4.4 Use of Electrofishing for Capturing Invasive Fish

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Background

Electrofishing is the use of electricity to capture fish. The response of fish to pulsed direct current (DC) occurs in five phases, as shown in Figure 4.5. Electrotaxis occurs as a result of the electrical effect on fish muscles that contract with each electrical pulse, rather than its effect on the central nervous system. Each pulse of electrical current in a pulsed DC field causes the fish's body to flex; it then relaxes between each of the pulses. This flexing and straightening action accentuates the involuntary swimming towards the anode (galvanotaxis). Pulsed DC causes tetany and narcosis at a much lower voltage gradient than continuous DC, so this is the preferred current delivery (Brousseau *et al*. 2005). Because invasive fish species inhabit a wide variety of non-wadeable habitats, this chapter will focus on boat electrofishing.

New Zealand has a light-handed approach to the regulation of electrofishing. Users are required to inform those responsible for fish conservation and management of the existence of devices, and when and where electrofishing is to occur. Electrofishing devices must be authorised by the Director General of the Department of Conservation, and authority is required from the Fish & Game council for use of an electrofishing machine in a specific region under the Freshwater Fisheries Regulations 1983. Under the Fisheries Act 1996, permission is required from the Ministry for Primary Industries (MPI) for the capture of fish by methods other than those allowed by recreational fishing regulations. Capture of fish by electrofishing, though legal as a research tool, is not a permitted recreational method and thus requires a special permit from MPI issued under s97 of the Fisheries Act 1996. Ethical considerations for the capture and handling of fish fall under the Animal Welfare Act 1999, and are usually administered at institutional level.

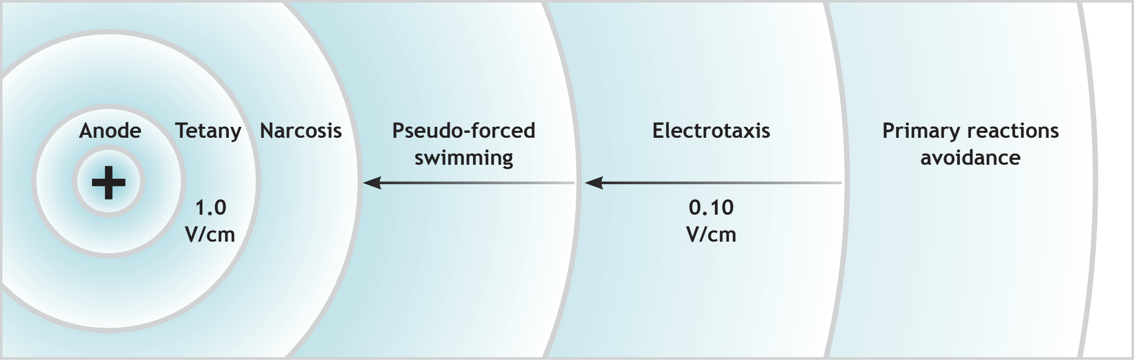

FIGURE 4.5 Generalised behaviour patterns of fish in pulsed direct current with approximate voltage gradient thresholds of fish (Lamarque 1967). Adapted from Vibert (1963).

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Electrofishing Boat

BOAT OPERATION: Currently, the only electrofishing boat in New Zealand is run by The University of Waikato (Plate 4.10). Their boat was built in 2003 based on the experience of Australian fishery researchers. It comprises a custom-built, 4.5 m long, 2.0 m beam, aluminium hull of pontoon design with a 6° V-shape to improve handling in choppy water (Orca Engineering and Marine Ltd, Rotorua, New Zealand). The boat electrofishing gear consists of a 5 kilowatt petrol-powered pulsator (GPP model 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 1 m long stainless steel wire droppers, create the fishing field in front of the bow, with the boat hull acting as the cathode. For standard operation in boat electrofishing, the pulsator is set to low range (50–500 V) or high range (50–1000 V), depending on the ambient electrical conductivity of the water, with pulsed direct current and a frequency of 60 Hz (pulses per second). The range of conductivity in which electrofishing is generally effective is about 50–500 µS/cm, which includes most lowland waters in New Zealand, although fishing habitats with up to 2,800 µS/cm (Muddy Creek, Hawkes Bay, in 2003) has been successful. The percent-of-range setting of the pulsator is adjusted to give a consistent applied current of 3–4 amps root mean square, adjusting the setting as necessary as the boat travels through water of different ambient conductivity.

From past experience (Hicks *et al*. 2006) an effective fishing field in which fish are immobilised equates to >1 V/cm. Fish affected by the field at depth (1–2 m below the surface) often float to the surface, still narcotised, beside the boat. Combined with the reach of the netters, the effective fishing field extends to about 2 m either side of the centre line of the boat (Figure 4.6), and the boat therefore fishes a transect 4 m wide, which is generally consistent with behavioural reactions of fish at the water surface. The boat's fishing path is tracked and linear distance fished estimated with a hand-held Garmin GPSMAP 60Cx global positioning system. The area fished is calculated by multiplying this length by the assumed width of the fishing field (i.e. 4 m).

PLATE 4.10 The 4.5 m long, aluminium-hulled electrofishing boat developed by The University of Waikato in 2003, showing the anode poles at the bow, the generator at stern positioned under the boat driver's seat, and fibreglass-handled dip nets for retrieving fish.

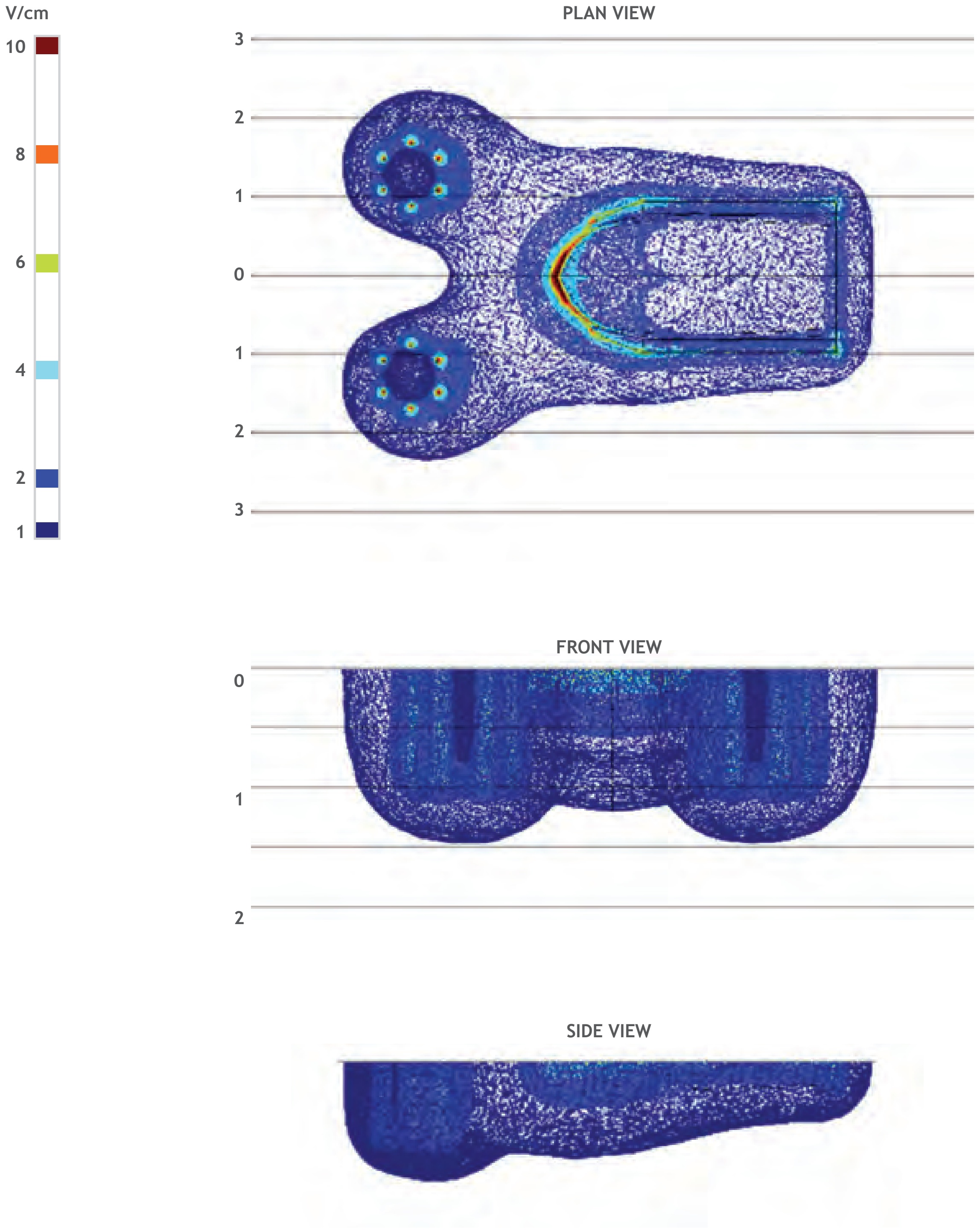

FIGURE 4.6 Simulated isosurface plot of voltage gradients ≥1 V/cm around The University of Waikato's electrofishing boat. The boat has bow-mounted anodes of two hexagonal drop-tail clusters (1 m drop) and a pulsator output of 500 V peak output drawing 5.0 A root mean square in water with ambient conductivity of 170 µS/cm. Source: Jones (2010).

PELAGIC ELECTROFISHING WITH SCOOP NETS: To maximise effort for pelagic species fine-meshed scoop nets were added to the electrofishing boat. These were aluminium-framed whitebait nets constructed from hexagonal polyester mesh (2 mm) and an ovoid mouth opening area of 0.79 m^2. These nets are deployed from the bow of the boat with a hinged, T-shaped attachment, with each scoop net positioned behind an anode (Plate 4.11).

PLATE 4.11 The first author (right) lowering fine-meshed scoop nets into position to fish for pelagic species.

HEALTH AND SAFETY: To address safety concerns, the boat's emergency shutdown circuits were designed in close cooperation with the Energy Safety Service of the then Ministry of Economic Development, the electricity safety regulator at the time. Two fishers at the bow are required because each has a foot switch, both of which must be depressed to activate the fishing field. The fishing crew wears rubber footwear and rubber gloves to insulate against possible electroshock. A cardiac defibrillator is a standard piece of equipment on board the boat for first aid in the event of an electrical accident.

EFFECTS OF WATER CLARITY AND VISIBILITY: The effectiveness of electrofishing is directly dependent on water clarity because in general fish have to be seen to be caught by the netters. A vertical Secchi disc depth measurement is the usual way of measuring water clarity from the surface (Tyler 1968; Preisendorfer 1986), but has the limitation that in some shallow habitats the bed is visible before the critical Secchi disc depth occurs. Horizontal black disk distance measurements provide a practical alternative to Secchi disc depths, and have a well-established relationship (Davies-Colley 1988). Before each boat electrofishing occasion we measure black disk distance to quantify the contribution of water clarity to the effectiveness of boat electrofishing. In lowland aquatic habitats, most black disc distances during electrofishing have ranged from 0.2 to 1.9 m.

Quantitative Fish Abundance Estimates

CAPTURE EFFICIENCY: Electrofishing captures only some of the fish encountered by the electric field because a proportion display the primary avoidance response before encountering the ranges of voltage gradients that produce galvanotaxis, narcosis, forced swimming or tetany (Figure 4.5). Thus, one goal of quantitative electrofishing is to estimate capture efficiency, which can be determined from comparisons of removal population estimates (Otis *et al.* 1978; White *et al.* 1982) and the number of fish caught in the first removal or pass.

Previous studies have used multiple-removal boat electrofishing, and Meador (2005) found that the first pass achieved 66% of the total species richness. Mitro & Zale (2000) compared first removals to multiple removal population estimates for the Snake River, Idaho, and found capture probabilities of 0.73–0.76. Bayley & Austen (2002) estimated capture efficiency from comparisons of boat electrofishing and independent population estimates of warm-water fishes in Illinois lakes by a combination of toxicants, explosives and drainage. They concluded that maximum catchabilities (fish capture efficiency) by taxon ranged from 0.0018 to 0.14, and also varied with fish length. One study used multiple removal boat electrofishing to estimate fish biomass directly in a Massachusetts river, without first calculating density, and concluded that total biomass equated to mean single-pass biomass in g/m^2 x 4.002 (Thompson *et al*. 2002).

For The University of Waikato boat, capture efficiency of single-pass boat electrofishing (first removal/population estimate, ± 95% confidence interval) averages 0.48 ± 0.10 (37 species' comparisons). Total population estimated from the Zippin method (Y) was significantly related to the number of fish caught in the first removal (X) (adjusted $r^2 = 0.86$, $n = 37$, $P < 0.001$; Figure 4.7). However, the relationship was non-linear for increasing number of fish in the first removals, as shown by least-squares regression converted from the log-linear form in Figure 4.7:

$$\text{Removal population estimate} = 1.87\ (\text{First removal})^{1.129} \qquad \text{(Equation 1)}$$

This relationship can be used to estimate the population size from a single pass of the electrofishing boat.

REPRESENTATIVENESS OF CATCH: The representativeness of boat electrofishing from 770 samples at sites throughout the North Island gives a unique view of fish community composition and relative abundance. On this basis, koi carp and goldfish are by far the most numerous and widespread invasive species (Table 4.5). The mean catch rates for koi carp from 205 fishing occasions in which they were found was 714 g/minute, or 0.46 fish/minute. Goldfish usually co-occur with koi carp and were more numerous (1.06 fish/minute), but had a much lower biomass because of their smaller size. Catfish and rudd were caught at fewer sites and with similar catch rates. Tench had a very restricted distribution, and were caught with koi carp on only three out of 13 fishing occasions when tench were caught. These were in the Paramuka Ponds, west Auckland, in 2007 and the Hikutaia Cut, eastern

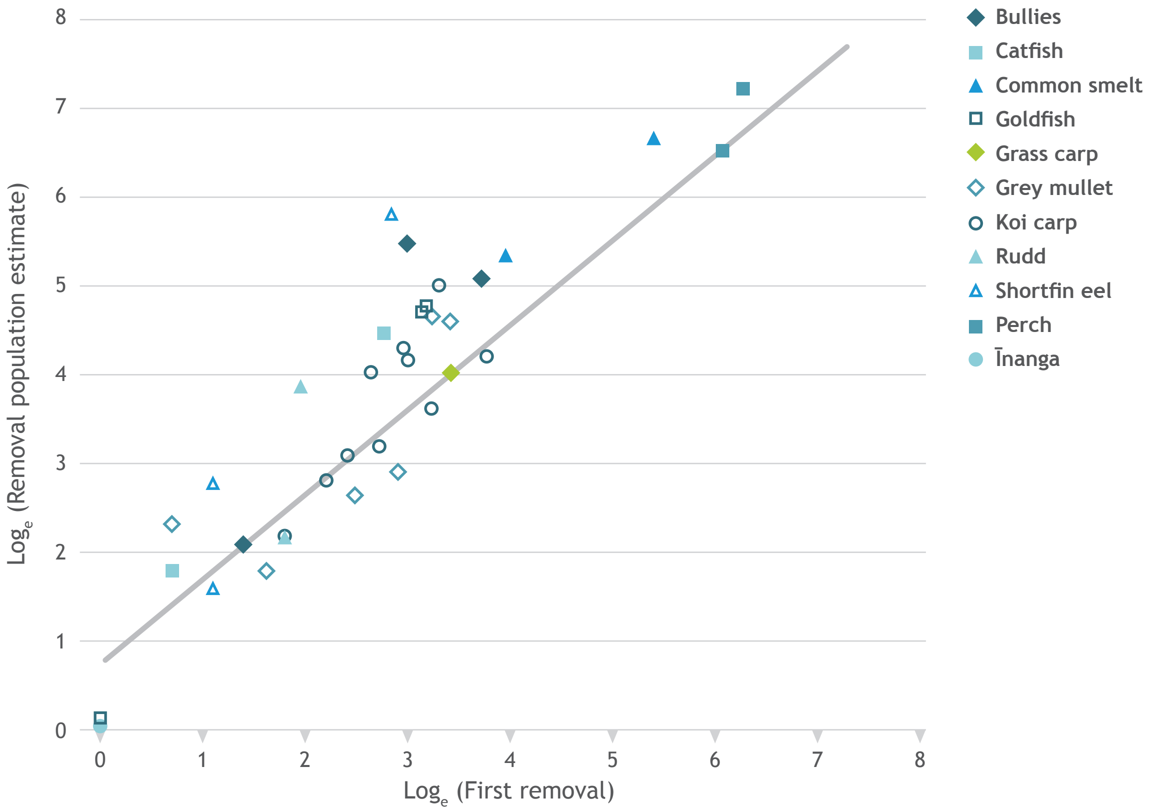

FIGURE 4.7 Relationship of first removals to population estimates from multiple-removal boat electrofishing.

Waikato, in 2003, 2006 and 2013. When the Hikutaia Cut was fished in 2014 and 2015 koi carp but no tench were caught, suggesting that the tench have disappeared. Given that tench occurred in the Whangamarino Wetland before the spread of koi carp (Strickland 1980) but no longer occur there (Hicks *et al*. 2008; Lake *et al*. 2009), koi carp appear to eventually exclude tench in the Waikato.

OPTIMISING TIME AND DURATION OF FISHING: Night fishing greatly increases catch rates of perch. In the lower Karori Reservoir, Wellington, and Lake Rotokare, Taranaki, where perch dominated the fish communities, catch rates were on average 12 times greater at night than during the day, though highly variable (Table 4.6). In Karori Reservoir, catch rates began to increase on dusk, presumably as fish moved into the shallow littoral zone and into the range of the electrofishing field (Hicks *et al*. 2007).

In Australia, fishery researchers have developed a protocol of 2-minute fishing shots, principally to fish around large woody debris (snags) in the water. Successive increases in the duration of fishing shots were evaluated by comparing mean catch rates in fish/minute for 2, 5 and 10 minute boat electrofishing shots in water of 0.8–1.5 m depth (Table 4.7). Catch rates increased with increasing time up to 10 minutes/shot. Given that 10 minutes plus handling time for each catch allows 3–5 shots/hour, we consider that 10 minutes/shot is optimal for most boat electrofishing in New Zealand. Occasionally 20 minute shots are more appropriate where replicates are less important than handling time.

TABLE 4.5 Number of sites and catch rates of key invasive fish species caught by boat electrofishing in 770 samples between July 2003 and February 2010 in the North Island.

SPECIES	N	CATCH RATE	
		(g/minute)	(fish/minute)
Koi carp	205	714	0.46
Goldfish	205	98	1.06
Catfish	115	36	0.17
Rudd	91	14	0.18
Perch	66	54	0.71
Tench	13	62	0.26

TABLE 4.6 Catch rates of perch in the lower Karori Reservoir, Wellington (20-minute shots), and Lake Rotokare, Taranaki (10-minute shots), during the day and night.

LOCATION	SITE	DATE	NUMBER OF FISH/SHOT		NIGHT/DAY
			DAY	NIGHT	
Karori Reservoir	K4	Feb 2007	230	522	2.3
	K5	Feb 2007	26	430	16.5
	K5	Feb 2007	105	430	4.1
	KD15	Feb 2008	29	115	4.0
	KD16	Feb 2008	1	31	31.0
Lake Rotokare	1/6	Feb 2013	8	125	15.6
MEAN					12.2

TABLE 4.7 Mean catch rates for boat electrofishing shots of 2, 5 or 10 minutes/shot in Lake Waahi, Waikato, during the day and 10 minutes/shot at night on 8 March 2007.

SPECIES	CATCH RATE (fish/minute)			
	2 MIN, DAY	5 MIN, DAY	10 MIN, DAY	10 MIN, NIGHT
n samples	3	3	5	6
n species	3	7	9	10
NON-INDIGENOUS SPECIES				
Goldfish	0.50	1.07	3.24	1.28
Koi carp	0.17	0.20	0.28	0.18
Rudd	0.00	0.07	0.20	0.23
Catfish	0.00	0.00	0.18	0.25
Perch	0.00	0.13	0.14	0.03
Gambusia	0.00	0.60	0.06	0.13
Grass carp	0.00	0.00	0.02	0.00
INDIGENOUS SPECIES				
Shortfin eel	0.33	0.33	1.70	1.43
Common bully	0.00	0.07	0.26	0.13
Common smelt	0.00	0.00	0.00	0.18
Īnanga	0.00	0.00	0.00	0.02
TOTAL	1.00	2.47	6.08	3.88

Fish Injuries

Electrofishing has a reputation for injuring fish and boat electrofishing is no exception. The real question, however, given that invasive fish control involves removing fish, is how injury rates for non-target species from electrofishing compare to rates for other capture methods. For instance, Reynolds & Holliman (2004) found spinal damage in 60% of 18 American eels (*Anguilla rostrata*) electrofished at 30 Hz pulsed DC, but in only 15% of 20 trap-netted eels. Haemorrhages were found in 30% of the electroshocked fish but in none of the trap-netted fish. The ambient conductivity was not given in that study.

Spinal damage was detected in only 8–12% of 25 shortfin eels (395–734 mm total length) caught with The University of Waikato electrofishing boat at 60 Hz on low range (50–500 V), compared to 0–4% of 25 trap-netted eels. Haemorrhages immediately after electrofishing were inconsistent (0% in eels from Lake Areare and 28% in eels from Lake Rotongaro, Waikato region). A possible cause of this difference was the water depth during fishing, which was c.1 m deep for Lake Areare and up to 2 m deep for Lake Rotongaro. As a consequence, the anode tails touched the lake bed during fishing in Lake Areare, which may have dissipated the electrofishing field. Recovery from haemorrhaging was rapid, as only 4% of a separate sample of eels from Lake Rotongaro had haemorrhages 30 days after electrofishing (de Villiers 2013).

Grey mullet (229–436 mm fork length), captured by boat electrofishing (*n* = 29 fish) and gill netting (*n* = 25 fish), were also analysed for injury. Spinal injury rates were 14% for boat electrofishing and 12% for gill netting, and were not significantly different. However, haemorrhaging occurred in 24% of electrofished grey mullet but only 8% of gill-netted mullet (de Villiers 2013). Common smelt (38–109 mm long), captured by boat electrofishing (*n* = 1,224 fish) and seine netting (*n* = 1,278 fish), were analysed for spinal damage, haemorrhaging and survival after a post-capture holding period of 30 minutes. Spinal injury rates were 10% for electrofished smelt and 5% for seine-netted smelt, but these rates were not significantly different. Smelt mortality after 30 minutes in 20°C aerated water following capture was 5% for electrofishing and 7% for seine netting. Haemorrhages were not detected in smelt from either capture method.

Summary

Boat electrofishing is a valuable tool for conducting population estimates of several invasive fish species because of their high catch rates, particularly for koi carp and goldfish in shallow water, but also for tench and perch. Eels and catfish, however, are under-represented in electrofishing catches compared to fyke netting (see Section 6.3). Boat electrofishing can provide rapid, quantitative estimates of fish density and biomass in non-wadeable rivers and lakes on an areal basis, and is far more efficient than other techniques such as mark-recapture. Large areas can be surveyed, which increases the representativeness of the sampling dramatically.

Electrofishing provides a unique view of the fish communities in littoral zones and shallow lakes because it has fewer biases than other capture techniques. Novel methods such as fine-mesh scoop nets extend the boat's sampling capability to pelagic fish near the surface, and lights permit night fishing which increases the catch rate of perch. Rates of spinal injury for non-target shortfin eels, grey mullet, and common smelt are similar to other capture methods that target these species, but the rate of haemorrhaging in eels and grey mullet can be greater for electrofishing. However, eels held for 30 days showed that this haemorrhaging apparently healed rapidly. The current limitation of this method is that New Zealand has only one electrofishing boat.

KOI
Photo: Nadine Gibbs (DOC)

GAMBUSIA
Photo: Denise Goodman (DOC)

TENCH
Photo: David West (DOC)