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Survey of tuna in customary areas of ANG 14

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EXECUTIVE SUMMARY

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The ANG14 Quota Management Area is bounded to the north by the Rakaia River and to the south by the Waitaki River. The catchments of most significance to the Arowhenua and Waihao runungas are the Orari, Opihi and Waihao – all these rivers suffer from ephemeral summer flows and periodic mouth closures. These rivers and their major tributaries and coastal lagoons, were sampled by electric fishing (49 sites) and baited fyke nets (18 sites) in February and March 2010. Totals of 406 eels (78% shortfins) were caught by electric fishing, and 2682 eels (75% shortfins) from fyke netting. Of the other 12 fish species and one invertebrate species (koura) caught, 10 were diadromous requiring access to the sea at some stage in their life history. Between 1 and 3% of all eels caught were migratory (heke) eels, with shortfin males being the best represented of the species and sexes.

The abundance of juvenile and larger shortfins declined with distance from the coast, but there were no obvious habitat associations for longfins. Unlike many other commercially fished areas, the average size of longfins caught by fyke nets (594 mm, SE 6 mm) exceeded that of shortfins (544 mm, SE 2 mm). From length-frequency plots, there was evidence of some depletion of larger shortfins, presumably by commercial fishing. However, CPUE was high (mean of 13.7 kg/net*night) relative to other South Island exploited rivers. Growth rates of eels from two locations, Temuka and Waihao Rivers, were below the average for shortfins from other South Island rivers, but above average for longfins. The main concern arising from this study is of recruitment of juvenile eels – although the density of small shortfins compared favourably with results from a national study, the density of small longfins was well below the national average, placing the ANG14 rivers in the lower third of rivers from the national study. Lack of small longfins might be partly attributable to river mouth closures during spring, but is also symptomatic of a more widespread recruitment issue for this species in South Island east coast rivers.

OVERALL OBJECTIVES

To characterise the population structure of eels in selected areas of customary significance in ANG 14.

Specific Objectives

To determine the distribution, species composition, size and age structure, and sex composition of eel populations in the areas of customary significance in ANG 14 to provide a reference point for any future monitoring of the population and management of the customary fishery.

BACKGROUND

Consultation and project development

The following section is from the MFish tender document:

Tuna (freshwater eels) are of significant value to customary fishers of Arowhenua and Waihao Runanga in the Quota Management Area 14 (ANG 14). In the past, tuna flourished in rivers, creeks, and waterways within close proximity to Arowhenua, Waihao and Punatarakao Pa. Today, there are fewer and smaller tuna in the waterways than in the past. The smaller eels tangata whenua are able to find are not of a good size to harvest.

The reduction in the size of tuna available within the Arowhenua and Waihao takiwā threatens the sustainability of the fishery for customary fishers. Establishing the present extent and well-being of mahinga kai species will provide a baseline for any future monitoring of the population and management of the customary fishery. Information on the species composition and size structure, and catch and effort data from the survey, will provide data for comparison with other eel population surveys. This will enable some assessment to be made of the status of the eel populations in the selected customary areas.

Objective 1
This Objective will determine the distribution, relative abundance, species composition, size and age structure and sex ratio of tuna in selected areas of customary importance in ANG 14. The by-catch of other species will also be determined. Comparisons will be made of the species and size composition of eels, and catch and effort, from the commercial fisheries sampling and other data sources.

ANG 14 includes several major rivers, lagoons and smaller rivers/creek that contain eel populations of significance to customary fishers, including:

Opihi Lagoon and tributaries
Orari River
Temuka River
Coopers Creek
Ohapi River
Washdyke Lagoon inlet tributaries
Orakipaoa River
Waihao River
Hook River
Wainono Lagoon
Waimate Stream
Hakataramea River.

There will necessarily be limitations on the number of locations that will be sampled. The location of sampling sites will be determined in consultation with the nominated Tangata Tiaki/Kaitiaki.

Because of ongoing concerns about the status of tuna with their rohe, Arowhenua runanga had made an application for a mataitai reserve between the Orton-Rangitata Mouth Road (north of the Orari River) to Washdyke Lagoon, an area bounded to the west by SH1. The South Island Eel Industry Association had previously met with the runanga to try and find a mutually acceptable solution, but when this was not forthcoming, the runanga lodged their application. At the time of writing, the application has not proceeded. In their tender for research on the eel populations, the Ministry of Fisheries extended the area to include significant waterways within the Waihao rohe.

In response to the tender document, NIWA held hui with both Arowhenua and Waihao runanga, and a joint tender was submitted. NIWA were subsequently awarded the tender, and both runanga were subcontracted to assist with advice and assistance for the field surveys. While the tender document and the NIWA tender provided a list of suggested rivers for sampling, final selection was done in consultation with runanga members.

METHODS

Site description

The ANG 14 area covers South Canterbury from south of the Rakaia River to the north bank of the Waitaki River. The area is dominated by two large (Rangitata and Waitaki Rivers, Figure 1) and a series of medium-sized rivers (Ashburton, Orari, Opihi, Pareora, and Waihao). A number of the tributaries of these medium-sized rivers are ephemeral, and dry up for an extended period during summer (Table 1). For instance, most of the tributaries of the Hook, the middle section of the Waihao, the Pareora (not sampled), and Orari all have sections of mainstem river that dry up in most summers. All three major catchments, Orari, Opihi and Waihao, have varying periods of river mouth closure associated with low flows and substrate build-up.

Sampling was carried out from 8–16 February 2010, with an additional visit to the Opihi Lagoon 2–3 March 2010. Most sites sampled were within 5 km of the coast although the upper Waihao and Orari River sites were approximately 15 km inland.

Electric fishing

An extensive electric-fishing survey was carried out within selected rivers, to provide a size range of eels smaller than caught by fyke netting as fyke nets are size-selective for eels greater 35–40 cm. All electric fishing used NIWA EFM300 backpack machines. As a major focus of the electric-fishing was to assess the distribution and abundance of juvenile eels, sites close to the coast were often selected, with a preference for shallow runs and riffles within such sites as juvenile eels are usually associated with such shallow habitats (Jellyman et al. 2003). Eels show differing habitat preferences according to species and size (Jowett & Richardson 1995; Jellyman et al. 2003), meaning that within the runs and riffles, a range of depths, substrates and velocities were required to be fished to obtain a representation of the eels present.

Sites electric fished are shown on Figures 2 and 3, and site descriptions are given in Appendix I. Habitat data were recorded according to the descriptors used in the New Zealand Freshwater Fish Database. At each site, a minimum area of 20 m^2 was electric fished although this varied according to the accessibility of the site and how "fishable" it was (e.g. banks not too steep, extent of macrophytes etc). The exception was one site on the mainstem Waitaki where the backwater habitat was of limited area (10 m^2). Fishing proceeded in a downstream direction, with stunned fish collected in either the operator's hand net or a downstream hand-held stop net (2 mm mesh). All fish caught were placed in buckets for later identification and measuring.

Combinations of multiple pass (quantitative) and single pass (semi-quantitative) electric fishing were carried out. The maximum likelihood method of Carle & Strub (1978) was used to generate population estimates from multiple-pass sites, which were then used to calculate capture efficiencies for electric fishing (i.e. the proportion of the estimated population caught during the first pass). Capture efficiencies were then used to adjust the single-pass electric fishing results to density (no/100 m^2) and biomass (g/m^2) estimates. To ensure consistency between sites, electric fishing at all sites was conducted by the same operator.

Fyke nets

Standard fyke nets, similar to those used by commercial fishers, were used to sample larger eels. Nets were 12 mm (stretched) mesh, with a 6 m single leader, and had no escapement tubes. They were set facing downstream, and secured by ropes, stakes and rock bags. Nets were baited with approximately 0.4 kg of pāua (*Haliotis* spp.) guts in a perforated canister. Sites with no or slow flows were not baited as experience has shown that baiting in these situations does not influence catches. Each net was referenced by GPS, and the predominant habitat type where each net was set was recorded. Fyke net sites are shown in Figures 2 and 3, and a summary of the sites is given in Appendix II.

The sampling strategy focused on maximising the number of sites able to be fished within the time available, but also included areas of high customary importance identified by Tangata Whenua (i.e. Orakipaoa and Waihao Rivers, and Opihi Lagoon). The number of nets set per site varied according to accessibility, fishable area, and the likelihood of getting large catches; for instance, only three nets were set in each of the Hook Drain and Dead Arm as previous experience had indicated the likelihood of getting substantial catches at these sites. It is appreciated that selection of sites in this manner might provide a bias towards larger catches, but experience has indicated that a purely random site-selection process is a very inefficient means of obtaining samples of larger eels. Further, such results would not be comparable to commercial catch data where fishers select fishing locations according to their perceived likelihood of obtaining good catches.

Nets were generally positioned at intervals of approximately 40–50m, or as close as possible to this spacing, depending on the availability of adequate depth and velocity. Nets were fished for one night only except at two sites (Temuka and upper Waihao Rivers) where depletion fyke netting was carried out. Depletion sites contained six nets approximately 50 m apart that fished for three consecutive nights. Catches were recorded after each night and eels were kept in a catch bag until the end of the three days to prevent re-capture. The maximum likelihood method of Carle & Strub (1978) was then used to estimate total population size over the area fished.

As the invasive alga, *Didymosphenia geminate,* had been reported from some rivers in the ANG14 area (Opihi, Orari, Waitaki) but not others (Temuka, Ohapi, Orakipaoa, Hook), care was taken to use either previously dried nets, or nets were sterilised in a hyper-saline salt solution, then thoroughly rinsed in chlorinated tap water and air-dried before reuse.

Data recorded

All fish caught were anaesthetised (2-phenoxyethanol), identified by species, and measured for total length to the nearest millimetre. With the exception of the eels retained for ageing and some from the Opihi Lagoon taken for customary usage, all fish were released unharmed at the point of capture. Due to time constraints, 369 eels were caught but not identified or measured from a large catch in the Dead Arm of Wainono Lagoon. Species composition of this catch was estimated according to the observed species composition of the 141 fish already identified from this net (121 shortfins and 20 longfins). The mean weight of the measured eels was then used to estimate the total weight of the 369 unmeasured eels.

The estimated capture efficiencies for both electric fishing and fyke netting were used to estimate densities (no eels/100m^2) for all sites. Fyke net catches were also expressed as Catch-Per-Unit-Effort (CPUE), either as number of eels/net*night or kg/net*night.

Eel otoliths were used to calculate growth rates from the Temuka and Waihao Rivers. A length-stratified system (roughly 5–10 eels/species per 10 cm length group) was used to collect about 40 otoliths from both species from each river. This was considered a sufficient sample size for generating an accurate estimate of growth rates across all size classes while minimising impacts on eel populations. Eels were killed by prolonged exposure to anaesthetic. Otoliths were prepared using a modified crack and burn technique (Graynoth 1999). A subjective 5-point scoring method was used to assess confidence in otolith readability, where 5 = clear demarcation of annuli and corresponding high confidence in ages, and 1 = very poor demarcation of annuli and very low confidence in ages. For age analysis, only otoliths scoring at least 3 are usually included. Annual growth increments of individual fish (mm/year) were determined by dividing their length by their age. Length upon arrival in freshwater (60 mm for shortfins and 62 mm for longfins) was first subtracted from the measured length to provide growth in fresh water only.

A length-stratified subsample (up to 10 eels/species per 10 cm length group for eels larger than 250 mm) of both eel species were also weighed to generate length-weight relationships. Eels covered a wide range of sizes of both species and were collected from a range of sites throughout the study area. Eels were individually weighed using an electronic hook scale (Bonso Electronics Handy Scale) with an accuracy level of ±20 g. Length and weight data were log (Ln) transformed to approximate data to a linear relationship before an equation was calculated for the length-weight relationship for each species. Length-weight relationships were then used to calculate weights for all eels that were not weighed. Condition (K) of those eels that were individually weighed was estimated by:

$$K = w*10^6/l^3$$

where w = weight in g, and l = length in mm.

As eels were weighed from a number of sites, comparisons of the length-weight relationships were made between these sites (ANCOVA) where the log of weight (ln) was the dependent variable, site was a factor, and the log of length (ln) was a covariate.

Migratory (heke) eels were identified by a combination of external features (Todd 1981, Jellyman & Todd 1982) i.e. size, enlarged eye size, head shape, and colour.

All data were entered onto Excel spreadsheets, and statistical analysis used SYSTAT.

RESULTS

Sampling effort

A total of 51 sites were electric fished. The length of river fished varied according to access, fishable area, and extent of macrophyte cover; the average length fished was 57 m (range 8–226 m), and the area fished averaged 81 m^2 (range 10–300 m^2). Eighteen fyke net sites were fished using a total of 91 nets (Appendix II) for a total of 115 net-nights (includes multiple sets).

Fish species caught

Eleven species of freshwater fish/crustaceans (koura) were caught by electric fishing, with shortfins dominating the occurrence, being recorded from 86% of sites (Table 2); longfins were the next most frequently encountered species being recorded from 67% of sites. Of the 11 species, 10 were native species. Only 4 of the combined total of 13 species caught by electric fishing were not diadromous (upland bully, Canterbury galaxias, koura, and brown trout) i.e. these species do not require access to the sea to complete their life history. Other species recorded from fyke netting were giant bullies and black flounders (Opihi Lagoon, and Dead Arm). The netting in the Opihi Lagoon on 3 March coincided with full moon spring tides, and many gravid inanga were seen in the shallows and about 30 were caught in fyke nets. Additional information on species caught by sampling site is given in Appendix III.

From the fyke nets, a total of 1849 shortfins and 600 longfins were caught and measured (as indicated above, an additional 369 eels were caught but not identified or measured). Thus an estimated 2818 eels were captured (1203 kg) were caught, with 29% of these coming from the Opihi Lagoon (Table 3).

Eel species composition

A breakdown of the species composition of eels by capture method and location (Table 4) shows that the overall species composition by the two methods was rather similar (78% shortfin for electric fishing and 75% shortfin for fyke netting). However, the species composition of eels caught in the same river by electric fishing and fyke netting were often very different. For instance, 17% of eels electric fished from the Opihi River (N = 81) were longfins, compared with 49 % of eels caught by fyke netting (N = 271); only 6% of electric fished eels from the Temuka River (N = 82) were longfins, whereas 90% of eels caught by fyke nets (N = 30) were longfins. For sites where more than 10 fish were captured by either method, 78% of electric fishing sites (N = 9) were dominated by shortfins, compared with 57% of fyke netted sites (N = 14).

There was also a tendency for the proportion of shortfins to decrease with distance inland. For example, for the Orari catchment, shortfins dominated in the lagoon (97%) but the proportion declined to 75% at the “mouth” (0.7 km inland) and to 62% at a river site 1.8 km inland, and to only 5% at a site 5.7 km inland (Ohapi River).

A number of migratory (heke) eels were identified during the fyke net sampling. A summary of these (Table 5) shows that all four combinations of species and sex were encountered, with shortfin males being the most common.

Size and condition

For both species, there were relatively few juvenile eels (less than 300 mm), and for shortfins, only 38% were less than 300 mm and these accounted for 2.9% of total biomass (Table 6). The proportion of juvenile longfins was even less (14%) and these represented only 0.7% of total biomass. Given that electric fishing selectively fished shallow riffles and runs to target juvenile eels, this overall lack of smaller eels was surprising. The percentages of eels less than 300mm from major catchments (Table 7) shows that for larger sample sizes (N > 10), the percentage of shortfins ranged from 22–52%, while the range for longfins was 8–21%.

The best representations of juvenile eels were from the lower Temuka, Opihi and Waihao Rivers (Figure 4), from sites less than 7 km inland. However, even at these sites, only a single shortfin was caught (84 mm) that might have come from the previous year's glass eel recruitment. No sites had a good representation of juvenile longfins.

For electric fished eels, comparisons of mean lengths by species showed that the average length of longfins exceeded that of shortfins (ANOVA, $P < 0.01$); a similar result was achieved comparing both species caught by fyke nets. From the length measurements for all netted eels (Table 8), at 10 of the 15 locations where both species were recorded, the average length of longfins exceeded that of shortfins.

The length distribution of fyke-netted shortfins (N = 1849) showed a near-normal distribution (Figure 5) and had a mean length of 544 mm (SE 2, range 242–966). The length distribution of fyke-netted longfins (N = 600) was slightly positively skewed due to the larger "tail" representing the greater length range than shortfins; the mean length of longfins was 594 mm (SE 6, range 261–1363). The length frequencies of the sites with largest sample numbers are given in Figure 5. Some sites had relatively small shortfins (Orari Lagoon, Orari River, Opihi Lagoon) and longfins (Opihi River), in contrast to sites like the upper Waihao which had the largest average size of both species (Fig 5, Table 8). The length distributions of shortfins from the Orari Lagoon and river were somewhat truncated and negatively skewed, whereas shortfins from the Opihi Lagoon showed a slight positive skewness.

As a large sample of shortfins was available from the Opihi Lagoon, this was subdivided into four geographic zones i.e. zone a = mainstem and southern lagoon (N = 294), zone b = mouth of Orakipaoa Creek (N = 89), zone c = northern lagoon (N = 326), zone d = northern channel (N = 76) (Figure 6). Comparisons of length distributions (ANOVA, Figure 7) showed significant differences ($P < 0.001$), and a post-hoc test (Tukey test) indicated that this was because eels from zone b (mouth of Orakipaoa Creek) were significantly smaller than eels from the other three zones i.e. Orakipaoa mouth (mean length 464 mm, SE 9) versus mean lengths of 545 mm (SE 6), 529 mm (SE 6), and 501 mm (SE11) for zones a, c and d respectively.

During the measuring of the lagoon eels, local Tangata Whenua selected a number of eels for consumption. The sizes of these eels were :
shortfins (N = 34), mean length 709 mm, range 624–842 mm, mean weight 867 g, range 542–1524 g)
longfins (N = 3), mean length 696 mm, range 606–812 mm, mean weight 1038 g, range 600–1660 g).
Eels were selected on size and condition, and a minimum length of approximately 600 mm (or approximately 500 g) seemed to be the acceptable lower limit.

To highlight the proportion of "larger"eels in the fyke net catches, the percentage of eels greater than 600 mm was calculated (Table 9). For shortfins where N >10, the upper Waihao had the largest percentage (66%) followed by the Orari Mouth (52%), Hook Drain (47%) and Temuka (45%). For longfins where N >10, the Hook River had a very high percentage (88%), followed by Ohapi (68%), upper Waihao (65%), and Taumatakahu Stream (60%); collectively, the three sites from the Waitaki catchment (Waitaki side braid and spring fed stream, Waikakahi) were completely comprised of eels greater than 600 mm.

The length-weight relationships for the two species (all sites combined) were:

Shortfin: ln weight = 3.241(ln length) – 14.566 (N = 153, R^2 = 0.97)

Longfin: ln weight = 3.187(ln length) – 13.997 (N = 114, R^2 = 0.98)

Where length is in millimetres and weight is in grams.

Thus for a given length, longfins weighed 18–22% more than shortfins.

Comparisons of length-weight relationships (ANCOVA) showed no significant differences (F = 0.054, P = 0.816) for the two sites where longfins were weighed (Hook River and Temuka River). For shortfins, there were significant differences between eels from the three sites (F = 39.770, P = 0.000), and a post-hoc test (Tukey) showed that all three sites (Hook Drain, Opihi Lagoon, and Temuka River), were significantly different from each other (P < 0.05).

Age and growth

All otoliths from the present study met the benchmark of readability (score at least 3) and were able to be included in age and growth calculations.

Temuka River

The total eels aged from this river were 40 shortfins (111–687 mm) and 42 longfins (240–938 mm). The range in ages for both species was 2–33 years. For both species, the relationship between length and age (Figure 8) was linear, but for longfins especially, the scatter in length for a given age increased with increasing age. The age-length regressions were:

Shortfins: length (mm) = age (21.681) + 100.586 (N = 40, R^2 = 0.89, P = < 0.001)
Longfins: length (mm) = age (19.629) + 167.412 (N = 42, R^2 = 0.61, P = < 0.001)

Both relationships overestimated length at age class 0 as the intercept for shortfins was 101 mm, and for longfins was 167 mm. These intercepts substantially exceed the sizes of glass eels at arrival in fresh water (this length varies seasonally and spatially, but ranges from 58–62 mm; Chisnall et al. 2002). The average annual increment in length from these regressions was 22 mm/year for shortfins and 20 mm/year for longfins. Average annual growth increments of individual fish were

Shortfins: 26.3 mm/year (SE 0.9), range 16.3–44.0 mm/year (N = 40)
Longfins: 27.1 mm/year (SE 1.7), range 14.2–90.0 mm/year (N = 42).

The maximum value of 90.0 mm/year for longfins was from a 2-year old eel that measured 240 mm. As a scatterplot of length versus length increment showed this to be an outlier, it was removed for the subsequent analysis. Exclusion of this datum reduced the mean annual length increment for longfins to 25.5 mm/year (SE 0.7), range 14.2–36.60 mm/year (N = 41).

To see whether there was any indication of growth rate changing with increasing size, individual lengths and length increments were regressed. From the resulting plot, there was no significant relationship between length and annual length increment for shortfins (P = 1.169 > 0.05) but there was a significant relationship for longfins (P = 0.001). When the relationship between age and annual length increment was determined, the situation was reversed with shortfins having a significant negative relationship ($P = 0.005$) meaning growth rates slowed with age, whereas longfins had no relationship ($P = 0.20$).

Waihao River:

Totals of 43 shortfins (122–763 mm) and 27 longfins (224–794 mm) were aged. Numbers collected from the lower and upper river respectively were (shortfins) 24 and 19, and (longfins) 13 and 14. For shortfins, ages ranged from 2 to 26 years, while longfins ranged from 7 to 41 years. For both species, the relationship between length and age (Figure 8) was linear, with increasing scatter with increased age. From observation of the scatterplot, there was a suggestion that juvenile shortfins (smaller than 300 mm) collected at the lower Waihao site, were growing at a slower rate than larger eels (Figure 8), although for the purposes of the age-length relationship, data from both upper and lower sites were combined. The regressions were:

Shortfins: length (mm) = age (26.796) + 76.012 ($N = 43$, $R^2 = 0.84$, $P = < 0.001$)
Longfins: length (mm) = age (16.621) + 217.613 ($N = 27$, $R^2 = 0.56$, $P = < 0.001$)

The average annual increment in length from these regressions was 26.8 mm/year for shortfins and 16.6 mm/year for longfins. The intercept of 76 mm for shortfins is close to the size of glass eels at arrival in fresh water, but in contrast, the intercept for longfins of 217 mm is substantially larger. Reference to Figure 8 indicates that this high intercept is largely a result of the leverage from a group of larger eels (larger than 450 mm) that had grown relatively rapidly (ages 15–20 years).

There was no significant linear relationship between length and annual length increment for shortfins ($P = 0.582 > 0.050$), but there was for longfins ($P = 0.042 < 0.05$). Neither species showed a significant relationship between age and annual length increment (shortfins $P = 0.093 > 0.05$; longfins, $P = 0.166 > 0.05$). The average annual length increments were:

Shortfins: 29.1 mm/year (SE 1.1), range 15.3 – 53.0 mm/year (N = 43)
Longfins: 25.2 mm/year (SE 1.0), range 16.4 – 38.4 mm/year (N = 27)

Sampling efficiency

Electric fishing

Three sites were 3-pass electric fished to determine sampling efficiency. In practice, it was difficult to find suitable sites for this as many sites were of mixed habitat type, several were too deep to fish with confidence, and many had substantial fringing growth of macrophytes making it difficult to secure stunned fish from within these beds. The three sites (sites number 10-Orari River, 20-Temuka River, and 41-Waihao River) produced totals of 25 eels on the first pass (15 shortfins, 10 longfins), 4 eels on the second pass (3 shortfins, 1 longfin) and a single shortfin on the third pass. The overall efficiency of the first pass fishing was 0.83, and this figure was subsequently used to adjust catches of electric fished eels to densities (no/100 m^2).

Fyke netting

Two sites (Temuka River and upper Waihao River) were depletion fished by fyke nets for three consecutive nights. Results (Table 10) showed that declining catches were experienced for both species in the upper Waihao River, and for longfins in the Temuka River, but catches of shortfins in the Temuka River increased over the three nights. Experience in other rivers has shown that the lowermost net often attracts eels from below the immediate fishing zone, and hence catches from this net are usually ignored (Jellyman & Graynoth 2005). Therefore population estimates were made on catches that excluded the lower net.

In the reach of the Temuka River fished, the estimated population size of shortfins of N = 150 (95% CL = ± 179) and 359.9 kg, was regarded as nonsensical, and the sum of the three nights catch (i.e. 30 eels and 12.00 kg) was used as a conservative alternative. For shortfins, the overall capture efficiency of 0.48 (the mean of nightly catches from both rivers) was a conservative figure as it included the catches from the Temuka River where catches did not reduce over time. Therefore, the estimate of 0.61 for the shortfins from upper Waihao was assumed to be the better measure of fyke net catch efficiency for this species. For longfins, the combined estimate from both sites, 0.71, was taken as the appropriate measure of catch efficiency.

Estimates of CPUE expressed as both number of eels/net/night or kg/net*night (Table 11) for a single night's fishing only, showed a considerable range in both measures (for both species combined) from 2.0 – 170.7 eels/net*night and 3.1 – 66.4 kg/net*night. Of the 18 sites, the CPUE (expressed as numbers) of longfins exceed those of shortfins at 8 sites (plus one site with equal CPUE), while biomass CPUE of longfins exceeded that of shortfin at 10 sites (plus one with equal CPUE). Average CPUE for the sites fished were 22.7 shortfins (8.8 kg) per net per night, compared with 6.6 longfins (5.0 kg). For shortfins, the mean kg/net*night was exceeded by catches from (in decreasing order) the Dead Arm, Opihi Lagoon, Hook Drain and Orari Lagoon, and upper Waihao, with the Orari mouth and Opihi River being at, or close to, the average. The distribution of CPUE was different for longfins with the Hook, Ohapi, lower Waihao, Opihi, upper Waihao, Waitaki braid, Orakipaoa, and Waitaki spring fed stream, all exceeding the average. Longfins were noticeably absent, or almost so, from slow flowing areas like the Hook Drain, Opihi Lagoon, but surprising numbers were caught in the Dead Arm (silty bottom, slow flow).

Density and Biomass estimates

Electric fishing

The mean densities for first pass fishing over all electric fishing sites (N = 51) were 6.1 shortfins /100m^2, and 1.8 longfins /100m^2. When these densities were adjusted by electric fishing efficiency, the totals were 7.3 shortfins /100m^2, and 2.2 longfins /100m^2. If juvenile eels only (less than 300 mm) were considered, then these first pass densities reduced to 2.4 shortfins /100m^2, and 0.3 longfins /100 m^2.

Fyke nets

The lengths of the reaches fyke netted to estimate sampling efficiency were 322 m in the Temuka River and 244 m in the upper Waihao River. These distances are measured from the mouth of the uppermost net to the codend of the second lowermost net, representing the sum length of the distance fished excluding the lowermost net. The average widths of these respective rivers (averages from 8 measurements per river) were 16.6 m for the Temuka and 27.8 m for the Waihao, giving total areas of 5345 m^2 for the Temuka and 6783 m^2 for the Waihao. Using the estimated population biomass for each species from these sites (Table 10) adjusted for net efficiencies, gave average biomasses of:

Temuka River: shortfins = 3.7 g/m^2, longfins = 6.7 g/m^2, total = 10.4 g/m^2
Waihao River: shortfins = 24.5 g/m^2, longfins = 7.0 g/m^2, total = 31.5 g/m^2

DISCUSSION

Background

In supporting documentation on the Opihi/Orari catchments to the mataitai application (Arowhenua marae, unpublished data), all eight marae members interviewed commented on the reduced availability of eels today. One 71 year old kaumatua summarised it as "Arowhenua were well known for putting eels on the table and it became an accepted part of our hospitality. Over the last few years we have not been able to do this but rather go elsewhere to get eels in order to sustain the marae. It belittles us. Due to the lack of eels, our mana has been lost. The fact that we have to go elsewhere does not do much for our wellbeing. But sometimes you have to bite your tongue in order to put kai on the table for manuhiri" (guests). Another (age 74) mentioned that "The rivers used to be our supermarket. Today my mokopuna (grandchildren) cannot enjoy this". While both species of eel are harvested by Tangata Whenua, it is the longfin that is more locally prized, both for its size (it has a larger girth for the same length as a shortfin, and it also grows larger), and taste (Mandy Home, Arowhenua runanga pers. comm.).

As well as the perceived reduced availability of tuna within the ANG14 rohe, there has also been extensive deterioration of habitats. For example, Washdyke lagoon (Waitarakao) was a very popular fishing place for tuna, and kanakana (lampreys). While the lagoon was once affected by sewage overflows and industrial wastewater, today the water quality is improved although there are still residues of contaminants in fish flesh. Thus, during a 2009 survey of the biochemistry of mahinga kai species in South Canterbury, high levels of organochlorine pesticides (dichlorodiphenyltrichloroethane, DDTs) were found in most of the eels, as well as in trout and flounder (Michael Stuart, ecotoxicologist, NIWA, pers. comm.). A larger eel caught from Washdyke Creek had high levels of organochlorides and other contaminants, and confirmed the wisdom of iwi not to collect eels from there.

In addition to contaminant residues, another concern about the lagoon is its longevity, as the bar suffers from gravel starvation. Like other coastal lagoons including Wainono Lagoon, Washdyke Lagoon is separated from the sea by a gravel bar which is subject to coastal erosion but historically has been replenished by a longshore drift of gravel. However, much of this gravel is now intercepted by Timaru Harbour, and the bar is narrower and frequently overtopped by large waves. Coastal erosion has substantially reduced the size of the lagoon, and in 1984 it occupied 48 ha, a reduction of 80% of the area existing in 1881 (Kirk & Lauder 2000). There are similar concerns about Wainono Lagoon which has decreased significantly in size over recent decades (John Wilkie, kaumatua, pers. comm.).

The Waikakahi Stream has been highly modified by dairying; irrigation runoff has reversed the seasonal flow regime of the stream to the extent that rather than being low in summer and higher in winter, the reverse situation occurs, and mean flows in summer are typically three to four times greater than in winter (Monaghan et al. 2009). Further, the water quality is characterised as having high concentrations of faecal coliforms, suspended solids and nutrients compared with other lower elevation streams in New Zealand (Monaghan et al. 2009). The stream has a history of high sediment loads attributable to poor riparian management, and current sedimentation may be the reason for the observed low survival rate for trout eggs (Wilcock et al. 2007). These examples are indicative of the changes that waterways in ANG14 are undergoing, and as such are of considerable concern to local iwi.

River characteristics

The study area has very few natural waterways with a permanent surface flow from their source to the sea. Most rivers are stony-bottomed, with hill-fed catchment areas (Opihi, Orari, Pareora, Otaio, Kohika, Makikihi, Hook, Waimate, and Waihao) with perennial flows in their upper reaches but upon reaching the permeable Canterbury Plains, flows are reduced and all rivers have varyingly intermittent flows in their mid to lower reaches. For instance, during a February 2008 survey of Canterbury mudfish, NIWA staff noted that the Pareora River at the northern end was dry at the SH1 Bridge. Most of the Otaio was dry downstream of the gorge. The Makikihi was dry above and below SH1. The Kohika was dry apart from a trickle below SH1. The Hook was dry from the foothills and only recharged from the Merry Stream in the lower reaches. The Waimate Stream was mainly dry apart from some by-wash water in the middle reaches. The Waituna Stream was also dry to just before its entry into Wainono Lagoon. The only catchment with a source to sea surface flow at the time of the survey was the Waihao River (J. Sykes, NIWA, pers. comm.).

As well as having ephemeral flows (with associated loss of habitat and reduced instream access for eels), many of these rivers are also affected by periodic mouth closures. For example, the Orari mouth closes periodically but for very limited periods and does not require any mechanical opening (Bruce Scarlett, ECan, pers. comm.). The Opihi is occasionally opened mechanically, but is regularly opened by whitebaiters during the whitebait season (15 August – 30 November) although such openings usually last for only a few days before the sea again closes the mouth. Environment Canterbury (ECan) records (since 2007) indicate three mechanical openings in June 2007 but none since that time. A study of closures of the Opihi River (1982–1985; Todd 1985) found that the mouth was closed 90% of the time that flows were less than 6 m^3/s. It is generally accepted that because of higher base flows since operation of the Opuha Dam in 1998, there are fewer mouth closures (Adrian Meredith, ECan, pers. comm.). However, while the mouth is open for more time than formerly, it now migrates further north (up to about 2 km) which results in a long and narrow channel and a lagoon that has little tidal or saline influence. So, while the increased flows resulting from operation of the Opuha Dam appear to keep the mouth open for longer periods, the reduced flood flows mean that the river is less likely to breach the barrier bar opposite the main channel, and hence the northward migration of the mouth. As a consequence, the lagoon has largely changed from a brackish water habitat to one that is frequently dominated by fresh water (Adrian Meredith, ECan, pers. comm.). Local hut owners have voiced concerns about the reduced numbers of species like flounders and mullet than were formerly present although it should not affect recruitment of glass eels or emigration of maturing eels.

The Waihao Box is a wooden flume designed to pass water through the centre (Appendix IV) although in practice this centre section is often choked with gravel. Historically, it was usually opened mechanically by a digger excavating a channel alongside the box itself with the box simply acting as a deflecting groyne. These days it is mainly self-opening, as the sea regularly scours the gravel away from the outlet allowing an outflow through the box itself – this means the box is typically open for most of the year. A recent agreement of maintaining a year-round environmental flow from the Morven-Glenavy irrigation scheme has added several hundred litres per second of flow to the lower Waihao River meaning that a 3.9 km reach downstream to the top of the tidal portion of the river (approximately 2.7 km to the sea) now maintains a year-round flow. This flow enables eels to colonise this previously dry reach of the river, and may assist in maintaining the opening of the Waihao Box.

A potential issue noted during the present survey was the Hook Drain site where the surface was entirely covered by the surface plant *Azolla*. Persistent growth of this plant typically results in severely deoxygenated water as the plant respires with the atmosphere and blankets the water surface, preventing aeration of the water. Discussion with a local farmer indicated that this prolific growth had only occurred two weeks prior to the survey; there were already indications of deteriorating water quality as evidenced by the release of hydrogen sulphide when sediments were disturbed, and two dead eels in one net, the only dead eels encountered during the entire survey.

Species composition

Shortfins are usually the dominant species in estuaries and river mouths, and results from the Opihi Lagoon (99% shortfins), and Orari Lagoon and mouth (97% and 75% shortfins respectively) are consistent with this observation. However, studies of other estuaries and lagoons have also recorded high proportions of longfins (Rakaia Lagoon, N = 630 eels, 46% longfin; Eldon & Greager 1983; Waimakariri Lagoon, N = 803 eels, 81% longfin, Eldon & Kelly 1985; Kakanui Estuary, N = 828 eels, 23% longfin, Jellyman et al. 1997), which indicates something of the adaptability of this species which has been described as a habitat generalist (Glova et al. 1998).

In river reaches above estuaries, longfins dominated fyke net catches with the exception of the upper Waihao where shortfins predominated (74%). High proportions of longfins were expected in riverine habitats as this species prefers flowing water (Jellyman et al. 2003) and is the dominant species in South Island braided river systems (e.g. Beentjes 1999; Beentjes et al. 2006). Unlike the other stony bed rivers (Orari, Temuka, Opihi, Waihi, Waitaki), the upper Waihao was slow-flowing with a high proportion of fine substrates, habitat features well-suited to shortfins. The large mean size of shortfins from here probably represents the denial of access to commercial fishers by the local farmer who has not allowed commercial fishing in this area for the past 14 years.

The northern tributaries to Wainono Lagoon (Hook River and Hook Drain) produced contrasting species proportions, again consistent with the habitats present – the muddy and slow-flowing drain and Dead Arm were dominated by shortfins and in contrast, the lower Hook River, which had a reasonable flow at the time of the survey and extensive areas of cobble substrate, was dominated by longfins. These associations are consistent with the preferred habitats of each species (McDowall 1990; Jellyman et al. 2003).

The sizes of the migratory (heke) eels recorded were within size ranges given by Todd (1980). The estimated proportions of longfin migrants slightly exceeded that of shortfins, which is probably indicative of the overall larger population size of longfins as they occur throughout the whole catchments, whereas shortfins are more abundant in the lower reaches. Most of the migratory eels were captured at sites close to the sea, and it seems that such eels move downstream in anticipation of their spawning departure which commences in mid February (shortfin males) and runs until June (longfin females).

Sizes of eels

The mean lengths for shortfins and longfins from the ANG14 rivers (Table 12) ranged from 518–620 mm and 473–687 mm respectively. Two rivers stood out as having particularly large eels, the Hook River and upper Waihao; the Hook is part of the non-commercial area of Wainono Lagoon that has been a reserve for several years, while the reach sampled in the upper Waihao had not been commercially fished for 14 years. If these rivers were excluded, the ranges of shortfins and longfins were 518–580 mm, and 473–579 mm respectively.

Shed sampling of commercial fyke net catches has been used to obtain information on species composition, relative sizes and growth rates of eels throughout New Zealand (e.g. Beentjes 1999; Beentjes and Chisnall 1997). Commercial fishers are required to use escapement tubes in their nets to minimise capture of eels below the commercial threshold of 220 g. Nets used in the present survey did not have escapement tubes fitted, meaning that a slightly wider size range of eel was captured (i.e. commercial nets should land few shortfins less than 480 mm, and few longfins eels less than 455 mm, the lengths corresponding to 200 g). As a result, the average lengths from the commercial landings will have a small bias towards larger mean lengths than data from the present study.

The size range and average length of shortfin eels in the present study was generally smaller than that of most other South Island rivers that have been sampled (Table 12), and this is likely to be indicative of extensive commercial fishing throughout ANG14 rivers. For longfins, the range in mean lengths for South Island rivers that are regularly fished was 481–579 mm, which is very similar to equivalent data for ANG14 rivers only (473–579 mm). Again, the much larger size of longfins from the upper Waihao and Hook Rivers will be the result of the refuge provided by nil or low harvest areas. When the percentage of “large” eels (over 600 mm) was considered (Table 9), the effect of refuge areas was again apparent with the Hook River having a high proportion of large longfins (88 %), while the upper Waihao had high proportions of both species (shortfins 66%, longfins 65%) compared with the overall means for all ANG14 rivers sampled in the present study of 32% for shortfins and 37% of longfins.

Sufficient shortfins were caught in the Opihi Lagoon to investigate size ranges in four zones within the lagoon. Eels from the Orakipaoa mouth were significantly smaller than those from the other three zones. There were reports that commercial eel fishing had taken place near the Orakipaoa mouth earlier in the year, and the length frequency for this zone (Figure 7) showed a truncated size distribution, especially in comparison with the north lagoon and the main channel sites.

Although longfins are a larger eel at maturity than shortfins, their mean size in fished populations is typically smaller than that of shortfins (e.g. Beentjes and Chisnall 1998). This was not true in the present study however as the overall mean length of longfins was greater than that of shortfins. The overall size frequencies (Figure 5) showed a near-normal distribution for shortfins, while the longfin distribution had a long “tail” in which fish as large as 1200 mm were recorded.

The range in average length of eels from ANG14 rivers can be compared with those from other South Island rivers (Table 12). With the exception of the Hook and upper Waihao Rivers, the range in mean lengths for shortfins from ANG14 rivers (518–580 mm) is slightly less than that of the other fished rivers listed in Table 12 (507 mm in the Kakanui estuary, to 747 mm in the Waitaki River). The range for ANG14 longfins, 430–579 mm, is very similar to that of other South Island fished rivers i.e. 481 mm (Kakanui Estuary) to 579 mm (Waimakariri Estuary).

From the overall consideration of sizes of eels, it is concluded that the ANG14 rivers show signs of significant depletion of larger shortfins in some of the areas accessible to commercial fishing. The sizes of longfins are nevertheless typical of those from other commercially fished areas.

The length-weight relationships from the present study were tested against similar historic data from Lake Pounui (NIWA unpublished data). The Lake Pounui data have been used to generate weights for given lengths in previous studies (e.g. Jellyman et al. 2009 b) when no weight data have been recorded in the field. Analysis (ANCOVA) showed that the differences between the two datasets were significant (shortfins $F = 4.763$, $P = 0.003$; longfins $F = 31.156$, $P = 0.000$). Differences between weights for particular lengths (for both species) were small until lengths exceeded 700 mm. Thereafter Lake Pounui shortfins were between 4 and 12 % heavier than equivalent- sized shortfins from the present study (with the difference increasing with increasing size), and Lake Pounui longfins were 2–12% heavier than equivalent-sized shortfins from the present study. These differences indicate that it would be unwise in future to use generic length—weight relationships to estimate weights for given lengths, and site-specific length-weight relationships should be developed for both species.

Age and growth

For both species, there was considerable variation in length at age from both the Temuka and upper Waihao Rivers (Figure 8). Such variability is typical of New Zealand eels, both in the wild (Jellyman 1997) and in captivity (Jellyman & Lokman 2003). When average annual growth (mm/year) for each species is compared with growth from other South Island rivers (Table 13), it is apparent that growth of shortfins is comparatively low, with only the two rivers (Hurunui and Grey Rivers) having growth rates less than the Waihao, and only the Grey River having growth rates less than the Temuka River. Likewise, average growth of longfins in both the Temuka and Waihao Rivers is relatively slow, with only longfins from the Buller River having slower growth than those from the Waihao, and longfins from four of the twelve rivers listed (Buller, Waiau, Oreti and Waimakariri Rivers) having slower growth than longfins from the Temuka River. The slow growth experienced by shortfins in the present study was unexpected, but may be in part a reflection that these rivers are ephemeral (Waihao) and suffer from low summer flows. Diminishing flows could impose some thermal stress as water temperatures increase, plus any eels within such areas would need to relocate to permanent water; either mechanism could potentially reduce growth rates.

Abundance

CPUE can be used as an indicator of abundance, and is an important measure of stock well-being. Low CPUE for shortfins would be expected from stony bed rivers like the Ohapi, Temuka, Opihi, Waihi, Hook and Waitaki, and this was generally the case except that catches from the Opihi were greater than average, probably because this site included a large backwater; an area of slow flow favoured by shortfins.

Average CPUE data from the present study are high relative to other South Island rivers (Table 14). Even with the exclusion of catches from the Dead Arm, the mean CPUE was 11.9 kg/net*night, the highest of those given in Table 14. Because of regional differences in net size and soak times, a CPUE index has been used to compare trends over time (MFish 2010). Using the data for ANG14, the shortfin index (1991–2004) shows a slight positive relationship over time, although the relationship was not significant (linear regression, $P > 0.05$). Likewise the relationship for longfins over the same period was not significant, although the slope was negative i.e. there was a trend to reduced CPUE over time.

Differences in electric fishing methods and protocols can influence catches and hence estimates of densities – the most obvious differences are usually associated with the type of habitat selected. Electric fishing is invariably biased towards fishing riffles and runs as pools are too deep for effective sampling (Jowett and Richardson 1996). As the present study employed a similar sampling strategy to Jowett and Richardson (1996), comparisons between the two studies are valid. From first pass electric fishing, overall averages of 7.9 shortfins and 2.3 longfins were estimated per 100 m^2 for first pass fishing. Comparable data from Jowett and Richardson (1996) from a range of 38 New Zealand streams and rivers were a mean density for shortfins of 5.7 per 100 m^2 (SE 2.2) with a range of 0–72.9 per 100 m^2; the mean for longfins was 7.9 per 100 m^2 (SE 1.8) with a range of 0–45.9 per 100 m^2, Thus the densities from the present study (7.9 shortfins and 2.3 longfins per 100 m^2) are above the average for shortfins from the national study of Jowett and Richardson (1996), but less than a third of the average longfin value. Of more relevance though is the fact that only 6 of the rivers sampled by Jowett and Richardson (1996) had shortfin densities greater than the average of ANG14 rivers, while 26 had longfin abundance equivalent to or greater than the ANG14 rivers. Therefore, although the density of shortfins compares favourably with results from the national study, the density of longfins is well below the national average, placing the ANG14 rivers in the lower third of rivers from the national study.

The most robust density data come from extensive longitudinal electric fishing surveys of three New Zealand streams over three years (Graynoth et al. 2008); the average densities of each species for these streams was 67.0 shortfins and 33.4 longfins per 100 m^2, figures that indicate the high abundance of eels in small streams relative to the larger waterways of the present study and those sampled by Jowett and Richardson (1996).

The mean measures of biomass calculated from fyke nets in the present study were 2.7 and 5.4 g/m^2, for shortfins and longfins respectively from the Temuka River, and 17.7 and 7.8 g/m^2 for the same species from the upper Waihao River. The totals of 8.1 g/m^2 and 25.5 g/m^2 for both species in the two rivers span the estimate of 19.9 g/m^2 for the middle Mataura (Jellyman et al. 2009b), but are considerably less than the average of 43.3 g/m^2 from the Kahutara River, Kaikoura (Crow & Jellyman 2009), a smaller river. However, electric fishing results are almost invariably from smaller waterways where densities generally exceed those from larger rivers. Thus estimates for eels longer than 400 mm in three large New Zealand streams (using electric fishing) ranged from 24.4–43.45 g/m^2 (Graynoth et al. 2008), while estimates of similar-sized eels from a small Canterbury stream were 47.2 – 66.6 g/m^2 (Jellyman & Graynoth 2005).

Recruitment

It became apparent during electric fishing that small eels were only being caught in modest numbers, so extra effort was placed on fishing downstream areas and likely habitats, especially in the Opihi. Despite this additional emphasis, the results indicated that there were relatively low proportions of small eels within ANG14 rivers. From electric fishing results, only 38% of shortfins and 14% of longfins were less than 300 mm (Table 7). Comparative data given in Jellyman (2009) for five small streams throughout New Zealand are that shortfins less than 300 mm comprised 92% of all shortfins caught (N = 2563) with the equivalent figure for longfins (N = 2050) being 59%. Thus, relative to these 'national' figures, the percentages of small eels, especially longfins in the ANG14 rohe, is low.

The relative lack of small eels raises concern about the regularity and adequacy of annual recruitment. Although the Opihi mouth closes regularly during the spring recruitment period, it is opened by whitebaiters but apparently such openings are of short duration as the bar does not become sufficiently scoured to enable a long term opening. As glass eels are thought to arrive in waves, mainly associated with spring tides (Jellyman & Lambert 2003), if an opening does not coincide with a spring tide, then recruitment may be minimal. Recruitment of shortfins to the Waihao catchment was generally similar to that of the Orari and Opihi catchments (i.e. the proportion of shortfins less than 300 mm is approximately 50%) and as the Waihao Box is open for prolonged periods, it seems unlikely that recruitment of shortfins is adversely affected by this opening regime.

The percentage of small longfins is of more particular concern, as this species dominates the adult populations yet levels of recruitment seem particularly low. The length frequency distribution of eels (Figure 4) shows a virtual absence of any longfins less than 200 mm. While it has been suggested that longfin populations may survive by episodic years of good recruitment followed by years of low recruitment (Jellyman and Boubée 2009), the virtual failure of recruitment over several years is of concern. Given the much higher proportions of small shortfins and the general overlap in recruitment times (Jellyman et al. 2002), it seems unlikely that the lack of longfins is as a result of mouth closures, and it is therefore assumed to represent a lack of longfin glass eels. Monitoring of elvers at the Waitaki Dam over recent years has also shown comparatively small numbers of juvenile longfins i.e. the average for the past 6 seasons is 12 530 longfins, but if the exceptional year season of 2007–08 when 57 600 longfins were recorded is excluded, then the average is 3510 longfins per year. By way of comparison, the number of longfin elvers caught over the same period at Karapiro Dam (Waikato River) and Matahina Dam (Rangitaiki River) averaged 620 000 and 415 000 respectively (Martin et al. 2010). On this basis, the availability of longfin glass eels recruiting to South Island east coast rivers would seem to be low.

Comparisons with previous data

From an earlier survey of the eel stocks of Wainono Lagoon (Jellyman & Sykes 1998), the previous species composition was very similar to that recorded in the present survey (Table 15). The earlier survey recorded a mean length of shortfins from the eastern side of the lagoon of 461 mm, compared with 555 mm from the Dead Arm in the present survey. Growth rates for shortfin are slightly faster today than in 1997, with eels from the Dead Arm averaging 16–19 mm/year in 1998, compared with 27 mm today for eels from the Waihao. Overall, the average size and growth rate of shortfins have both increased over the past 13 years. Density comparisons are less relevant as the present survey set only 3 nets in the Dead Arm; however, mean CPUE here was 66.4 kg/net*night, and far exceeded the average of 2.3 kg/net*night from 10 nets in the Dead Arm in 1997. Presumably the difference will partly reflect improved eel stocks the intervening 13 years, but it is also suspected that because Wainono Lagoon was very low during the 2010 survey, this had forced many eels to take refuge in the Dead Arm and elevated the CPUE.

SUMMARY

A number of key population parameters were investigated for key waterways within the ANG14 rohe. In summary:

- The species composition was dominated by shortfins, although the abundance of this species declined away from the coast
- The abundance of small eels of both species was lower than expected, especially for longfins
- The size of eels varied considerably between rivers; there were signs of depletion of larger shortfins in some of the areas commercially fished, but the sizes of longfins were typical of those from other commercially fished rivers
- Growth rates of larger shortfins were below the averages of other South Island rivers, but rates for longfins were above average
- Average CPUE from the present study was high relative to other South Island rivers, even in areas understood to be regularly harvested

- The main concern arising from this study was low recruitment of juvenile eels. River mouth closures during spring would compound this issue, although the lack of juvenile longfins appears to be symptomatic of a more widespread issue for this species

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Table 1: Characteristics of the waterways sampled. The catchment area and mean flow data are from the New Zealand Freshwater Fish Database. Mouth closure indicates whether the river mouth naturally closes. * = separated into 4 zones.

Catchment	River	No. electric fishing sites	No. fyke net sites	Catchment area (km^2)	Mean flow (m^3/s)	Ephemeral	Mouth closure occurs
Orari	Lagoon		1				
	Mouth		1				
	Mainstem	6	1	714	12.8	Yes	Yes
	Coopers Creek	2		75	1.2	Yes	
	Ohapi	5	1	28	0.2	No	
Opihi	Lagoon		4*				
	Mainstem	7	1	2369	28.1	No	Yes
	Temuka	5	1	618	7.7	No	
	Taumatakahu		1	2	>0.1	No	
	Waihi	4	1	200	3.1	Yes	
	Orakipaoa	1	1		0.2	No	
Waihao	Mainstem	9	3	548	3.5	Yes	Yes
	Hook	3	1	74	0.5	Yes	
	Hook Drain		1				
	Dead Arm		1				
Waitaki	Waikakahi	2	1	136	0.4	No	No
	Mainstem braids	5	2	11713	369.9	No	No

Table 2: Frequency of occurrence: the percentage of sites where various species were collected (%) by electric fishing or fyke netting.

Common name	Species	Electric fishing %	Fyke netting %
Shortfin eel	*Anguilla australis*	86	89
Longfin eel	*Anguilla dieffenbachii*	67	95
Upland bully	*Gobiomorphus breviceps*	29	16
Brown trout	*Salmo trutta*	24	
Bluegill bully	*Gobiomorphus hubbsi*	20	
Torrentfish	*Cheimarrichthys fosteri*	14	
Common bully	*Gobiomorphus cotidianus*	12	32
Canterbury galaxias	*Galaxias vulgaris*	10	
Koura	*Paranephrops sp.*	6	5
Lamprey	*Geotria australis*	4	5
Inanga	*Galaxias maculatus*	2	9
Giant bully	*Gobiomorphus gobioides*		5
Yelloweye mullet	*Aldrichetta forsteri*		11
Black flounder	*Rhombosolea retiaria*		11
Common smelt	*Retropinna retropinna*		5

Table 3: Total number and weight (kg) of eels caught by fyke net at sites fished within ANG14. * indicates that overall numbers were estimated from a subsample of eels.

River	Site	No. nets	Shortfin		Longfin		Both species	
			N	Total weight	N	Total weight	N	Total weight
Orari	Lagoon	5	218	67.5	7	4.8	225	72.3
	Mouth	3	50	26.4	17	11.1	67	37.5
	River	9	119	39.4	73	39.5	192	78.9
Ohapi	River	4	2	1.1	38	44.7	40	45.8
Temuka	River	6	3	1.8	27	16.6	30	18.4
Orakipaoa	Stream	5	48	17.8	48	29.9	96	47.7
Opihi	Lagoon	17	795	279.6	11	5.8	806	285.4
	River	7	139	60.1	132	56.1	271	116.2
Taumatakahu	Stream	3	3	0.8	20	22.4	23	23.2
Waihi	River	2	3	1.2	10	7.6	13	8.8
Wainono *	Dead Arm	3	434	134.4	79	24.6	513	159.0
Hook	River	3	3	2.5	41	54.2	44	56.7
	Drain	3	81	40.5	0	0	81	40.5
Waihao	Lower	5	22	9.1	62	37.2	84	46.3
	Upper	7	122	68.5	42	52.2	164	120.7
Waitaki	braid	2	0	0	9	14.9	9	14.9
	Spring fed	3	0	0	8	18.0	8	18.0
Waikakahi	stream	3	3	3.7	3	9.3	6	13.0
Totals		**90**	2045	754.4	627	448.9	2672	1203.3

Table 4: The proportion of shortfins and longfins caught on first electric fishing pass or on first nights fyke netting in ANG14 area. - = not sampled.

Site	Electric fishing			Fyke netting			Both methods		
	N	% shortfin	% longfin	N	% shortfin	% longfin	N	% shortfin	% longfin
Coopers Creek	14	57	43	0	-	-	14	57	43
Dead Arm	-	-	-	143	85	15	143	85	15
Hook	16	25	75	44	7	93	60	12	88
Hook Drain	-	-	-	81	100	0	81	100	0
Ohapi	27	85	15	40	5	95	67	37	63
Opihi	81	83	17	271	51	49	352	59	41
Opihi Lagoon	-	-	-	806	99	1	806	99	1
Orakipaoa	4	100	0	96	50	50	100	52	48
Orari	38	47	53	192	62	38	230	60	40
Orari lagoon	-	-	-	225	97	3	225	97	3
Orari Mouth	-	-	-	67	75	25	67	75	25
Temuka	82	94	6	30	10	90	112	71	29
Waihi	21	81	19	13	23	77	34	59	41
Waikakahi	1	0	100	6	50	50	7	43	57
Waitaki - side braid	14	71	29	9	0	100	23	77	23
Waitaki - spring fed	-	-	-	8	0	100	8	0	100
Taumatakahu Stream	-	-	-	23	13	87	23	13	87
Waihao lower	83	89	11	84	26	74	167	57	43
Waihao upper	25	56	44	165	74	26	189	72	28
Grand Total	406	78	22	2303	75	25	2709	76	24

Table 5: The numbers and lengths of migratory eels identified during sampling in ANG14.

Species	Sex	N	Mean length (SE)	Length range
Shortfin	Male	15	496 (12)	401–590
	Female	9	744 (11)	674–791
Longfin	Male	6	578 (3)	568–584
	Female	2	1 272 (91)	1 182–1 363

Table 6: Numbers (N) and biomass (g) of shortfin and longfin eels caught by electric fishing (one pass only), and percent of numbers and biomass for eels less than 300 mm. The density estimates (per 100 m2) are adjusted for the electric fishing catch efficiency rate.

River	Site no.	Shortfin		Longfin		Shortfin < 300 mm		Longfin < 300 mm		Shortfin density	Longfin density
		N	Biomass	N	Biomass	% N	% Biomass	% N	% Biomass	Estimated total /100m^2	Estimated total /100m^2
Coopers Creek	1	6	1 402	4	2 531	0	0	0	0	6.7	5.4
Orari	2	5	1 968	6	1 868	20	1.3	17	0.7	14.9	17.8
Coopers Creek	3	2	832	2	2 305	0	0.0	0	0.0	1.8	1.8
Ohapi	4	6	447	1	1 896	67	15.9	0	0.0	11.3	1.9
Ohapi	5	4	123	0	0	75	32.5		0.0	8.0	0.0
Ohapi	6	7	1 394	0	0	43	5.5		0.0	17.6	0.0
Ohapi	7	5	785	1	292	40	10.1	0	0.0	16.7	3.3
Ohapi	8	1	249	2	3 519	0	0.0	0	0.0	1.8	5.3
Orari	9	1	420	6	1 449	0	0.0	17	4.3	2.5	12.6
Orari	10	2	276	7	1 755	0	0.0	14	3.5	2.0	7.0
Orari	11	0	0	0	0		0.0		0.0	0.0	0.0
Orari	12	10	1 964	2	826	30	4.7	0	0.0	20.1	4.0
Orari	13	0	0	0	0		0.0		0.0	0.0	0.0
Opihi	14	8	1 373	1	777	38	6.3	0	0.0	13.7	1.4
Opihi	15	4	635	1	777	25	3.3	0	0.0	21.9	5.5
Opihi	16	0	0	0	0		0.0		0.0	0.0	0.0
Temuka	18	14	4 474	2	2 247	7	0.3	50	1.4	14.8	2.1
Temuka	19	23	7 085	0	0	0	0.0		0.0	43.3	0.0
Temuka	20	13	2 909	2	441	29	4.9	50	12.9	45.9	5.7
Temuka	21	17	2 691	1	121	29	3.2	0	0.0	16.3	1.0
Orakipaoa	22	4	992	0	0	25	0.2		0.0	60.2	0.0
Temuka	23	10	120	0	0	100	100.0		0.0	16.7	0.0
Waihi	24	5	1 114	1	1 200	40	1.4	0	0.0	6.9	1.4
Waihi	25	4	237	1	2 391	50	11.3	0	0.0	7.0	1.7
Waihi	26	5	371	2	271	60	22.6	50	21.0	8.9	3.6
Waihi	27	3	210	0	0	33	1.4		0.0	5.4	0.0
Opihi	28	7	227	1	1 100	86	51.1	0	0.0	19.6	2.8
Opihi	29	22	847	1	3	86	23.6	100	100.0	28.2	2.6
Opihi	30	25	4 885	7	3 298	24	4.0	14	1.4	50.2	14.1
Opihi	32	1	76	2	167	0	0.0	50	14.9	1.6	3.3
Hook	33	0	0	1	4 154		0.0	0	0.0	0.0	0.5
Hook	34	2	803	5	2 613	0	0.0	0	0.0	2.2	5.6
Hook	35	2	1 713	7	10 521	0	0.0	14	0.2	1.8	6.4
Waihao	36	35	2 075	3	734	80	12.6	0	0.0	70.3	6.0
Waihao	37	1	2	0	0	100	100.0		0.0	2.6	0.0
Waihao	38	7	1 787	3	2 944	0	0.0	0	0.0	8.4	3.6
Waihao	39	14	6 046	3	510	43	2.4	0	0.0	11.2	2.4
Waihao	40	17	6 491	0	0	18	0.2		0.0	29.3	0.0

Waihao	41	1	241	2	1 317	0	0.0	0	0.0	2.7	5.5
Waihao	42	2	789	10	5 893	0	0.0	30	1.6	3.0	15.1
Waihao	43	3	948	1	83	33	5.1	0	0.0	4.5	1.5
Waihao	44	8	2 326	0	0	25	1.8		0.0	8.0	0.0
Waikakahi	45	0	0	0	0		0.0		0.0	0.0	0.0
Waikakahi	46	0	0	1	2 969		0.0	0	0.0	0.0	4.8
Waitaki	47	5	4 834	1	784	0	0.0	0	0.0	2.0	0.4
Waitaki	48	1	618	0	0	0	0.0		0.0	0.8	0.0
Waitaki	49	1	860	0	0	0	0.0		0.0	12.0	0.0
Waitaki - Welcome Ck	50	3	916	3	1 740	0	0.0	0	0.0	2.3	2.3
Waitaki - irrigation race	51	0	0	0	0		0.0		0.0	0.0	0.0
Totals		316	68 555	90	62 117	38	2.9	14	0.7		

Table 7: The percentage of all electric fished eels less than 300 mm in major catchments. The number in brackets is the total number of eels.

Catchment	River	% shortfin	% longfin
Orari	Orari	22 (18)	14 (21)
	Ohapi	52 (23)	0 (4)
Opihi	Opihi	52 (67)	21 (14)
	Temuka	26 (81)	40 (5)
	Waihi	47 (17)	25 (4)
Waihao	Waihao	49 (84)	14 (22)
	Hook	0 (4)	8 (12)

Table 8: Numbers (N) and lengths (mm) of measured eels caught by fyke nets (over all nights fished) at sites fished within ANG14.

River	Site	Shortfins				Longfins			
		N	Mean length	SE	Range	N	Mean length	SE	Range
Orari	Lagoon	218	508	6	252–791	7	536	89	293–929
	Mouth	50	607	12	385–779	17	598	24	470–778
	River	119	518	8	280–869	73	546	14	395–1 182
Ohapi	River	2	612	65	548–677	38	696	26	516–1 195
Temuka	River	33	561	14	400–687	50	549	20	270–938
Orakipaoa	Stream	48	550	7	443–643	48	579	17	373–968
Opihi	Lagoon	795	522	4	242–888	11	543	41	343–812
	River	139	568	7	345–815	132	519	8	261–1 004
Taumatakahu	Stream	3	494	27	442–536	20	483	47	469–1 067
Waihi	River	3	565	29	536–623	10	598	51	486–1 019
Wainono *	Dead Arm	121	555	8	377–883	22	473	17	370–719
Hook	River	3	715	10	695–730	41	745	20	512–1 148
	Drain	81	580	14	254–792	0			
Waihao	Lower	22	564	16	394–721	62	566	16	367–1 048
	Upper	209	620	5	401–834	49	687	23	479–1 363
Waitaki	braid	0				9	800	45	641–1 081
	Spring fed	0				8	880	57	652–1 154
Waikakahi	stream	3	774	101	623–966	3	971	121	840–1 214
Totals		1849	544	2	242–966	600	594	6	261–1 363

Table 9: The number (N) of fyke netted eels (first night fishing) greater than 600 mm expressed as a percentage of total eels caught at that site.

Site	Shortfins (%)		Longfins (%)	
	N	%	N	%
Dead Arm	33	27	2	22
Hook	3	100	36	88
Hook Drain	38	47	0	0
Ohapi	1	50	26	68
Opihi Lagoon	199	25	4	36
Opihi	49	35	12	9
Orakipaoa	13	27	17	35
Orari	17	14	16	22
Orari lagoon	35	18	2	40
Orari Mouth	26	52	7	41
Taumatakahu Stream	0	0	12	60
Temuka	15	45	12	24
Waihao lower	6	27	18	29
Waihao upper	138	66	32	65
Waihi	1	33	3	30
Waikakahi	3	100	3	100
Waitaki - side braid	0	0	9	100
Waitaki - spring fed	0	0	8	100
Overall mean		32		37

Table 10: Number of shortfin and longfin eels caught per night (excluding catch in lowest net), estimated total population number and biomass, and estimated sampling efficiency, for fyke net depletion fishing sites in Temuka and Waihao Rivers. Sampling efficiency (first night's catch) is expressed in terms of numbers, and biomass (in brackets). 95% confidence limits (CL) are given for the estimated populations. Lengths in brackets for Nights 1-3 are the mean length of eels caught per night.

Species	River	Night 1	Night 2	Night 3	Estimated population ± CL (Estimated biomass; kg)	Sampling efficiency: numbers (biomass)
Shortfin	Temuka	3 (639 mm)	11(554 mm)	16 (545 mm)	150 ± 179 (359.9)	0.02 (< 0.01)
	Waihao	108 (621 mm)	44 (633 mm)	16 (590 mm)	177 ± 9 (99.6)	0.61 (0.60)
	Total (both sites)	111 (621 mm)	55 (618 mm	32 (568 mm)	229 ± 23 (118.8)	0.48 (0.52)
Longfin	Temuka	24 (591 mm)	9 (514 mm)	8 (467 mm)	46 ± 8 (23.9)	0.52 (0.67)
	Waihao	36 (701 mm)	4 (562 mm)	2 (615 mm)	42 ± 2 (44.2)	0.85 (0.93)
	Total (both sites)	60 (657 mm)	13 (528 mm	10 (496 mm)	85 ± 3 (68.1)	0.71 (0.84)

Table 11: Catch Per Unit Effort (CPUE) expressed as number (N) of eels/net*night and biomass (kg) kg/net*night for both species of eel caught during a single night's fishing. * indicates overall numbers were estimated from a subsample of eels.

River	Site	No. nets	Shortfin		Longfin		Both species	
			CPUE (N)	CPUE (kg)	CPUE (N)	CPUE (kg)	CPUE (N)	CPUE (kg)
Orari	Lagoon	5	43.6	13.5	1.4	1.0	45.0	14.5
	Mouth	3	16.7	8.8	5.7	3.7	22.3	12.5
	River	9	13.2	4.4	8.1	4.4	21.3	8.8
Ohapi	River	4	0.5	0.3	9.5	11.2	10.0	11.5
Temuka	River	6	0.5	0.3	4.5	2.8	5.0	3.1
Orakipaoa	Stream	5	9.6	3.6	9.6	6.0	19.2	9.5
Opihi	Lagoon	17	46.8	16.4	0.6	0.3	47.4	16.8
	River	7	19.9	8.6	18.9	8.0	38.7	16.6
Taumatakahu	Stream	3	1.0	0.3	4.7	5.4	5.7	5.7
Waihi	River	2	1.5	0.6	5.0	3.8	6.5	4.4
Wainono *	Dead Arm	3	144.3	58.2	26.3	8.2	170.7	66.4
Hook	River	3	1.0	0.8	13.7	18.1	14.7	18.9
	Drain	3	27.0	13.5	0.0	0.0	27.0	13.5
Waihao	Lower	5	4.4	1.8	7.6	8.9	8.0	9.2
	Upper	7	17.6	9.9	6.0	7.5	23.6	17.3
Waitaki	Braid	2	0.0	0.0	4.5	7.5	4.5	7.5
	Spring fed	3	0.0	0.0	2.7	6.0	2.7	6.0
Waikakahi	Stream	3	1.0	1.2	1.0	3.1	2.0	4.3
Means			22.7	8.8	6.6	5.0	29.1	13.7

Table 12: Mean lengths of fyke netted eels from other South Island waterways. * = regularly fished reach; ** = seldom fished reach; * = unfished.**

	Shortfin				Longfin				
Location	N	Mean	SE	Range	N	Mean	SE	Range	Reference
South Island Rivers									
Orari Lagoon	218	508	6	252–791	7	536	89	293–929	This report
Orari River	119	518	8	280–869	73	546	14	395–1 182	This report
Temuka River	33	561	14	400–687	50	549	20	270–938	This report
Orakipaoa Stream	48	550	7	443–643	48	579	17	373–968	This report
Opihi Lagoon	795	522	4	242–888	11	543	41	343–812	This report
Opihi River	139	568	7	345–815	132	519	8	261–1 004	This report
Dead Arm	121	555	8	377–883	22	473	17	370–719	This report
Hook River	3	715	10	695–730	41	745	20	512–1 148	This report
Hook Drain	81	580	14	254–792	0				This report
Waihao Lower	22	564	16	394–721	62	566	16	367–1 048	This report
Waihao Upper	209	620	5	401–834	49	687	23	479–1 363	This report
Company Creek***	122	637	14	260–990	211	766	18	250–1 330	NIWA unpubl. data
Lake Rotoiti [1]***	8	732		569–876	107	705		398–1 203	Jellyman (1995)
Buller River	1				282	532	5	410–930	Beentjes & Chisnall (1997)
Grey River *	219	592	51	430–850	210	516	6	410–1 050	Beentjes (1999)
Grey River **	0				106	702	14	440–990	Beentjes (1999)
Hokitika River	1				109	548	7	440–930	Beentjes & Chisnall (1997)
Kakanui River - estuary	532	507	6		154	481	11		Jellyman et al. (1997)
Waitaki River - lower	29	607	15	470–780	49	543	11	430–820	Beentjes & Chisnall (1997)
Waiataki River - near Waitaki Dam	114	747	15	410–1130	756	548	3	420–1 040	Beentjes & Chisnall (1997)
Clutha River - lower	80	668	13	470–1110	689	499	2	360–770	Beentjes & Chisnall (1997)
Clutha River – Balclutha - Clydevale	163	616	9	460–1090	923	493	0	380–940	Beentjes & Chisnall (1997)
Taieri River *	441	625	40	470–940	185	532	5	430–1 100	Beentjes (1999)
Taieri River **	0				218	619	7	470–950	Beentjes (1999)
Mataura River	117	635	94	480–970	885	517	2	430–1 050	Beentjes (1999)
Oreti River	55	669	148	470–910	570	534	3	350–1 090	Beentjes (1999)
Rakaia estuary**	342	575			288	678			Eldon & Greager (1983)
Waimakariri River	1				183	579	7	450–1 030	Beentjes 1999

[1] = in National Park.

Table 13: Mean annual length increments (mm/year) of both species of eels from South Island rivers.

River	Shortfins		Longfins		Reference
	N. aged	Mean increment	N. aged	Mean increment	
Waihao	43	26.8	27	16.6	This study
Temuka	40	21.7	42	19.6	This study
Waiau	11	27.5	60	18.7	Beentjes & Chisnall (1998)
Aparima	76	33.8	106	22.9	Beentjes & Chisnall (1998)
Oreti	19	36.1	108	18.1	Beentjes & Chisnall (1998)
Mataura	75	41.0	93	27.5	Beentjes & Chisnall (1998)
Clutha (lower)	26	38.2	36	23.2	Beentjes & Chisnall (1998)
Waitaki (lower)	70	39.5	-	-	Beentjes & Chisnall (1998)
Waiatki (middle)	42	34.7	98	27.6	Beentjes & Chisnall (1998)
Rangitata	-	-	27	23.7	Beentjes & Chisnall (1998)
Rakaia	-	-	63	30.2	Beentjes & Chisnall (1998)
Lake Ellesmere	116	35.3			Beentjes & Chisnall (1998)
Hurunui	46	23.3	53	21.3	Beentjes & Chisnall (1998)
Grey	65	18.4	71	23.0	Beentjes & Chisnall (1998)
Buller	-	-	68	16.0	Beentjes & Chisnall (1998)
Waimakariri			22	18.7	Beentjes (1999)
Wainono Lagoon (east)	115	38.0	-	-	Jellyman & Sykes (1998)

Table 14: Measures of CPUE (catch per unit effort, kg/net*night) from various New Zealand studies.

Location	Kg/net*night		Reference
	Mean	Range	
ANG14 rivers	13.7	3.1–66.4	This study
ANG14 rivers excluding Dead Arm	11.9	3.1–18.9	This study
Motu	1.7	< 0.1–6.1	Jellyman et al. 2009a
Aparima	7.5	4.1–113.9	Jellyman & Graynoth (2005)
Mataura – reserve	6.4	4.0–9.2	Jellyman et al. (2009b)
Mataura – commercially fished	2.0	1.8–2.2	Jellyman et al. (2009b)
Kaikoura rivers	10.6	3.0–30.7	Crow & Jellyman (2009)
South Canterbury rivers 1983–1989	4.7	3.1–8.8	Jellyman (1993)
South Canterbury, Waitaki, Otago, 1990–1999	4.7	3.9–6.6	Beentjes & Bull (2002)

Table 15: Comparison of species composition in Wainono Lagoon/lower Waihao catchment, 1997 and 2010.

Site		1997		2010	
		N	%	N	%
Dead Arm	Shortfin	75	84	122	85
	Longfin	14	16	21	15
Hook Drain/Wainono Lagoon	Shortfin	600	99	81	100
	Longfin	5	1	0	0
Waihao River	Shortfin	108	89	74	89
	Longfin	14	11	9	11

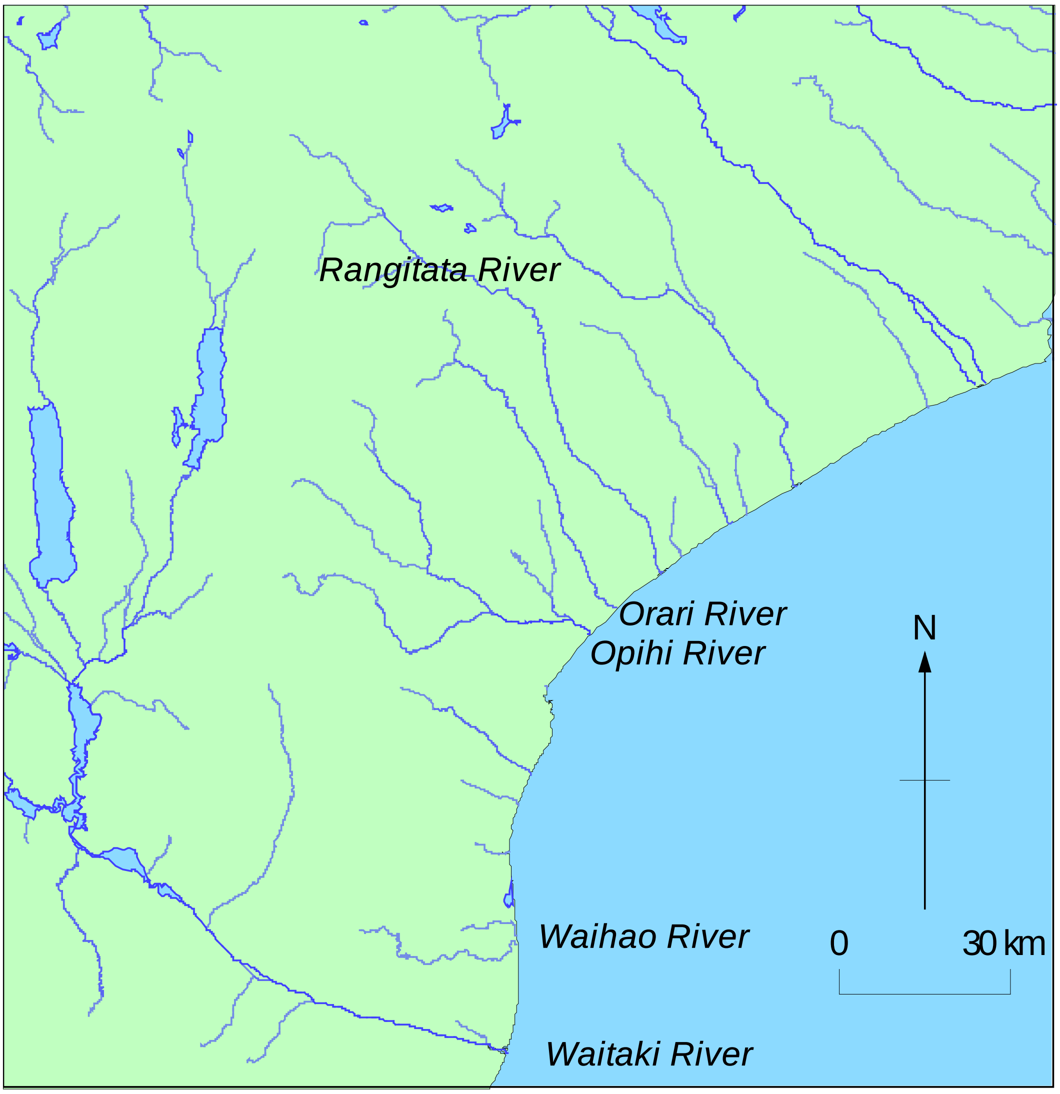


Figure 1: General location of sampling areas in ANG14.

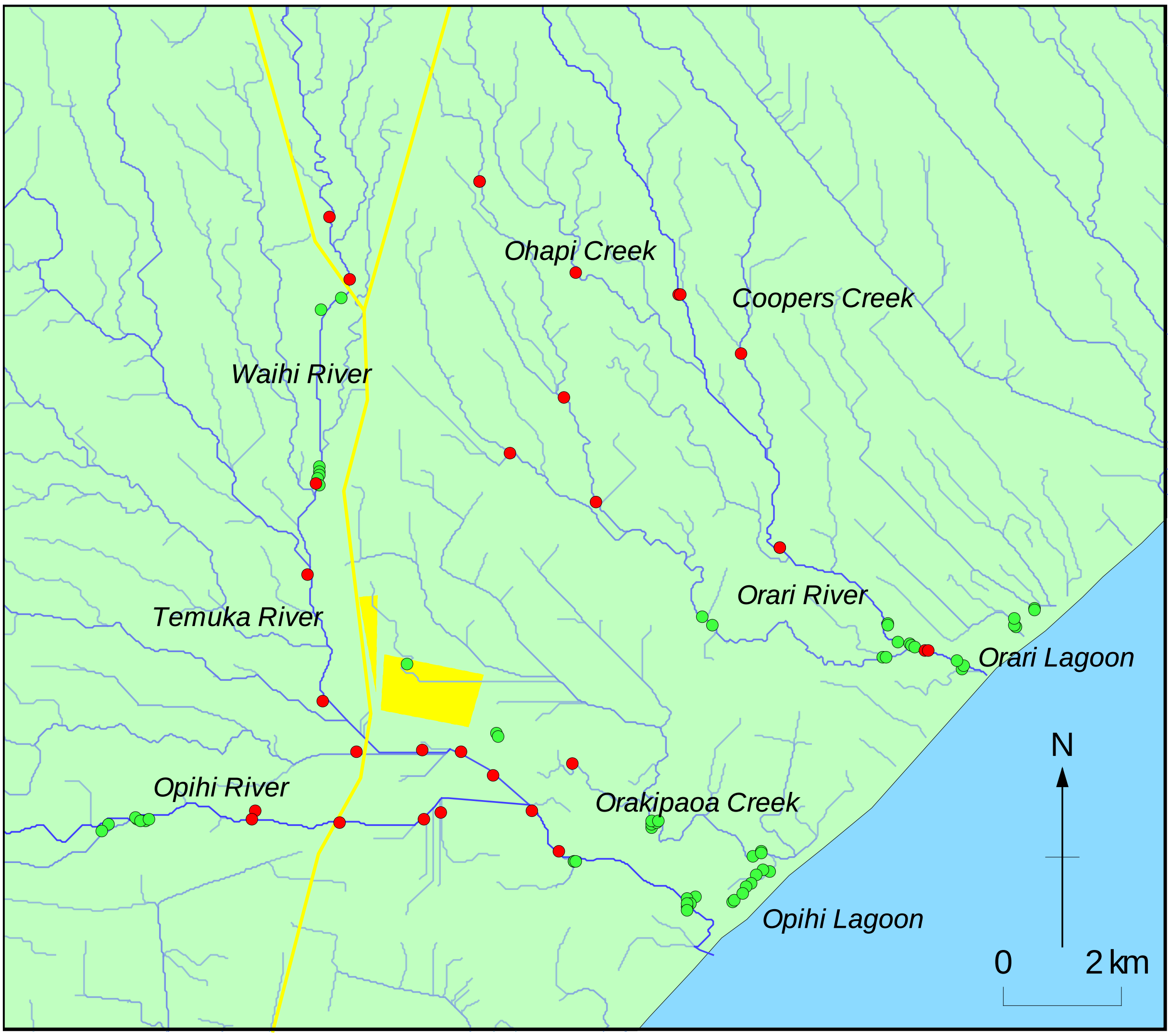


Figure 2: Sampling sites in the Orari and Opihi catchments. Green circles are fyke net sites, red circles are electric fishing sites.

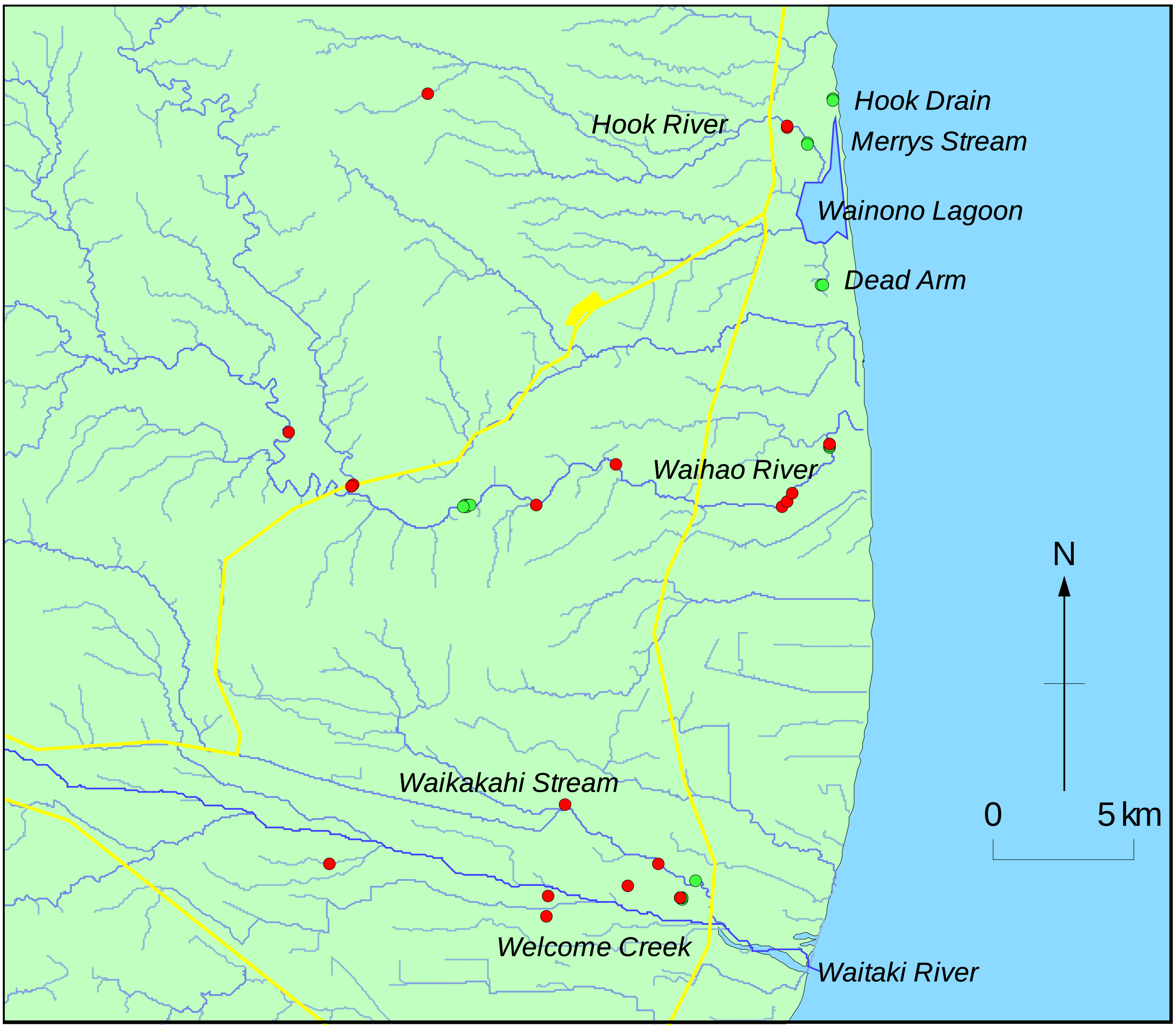


Figure 3: Sampling sites in the Waihao and lower Waitaki catchments. Green circles are fyke net sites, red circles are electric fishing sites.

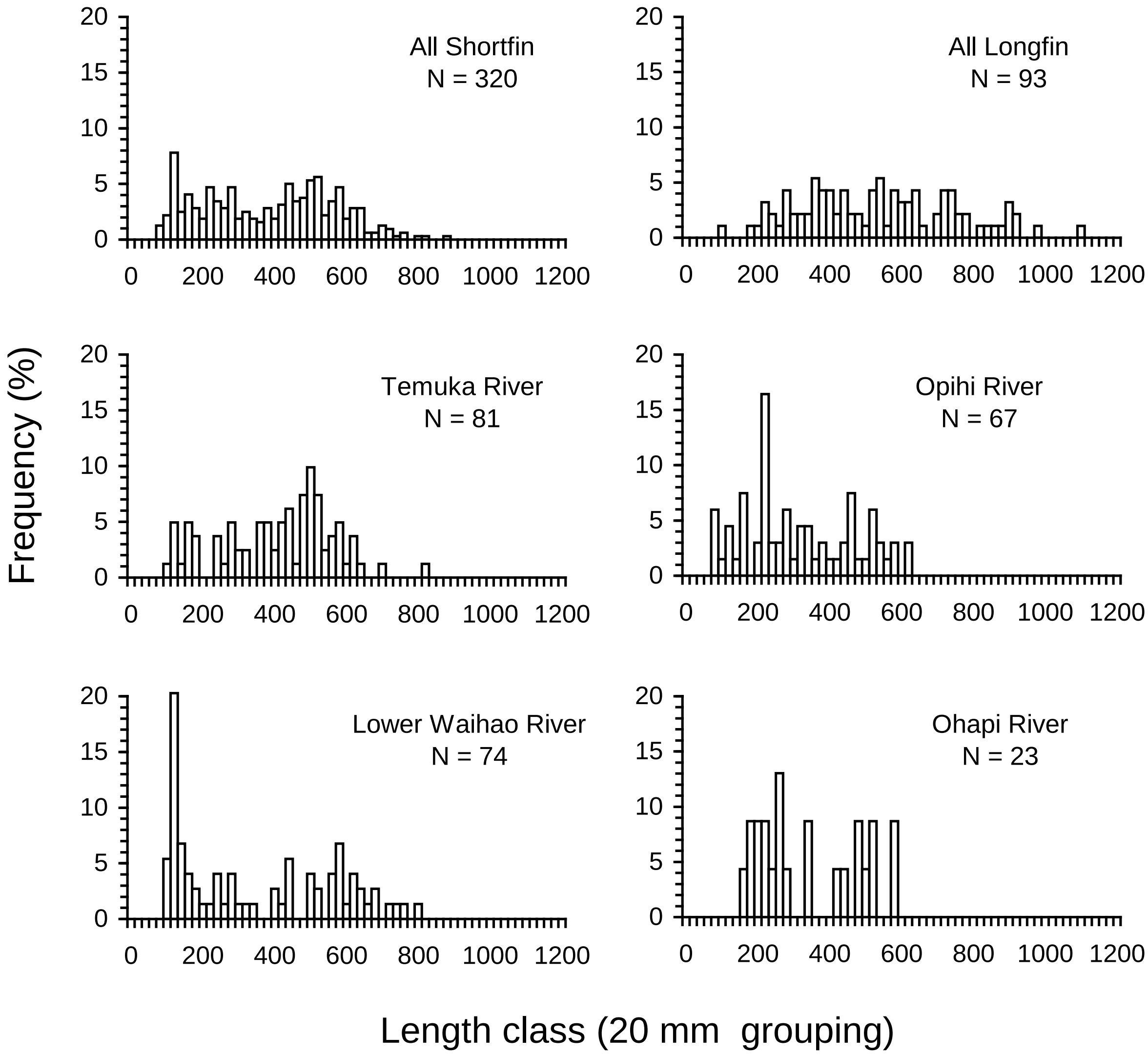


Figure 4: Length frequency distributions of the total number of each species of eel caught by electric fishing (top row), and shortfins from four sites with largest catches.

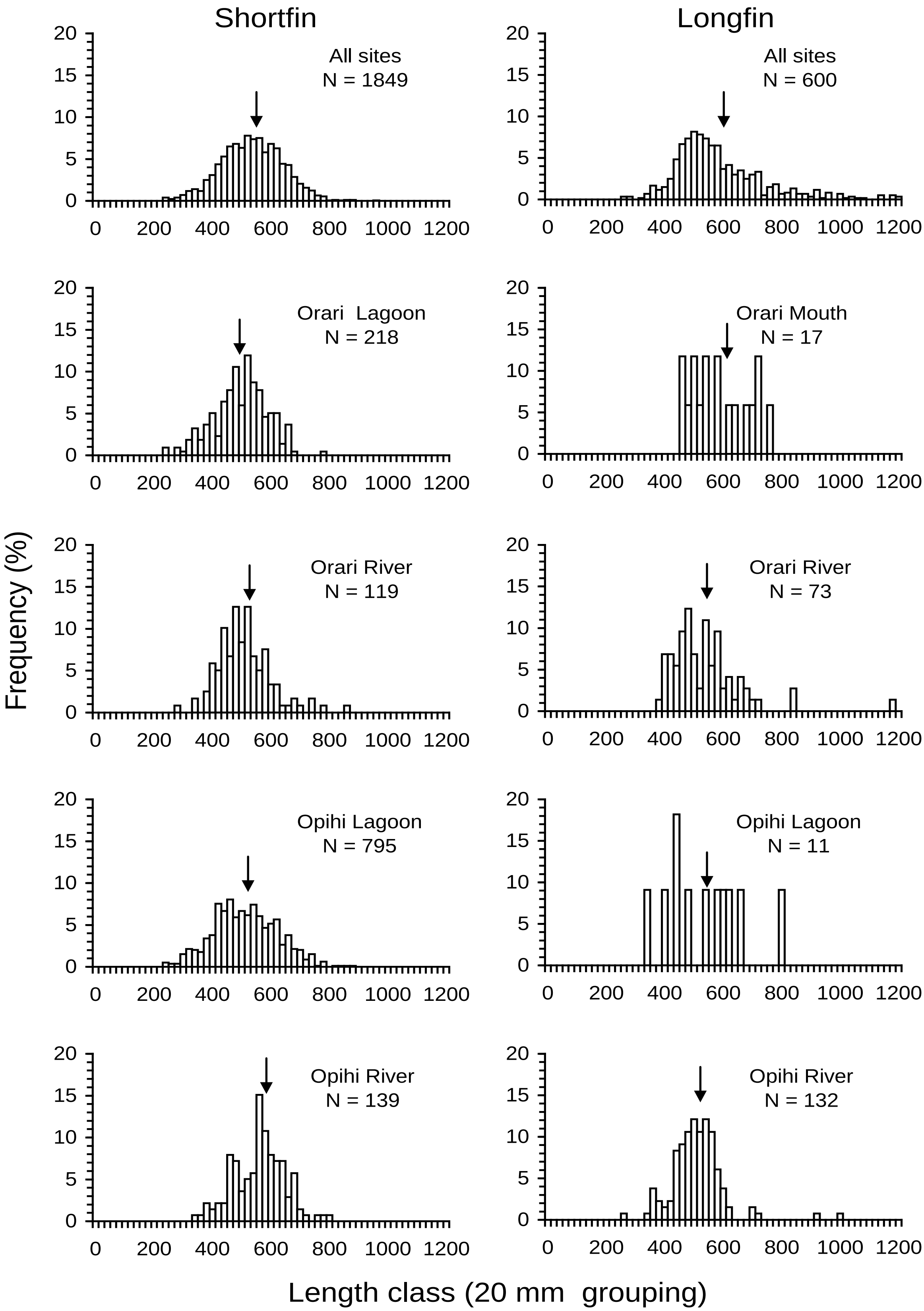


Figure 5: Length frequency distributions of fyke netted eels from sites in ANG14. The arrows show the mean lengths of samples.

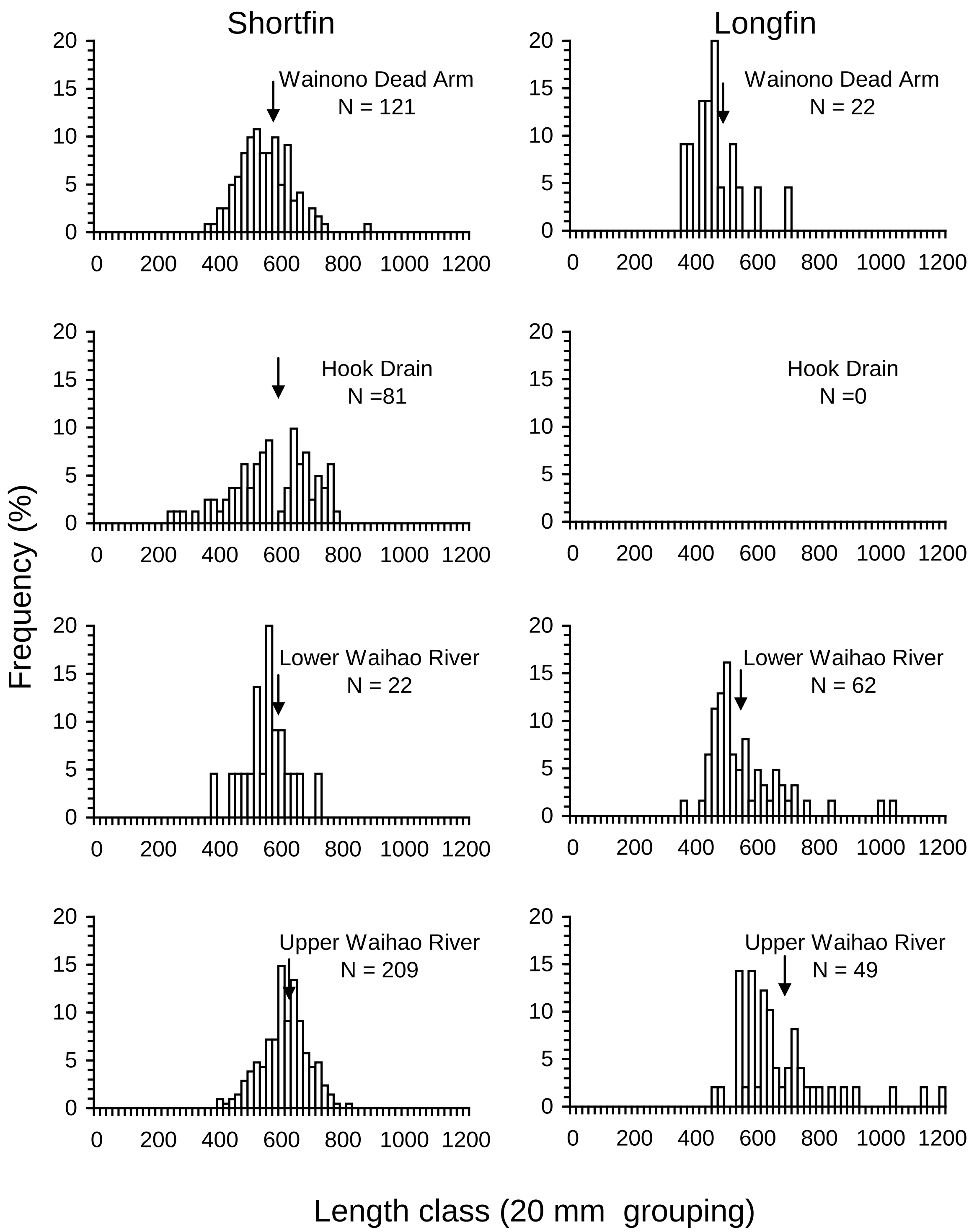


Figure 5 (cont.)

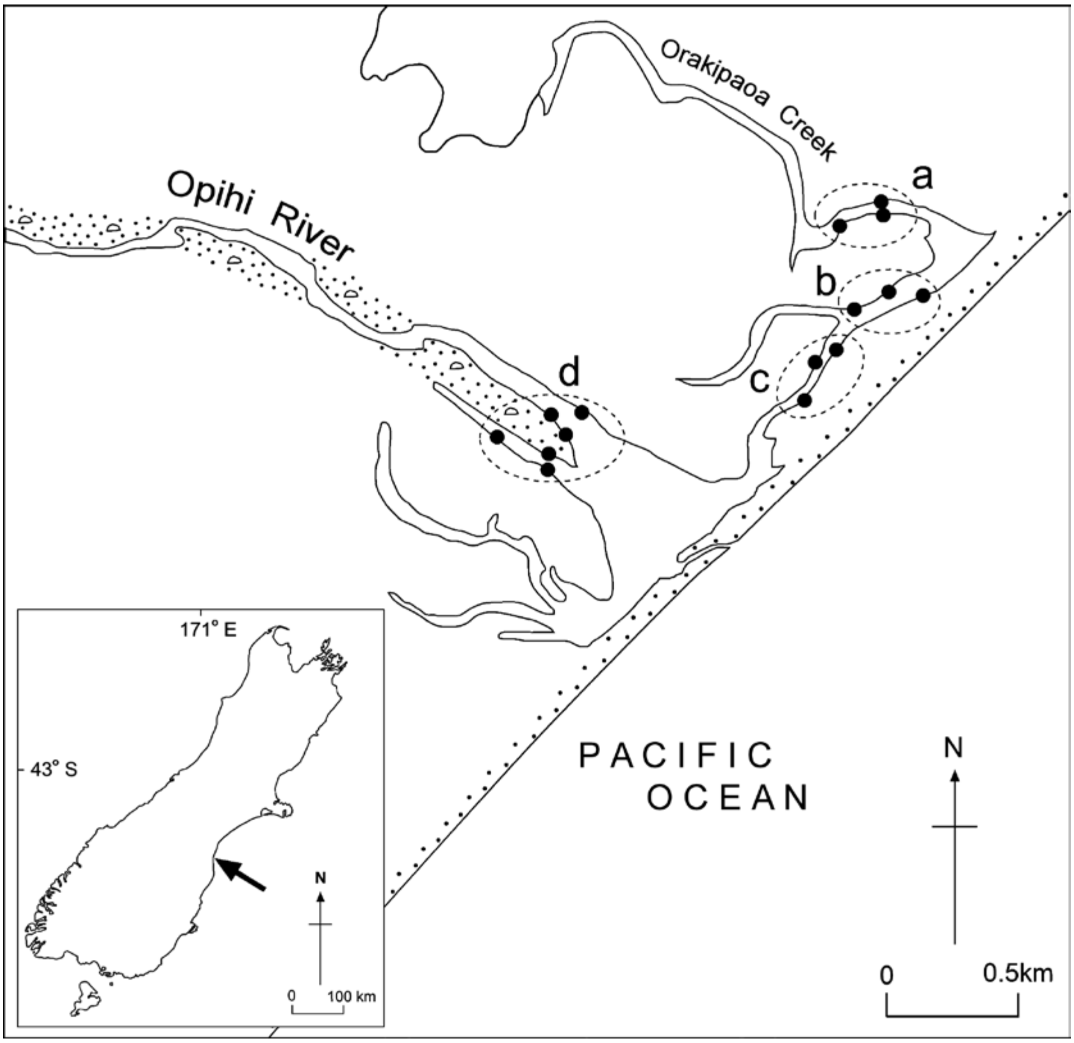


Figure 6: The Opihi River lagoon, showing location of fyke nets (black circles) and the 4 zones (a-d) described in the text.

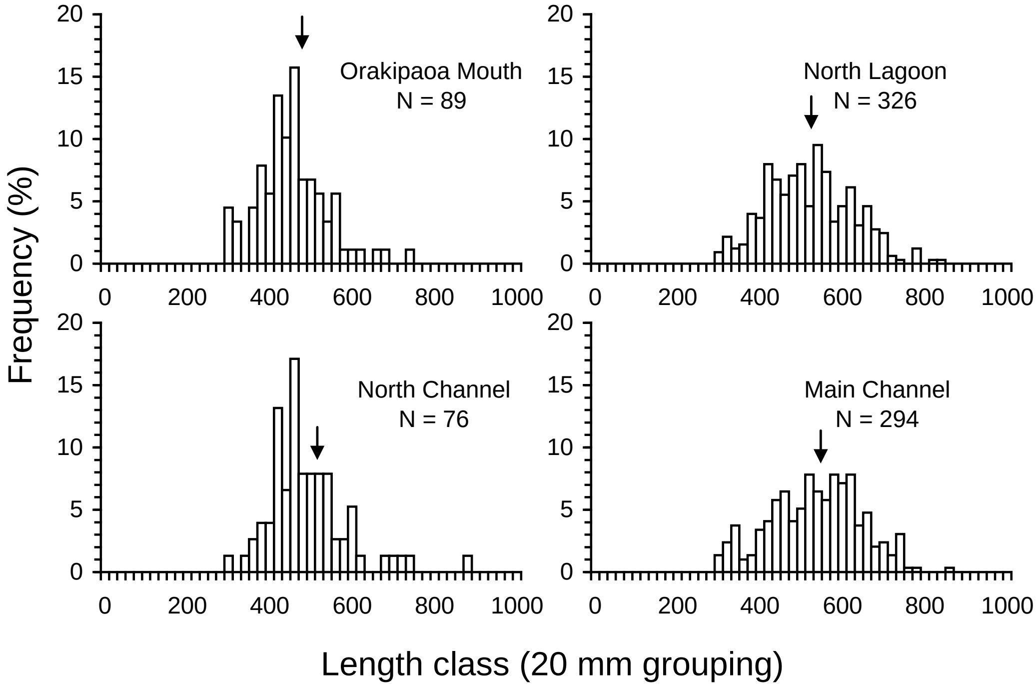


Figure 7: Length frequency distributions of shortfin eels caught at four sites in the Opihi Lagoon. The arrows show the mean lengths of samples.

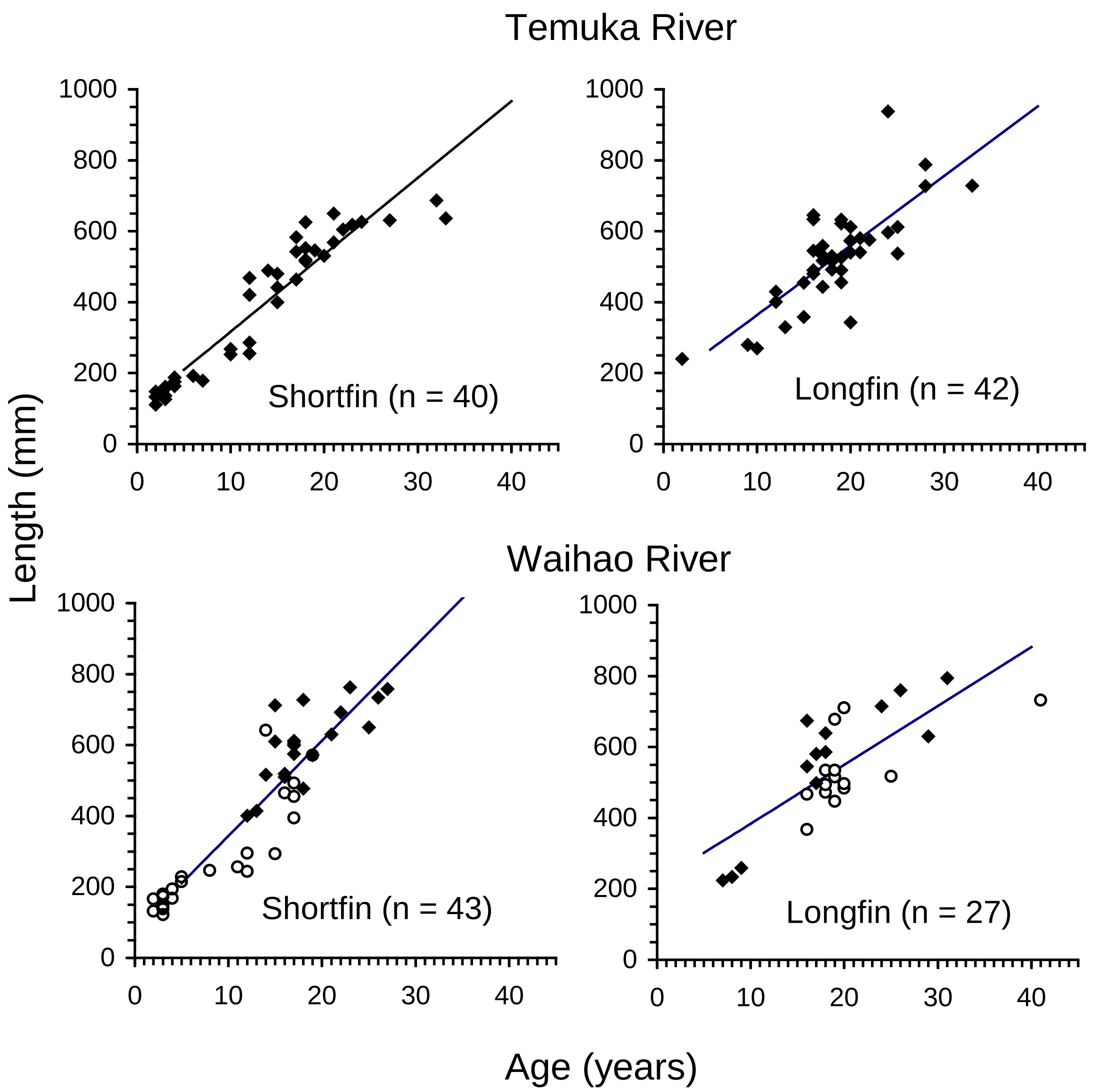


Figure 8: Length at age plots for shortfins and longfins from the Temuka and Waihao Rivers. The open circles in the Waihao plots are for eels collected from the lower river, while the filled diamonds show eels collected in the upper river. The lines are the least squares regression lines (see text).

Appendix 1: Electric fishing site descriptions.

Site #	Location	Water temperature	Length sampled (m)	Area sampled (m^2)	Habitat type: still	back water	pool	Run	riffle	rapid	Substrate: mud	Sand	fine gravel	coarse gravel	cobble	boulder	Bedrock	Shortfins (no)	Longfins (no)
1	Coopers Creek	19.7	45	90	10	10	60	20			5		15	50	30			5	4
2	Orari	19.8	27	40.5		50		20	30					60	40			5	6
3	Coopers Creek		54	135				100				40	30	20	10			2	2
4	Ohapi	17.1	32	64			10	90			40	20	20	20				6	1
5	Ohapi		30	60				100			50			20	30			4	0
6	Ohapi		24	48				100			75		20	5				7	0
7	Ohapi		9	36				100				10	20		70			5	1
8	Ohapi	14.4	34	68				100					20	50	30			1	3
9	Orari	18.8	24	48			10	30	60				10	30	60			1	5
10	Orari	17.5	40	120				100					20	40	40			2	7
11	Orari		8	88				90	10				35	40	20	5		0	0
12	Orari	18	15	60				100				10	20	50	20			10	2
13	Orari	18	36	36				50	50				50	40	10			0	0
14	Opihi	17.9	44	88				75	25				50	30	20			10	1
15	Opihi		11	22				100					20	30	50			4	1
16	Opihi		36	36					100				5	30	60	5		0	0
18	Temuka	16.7	57	114				100					35	40	25			14	2
19	Temuka	16.1	32	64				100					30	60	10			23	0
20	Temuka	16.3	21	42				60	40				10	80	10			16	2
21	Temuka	15.5	63	126				100				10	10	50	30			17	1
22	Orakipaoa	15.9	20	20				100			100							10	0
23	Temuka	16	24	72				50	50				30	40	30			10	0
24	Waihi	17.5	58	87				95	5				60	30	10			5	1
25	Waihi	19	46	69				90	10				50	40	10			4	1
26	Te Awa	18.8	45	67.5				100					60	30	10			5	2
27	Waihi	19.1	67	67				75	25				30	60	10			3	0
28	Opihi	17.7	43	43				100					30	50	20			7	1
29	Opihi	18.5	47	94				100			5		70	20	5			22	2
30	Opihi	18	30	60		40		40	20				20	40	40			25	7
32	Opihi	16.7	49	73.5				50	50				20	30	50			1	2
33	Hook	12.5	226	226				30		70			10	25	60	5		0	1

Site #	Location	Water temperature	Length sampled (m)	Area sampled (m^2)	Habitat type: still	back water	pool	Run	riffle	rapid	Substrate: mud	Sand	fine gravel	coarse gravel	cobble	boulder	Bedrock	Shortfins (no)	Longfins (no)
34	Hook	16.3	54	108				100					20	30	50			2	5
35	Hook	16.3	66	132				100					70	20	10			2	7
36	Waihao	19.6	60	60		50	50				10	10	40	30	10			35	3
37	Waihao		23	46					100		10		20	50	20			1	0
38	Waihao	21	100	100			30	70			10	10	60	20				7	3
39	Waihao	18	150	150		20	60	20			20		60	20				14	3
40	Waihao	18	70	70			100				10		30	30	30			17	0
41	Waihao	16	22	44				100					20	20	50	10		1	2
42	Waihao		80	80		10	10	50	30				10	30	30	30		2	10
43	Waihao	17.2	80	80	75			25			10		10	10	35	35		3	1
44	Waihao	20	120	120			90		10					30	30		40	8	0
45	Waikakahi	18	50	50				100					20	20	60			0	0
46	Waikakahi	17.8	50	50				100					20	60	20			0	2
47	Waitaki	14.7	300	300		20	20	30	30		20	10	20	40	10			5	1
48	Waitaki	15.8	150	150		20	20	55	5		40		10	50				1	0
49	Waitaki	19	10	10		100					90			10				1	0
50	Waitaki - Welcome Ck	16.6	80	160				100			10		20	50	20			3	3
51	Waitaki - irrigation race		20	20				100					50	50				0	0

Appendix II. Fyke net site locations and catches. Note: catches of each species for Dead Arm are estimated from partial species proportions and counts

Site #	Location	Baited	Easting	Northing	Distance inland (km)	Shortfins (no)	Longfins (no)
52	Orari Lagoon	n	2383358	5662368	0.4	5	0
51	Orari Lagoon	n	2383335	5662385	0.4	19	2
53	Orari Lagoon	n	2383340	5662496	0.4	167	2
54	Orari Lagoon	y	2383669	5662668	0.4	16	2
55	Orari Lagoon	y	2383673	5662654	0.4	12	1
56	Orari mouth	y	2382452	5661654	0.7	15	5
58	Orari mouth	y	2382474	5661707	0.7	18	3
57	Orari mouth	y	2382351	5661797	0.7	16	9
60	Orari River	y	2381195	5662415	1.8	6	8
59	Orari River	y	2381198	5662379	1.8	0	9
63	Orari River	y	2381357	5662101	1.8	3	3
61	Orari River	y	2381544	5662072	1.8	2	4
64	Orari River	y	2381593	5662052	1.9	7	19
62	Orari River	y	2381635	5662020	1.9	7	10
66	Ohapi	y	2381101	5661834	5.7	0	5
65	Ohapi	y	2381165	5661850	5.7	0	11
67	Ohapi	y	2378042	5662524	5.7	1	12
68	Ohapi	y	2378221	5662374	5.7	1	10
69	Orari	y	2375868	5658400	1.8	47	11
71	Orari	y	2375879	5658395	1.8	15	4
70	Orari	y	2375910	5658393	1.8	11	5
72	Temuka night 1	y	2371583	5665061	12.6	0	13
75	Temuka night 1	y	2371580	5664969	12.6	1	2
74	Temuka night 1	y	2371559	5664926	12.6	2	2
73	Temuka night 1	y	2371548	5664878	12.8	0	4
76	Temuka night 1	y	2371544	5667892	12.8	0	3
77	Temuka night 1	y	2371564	5664746	12.8	0	2
82	Orakipaoa	y	2377186	5658970	3.6	13	22
79	Orakipaoa	y	2377193	5659021	3.6	0	1
78	Orakipaoa	y	2377287	5659058	3.6	0	11
81	Orakipaoa	y	2377202	5659069	3.6	13	12
80	Orakipaoa	y	2377315	5659061	3.6	22	2
72	Temuka night 2	y	2371583	5665061	12.6	5	4
75	Temuka night 2	y	2371580	5664969	12.6	3	3
74	Temuka night 2	y	2371559	5664926	12.6	0	0
73	Temuka night 2	y	2371548	5664878	12.8	1	0
76	Temuka night 2	y	2371544	5667892	12.8	2	2
77	Temuka night 2	y	2371564	5664746	12.8	1	4
86	Opihi River	y	2368500	5659105	12.2	0	0
84	Opihi River	y	2368455	5659130	12.2	24	36
89	Opihi River	y	2368620	5659070	12.2	29	21
88	Opihi River	y	2368550	5659075	12.2	24	52
83	Opihi River	y	2368675	5659095	12.2	17	7
84	Opihi River	y	2368010	5659010	12.2	10	17
85	Opihi River	y	2367900	5658910	12.2	23	11
95	Opihi Lagoon	n	2378559	5657706	0.6	6	0
96	Opihi Lagoon	n	2378583	5657740	0.6	17	1
72	Temuka night 3	y	2371583	5665061	12.6	3	2
75	Temuka night 3	y	2371580	5664969	12.6	1	3
74	Temuka night 3	y	2371559	5664926	12.6	5	1
73	Temuka night 3	y	2371548	5664878	12.8	3	0
76	Temuka night 3	y	2371544	5667892	12.8	4	2

77	Temuka night 3	y	2371564	5664746	12.8	2	3
92	Taumatakahu Stream	y	2373051	5661718	10.3	0	6
93	Taumatakahu Stream	y	2374572	5660549	7.9	1	10
94	Taumatakahu Stream	y	2374603	5660494	7.9	2	4
90	Waihi River	y	2872021	5667972	15.9	0	4
91	Waihi River	y	2371951	5667913	15.9	3	6
109	Hook River	n	2363322	612571	11.9	0	12
110	Hook River	n	2363324	5612571	11.9	0	10
111	Hook River	n	2363352	5612523	11.9	1	21
108	Hook drain	n	2364229	5614129	13.9	38	0
107	Hook drain	n	2364229	5614129	13.9	26	0
106	Hook drain	n	2364239	5614072	13.9	17	0
103	Dead Arm	y	2363851	5607460	6.3	239	65
104	Dead Arm	y	2363900	5607502	6.3	51	14
105	Dead Arm	y	2363938	5607555	6.3	121	33
97	upper Waihao night 1	y	2351154	5599599	20.4	10	0
98	upper Waihao night 1	y	2351153	5599597	20.4	9	16
102	upper Waihao night 1	y	2351192	5599589	20.4	15	6
101	upper Waihao night 1	y	2351232	5599609	20.4	42	4
100	upper Waihao night 1	y	2351283	5599628	20.2	12	4
99	upper Waihao night 1	y	2351325	5599652	20.2	4	8
117	upper Waihao	n	2351052	5599560	20.5	31	4
115	lower Waihao	y	2364154	5601699	2.6	2	7
116	lower Waihao	y	2364146	5601728	2.6	1	7
113	lower Waihao	y	2364152	5601718	2.6	5	7
114	lower Waihao	y	2364149	5601736	2.5	8	17
112	lower Waihao	y	2364127	5601798	2.5	8	22
97	upper Waihao night 2	y	2351154	5599599	20.4	10	2
98	upper Waihao night 2	y	2351153	5599597	20.4	18	0
102	upper Waihao night 2	y	2351192	5599589	20.4	10	1
101	upper Waihao night 2	y	2351232	5599609	20.4	11	1
100	upper Waihao night 2	y	2351283	5599628	20.2	4	0
99	upper Waihao night 2	y	2351325	5599652	20.2	1	1
121	Waitaki springfed stream	y	2358785	5585592	5.5	0	3
122	Waitaki springfed stream	y	2358785	5585591	5.5	0	0
118	Waitaki springfed stream	y	2358855	5585590	5.5	0	2
120	Waitaki springfed stream	y	2358864	5585561	5.5	0	3
123	Waitaki braid	y	2358888	5585606	5.6	0	0
119	Waitaki braid	y	2358889	5585613	5.6	0	9
127	Waikakahi	y	2358814	5585591	5.6	0	2
124	Waikakahi	y	2358814	5585591	5.6	2	0
125	Waikakahi	y	2359354	5586208	5.6	1	1
97	upper Waihao night 3	y	2351154	5599599	20.4	2	1
98	upper Waihao night 3	y	2351153	5599597	20.4	3	0
102	upper Waihao night 3	y	2351192	5599589	20.4	16	0
101	upper Waihao night 3	y	2351232	5599609	20.4	4	0
100	upper Waihao night 3	y	2351283	5599628	20.2	5	0
99	upper Waihao night 3	y	2351325	5599652	20.2	2	1
128	Opihi Lagoon	y	2377920	5657779	0.3	57	3
129	Opihi Lagoon	y	2377779	5657752	0.3	28	0
130	Opihi Lagoon	y	2377843	5657683	0.3	65	0
131	Opihi Lagoon	y	2377782	5657624	0.3	47	2
132	Opihi Lagoon	y	2377794	5657686	0.4	20	1
133	Opihi Lagoon	y	2377780	5657558	0.4	78	2
134	Opihi Lagoon	y	2379048	5658568	1.4	32	0
135	Opihi Lagoon	y	2378893	5658482	1.4	36	0
136	Opihi Lagoon	y	2379052	5658522	1.4	25	1
137	Opihi Lagoon	y	2379203	5658218	1	38	0
138	Opihi Lagoon	y	2379075	5658247	1	48	0
139	Opihi Lagoon	y	2378949	5658152	1	158	0

140	Opihi Lagoon	y	2378867	5658020	1	87	1
141	Opihi Lagoon	y	2378781	5657968	0.8	32	0
142	Opihi Lagoon	y	2378742	5657839	0.8	21	0

Appendix III. Locations of electric fishing sites (GPD eastings and northings), and species caught. c = common, o = occassional

Site	Rover	Easting	Northing	Distance inland	Area fished (m^2)	Shortfin eels	Longfin eels	Brown trout	Common bully	Koura	Torrentfish	Bluegill bully	Lamprey	Upland bully	Inanga	Canterbury galaxias
1	Coopers Creek	2378713	5666966	8.3	90	5	4	c	c							
2	Orari	2381896	5662120	9.7	40.5	5	6		c		12	c	1	2		
3	Coopers Creek	2381896	5662120	1.3	135	2	2									
4	Ohapi	2376247	5664461	10.2	64	6	1									
5	Ohapi	2374786	5665296	12.4	60	4	0									
6	Ohapi	2375713	5666225	12.5	48	7	0			1						
7	Ohapi	2375903	5668361	10.9	36	5	1			2						
8	Ohapi	2374279	5669895	14.6	68	1	3	4	2	4						
9	Orari	2376774	5670287	12.6	48	1	5									
10	Orari	2377647	5667987	10.0	120	2	7									
11	Orari	2377672	5667983	9.8	88	0	0	1			2	c		c		1
12	Orari	2379350	5663704	11.9	60	10	2									
13	Orari	2379350	5663704	4.9	36	0	0				8	17		15		30
14	Opihi	2370484	5659236	10.1	88	10	1									
15	Opihi	2370484	5659236	10.1	22	4	1									
16	Opihi	2371904	5659041	8.5	36	0	0									
18	Temuka	2372207	5660251	8.1	114	14	2									
19	Temuka	2373372	5660030	6.7	64	23	0									
20	Temuka	2374504	5659832	5.6	42	16	2				c	c		c		
21	Temuka	2373929	5659988	6.1	126	17	1									
22	Orakipaoa	2375847	5660050	6.2	20	10	0									
23	Temuka	2371625	5661111	9.7	72	10	0									
24	Waihi	2371743	5669300	18.8	87	5	1									
25	Waihi	2372088	5668223	17.9	69	4	1							c		
26	Te Awa	2371516	5664775	11.5	67.5	5	2									
27	Waihi	2371384	5663243	11.4	67	3	0				c	c				
28	Opihi	2375632	5658569	3.6	43	7	1									
29	Opihi	2375048	5659022	4.8	94	22	2				c	c				
30	Opihi	2373616	5659211	6.6	60	25	7									
32	Opihi	2373341	5659113	6.9	73.5	1	2									

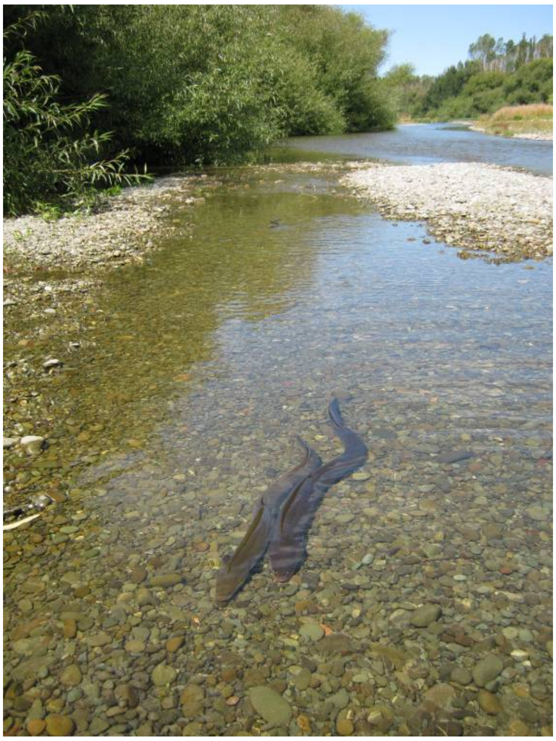
33	Hook	2349834	5614332	24.9	226	0	1	c					1		1
34	Hook	2362623	5613110	14.0	108	2	5								
35	Hook	2362610	5613165	13.2	132	2	7								
36	Waihao	2362456	5599572	6.5	60	35	3		c		o				
37	Waihao	2362593	5599752	5.7	46	1	0		c		o			o	
38	Waihao	2362785	5600039	5.6	100	7	3	o	c						
39	Waihao	2364127	5601820	2.9	150	14	3								
40	Waihao	2356520	5601085	14.3	70	17	0								
41	Waihao	2347131	5600324	25.4	44	1	2	c					c		
42	Waihao	2347105	5600265	25.3	80	2	10	c				1	c		1
43	Waihao	2344850	5602245	30.6	80	3	1						c		
44	Waihao	2353690	5599615	17.7	120	8	0	o					o		
45	Waikakahi	2358005	5586803	7.0	50	0	0	o					o		
46	Waikakahi	2354714	5588954	11.3	50	0	2	o					o		
47	Waitaki	2358821	5585587	5.5	300	5	1	c		o	o		c		
48	Waitaki	2356911	5586055	7.4	150	1	0	o			o		o		o
49	Waitaki	2354116	5585686	10.0	10	1	0								
50	Waitaki - Welcome Ck	2354012	5584941	10.5	160	3	3								
51	Waitaki - irrigation race	2346283	5586824	19.5	20	0	0								

Appendix IV. Photographs of a selection of sampling sites and catches.

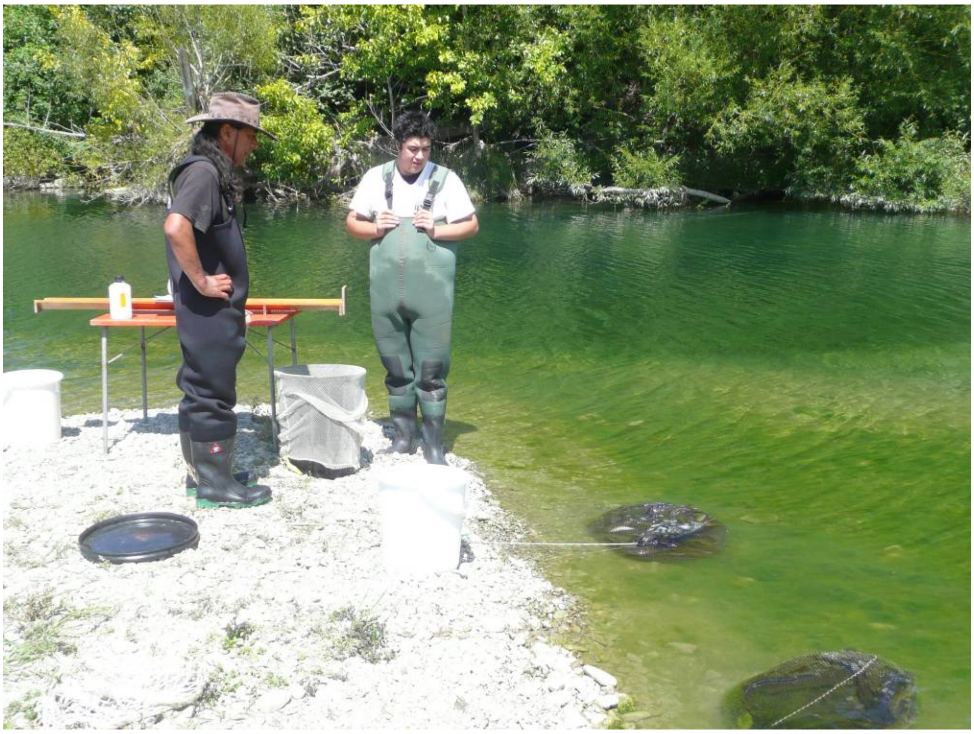
Retrieving fyke nets, Orari Lagoon

Drain, lower Orari River. While the waterway had flow at the time of the survey, further upstream it was dry and there were reports of stranded and dead eels.

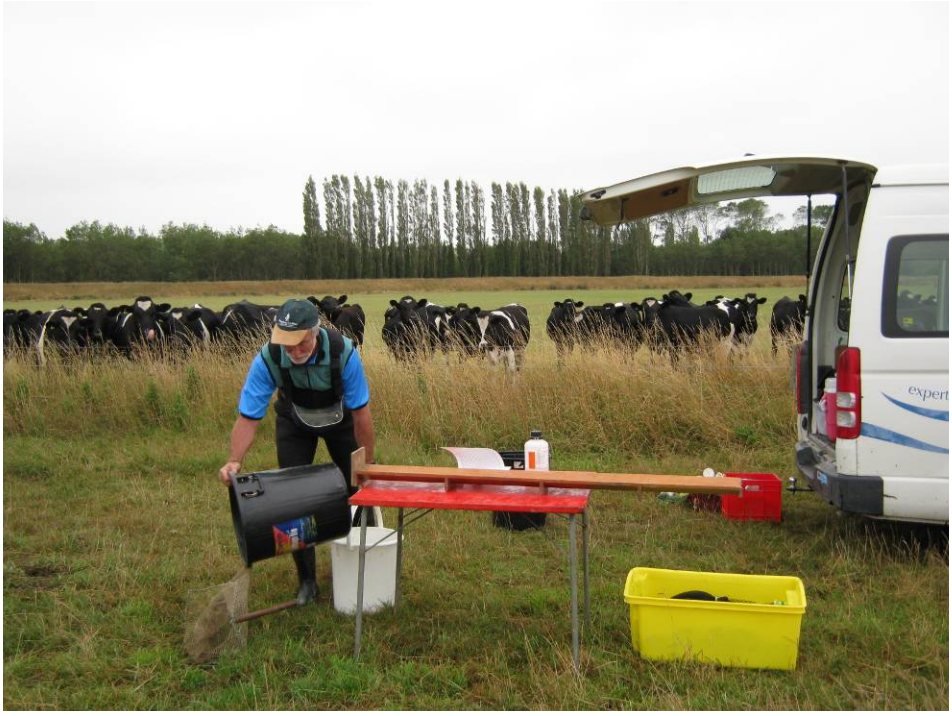
Opihi River: measuring a reluctant shortfin migrant female (note silver belly and prominent black pectoral fins)



Released longfin eels, Orari River. Shallow water with eel habitat confined to pools lined by willows



Opihi River, backwater. Keep nets of eels at right and netful in bucket being anaethsetised.



Measuring eels at drain in lower Ohapi River before a crowd of interested onlookers

Hook Drain. Note complete coverage of *Azolla*

Lower Hook River. Slow flowing with extensive marginal and aquatic plant habitat. Large longfins were caught here.

Large longfin eels, Hook River; the white perforated canister contains bait. The local farmer reported not seeing eels in this stream for several years.

Net (unbaited) containing 304 eels, Dead Arm, Wainono Lagoon

Large longfin eel (1363 mm, ~ 8.1 kg), upper Waihao River

Spring fed stream, Waitaki River. A fyke net is just visible below the fork of the two stream branches.

Waihao Box, Wainono Lagoon. The bar was closed to the sea at this time but usually breaches naturally on the far (north) side of the box

Upper Waihao River, depletion netting site. Note the extensive cover provided by willows (*Salix* spp.) on the far bank, excellent habitat for longfin eels.

Head of migrating longfin female eel. Note tapered head, large eye with blue ring, thin lips and dark colouration.

Lower Waihao River. Flow in this reach is maintained from negotiated discharges from the Morven-Glenavy irrigation scheme.