result of movement to spawning sites in August or September (Figure 3). Water clarity was generally poor; black disc (Davies-Colley 1988) ranged from 0.2-1.9 m.

Conclusion

Capture probabilities that we estimated from boat electro-fishing (mean 0.47±0.10, 95% CI) were somewhat lower than those for native fish species and brown trout in wadeable streams (range 0.54-0.86; Jowett and Richardson 1996). Water clarity was often poor in our study, which may account for our lower capture probabilities. In addition, water depth was 1-3 m, and fish that did not float on immobilisation may have remained unseen.

In the USA, catchability has been estimated by comparison of boat electro-fishing with independent population estimates by toxicants, explosives, and draining. The proportion of fish caught by electro-fishing was species and size dependent, with maximum catchability for each species about 0.03 to 0.08 in the presence of macrophytes, and 0.08 and 0.16 without macrophytes (Bayley and Austen 2002). Whether our capture probability truly represents catchability, in the sense of Bayley and Austen (2002), remains to be tested. We intend to combine mark-recapture with removal methods to carry out this test.

Where numerous fish species are present, multiple removal boat electro-fishing can be useful to fully characterise fish assemblages (Meador, 2005). The effectiveness of fishing was greatest when species richness was low (about 10 species), as was the case in our study, where a maximum of 8 species were caught at any site.

In our boat electro-fishing, the estimated population increased dramatically as number caught in the first removal increases. When $X = 5$, equation 1 predicts that $Y = 11$ (2.2 times the number caught in the first removal). However, when $X = 500$, $Y = 3236$, or about 6.5 times the first removal. Catchability of largemouth bass (*Micropterus salmoides*) sampled with boat electro-fishing also declined with increasing density (McInerny and Cross 2002). In wadeable habitats, this problem is less severe. The true population density (Y) has been estimated as

$$Y = 1.96\,X^{1.028} \text{ equation 2,}$$

where X = number of fish caught in the first removal for a number of native and introduced New Zealand fish species. This means that about half the fish present will be caught on the first pass almost regardless of the magnitude of the first removal. Reworking the results of Hayes and Baird (1994) for age 0 brown trout in wadeable streams yielded a remarkably similar result:

$$Y = 1.93\, X^{0.955} \text{ equation 3.}$$

Though we have yet to establish the ecological effects of koi carp in the Waikato, the high biomasses estimated in these results suggest that koi carp can reach problematic abundances in New Zealand. At the biomasses that we have estimated, koi are likely to compete with other benthic fish such as eels, bullies, and catfish, and to reduce water quality significantly.

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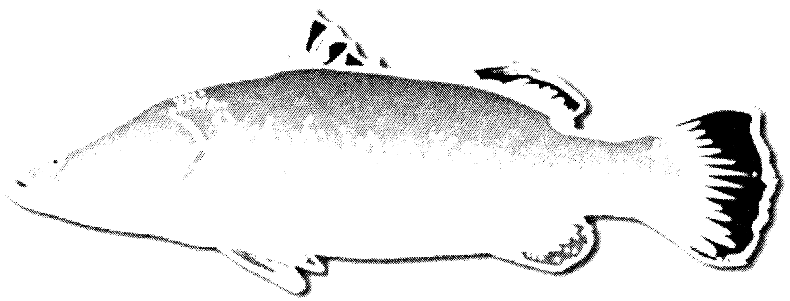
Table 1. Density and biomass of fish in lakes and rivers of the North Island, New Zealand, estimated from multiple removal boat electro-fishing

Site	Date	Common smelt	Common bullies	Grey mullet	Inanga	Shortfin eel	Catfish	Goldfish	Grass carp	Koi carp	Mosquitofish	Rainbow trout	Rudd	*N* removals	Length fished (m)	Area fished (m^2)	Density (fish 100 m^{-2})	Biomass (g m^{-2})
Huntly side channel, Waikato River	19 May 2004			•						•				2	636	2544	11	31
Kimihia Stream, Waikato River	29 Jan 2004							•		•			•	2	183	1281	21	175
Kimihia Stream, Waikato River	5 May 2004									•				4	167	1169	17	62
Kimihia Stream, Waikato River	8 Oct 2004									•				3	173	1730	7	83
Kimihia Stream, Waikato River	23 Jun 2005	•	•	•	•	•	•	•		•				3	196	1427	97	33
Lake Waiwhakareke, Waikato, site 1	13 May 2005					•								4	53	212	154	228
Lake Waiwhakareke, Waikato, site 2	13 May 2005						•							2	987	3948	2	17
Mokoia Pond, southern Taranaki	9 June 2005									•				7	215	951	2	62
Muddy Creek, Hawke Bay	6 Nov 2003								•					2	370	2959	2	125
Waikato River near Kimihia Stream	10 May 2004	•	•	•						•	•			3	264	1056	26	41
Waikato River near Kimihia Stream	8 Oct 2004									•				2	410	1640	5	99
Waikato River, Pukete	24 May 2005									•				4	199	796	16	35
Waikato River, Pukete	26 May 2005		•	•		•		•		•		•	•	5	199	796	33	29

Species identification Native species: common smelt (*Retropinna retropinna*), common bullies (*Gobiomorphus cotidianus*), grey mullet (*Mugil cephalus*), inanga (*Galaxias maculatus*), shortfin eel (*Anguilla australis*). Introduced species: catfish (*Ameiurus nebulosus*), goldfish (*Carassius auratus*), grass carp (*Ctenopharyngodon idella*), koi carp (*Cyprinus carpio*), mosquito fish (*Gambusia affinis*), rainbow trout (*Oncorhynchus mykiss*), rudd (*Scardinius erythrophthalmus*).



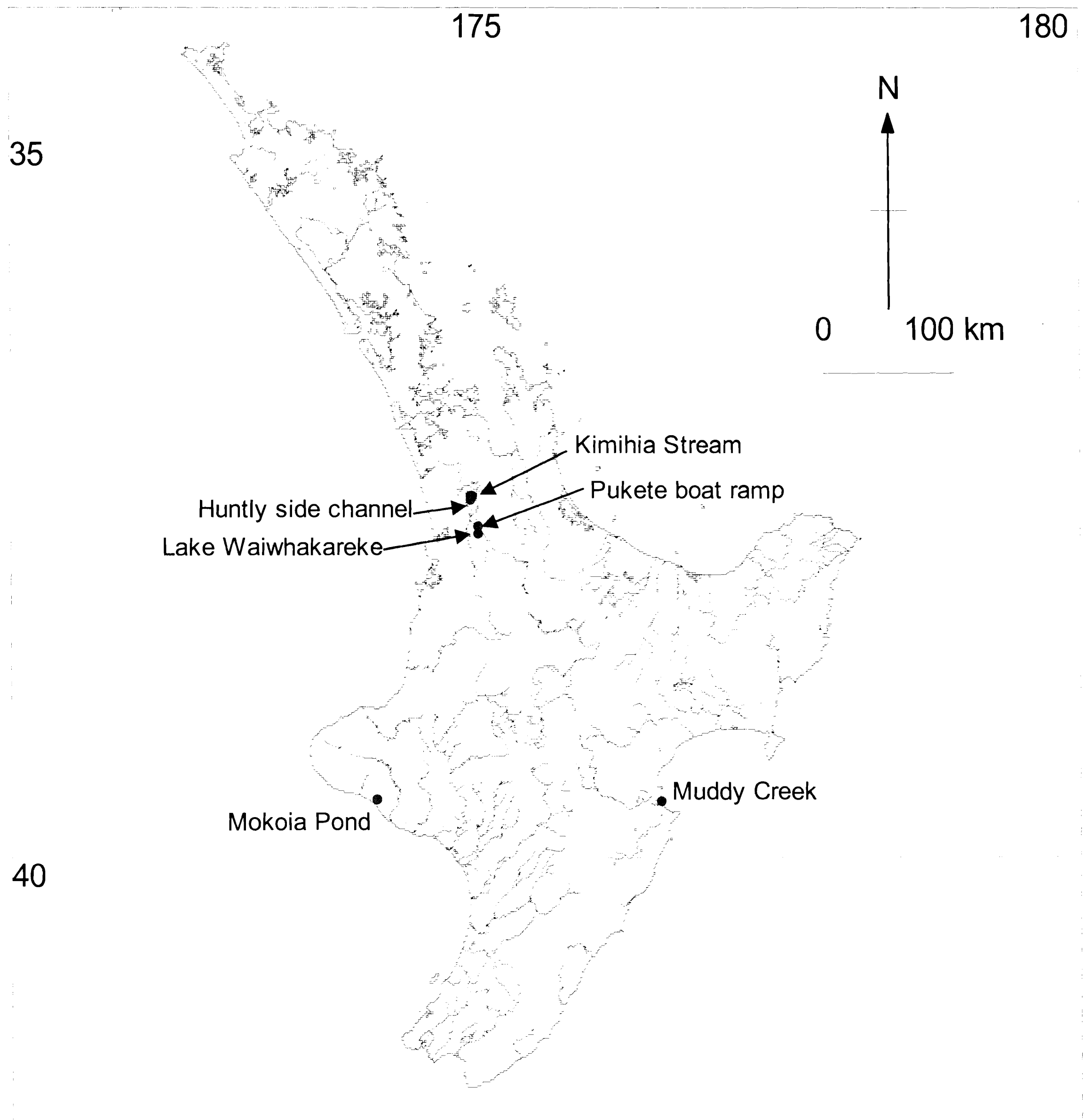


Figure 1. Location of study sites in the North Island of New Zealand

A Guide to Monitoring Fish Stocks and Aquatic Ecosystems

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