Boat electrofishing survey of fish populations in the Ohau Channel in December 2010

CBER Contract Report 124

Client report prepared for
Environment Bay of Plenty

by

Brendan J. Hicks, Ray Tana, and Dudley G. Bell

Centre for Biodiversity and Ecology Research
Department of Biological Sciences
School of Science and Engineering
The University of Waikato
Private Bag 3105
Hamilton, New Zealand

15 November 2011

Email: b.hicks@waikato.ac.nz

THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

CBER University of Waikato
Centre for Biodiversity and Ecology Research

Page

Contents

Tables

Figures

Reviewed by:

Rob Donald
Environment Bay of Plenty

Approved for release by:

Nicholas Ling
University of Waikato

Executive summary

The original purpose of this series of surveys was to apply an independent method to estimate the densities of common smelt and bullies in the Ohau Channel at fixed points along the bank which coincided with trap netting sites used by the National Institute of Water and Atmospheric Research (NIWA). Since the low number of smelt captured by a single day's boat electrofishing became apparent compared to the numbers captured by seasonal trapping, the aim of the survey has been modified to provide on-going monitoring of the fish communities and abundance in the Ohau Channel, especially fish species that are taonga to Maori (eels, goldfish, and koura).

Eleven sites were fished that averaged 317 m long (1,268 m^2 in area). These sites were numbered 1-11 from upstream (Lake Rotorua end) to downstream (Lake Rotoiti end of the channel). A total of 921 fish (22.7 kg) were collected from eleven 10 min passes in the Ohau Channel that covered a combined distance of 3,488 m (13,952 m^2 in area). Five species were present with the most abundant being common bully, followed by common smelt, rainbow trout, goldfish and longfin eel. Goldfish were most abundant in the lower channel sites 7, 8, and 10, and a single longfin eel (650 mm total length, 733 g calculated weight) was caught in edge habitat at site 8.

As reflected in total numbers, common bullies had the highest densities of any fish species (up to 21.1 fish 100 m^{-2}), the majority of which were taken from edge habitats at sites 4 and 7. However, despite these high densities, fish biomass was low (e.g., 0.099 g m^{-2} at site 4), compared to low common bully densities at site 8 which had higher biomass (0.151 g m^{-2}). These patterns reflect differences in size structure between sites. The majority of common bullies in edge habitats of site 8 tended to be larger adults compared to smaller juveniles or subadults taken from edge habitats in site 4.

Common smelt had variable densities in the Ohau Channel, the largest number of which was found in edge habitats (10.1 fish 100 m^{-2}) below the weir (site 1). Common smelt biomass was also relatively higher in the same sites. Lower smelt densities were consistently taken from edge and willow habitats in downstream sites 7-11 (ranging between 0.4-1.3 fish 100 m^{-2}), towards Lake Rotoiti.

Densities of rainbow trout in the Ohau Channel up to 2.24 fish 100 m^{-2} were measured mainly at the upper (sites 1-3) near Lake Rotorua and mid-reach sites 6-8. Biomass varied considerably between sites with the highest biomass in rainbow trout taken from edge habitats in site 1-6 (up to 4.43 g m^{-2} biomass), compared to edge habitats nearer Lake Rotoiti (sites 7-11, up to 0.29 g m^{-2} biomass). Goldfish densities were relatively low (up to 1.1 fish 100 m^{-2}), with biomass up to 2.24 g m^{-2}.

In 2010, 33% more smelt, four times more bullies, twice as many goldfish, and four times more trout were caught than in 2009. Koura (*Paranephrops planifrons*) were caught for the first time. From the timing of the smelt runs as revealed by NIWA's trapping it is clear that the single day's boat electrofishing did not coincide with the peak run, suggesting that boat electrofishing is less useful than seasonal trapping for estimating changes in common smelt abundance. This is consistent with a site-by-site comparison of boat electrofishing smelt capture with NIWA's trapping catches, which showed that trapping caught far more smelt than electrofishing (Brijs et al. 2010).

1. Introduction

Environment Bay of Plenty (EBOP) contracted the Centre for Biodiversity and Ecology Research (CBER) to conduct a survey of common smelt and common bully abundance by boat electrofishing in the Ohau Channel. Similar surveys had been previously carried out in December of 2007, 2008 and 2009 (Brijs et al. 2008, 2009, 2010). The original purpose of this series of surveys was to apply an independent method to estimate the densities of common smelt and bullies in the Ohau Channel at fixed points along the bank which coincided with trap netting sites used by the National Institute of Water and Atmospheric Research (NIWA). Since the low number of smelt captured by a single day's boat electrofishing became apparent compared to the numbers captured by seasonal trapping, the aim of the survey has been modified to provide on-going monitoring of the fish communities and abundance in the Ohau Channel, especially fish species that are taonga to Maori (eels, goldfish, and koura). In the current study we present the findings from the fourth year of sampling (2010) in view of previous year's results using boat electrofishing in the Ohau Channel.

2. Methods

We used a 4.5 m-long, aluminium-hulled electrofishing boat with a 5-kilowatt 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 stainless steel droppers, created the fishing field at the bow, with the boat hull acting as the cathode. A total of 11 sites in the Ohau Channel were fished, 10 of which were locations fished in previous surveys, with 1 additional site in the Ohau Channel near the entrance to Lake Rotoiti (site 11, Table 1, Figure 1).

Table 1. Fishing transect locations (latitude/longitude) from start to finish and habitat types sampled on the 7 December (2010) in the Ohau Channel.

Site	Habitat	Lattitude/longitude	Lattitude/longitude
Lake Rotorua			
Site 1	Edge habitat below weir	S37 31.972 E175 09.287	S38 02.700 E176 19.477
Site 2	Edge habitat by net site 1	S38 02.700 E176 19.478	S38 02.762 E176 19.572
Site 3	Mid channel habitat by net site 1	S38 02.708 E176 19.469	S38 02.697 E176 19.670
Site 4	Edge habitat by net site 2	S38 02.765 E176 19.518	S38 02.732 E176 19.653
Site 5	Edge habitat	S38 02.709 E176 19.669	S38 02.631 E176 19.656
Site 6	Mid channel habitat	S38 02.700 E176 19.671	S38 02.629 E176 19.828
Site 7	Edge habitat with artificial enlargement	S38 02.605 E176 19.727	S38 02.608 E176 19.846
Site 8	Edge habitat by net site 3	S38 02.643 E176 19.986	S38 02.557 E176 20.017
Site 9	Willow edge	S38 02.547 E176 20.008	S38 02.484 E176 19.990
Site 10	Edge habitat by net site 4	S38 02.335 E176 20.042	S38 02.281 E176 20.124
Site 11	Edge habitat	S38 02.613 E176 19.709	S38 02.725 E176 19.483
Lake Rotoiti			

As in previous seasons, electrofishing sites were selected in accordance with NIWA trap netting locations so that direct comparisons of fish densities using two different methods could be made. In particular, sites 2, 4, 8 and 10 coincided with NIWA trap netting sites. Electrofishing subsequently commenced upstream of NIWA trap locations and proceeded to move downstream past them. The remaining 7 sites were spread throughout the Ohau Channel and generally incorporated different habitat characteristics representative of the entire channel. All of the sites had a fishing effort of 10 minutes across each of the habitats which included littoral areas, macrophyte beds and mid-channel habitats for the specified target species.

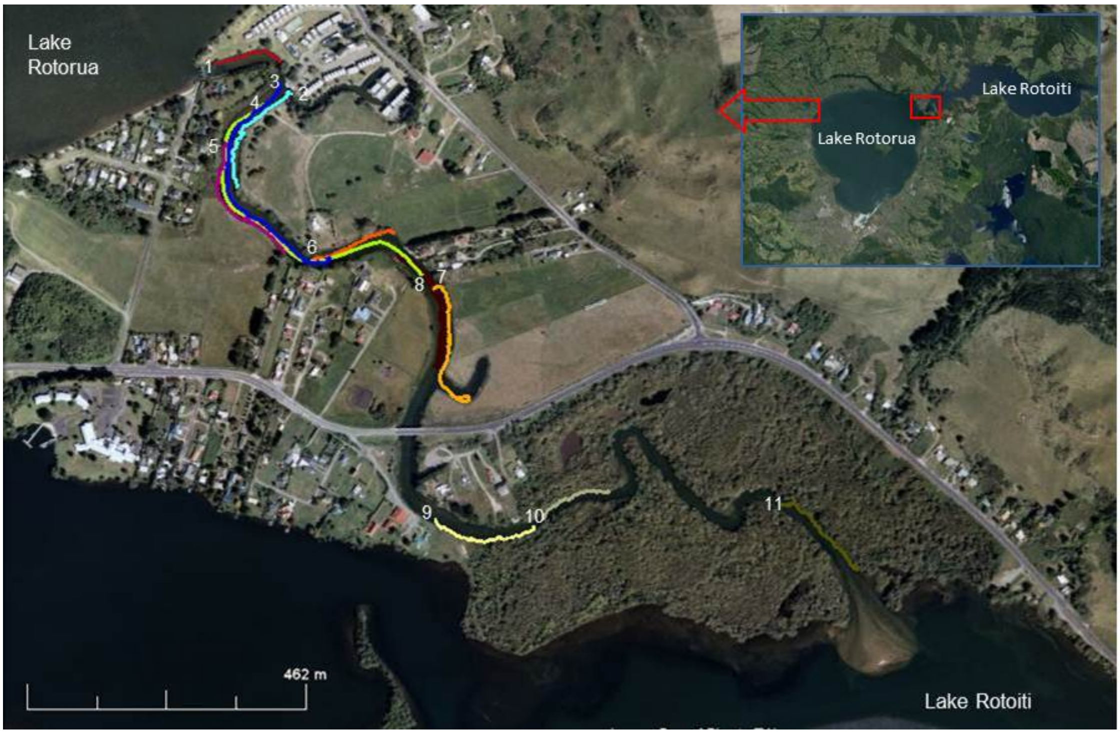

Figure 1. Fishing transects sampled in the present study (7 December 2010) of the Ohau Channel starting from Lake Rotorua and ending at Lake Rotoiti. Site codes correspond to locations in Table 1.

All smelt, goldfish, and bullies were euthanized in benzocaine after collection then transferred into labelled bags for weighing (g) and measurement (mm) back at the lab. Because of the longer time period required to anaesthetise and revive eels and trout (for release), we fished all 11 sites consecutively with trout and eels from each sampling station placed in labelled mesh bags (4 mm mesh) and secured in the channel at each sample station. Data coordinates (GPS) were taken for each holding bag, before fishing the next sampling station. When all sites had been fished, holding bags at each sample station were recovered using the GPS. Fish were then anaesthetised in benzocaine, measured, and monitored for recovery before being released at their sample location. Weights were calculated from length frequency data as in Brijs et al. (2008, 2009, 2010).

Prior to fishing, electrical conductivity was measured with a YSI 3200 conductivity meter and horizontal water visibility was measured using a black disc. Specific conductivity, i.e., standardised to 25^{o}C, was 187.4 µS cm^{-1}, and ambient conductivity, which controls power transfer of the electrical field, was 169.7 µS 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. With the percent of range of the GPP set to 70% this gave an applied current of 3-4 A root mean square. From past experience, an effective fishing field was noted to achieve a depth of about 2-3 m, and 2 m either side of the centre-line of the boat. This denotes that the boat fished a transect about 4 m wide, which was consistent with behavioural reactions of fish at the water surface. This assumption was used to calculate the area fished from the linear distance measured with the onboard GPS.

Trap capture of smelt by NIWA had been conducted previously at four sites in the Ohau Channel between September and May in 2007, 2008, and 2009. Fine-mesh (2-mm) traps were set during daylight hours, and emptied every 3-4 h between early morning and late evening (Rowe et al 2008). Traps were operating continuously apart from the 2-5 mins when each trap was emptied, and the fishing time thus varied with day length from about 10 h in May to about 14 h in December, with a day length of about 11.5 h in September (D. Rowe, NIWA Hamilton, pers. comm.).

3. Study site

Water temperature at the starting point of fishing was 20.1^{o}C with the fishing depth ranging between 0.20 to 2.3 m. The littoral zones of the Ohau Channel remained much the same as in previous seasons and consisted mainly of residential gardens and pasture in the upstream half of the channel (Lake Rotorua end) and riparian willows in the downstream half of the channel (Lake Rotoiti). Submerged macrophytes, such as pondweed (*Potamogeton crispus*) and parrot's feather (*Myriophyllum aquaticum*), were observed throughout the channel as well as the presence of freshwater mussels (*Echyridella menziesi*) in bare sandy areas. The black disc reading, which measures horizontal underwater visibility, was 0.5 m, significantly lower than in previous surveys (0.65 m in 2009, 0.8 m in 2008 and 2.0 m in 2007).

The Ohau Channel begins where a weir has been constructed to control the outflow of Lake Rotorua (Figure 2) and the current is relatively strong and fast at this point. As distance from the weir increases the current slows as the channel widens and deepens (Figure 3) and an increase in the extent of macrophyte beds occurs. At the downstream end of the Ohau Channel before it discharges into Lake Rotoiti the littoral zone is mainly dominated by willows (Figure 4).

Figure 2. The weir between Lake Rotorua and the Ohau Channel where currents are relatively strong and fast. Photo: Brendan Hicks.

Figure 3. Halfway down the Ohau Channel at old oxbow on the true left bank. Photo: Brendan Hicks.

Figure 4. Willows dominating the true left bank of the lower Ohau Channel. Photo: Brendan Hicks.

4. Results

A total of 921 fish (22.7 kg) were collected from eleven 10 min passes in the Ohau Channel that covered a combined distance of 3,488 m (13,952 m^2 area, Table 2). Five species were present with the most abundant being common bully, followed by common smelt, rainbow trout, goldfish and longfin eel (Table 2). Common smelt were most abundant at site 1 but were absent from sites 2, 4 and 5. Common bully and rainbow trout were also reasonably well spread being present in all but 4 sites out of the 11 that were sampled (Table 2). Goldfish were most abundant in the lower channel sites 7, 8, and 10, and a single longfin eel (650 total length, 733 g calculated weight) was caught in edge habitat at site 8.

Table 2. Total number of fish species collected in each 10 min pass from each sample site using boat electrofishing in the Ohau Channel (7 December 2010).

Site	Distance fished (m)	Area fished (m^2)	Number of fish per site					
			Common bully	Common smelt	Goldfish	Longfin eel	Rainbow trout	Total
Site 1	276	1104	79	111	0	0	5	195
Site 2	263	1052	0	0	1	0	8	9
Site 3	470	1880	0	2	0	0	41	43
Site 4	317	1268	267	56	0	0	0	323
Site 5	205	820	0	0	0	0	0	0
Site 6	439	1756	0	0	0	0	23	23
Site 7	302	1208	147	6	4	0	3	160
Site 8	235	940	31	7	3	1	3	45
Site 9	168	672	5	9	0	0	0	14
Site 10	234	936	2	5	10	0	0	17
Site 11	579	2316	73	10	0	0	9	92
Total	3488	13952	604	206	18	1	92	921

As reflected in total numbers (Table 2), common bullies had the highest densities of any fish species (up to 21.1 fish 100 m^{-2}), the majority of which were taken from edge habitats at sites 4 and site 7 (Table 3A). However, despite these high densities, fish biomass was low (e.g., 0.099 g m^{-2} at site 4), compared to low common bully densities at site 8 which had higher biomass (0.151 g m^{-2}, Table 3B). These patterns reflect differences in size structure between sites. The majority of common bullies in edge habitats of site 8 tended to be larger adults compared to smaller juveniles or subadults taken from edge habitats in site 4.

Common smelt had variable densities in the Ohau Channel, the largest number of which was found in edge habitats (10.1 fish 100 m^{-2}) below the weir (site 1). Common smelt biomass was also relatively higher in the same sites. Lower smelt densities were consistently taken from edge and willow habitats in downstream sites 7-11 (ranging between 0.4-1.3 fish 100 m^{-2}), towards Lake Rotoiti (Table 3A).

Density of rainbow trout in the Ohau Channel up to 2.24 fish 100 m^{-2} were measured mainly at the upper (sites 1-3) near Lake Rotorua and mid-reach sites 6-8 (Table 3B). Biomass varied considerably between sites with the highest biomass in rainbow trout taken from edge habitats in site 1-6 (up to 4.43 g m^{-2} biomass), compared to edge habitats nearer Lake Rotoiti (sites 7-11, up to 0.29 g m^{-2} biomass). Goldfish densities were relatively low (up to 1.1 fish 100 m^{-2}), with biomass up to 2.24 g m^{-2} (Tables 3A, B).

Table 3. A. Density and B. biomass of fish collected in each 10 min pass in the Ohau Channel on 7 December 2010.

A. Density

Site	Distance fished (m)	Area fished (m^2)	Density fish per site (number 100 m^{-2})					
			Common bully	Common smelt	Goldfish	Longfin eel	Rainbow trout	Total
Site 1	276	1,104	7.2	10.1	0.0	0.0	0.5	17.7
Site 2	263	1,052	0.0	0.0	0.1	0.0	0.8	0.9
Site 3	470	1,880	0.0	0.1	0.0	0.0	2.2	2.3
Site 4	317	1,268	21.1	4.4	0.0	0.0	0.0	25.5
Site 5	205	820	0.0	0.0	0.0	0.0	0.0	0.0
Site 6	439	1,756	0.0	0.0	0.0	0.0	1.3	1.3
Site 7	302	1,208	12.2	0.5	0.3	0.0	0.2	13.2
Site 8	235	940	3.3	0.7	0.3	0.1	0.3	4.8
Site 9	168	672	0.7	1.3	0.0	0.0	0.0	2.1
Site 10	234	936	0.2	0.5	1.1	0.0	0.0	1.8
Site 11	579	2,316	3.2	0.4	0.0	0.0	0.4	4.0
Mean	317	1,268	4.3	1.6	0.2	0.0	0.5	6.7

B. Biomass

Site	Distance fished (m)	Area fished (m^2)	Fish biomass per site (g m^{-2})					
			Common bully	Common smelt	Goldfish	Longfin eel	Rainbow trout	Total
Site 1	276	1,104	0.081	0.047	0.000	0.000	1.560	1.69
Site 2	263	1,052	0.000	0.000	0.228	0.000	1.232	1.46
Site 3	470	1,880	0.000	0.001	0.000	0.000	4.433	4.43
Site 4	317	1,268	0.099	0.030	0.000	0.000	0.000	0.13
Site 5	205	820	0.000	0.000	0.000	0.000	0.000	0.00
Site 6	439	1,756	0.000	0.000	0.000	0.000	3.059	3.06
Site 7	302	1,208	0.032	0.002	0.818	0.000	0.049	0.90
Site 8	235	940	0.151	0.007	0.513	0.780	0.287	1.74
Site 9	168	672	0.007	0.012	0.000	0.000	0.000	0.02
Site 10	234	936	0.001	0.004	2.241	0.000	0.000	2.25
Site 11	579	2,316	0.012	0.003	0.000	0.000	0.262	0.28
Mean	317	1,268	0.035	0.010	0.345	0.071	0.989	1.45

Trends in catch per unit effort (CPUE) between each site for common bullies and common smelt were consistent with fish density patterns (Table 4 & 3). Like fish density, CPUE for common bullies in the Ohau Channel was highest in edge habitats of site 4 (26.7 fish per min^{-1}) and site 7 (14.7 fish per min^{-1}), (Table 4). CPUE was also more consistent in the lower reach sites of the Ohau Channel, with common bully taken in all sites from 7-11 but were absent from sites 2, 3, 5 and 6 (Table 4). Similarly, common smelt CPUE overall was highest in the edge habitats of site 1 (11.1 fish per min^{-1}), and site 4 (5.6 fish per min^{-1}). In much the same way as common bully, common smelt CPUE was consistent in the lower reaches of the Ohau Channel (sites 7-11), but were also common in the upper reach sites of (1, 3 and 4) but absent in the mid reaches (sites 5-6). CPUE for rainbow trout was highest overall in two sites within the mid channel habitats of site 3 (4.10 fish per min^{-1}) and site 6 (2.3 fish per min^{-1}). Although lower CPUE for rainbow trout was observed in edge habitats (0.3-0.80 fish per min^{-1}), they were spread out across a larger number of sites (1, 2, 7, 8, and 11), within the Ohau Channel (Table 4).

Table 4. CPUE (fish min^{-1}) of common bully and common smelt in sites throughout the Ohau Channel caught on 7 December 2010.

		Catch per unit effort (fish per min^{-1})		
Site	Time fished (min)	Common bully	Common smelt	Rainbow trout
Site 1	10.0	7.9	11.1	0.5
Site 2	10.0	0.0	0.0	0.8
Site 3	10.0	0.0	0.2	4.1
Site 4	10.0	26.7	5.6	0.0
Site 5	10.0	0.0	0.0	0.0
Site 6	10.0	0.0	0.0	2.3
Site 7	10.0	14.7	0.6	0.3
Site 8	10.0	3.1	0.7	0.3
Site 9	9.2	0.5	1.0	0.0
Site 10	10.0	0.2	0.5	0.0
Site 11	12.5	5.8	0.8	0.7

Boat electrofishing at the NIWA trap sites over the four surveys have shown that over 80% of the common smelt that were captured at the trap sites were found at trap sites 1 and 2 which are located in the upper section of the Ohau Channel (Table 5). Common smelt captured at these trap sites in 2009 (73 fish) and 2010 (56 fish) show slight declines in numbers since 2007 (75 fish) and 2008 (192 fish, Table 5).

Table 5. Numbers and proportions of common smelt captured by boat electrofishing at each NIWA trap site in the Ohau Channel from 2007 to 2010.

NIWA trap site	Site code	2007 No. Smelt	2007 % Total per trap site	2008 No. Smelt	2008 % Total per trap site	2009 No. Smelt	2009 % Total per trap site	2010 No. Smelt	2010 % Total per trap site
1	2	37	44	47	24	44	58	0	0
2	4	37	44	145	74	29	39	56	82
3	8	10	11	3	1	0	0	7	10
4	10	1	1	2	1	2	3	5	8
Total		85	100	197	100	75	100	68	100

The overall proportions of common bullies in each size class are fairly similar between 2007 and 2008 with over 80% of the catch in both years being smaller than 51 mm. whereas in 2009 a higher proportion of larger bullies were caught (Table 6). In 2010, the majority of bullies were < 35 mm (75%) and between 36-50 mm (14%), representing a considerable influx of juveniles. Larger mature common bullies (> 51mm) were less evident ranging between 5-7%.

Table 6. Numbers and proportions of common bully in each size class in the Ohau Channel from 2007 to 2010.

Size class	2007 No. bullies	2007 % total catch	2008 No. bullies	2008 % total catch	2009 No. bullies	2009 % total catch	2010 No. bullies	2010 % total catch
<35mm	581	54	203	47	37	25	445	74
36-50 mm	303	28	155	36	57	38	82	14
51-60 mm	141	13	48	10	27	18	45	7
>60 mm	60	5	29	7	28	19	32	5
Total	1085	100	435	100	149	100	604	100

The size of the rainbow trout ranged from 81 mm FL (juvenile) to 565 mm FL (adult) with a mean size of 285 mm FL. One 925 mm TL longfin eel was captured at site 1 and another one of similar size was observed but escaped capture at site 8. Goldfish were found at sites 7 and 10 with densities of 0.3 and 0.5 fish 100 m^{-2} respectively.

Common bully in the Ohau Channel had a wide size range (15-90 mm total length, Fig. 5). However, the size ranges were disproportionately weighted towards higher frequencies of smaller fish (< 30 mm) than larger adults (> 45mm). Common smelt ranged between 25-78 mm fork length, which included two probable size classes made up of 38 juveniles (<40 mm) and a larger proportion of adults (> 45 mm, Fig. 6).

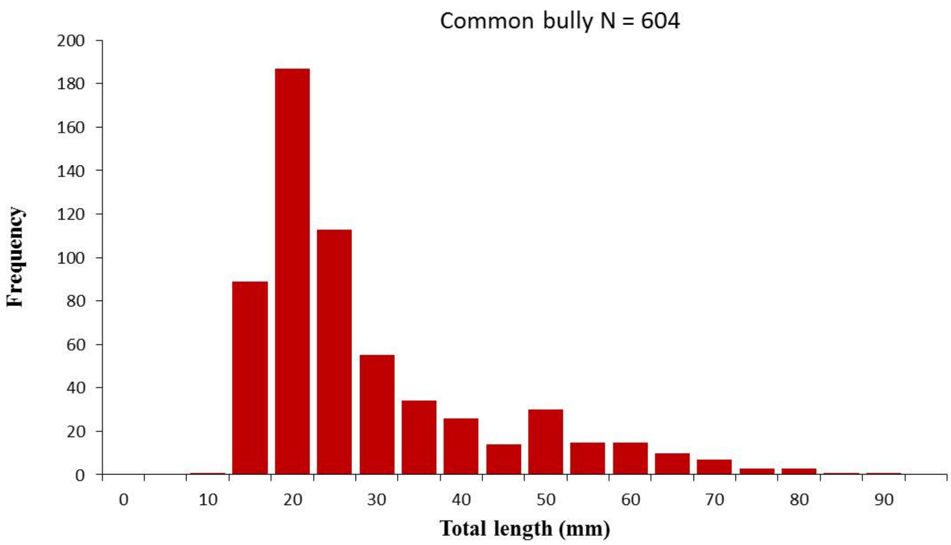

Figure 5. Length-frequency distribution of common bully captured by boat electrofishing in the Ohau Channel on 7 December 2010.

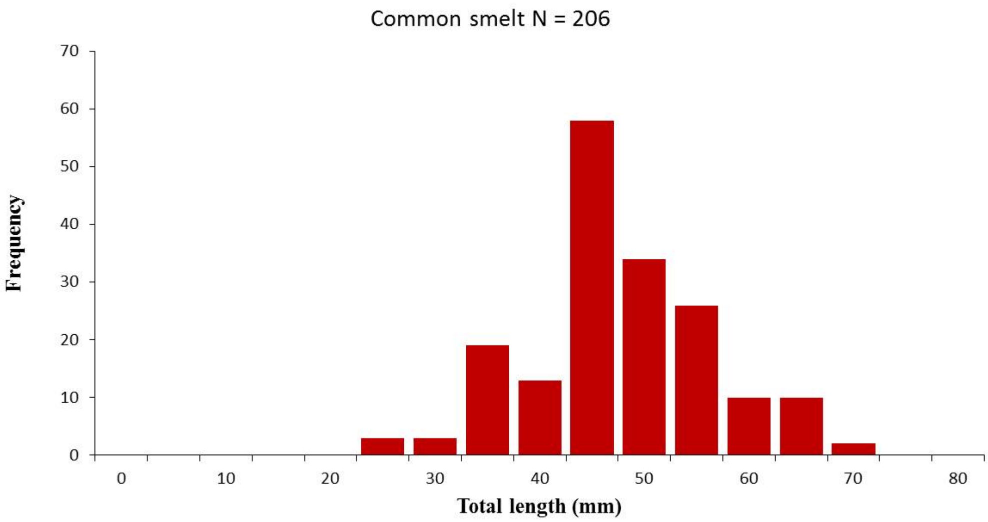

Figure 6. Length-frequency distribution of common smelt captured by boat electrofishing in the Ohau Channel (December 2010).

5. Discussion

In 2010, 33% more smelt, four times more bullies, twice as many goldfish, and four times more trout were caught than in than 2009. Koura (*Paranephrops planifrons*) were caught for the first time (Table 7). From the timing of the smelt runs as revealed by NIWA's trapping it is clear that the single day's boat electrofishing did not coincide with the peak run (Fig. 7), suggesting that boat electrofishing is less useful than seasonal trapping for estimating changes in common smelt abundance. This is consistent with a site-by-site comparison of boat electrofishing smelt capture with NIWA's trapping catches, which showed that trapping caught far more smelt than electrofishing (Brijs et al. 2010).

Table 7. Fish densities in the Ohau Channel measured by boat electrofishing between 2007 and 2010.

Year	Fish density (fish 100 m^{-2})								Time fished (min)	Distance fished (m)	Area fished (m^2)
	Common bully	Common smelt	Goldfish	Longfin eel	Rainbow trout	Juvenile trout	Koura	Total			
2007	22.28	3.30	0.14	0.03	0.30	0.11		26.15	82	1,582	6,328
2008	6.14	4.12	0.03	0.01	0.04	0.18		10.52	100	2,033	8,133
2009	1.45	1.46	0.07	0.01	0.36			3.34	101	2,721	10,884
2010	4.34	1.65	0.16	0.01	0.53		0.10	5.88	112	3,488	13,952

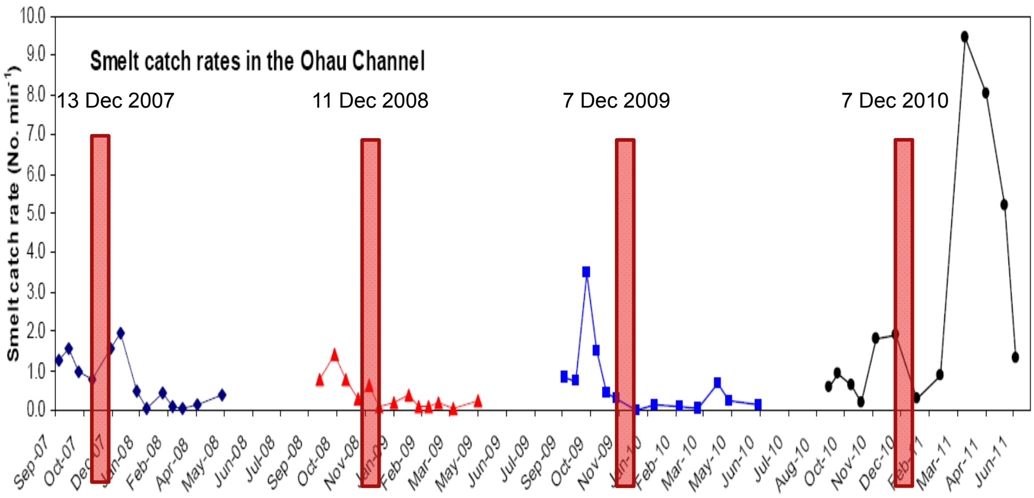

Figure 7. NIWA trapping data compared to electrofishing boat surveys. ▯ denotes the timing of boat electrofishing. Source of smelt catch rate: NIWA unpublished data.

6. Acknowledgements

This research was funded by Bay of Plenty Regional Council. We thank Jennifer Blair for assisting with the field sampling.

7. References

Brijs, J., Hicks, B. J. and Bell, D. G. (2008). Boat electrofishing survey of common smelt and common bullies in the Ohau Channel. *CBER Contract Report No. 66.* Client report prepared for Environment Bay of Plenty. Centre for Biodiversity and Ecology Research, Department of Biological Sciences, The University of Waikato, Hamilton.

Brijs, J., Hicks, B. J. and Bell, D. G. (2009). Boat electrofishing survey of common smelt and common bullies in the Ohau Channel. *CBER Contract Report No. 97.* Client report prepared for Environment Bay of Plenty. Centre for Biodiversity and Ecology Research, Department of Biological Sciences, The University of Waikato, Hamilton.

Brijs, J., B.J. Hicks, and D.G. Bell. 2010. Boat electrofishing survey of common smelt and common bully in the Ohau Channel in December 2009. *CBER Contract Report No. 112.* Prepared for Environment Bay of Plenty. Centre for Biodiversity and Ecology Research, Department of Biological Sciences, School of Science and Engineering, The University of Waikato, Hamilton.

Hicks, B. J., Ling, N., Osborne, M. W., Bell, D. G., and Ring, C. A. (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.

Rowe, D.K., Bowman, E., Dunford, A. and Smith, J. (2008). Smelt in Lake Rotoiti and the Ohau Channel, 2007-2008. *NIWA Client Report: HAM2008-081*. Client report prepared for Environment Bay of Plenty. National Institute of Water & Atmospheric Research Ltd, Hamilton.

Rowe, D.K., Bowman, E., Dunford, A. and Smith, J. (2008). Smelt in Lake Rotoiti and the Ohau Channel, 2008-2009. *NIWA Client Report: HAM2009-077*. Client report prepared for Environment Bay of Plenty. National Institute of Water & Atmospheric Research Ltd, Hamilton.

Ward, F. J., Northcote, T. G. and Boubee, J. A. T. (2005). The New Zealand common smelt: Biology and ecology. *Journal of Fish Biology* 66: 1-32.