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Recruitment of freshwater eels 1995–2015

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The recruitment of freshwater eels was assessed using information from monitoring of elver trap and transfer operations in New Zealand from 2012 to 2015. The three year study was undertaken for the Ministry for Primary Industries (MPI) under project EEL201203 and commenced in the 2012–13 migration season. Data collected from existing trap and transfer operations at hydro-electric power stations (HEPS) were used to monitor the relative recruitment of shortfin and longfin eels by analysing elver abundance, timing of migration and species composition of elver runs at six locations: Wairua Falls Power Station, Karapiro Dam, Matahina Dam, Patea Dam, Waitaki Dam and Arnold Dam. Excluding Matahina, otoliths from elvers at five sites were aged using the crack and burn method. The median elver ages at each site were used to estimate the year of entry into freshwater of glass eels.

The total catch from the 17 monitored sites in 2012–13 was 10.4 million elvers which is the largest catch ever recorded. Over half of this total was from Wairua Falls in Northland (5.5 million elvers). In the 2013–14 season, data was received from 16 sites and the total catch was 7.4 million elvers, the fifth largest catch since monitoring began. Eighteen sites were monitored in 2014–15 and 10.3 million elvers were captured and transferred upstream of the barriers. The weight and number of elvers and the transfer locations where recorded are included.

Elver catches have varied at each site markedly through the seasons and between sites. A catch index was developed from the long-term mean and standard deviation of the annual catch. This index was used to examine annual catch trends. Two sites with twenty years of records (Karapiro and Matahina) peaked between 2007 and 2009, declined to a relatively low catch in the 2011–12 season but then increased again with the catch in 2014–15 almost as large as that obtained between 2007 and 2009. In contrast the total catch from Patea which peaked about a year before Karapiro and Matahina (i.e. between 2006 and 2008) has been lower ever since, although there are signs of a recovery in the last three seasons.

In the South Island, Waitaki annual elver catches have fluctuated markedly over time with large gaps in the records which make trends difficult to discern. Arnold elver catches show a gradual decline since the 2007–08 (shortfins) and 2008–09 (longfins) seasons, but numbers of both species increased in 2014–15.

Elver otoliths from five sites were aged and age length keys applied to calculate age and length distributions, mean length for each age class and median ages. Age distributions show that several year classes are present at each site, but age zero shortfins dominate at Patea and Wairua. Age one year longfins dominate at Karapiro and Patea. There was considerable variability of elver lengths for the same age classes between sites. Combined age length keys for shortfins and longfins were calculated using these aged elvers and applied to sites where no ageing was completed. The resulting age distributions and mean lengths were similar to comparable sites.

The catch indices were adjusted using the median elver age at each site to derive recruitment indices providing an indication of the relative abundance of glass eels (i.e. age 0) that enter each catchment annually. There was a peak recruitment for both shortfins and longfins on the West Coast in the Waikato, Mokau, Patea and Grey rivers around 2006–2007. A recruitment peak also occurred at the same time on the Rangitaiki River on the East Coast.

In addition, the Waikato and Northern Wairoa rivers and possibly the Patea River on the West Coast and the Rangitaiki and Wairoa rivers on the East Coast of the North Island all showed an increased recruitment of shortfins around 2011 and 2012. In the South Island the Grey River on the West Coast and the Waitaki River on the East Coast also showed increased recruitment of shortfins in 2012.

Average recruitment indices for shortfins and longfins show a four to seven year short term recruitment cycle which has been occurring since the early 1990s, and there has been no decline of recruitment over this period.

Comparison of the recruitment indices for all the sites and comparing these records to the Southern Oscillation Index (SOI) trends did not indicate a consistent link of elver recruitment with La Niña or El Niño phases of the SOI.

Water temperatures and river discharges were compared to annual elver catches and showed some weak influences which were not statistically significant. These weak correlations indicate that the timing and magnitude of elver migrations may be site-specific and influenced by multiple environmental factors. Further examination using multiple regression and multivariate analysis of the influence of all factors that could potentially affect the catch is recommended.

Continued collection of robust information from the main trap and transfer sites (Karapiro, Matahina, Patea, Wairua, Arnold and Waitaki), with the inclusion of some supplementary sites is essential for providing an understanding of the drivers of freshwater eel recruitment. In this respect, minimum standards for data collection and reporting through the transfer permit system issued by MPI is required. Detailed protocols for future monitoring are described.

2. INTRODUCTION

The New Zealand commercial eel fishery is a moderate volume fishery of around 750 t per year spread throughout the North and South Islands, and the Chatham Islands. The fishery is based on two species of eel found throughout New Zealand, the shortfin *Anguilla australis* and the longfin *A. dieffenbachii*. The Australian longfin (*A. reinhardtii*) has also been found in North Island catches in relatively low numbers. The South Island fishery was introduced into the QMS in October 2000, the Chatham Island fishery in October 2003 and the North Island fishery on 1 October 2004 (MPI 2014).

There is very limited stock assessment information available for eels, and it is not known if current catch levels are sustainable. The stock assessment of eels presents particular problems because of the biology of the species. As adults, eels undertake a long homing migration to their oceanic spawning grounds and die after spawning. The precise location of spawning is not known, but is likely to be in the south-west Pacific, possibly between Fiji and New Caledonia (Jellyman & Tsukamoto 2010). Larvae develop and migrate to New Zealand and glass eels appear to distribute randomly into freshwater habitats. After a period of residence in the lower reaches elvers (8–15 cm) undertake seasonal upstream migrations to disperse throughout the catchment. Because of their biology, eels are at risk of harvest before spawning (Jellyman 2014).

In the Northern Hemisphere the eel fisheries are based on the European eel *Anguilla anguilla*, the Japanese eel *A. japonica* and the American eel *A. rostrata.* Data from these glass eel fisheries and elver migrations showed a steady decline in recruitment from almost all data sets over the past 30 years (e.g., Jacoby & Gollock 2014; SSCE 2013; Prosek 2013; Henderson et al. 2012; Tsukamoto et al. 2009; Dekker 2004). The decline in recruitment for the European eel covered a period equivalent to the average life cycle of the species. Following concerted efforts to mitigate anthropogenic impacts, there are indications of a recovery in Europe over the last three years (ICES 2014).

Unlike the Northern Hemisphere, there are as yet no long-term data sets of New Zealand eel recruitment. However, Ministry for Primary Industries[1] (MPI) research projects completed over the past twenty years (EEL2000/1, EEL2002/01, EEL2004/01, EEL2006/01, EEL2008/01 are establishing a time series of data on the relative abundance of elvers at selected locations in the North and South Islands.

The monitoring of elver runs at hydro dams, and other locations where upstream migration is blocked, provides a means of establishing a long-term data series on the relative abundance of migrating elvers. Provided that data are collected in a consistent manner each year, the data can be used to determine overall trends in recruitment. The use of these existing elver trap and transfer programmes authorised by Ministry for Primary Industries (MPI) Special Permits provide a cost effective means of using existing data sources to provide a measure of relative recruitment in New Zealand (MPI 2014).

The MPI Medium Term Eel Research Plan proposes that research on recruitment to establish a time series of relative abundance should be ongoing (MPI 2012). The relative abundance will not be used in modelling to predict future recruitment into the eel fishery. The index will provide critical indicator of recruitment, which will over time provide information on the relative status of each eel stock.

In 2013 an independent international expert panel examined the efficacy of current and alternative methods for monitoring and assessing trends and the status of freshwater eels in New Zealand. A key conclusion was that the monitoring of elver catches at hydro dams was an effective method for assessing general recruitment trends (of multiple size classes) to freshwater habitats. The panel recommended inclusion of age structure so that the absolute numbers of 0+ eels, and other size classes could be derived. In addition, the Panel recommended increasing the number of monitoring sites close to the tidal limits (Haro et al. 2013). Based on this advice two more monitoring sites (Wairua Power station

[1] Formerly Ministry of Fisheries.

and Patea Dam) were added to the existing four main sites (Karapiro Dam, Matahina Dam, Arnold Dam and Waitaki Dam). Elvers were collected and aged to establish age distributions of elvers arriving at these main sites.

Following extensive consultation with organisations and individuals undertaking elver catch and transfer operations, NIWA developed standard methods in the early 1990s for recording elver catches (Martin et al. 2007). Since then, the methods have been used at 22 locations (Figure 1). During the 2012–13, 2013–14 and 2014–15 elver migration season there were six main sites at which trapping was intensively monitored and supervised by NIWA staff. Information from eleven supplementary sites which were operated by on-site personnel was also received. Data from some supplementary sites was not received for all three years of the project. At three sites, operations have either been discontinued (e.g. Lake Waikare) or no recent records have been received. In the 2014–15 season two new supplementary sites commenced trap and transfer operations (Mataura Falls and Lake Otamangakau) and supplied monitoring records.

Although there are records of elver transfers at some locations for over 25 years, the early records suffer from year-to-year fishing effort variability, unreliable species identification, and inconsistent trapping methods. There have also been some inevitable operational constraints (e.g., floods, structural damage etc.) at a number of sites and consequently, some of the records are considered unsuitable for establishing long-term recruitment trends (Appendix A). Including the 2014–15 season, the longest reliable time series available is 20 years of robust records from Karapiro Dam.

This report provides the results of the MPI research project EEL201203 and is a step towards a reliable long-term record of elver recruitment that will assist with the management of the eel fishery.

2.1 Objectives:

1. To contribute to a time series of data to monitor the relative recruitment of shortfin and longfin eels by co-ordinating to specific standards the collection of data on abundance, timing of migration and species composition of elver runs at six locations: Wairua Falls Power Station, Karapiro, Matahina, Patea Dam, Waitaki and Arnold for the elver migrations in 2012–13, 2013–14 and 2014–15.

2. To age a representative sample of elvers from three sites (amended objective).

3. To investigate the correlation between elver movement and environmental factors such as water temperature and flow.

Note:

(i) In December 2013 the Eel Fishery Assessment Working Group (EEL FAWG) recommended cancellation of the original Objective 2 (a quantitative survey of three streams) and the inclusion of the Wairua Falls Power Station and Patea Dam as main monitoring sites. Ageing of elvers from five main sites (Karapiro, Wairua, Patea, Arnold and Waitaki) was also included. The age structure of the elver catches at these five main sites were analysed using age length keys from 50 pairs of otoliths. As a wider length range of elvers is recorded at Waitaki, only 25 pairs of otoliths were required.

3. METHODS

During the 2012–13, 2013–14 and 2014–15 elver migration seasons, detailed information regarding the fishing effort, catch, and species composition was collected at six main sites by fully trained NIWA staff and/or accredited contractors. Four main sites are in the North Island (Wairua Falls or Titoki Power Station on the Wairua River), Karapiro Dam on the Waikato River, Matahina Dam on the Rangitaiki River, Patea Dam on the Patea River). Two main sites are in the South Island (Arnold Dam on the Arnold River and Waitaki Dam on the Waitaki River) (Figure 1).

In addition to records from the main sites, seasonal catch records and/or species compositions (limited records from some sites) were obtained from the operators of eleven supplementary sites in the North Island and four supplementary sites in the South Island. Monitoring of the Roxburgh Dam was discontinued in 2004 and was reinstated in December 2012. Development of the traps at this site has been on-going.

Catch records were received from Turitea Dam for the 2012–13 season, but not for 2013–14 or 2014–15. Elver trap and transfer programmes commenced at Mataura Falls and Lake Otamangakau Valve in 2014–15 (Table 1).

Standard monitoring protocols and recording forms developed by NIWA (Martin et al. 2007), were supplied to the operators at five of the six main sites at the start of the season. At Patea the monitoring is supervised by Ryder Consultants Ltd and uses protocols that are equivalent to the NIWA protocols used at the other main sites. Operators and NIWA personnel not familiar with the procedures were given training in the data collection, species identification and recording methods. Monitoring equipment was also provided. Site visits by NIWA staff were made to the six main sites at regular intervals throughout the season.

At the supplementary sites, operators usually recorded catches and observations on daily log sheets through the season. Operators and contractors at these sites have also received training and written instructions on data collection and recording methods. Occasional site visits by NIWA staff have also been made in conjunction with adjacent studies in the area.

3.1 Catch sampling

Representative random sub-samples of the elver catches from all the main sites were examined regularly throughout the season and analysed for species composition and average weight by NIWA staff or trained operators at the sites. The average weight was determined by dividing the weight of the sample by the number of elvers in the sample. The average elver weight for the season was determined by summing all the sample weights throughout the season and dividing by the total number of elvers measured.

At the six main sites and Piripaua in 2013–14 and 2014–15 monthly samples of the elver catches were collected as follows:

- The individual weights and lengths of 100 elvers of each species (when available) from a representative random (i.e. well mixed) sub-sample of the catch were measured monthly;

- Twenty elvers of each species were collected over the full length range present at each site. Each elver was weighed and measured, placed in individual zip-lock bags labelled with location, date, species, weight, length and preserved by freezing.

3.2 Otolith preparation and reading

The crack and burn method first described by Moriarty (1973) and subsequently Hu & Todd (1981) has been validated for New Zealand shortfin and longfin eels (Chisnall & Kalish 1993). The methodology was subsequently revised by Jellyman et al. (2007) and to date has been the main method used to age New Zealand eels.

In this method, each otolith is bisected through the centre or “nucleus” (the transverse half plane), and each piece is scorched for a few seconds at a high temperature to enhance the visibility of the growth rings. The otolith are then mounted on a glass slide with the broken side against the slide and held in place with clear silicone (Selleys marine sealant RTV acidic cure) for viewing under a microscope using reflected light (Jellyman et al. 2007).

Grinding, polishing and staining methods are also used to determine eel ages from otoliths (ICES 2009). For the toluidine blue staining method an otolith is mounted on a glass slide using a clear resin (Crystal Bond), followed by polishing the sagittal plane using up to 2400 grit polishing paper (Panfili et al 1990). The otoliths are etched with 1% EDTA for at least five minutes, rinsed with distilled water, then stained with a 5% Toluidine blue solution for at least 15 minutes. The stained otoliths are dabbed dry with tissue paper and examined under a compound microscope (100× magnification) using reflected light at an oblique angle.

In April 2014 a four day internal NIWA workshop compared the crack and burn method with the toluidine blue stain procedure, and standardised a method for reading elver otoliths. Otoliths from the same elver were prepared using each method and aged by three readers. The results were compared to the ages determined by Don Jellyman, a NIWA Principal Scientist with extensive experience in the determination of the age of freshwater eels using otolith readings. Otoliths from two juvenile eels were also prepared using only the toluidine blue staining method.

Otoliths were extracted from elvers collected over the representative length range present at five sites (Wairua, Karapiro, Patea, Arnold and Waitaki). The otoliths were aged using the crack and burn method (Jellyman et al. 2007). Ages were determined by multiple readings using primary and secondary readers, and where differences between readers occurred the otolith was re-examined, discussed and an agreed age was assigned.

The age of the elvers was determined using the standard practise of counting the number of annual hyaline rings across the largest axis ignoring the first ring (freshwater check) that surrounds the core which represents marine larval growth (ICES 2009).

The readability of each otolith was scored according to how easy they were to interpret, using the following rating scale[2] (Jellyman et al. 2007):

1 = impossible to read

2 = slightly better but not very confident of ages

3 = better, but some doubt about some rings

4 = reasonable preparation, reasonably confident of age.

5 = excellent preparation, easy to read, confident of age.

[2] This rating scale differs from the standard scale which uses 1 for excellent and 5 for unreadable. An MPI ageing protocol is now published which corrects this anomaly (Walsh et al. 2016).

3.3 Age length regression

For each site an age-length regression was determined using a linear model. Otoliths from juvenile eels (greater than 250 mm and/or 20 g) and obvious outliers were excluded from the age length regressions. The age-length regressions for each species at individual sites were statistically compared using ANCOVA analysis. The length-age relationships and the length distribution of the elvers through the season were then used to determine the median age of elvers at each site.

3.3.1 Age length key (ALK)

The age composition of a fishery can be used to infer information about growth rates, mortality and the results of relevant management policies. However collection of accurate age composition data is often costly to obtain, and sample sizes are often limited due to cost.

The age length key approach uses a small sub-sample of fish which are accurately aged. The length and age distribution of these fish are arrayed by length class and the proportion of fish in each age class is calculated. Using the ALK these proportions were applied to measured but unaged fish from catch samples. The resulting distribution provides an estimate of the age distribution of the entire population (Devries & Frie 1996).

For the 2013–14 elver season elvers from five sites were collected for ageing. Fixed length sub-sampling was used with five elvers in each of 10 mm length classes, covering the expected lengths measured in previous seasons (i.e. ideally 25 otolith pairs for each species per site).

3.4 Catch and Recruitment indices

Catch records were normalised as outlined in Durif et al. (2008). A “normalised” catch index (X_{ij}) was calculated for the total catch, catch of each species and for each season and location. The index was calculated as follows:

$X_{ij} = (x_{ij} - \mu_j)/\sigma_j$

x_{ij} = elver catch for a season

μ_j = mean elver catch at a site for all seasons

σ_j = standard deviation of elver catch at a site for all seasons.

The catch index was adjusted using the median elver age to account for the average time taken for glass eels (i.e. age 0) to reach the collection site, (assuming constant mortality rate between years and deriving a “normalised” recruitment index for each catchment).

3.5 Environmental data

Rainfall information, where available, was obtained from either the NIWA National Climate Database (http://cliflo.niwa.co.nz/) or from the power station records. River flows were obtained from power station operators or from the closest Regional Council downstream gauging station.

Water temperatures were monitored using HOBO water temp pro V2® temperature loggers provided to most operators by NIWA at the start of the season. In most situations the temperature loggers were deployed in the tailraces or in the downstream river adjacent to the elver traps, and recorded water temperature at 15 minute intervals. The records were then used to calculate average daily temperatures.

3.6 Catch analysis

Estimates of the total weight and numbers of elvers, average elver weights, and the species composition of the catches were calculated using the methods described by Martin et al. (2007). For days where the average elver weight was not measured, the closest available record was used. The catch results for each location are expressed as total catch and average daily catch. Average daily catch was calculated by dividing the weight or number of elvers obtained for each collection by the number of days since the traps were last cleared.

Timing of the elver migration was established using total catch (i.e., total of live and dead elvers). However, when total catch data were not available, the number of elvers transferred was used. From these data, the time to 50% and 95% of the total cumulative catch was calculated for the total elver catch, and for the estimated shortfin and longfin elver catch (when reliable species composition information was available). Comparisons with historical migration timing records were made, but it is important to note that the dates of the start and end of monitoring as well as methodology may have differed between years and between sites.

3.7 New site details

Details of the sites monitored and procedures in place at each location have previously been described (Martin et al. 2007; Martin et al. 2008; Martin et al. 2009a; Martin et al. 2009b, Martin et al. 2013) and any changes to procedures or descriptions of the new monitoring sites are included below. Timelines and significant events for the monitoring sites are included in Appendix A.

3.7.1 Turitea Dam

The Turitea Stream originates on the western side of the Tararua Ranges and flows to join the Manawatu River on its true left towards the bottom end of Palmerston North City. The headwaters of the Turitea Stream contain two dams which are used to capture water for the water supply to the city (Brown et al. 2013).

A trial trap and transfer system was established at the base of the Lower Turitea Dam (-40.4319 S; 175.6681 E) in late November 2012. During the initial stages of the trial, the trap was checked at least weekly. Any fish species present were identified (if possible), counted and transferred into the lower reservoir. The trap was not re-installed in 2013–14 and 2014–15 but there are plans to operate a new system in 2015–16 (Paul Horton, Rangitaane. Tanenuiarangui Manawatu Inc. pers. comm.)

3.7.2 Mataura Falls

Mataura Falls (-46.1909 S; 168.8710 E Lat/Lon WGS84) is located on the Mataura River within the town of Mataura, about 50 km from the mouth of the Mataura River. The site has been industrialised on both banks including small hydro-electricity power stations. A weir was constructed across the full width of the river immediately above the falls to provide additional head for the power plants. This weir also forms the river side of the hydro head races on each side of the falls. The weir has a vertical downstream face and slightly overhanging capstone along the Mataura Industrial Estate headrace (Holloway Environmental Services 2015).

An elver trap was constructed and deployed in early February 2015, but had to be promptly removed due to elevated river flows. The trap was reinstated on 13 February, and further modifications were made to prevent elvers from escaping, and improve the access ramp near the end of the elver run.

3.7.3 Otamangakau Valve - Upper Whanganui River

Situated in the central North Island, the Otamangakau valve (-39.0056 S; 175.6171 E) is part of the Tongariro Power Scheme (TPS) operated by Genesis Energy Limited (Genesis). The site is about 300 km inland from the Mouth of the Whanganui River. Genesis is required by resource consents to open the Otamangakau Valve at the base of the Otamangakau Reservoir to provide minimum flows on the Whanganui River at Te Maire. Although never observed, even this flow of water was thought to have the potential to attract elvers (Smith et al. 2015).

On 11 January 2015 a wetted surface was provided on the end of the valve building to entice any accumulated elvers to a location where they could more easily be observed and collected. This proved effective and from 21 January, elvers were manually collected and transferred to above the power scheme structures. A permanent trap has been installed for the 2015–16 season.

3.8 Data accuracy

A close examination of historical catch records shows that standardised methods for collecting and reporting elver catches have only been used from the mid-1990s. Data that predate the introduction of standardised recording are considered to be inaccurate and not suitable for examining recruitment trends. Similarly, records from sites with fewer than five species composition records through the migration season are judged inaccurate and therefore also unsuitable for examining recruitment trends.

4. RESULTS

4.1 Results 2012–13

4.1.1 Monitoring duration in 2012–13

Monitoring began at Wairua Falls in late September 2012 and at other sites from late October to early December. Trapping continued at all sites except Mokauiti at least into March 2015. Monitoring of the elver trap ceased on 6 February at Mokauiti and an explanation for doing so was not provided by the operator. At Wairere, Arnold, Mangorei and Motukawa monitoring continued until early April but with few elvers captured this late in the season. Durations of the monitoring periods were from 99 days (Mararoa) to 175 days (Piripaua) (Table 2). Trapping was stopped at Mararoa for 25 days in January due to river high flows.

4.1.2 Elver size

The average weights of elvers were measured at twelve sites in the 2012–13 season. Some sites had fewer than five samples (e.g., Wairere and Mokauitit), but at ten sites at least five samples were examined through the season. Average weights varied between sites and those closest to the ocean usually had smaller average weights than further inland sites. For instance, shortfin elvers from the closest station to the ocean (Wairua Falls) had an average weight of 0.31 g. This station is within the tidal range of the Kaipara Harbour. At Karapiro (166 km inland, altitude about 20 m) the average shortfin elver weigh was 0.9 g (Table 3). However Waitaki in the South Island had the largest average weight for shortfins (2.91 g), and longfins (11.6 g). Although only77 km inland Waitaki is at an altitude of about 220 m.

Average elver weights varied during the season at some sites. Average shortfin elver weights at Karapiro declined during the season. In early December the average was 1.1 g, but at the end of March the average weight was 0.8 g. At Arnold no such pattern was evident. The average weight of longfin elvers was more variable through the season, but notably at Mararoa the average weight declined through December (Figure 2).

4.1.3 Elver Catch

The number and location of sites operating can change annually. While the main sites provide data every season the number of supplementary sites providing catch records changes every season. Catch records were received from fifteen sites for the 2012–13 season, and we estimate that 6962 kg (about 10.4 million elvers) were captured and transferred to upstream habitats (Table 4). At this point in time this was the largest total catch ever recorded (Table 5).

Elver catch by site

The largest number of elvers captured at any site in 2012–13 was 5.4 million elvers (1621 kg) at Wairua, which is 53% of the national total. The next highest catch was 2.4 million (2764 kg) at Matahina. Together with Karapiro (1.8 million elvers; 1628 kg) these three sites account for 95% of the total elver catch from the monitored sites.

The 2012–13 season was the second full season of monitoring at Wairua, and the total catch was 1.7-fold greater than for 2011–12. At Karapiro and Matahina the elver catches were consistent through the season with total catches for the season near the respective medians. The single greatest daily catch at Matahina was 152 kg on 16 January 2013. The Piripaua total catch was the largest to date, and elvers continued to be captured into April 2013 (Figure 3).

In the South Island, Waitaki total catch was the highest ever recorded (8917 elvers, 89.1 kg). However, at Arnold the total catch was one of the lowest, although similar to 2006–07, and greater than when the trap was being developed between 2004 and 2006, and when migration was disrupted by maintenance in 2009–10 (Figure 3). The largest daily catch at Arnold was 6.20 kg in late January. At Mararoa, the total catch was about half the previous season’s total, and trapping was stopped in early January 2013 for 25 days due to high river flows which occur frequently in January at this site (Figure 3).

There were 242 000 elvers captured at the South Island sites, about 2.4% of the national total catch. The majority (53% or 128 000 elvers) were captured at Mararoa (Table 4).

Elver catch by species

Species composition analyses of the elver catches were undertaken at twelve sites in 2012–13, although there were a limited number of analyses from Wairere, Mokauiti, Roxburgh and Waihopai.

The estimated number of longfin elvers captured from these sites (797 000) was greater than the median for the previous 14 seasons (419 000). The largest number of longfins were captured at Matahina (317 000), and 139 000 longfin elvers were captured at Karapiro (Table 3). At Wairua, longfins were mostly captured in late November and December. For the South Island, 128 000 longfins were captured at Mararoa (Table 3), 16% of the national total longfin catch.

The total catch of shortfin elvers for the 2012–13 season was at about 9.4 million elvers, the highest total ever recorded, mainly attributable to the elver catch at Wairua (5.4 million shortfin elvers). Over 99% of the shortfin elvers were from the North Island sites, although 55 000 shortfins were captured at Arnold, and 1800 at Waitaki (Table 4).

4.1.4 Migration Timing

A few elvers were captured in early September at Wairua Falls, but the run commenced in late November, a little later than the previous seasons (Figure 3). At Matahina the run can start in early November, but for 2012–13 the first elvers were captured in mid-December, later than usual. At the other monitored sites migrations began around mid-December at most of the North Island sites. At Piripaua and the South Island sites migrations commenced in late December to early-January (Figure 3).

The dates when 50% and 95% of the cumulative elver catch occurs provides a means of comparing the relative timing of the migration between sites and seasons. Analysis of past seasons catches show that in general 50% of the catch is usually obtained by late December to early February at the upper North Island sites (Wairua, Karapiro and Matahina). At the lower North Island and at the South Island sites 50% of the catch occurs from early January to late February (Table 6). In the 2012–13 season the dates when 50% of the catch occurred are mostly within the expected ranges, although at Karapiro, Waitaki and Motukawa the 50% catch was at the early end of the range (Table 6).

The length of the run during the 2012–13 season varied from 10.3 weeks to 16.9 weeks (Table 7).

4.1.5 Environmental variables

Temperature

Tailrace or downstream water temperature was measured at Piripaua and all the main sites except Mararoa in 2012–13. Average daily water temperatures were low in December and steadily increased through the summer, reaching maximum values in late January or early February. At Piripaua, temperature was erratic, rising and declining every few days. This cycle is most likely due to operating regimes of the power stations. Other sites also had erratic temperature, but less frequently than at Piripaua (Figure 4).

At Karapiro temperature increased rapidly in December 2012 from 18 °C to almost 22 °C, but then remained around 22 °C until the end of February 2013. A similar pattern also occurred at Matahina, although the temperature there only reached 19 °C. At Patea also water temperature quickly increased in December, but fluctuated between 21 and 23 °C through January. The maximum temperature at Patea was 23.5 °C in early February (Figure 4).

At Arnold the water temperature dropped in mid-January from 20.2 °C to 16.4 °C in 2 days, then increased to 20.2 °C by the end of February. At Waitaki at the end of December water temperature was 17 °C, but dipped to 16 °C in the middle of January, then increased again reaching the maximum of 18 °C at the end of February (Figure 4).

Water temperatures at the sites monitored in 2012–13 varied between 14.8 °C and 20.2 °C at the start of the migration and were between 16.7 °C and 21.4 °C at the end of the season (Table 7)

River level

Downstream discharge data were obtained from three sites; Matahina, Piripaua and Mararoa in 2012–13 (Figure 5). At Matahina there were several high flow periods in early December, and the elver migration did not commence until mid-December. Elver catches in January fluctuated, but river discharge was relatively steady. The daily elver catches were not correlated with the river discharge at any of these three sites (Figure 5).

At Piripuau the Waikaretaheke River stage height did not show any large changes through most of the migration season. However there were regular small fluctuations over a few days, which occasionally corresponded with water temperature changes, but this was not consistent (Figure 6).

4.2 Results 2013–14

During the 2013–14 elver migration season the first elvers were captured in Northland at Wairua Falls in early August, and small catches continued to be made throughout September and October with the migration only beginning in earnest in November. Monitoring at the other sites began mostly in November or early December, except for Waitaki Dam (7 October 2013) and Roxburgh Dam (20 January 2014). Trapping continued at all sites into March 2014, although trapping at Patea Dam continued until 27 April 2014. Durations of the monitoring periods were from 214 days (Wairua Falls) to 61 days (Roxburgh Dam) (Table 2). At Mararoa high flows in January 2014 prevented trapping from 2 to 24 January. At Wairua Falls Power Station, no catch records were made between 29 December 2013 and 19 January 2014, but as the traps remained in operation we can but presume that the catch over this period was very small.

The average weights of shortfins and longfins were lower at the North Island sites than elvers from South Island sites. The smallest average shortfin weight was 0.34 g (Wairua Falls, n=2249), and at Patea Dam the average weight of shortfin elvers was 0.46 g (n = 1241). The largest shortfins were captured at Waitaki Dam (2.72 g, n = 127). For longfins a similar pattern was evident, with the smaller elvers recorded at Wairua Falls (0.46 g, n = 17) and Patea Dam (0.62 g, n = 130), and the largest elvers at the inland sites (e.g., Waitaki, 10.36 g, n = 56) (Table 3).

Very low catches at Waitaki and Roxburgh dams prevented an accurate determination of the length of the run at these two sites. For the other sites, the migrations lasted from 20.7 weeks (145 days) at Wairua Falls to 11 weeks (77 days) at Wairere Falls. The migrations were mostly shorter in the South Island (about 12 weeks) than in the North Island (Table 7).

4.2.1 Catch Summary

During the 2013–14 migration season it is estimated that at the sixteen monitored sites 5811 kg of elvers (about 7.4 million) were captured and transferred to upstream habitats (Table 4). The total number of elvers transferred was lower than the record catch recorded for the 2012–13 season, but ranks as the fifth highest since standardised monitoring was introduced in the 1995–96 season. However it is important to note that the number and location of sites operating is changing annually (Table 4).

The largest number of elvers captured at any site during the 2013–14 season was at Wairua Falls (2.8 million), which is 38% of the monitored sites' total catch for the season. Matahina Dam (2.1 million elvers) and Karapiro Dam (1.8 million elvers) recorded the next largest catches. Together these three sites account for 91% of the total elver catch from the monitored sites. However, based on weight, Matahina Dam (2188 kg) had the largest catch (Table 4).

The elver catch at Piripaua Power Station (75.8 kg, 68 734 elvers) is the highest ever recorded from this site, over twice the previous maximum record obtained in the 2012–13 season (Table 8).

Elver catches were relatively consistent through the season at Karapiro, Matahina, Piripaua, Patea and Arnold dams. At Mararoa Weir and Wairua Falls there were sharp increases in late January and the middle of February 2014 respectively (Figure 3).

There were 217 000 elvers captured at the South Island sites. Few elvers (188 total) were recorded at Waikati Dam in the 2013–14 season, and the reason for this sharp decline in comparison to previous years is not clear although it is thought unlikely to have been caused by trapping efficiency or other operational constraints.

Trap and transfer operations have been intermittent at Roxburgh since the first floating trap was installed in 1996 (G. Ryder, email 7 February 2012). For the 2013–14 season an additional elver trap (New Trap) was trialled at Roxburgh Dam in December 2013, but this was not serviceable until late January 2014 due to high river flows (over 700 $m^3 s^{-1}$). This new trap was decommissioned on 20 February due to water supply issues but while operating caught no elvers. The elver catch at this site with the two older ramps and traps (511) was similar to total catches from 2001 to 2004, but 14-fold lower than in the 2012–13 season (Table 8).

The number of longfin elvers captured in 2013–14 (608 000) was greater than the median for the previous 15 seasons (419 000). The majority of the longfins (62.5%) were from Karapiro and Matahina dams, and about 30% were captured at South Island sites. Longfins comprised a very small proportion of the total elver catch at Wairau Falls in the 2013–14 season (16 200, 0.6%). In contrast, almost all the elvers captured at Mararoa Weir were longfins (150 400, 99.9%) (Table 4).

The total catch of shortfin elvers for the 2013–14 season was at least 6.5 million, 2.3-fold greater than the median of the last 15 seasons (2.8 million). The majority of shortfins (96%) were from the three main sites in the North Island (Karapiro and Matahina dams and Wairua falls Power Station). Few shortfins were captured at most of the South Island sites (36 000), although at Arnold Dam they composed 55% of the total catch. Shortfins were captured at Mararoa Weir in 2013–14 (about 500 elvers) for the first time since the 1998–99 season when about 1 100 shortfins were estimated to have been present in the catch (Table 8).

4.2.2 Migration Timing

The first elvers were captured in mid-August 2013 at Wairua Falls, earlier than previously recorded at any of the monitored sites. Data from previous seasons show that the migration timing has changed little at Karapiro, but at Matahina it sometimes occurs early, such as in 2003–04 and also in 2013–14 (Figure 3). Migration also started early at Patea in 2013–14. At the other sites in 2013–14, migrations began around the beginning of December in the North Island, and mid-December in the South Island (Figure 3).

The dates when 50% and 95% of the cumulative elver catch is made provides a means of comparing the relative timing of the migration between sites and seasons. The records indicate that in general 50% of the seasonal catch is usually obtained by late January to early February, and the bulk by late February to the middle of March (see Figure 3). For the 2013–14 season, most sites had reached 50% within the expected time-frame compared with previous seasons. Wairua Falls reached 50% of total catch for the season in late December, while at Arnold Dam this occurred in early February (Table 6).

4.2.3 Environmental variables

Temperature

Temperature records were collected from eight sites for the 2013–14 season but at Wairua the power station shut down in early March 2014 for 14 days, and the temperature logger was removed from the tailrace. The logger at Arnold also malfunctioned at the end of January.

In early December average daily water temperatures were relatively high compared to other seasons at Karapiro, Wairua and Matahina. At Piripaua, temperature was erratic, as in 2012–13, continually rising and declining every few days. Some other stations (e.g. Arnold, Wairua and Mararoa) also had erratic water temperature, but large variations were less frequent than observed at Piripaua (Figure 4).

At Karapiro temperature increased slowly in December and January to the maximum value of 21.8 °C on 6 February, and then slowly declined until the end of the run in early April 2013. At Matahina water temperature increased quickly in December then declined. The maximum for the season was 19.8 °C in late February. In the South Island, water temperature rose to 17.6 °C at Waitaki in late February, 3.1 °C greater than the temperature at the beginning of December (Figure 4).

River discharge

In 2013–14, river flows were collected from five main sites (all but Patea), Piripaua, Mararoa and Roxburgh. As for previous seasons, there appeared to be very little relationship between elver catches and average daily river flow at most sites although at Piripaua the peak average daily catch for the season was slightly ahead of a flow increase (Figure 7). Consistently higher catches were also made at this site in February when the river level remained relatively high (Figure 7).

On some occasions a large elver catch occurred after significant rainfall and subsequent high flows. For instance at Matahina a significant rainfall event occurred on 5 December 2013 (70 mm), which resulted in high river flows from 6 to 9 December. The highest daily catch at this site occurred shortly after on 12 December (Figure 7). In general, however, such marked potential correspondence between flow and catch were not seen at the other sites.

4.2.4 Elver size distribution and age

Elver Length

Individual elver lengths were obtained from nine sites during the 2013–14 season (Table 9). At some sites few elvers were measured, which limited analysis. For instance at Roxburgh only sixteen longfin elvers were measured by the site operator. At Mararoa only fifteen shortfins were identified (and measured) in the entire season. Similarly at Wairua only seven longfins were available to be measured while 1318 shortfins were measured.

The length distributions of the elvers were plotted for eight sites (Figure 8), with six sites showing differences between longfin and shortfin elvers. For these six sites (Karapiro, Matahina, Patea, Piripaua, Arnold and Waitaki) the mean lengths of shortfins were significantly less than longfins (α=0.05, 1 tail *t*-Test).

Elver Ages

The NIWA elver ageing workshop held in April 2014 found that otoliths prepared using the crack and burn method consistently had better readability scores than otoliths prepared using toluidine blue staining (Appendix A). All but one otolith was within 1 year of the reference reader's interpretation. Three of the stained stained otoliths agreed with the reference reader, while two crack and burn otoliths agreed with the reference reader (Figure 9). The crack and burn method was preferred for ageing elvers collected in the 2013–14 season.

In addition to the 10 otoliths described above, two otoliths from larger elvers (over 200 mm) were ground, polished and stained with toluidine blue and examined under the microscope to determine their ages. There were numerous false checks on these two otoliths and their ages could not be determined (Appendix A).

Otoliths were extracted and aged from elvers collected at Wairua, Karapiro, Patea, Arnold and Waitaki. The slope of the length-age regression is an estimate of average annual growth rate (mm y^{-1}). Growth rates varied between species and between sites. The largest growth rate for longfins was 21.4 mm y^{-1} at Patea (n = 25), and the lowest was 9.0 mm y^{-1} at Wairua (n=5[3]). For shortfins, the largest growth rate was at Patea (26.0 mm y^{-1}; n = 27) (Figure 10).

For Patea and Arnold there was no significant difference (α=0.01) between the age-length regressions for shortfins and longfins. However, the growth rate for longfins was significantly greater than shortfins at Karapiro. The slopes of the Waitaki age-length regressions for shortfins and longfin were significantly divergent (α=0.01), but for shortfins the relationship predicts little to no annual growth which brings the accuracy of the records into question and the results were not used for estimating shortfin elver age distribution at the dam.

Comparison of the shortfin age-length regressions from Karapiro, Wairua, Patea and Arnold indicate significant differences (α=0.01) between the sites. Similarly the longfin age-length regressions for longfins from Waitaki, Karapiro, Patea and Arnold also showed significant differences in growth rate between the sites. Overall the derived age-length regressions indicate that growth rate is most likely site and species specific, but there was considerable length variability for each age (Figure 10).

Age length keys (ALK)

About 25 elvers of each species were aged from Karapiro, Patea and Arnold and Waitaki. At Wairua twenty seven shortfin elvers were aged, but an insufficent number of longfins were collected for calculating an ALK. An ALK was also not calculated for shortfins from Waitaki.

Age distributions derived from ALKs for sites where elvers were aged show the frequency of the age classes (Figure 11). At each site there are several age classes, such as Patea where ages zero, one and two years were present. At the South Island sites elvers are generally older than at North Island sites.

For shortfins at Wairua and Patea age zero is the dominant size class, but age one year dominates at Karapiro and Arnold. For longfins age one year is the dominant size class at Karapiro and Patea. At the Arnold and Waitaki the longfin age distributions are elongated with older elvers present, while the Waitaki distribution is bimodal (Figure 11).

The mean lengths for each age class and the median lengths for each site were calculated from the ALKs and the age corresponding to the median lengths were estimated (Table 10). The mean lengths for size classes show variations between sites for the same age class. For instance age zero shortfins can be from 62 mm (Wairua) to 85 mm (Piripaua). Age one year longfins were from 83 mm (Patea) to 117 mm (Waitaki).

[3] With such a small number of elvers aged the resulting regression was not considered valid.

The median ages for shortfins were from age zero (Wairua and Patea) to age two years for Waitaki. For longfins the median ages were from age one year at Karapiro to age four years at Waitaki (Table 10).

A combined ALK was calculated for shortfins and for longfins using elver ages from the five sites where ageing was undertaken. These combined ALKs were applied to length measurements at sites where ageing was not undertaken (Matahina, Piripaua, and Mararoa) and to shortfins from Waitaki. However there were large variances for some mean lengths, due to length variations between sites. The mean lengths for each age class were comparable to similar sites where elvers were aged. For instance Matahina shortfins have mean lengths similar to Karapiro, and Piripaua is similar to Arnold (Table 10).

4.3 Results 2014–15

4.3.1 Monitoring duration in 2014–15

Monitoring began at Wairua Falls in early September 2014 and at other sites from mid-October to December, except for Mararoa Weir (8 January), Mataura (1 February) and Lake Otamangakau Valve (21 January). Trapping continued at all sites into March 2015, although monitoring of the elver traps at Patea Dam, Mangorei and Motukawa continued until the end of April but with few elvers captured this late in the season. Durations of the monitoring periods were from 26 days (Mataura) to 193 days (Wairua Falls) (Table 1). At Wairua falls trapping was halted for about 10 days from 15 December 2014 when the traps were inaccessible due to high river levels.

The start and end points of the migrations were determined by examining the elver catch records at each of the monitored sites. Irregular monitoring of the traps, or delayed commencement at some of the supplementary sites prevented an accurate determination of the length of the run at these sites. Migrations lasted from 16 weeks (112 days) at Wairua Falls to 26 days at Mataura Falls, and were mostly shorter in the South Island (less than 12 weeks) than in the North Island (Table 2).

4.3.2 Elver size

The average weights of shortfins and longfins captured at the North Island sites was lower than the South Island sites. The smallest average shortfin weights were at Wairua Falls (0.4 g, n = 546), and at Patea Dam (0.6 g, n = 1261). The largest average shortfin weight was at Waitaki Dam (2.6 g, n = 271) (Table 3).

For longfin elvers a similar pattern was evident between the two islands, with the smaller elvers at Wairua Falls (0.7 g, n = 40) and Patea Dam (0.7 g, n = 130), and the largest elvers at sites further inland (e.g., Waitaki, 11.7 g, n = 698) (Table 3).

4.3.3 Elver Catch

Elver catch by site

During the 2014–15 migration season we estimate that at the eighteen monitored sites 8735 kg (about 10.3 million elvers) were captured and transferred to upstream habitats (Table 3). The total number of elvers transferred was just below the previous record (2012–13 season Table 5). However it is important to note that the number and location of sites operating changes annually.

The largest number of elvers captured at any site in 2014–15 was at Matahina (4.7 million elvers), which is 46% of the monitored sites total catch, followed by Wairua Falls (3.0 million elvers) and Karapiro Dam (1.6 million elvers). Together these three sites account for 91% of the total elver catch from the monitored sites.

The elver catch at Matahina (4838 kg, 4.7 million elvers) is the highest ever recorded from this site, about 10% greater than the previous maximum record obtained in 2008–09. The catch included 1.8 million shortfin elvers.

Elver catches were relatively steady (i.e. constant slope on the cumulative catch graphs) through the season at Karapiro, Matahina, Piripaua, Patea and Arnold dams (Figure 3). However, catch rates significantly increased at Piripaua in late February and at Matahina in mid-December. At Wairua Falls trapping ceased in mid-December due to high river levels. In the South Island, there were sharp daily catch increases in mid to late January at Arnold and Mararoa (Figure 3). However, it is important to note that trapping did not begin at Mararoa till mid-January and the run may well have started much earlier.

There were 300 000 elvers captured at the South Island sites, 51% of these elvers were captured at Arnold and 45% were captured at Mararoa. Relatively few elvers were recorded at Waitaki, Roxburgh and Mataura, although the Waitaki catch was the second largest since 1999.

Elver catch by species

Species composition analyses of the elver catches were undertaken at thirteen sites in 2014–15 (Table 3).

The number of longfin elvers captured from these sites (791 000) was greater than the median for the last 16 seasons (475 100). The season total for Wairua Falls was over 10-fold greater than the previous season, but similar to 2012–13. The majority of the longfins (55%) were from Karapiro and Matahina, and about 30% were captured at South Island sites, mostly Mararoa (136 000) and Arnold (65 000).

The total catch of shortfin elvers for the 2014–15 season was at least 9.2 million elvers, 3-fold greater than the median of the last 20 seasons (3.0 million). The majority of shortfins (96%) were from the three main sites in the North Island (Karapiro and Matahina and Wairua Falls). Few shortfins were captured at most of the South Island sites (90 100), although at Arnold Dam they composed 57% of the total catch. A few shortfins were captured at Mararoa Weir (132 elvers) and Mataura (78 elvers) (Table 4).

4.3.4 Migration Timing

A few elvers were captured in October at Wairua Falls, but the run commenced in earnest in early December, later than in the last three years (Figure 3). Data obtained at other sites in previous seasons show that the start of the migration in December is somewhat variable and, for example, at Matahina can start as early as November and as late as January with an early start often preceding a high season's catch (Figure 3).

In 2014–15 at Matahina, migration commenced in early December, and the four largest daily catches for the season occurred between 12 and 16 December (144 to 187 kg). At the other sites that were monitored in 2014–15, migrations began around mid-December in the North Island, and late December to mid-January in the South Island (Figure 3).

Analysis of past seasons' catches show that in general 50% of the seasonal catch is usually obtained by late January to early February, and the bulk (95%) by late February to the middle of March (Table 6).

For the 2014–15 season, at most sites 50% of the season's catch had been obtained within the expected time-frame. However, at Wairua Falls half of the of total catch for the season was only obtained by late January, later than expected from the previous three seasons. At the South Island sites half of the season's catch is normally obtained by mid to late February, later than North Island sites (Table 6).

Examination of the more recent records indicate that the temperature range at the start of the season ranges from 17–20 °C (Table 7). At the end of the migrations water temperature had dropped to 15 °C at Piripaua in 2014–15, but was still 22 °C at Wairua, the northernmost site monitored (Table 7).

4.3.5 Elver size distributions

The average weights and lengths of elvers were obtained from thirteen sites during the 2014–15 season (Table 3). As in the previous season, the smallest elvers were found at sites close to the tidal zone (e.g., Wairua Falls and Patea Dam) and the largest at inland monitoring sites (e.g., Waitaki Dam and Mararoa Weir). At sites where longfins and shortfins were measured, length distributions show longfins are more common in the larger size classes than shortfins (Figure 12). At Arnold, Karapiro and Matahina the differences in length between shortfins and longfins were statistically significant (*t*-Test, α=0.05).

Ageing of elvers from the 2014–15 migration season was not undertaken, but samples were collected from the main sites, Matahina, Piripaua and Mararoa, and have been frozen for later analysis if required.

4.3.6 Environmental variables

Temperature

Accurate temperature records from dam tailraces or nearby downstream river sites were obtained from eight sites over the 2014–15 season (Figure 4). Excluding Piripaua, the average daily temperatures show warmer water temperature in 2014–15 than in the previous two seasons (Figure 4). Maximum temperatures during the season were about 24 °C at Karapiro, Patea had the highest maximum temperature of the last ten years. At Wairua the maximum average daily temperature was 24.3 °C, the highest since monitoring commenced in 2011–12.

Average daily water temperatures at Piripaua and Mararoa were erratic, with large fluctuations over several days (Figure 4). The changes are most likely to be due to operating regimes of the power schemes.

River discharge

Daily elver catches were compared to river flows over the 2014–15 migration season at Matahina and Mararoa and to stage height at Piripaua (Figure 13). No consistent relationship was evident at any of these sites.

Monthly average Waikato River flows for December to March at the Hamilton City gauging station from 1995 to 2015 were used to examine the potential effect of river flow on the annual elver catches from Karapiro. Catches appeared to decline with increasing average flows for the period spanning 1 December to 31 March and 1 January to 28 February but the relationships were not statistically significant (α=0.05, n=10) (Figure 14).

4.3.7 Catch Index

Catch indices were calculated for eight sites that had accurate data and at least five species composition analyses done through each season. Although being a requirement of the transfer permit issued by MPI for Wairere Falls power station there were unfortunately no species compositions examined or samples retained at Wairere from 2012–13 to 2014–15 so this site was discarded.

At Karapiro, and Patea as well as Mararoa the indices show that the 2014–15 longfin and shortfin catches are close to the average for each site (Figure 15). At Matahina the catch index shows an ascending trend for shortfins since 2011–12, but longfin numbers have not changed as greatly over this period. The shortfin catch at Piripaua Power Station in 2014–15 is similar to 2013–14 and may have reached a peak, but longfins show a much more apparent decline relative to 2013–14 (Figure 15).

At Arnold Dam, there was an increase of both shortfin and longfin elvers in 2014–15, interrupting the trend of declining catches which has been occurring since the 2009–10 season. Waitaki and Wairua catches remain highly variable and no trends are discernible at present (Figure 15).

4.3.8 Recruitment Index

Adjusting the catch index for the median age of the elvers at each site (Table 9) provides a means to assess the recruitment trends of glass eels (age 0) at entry into freshwater for each catchment (Figure 16). This analysis assumes that mortality of elvers and upstream migration rate has remained similar over the entire monitoring period.

The indices indicate that there was a peak recruitment for both shortfins and longfins in the Waikato, Mokau, Patea and Grey rivers around 2006–2007 (Figure 16). A recruitment peak also occurred at the same time on the Rangitaiki River which, unlike the other four rivers, is on the East Coast.

In addition, the Waikato and Northern Wairoa rivers and possibly the Patea River on the West Coast and the Rangitaiki and Wairoa rivers on the East Coast of the North Island all show an increased recruitment of shortfins around 2011 and 2012. In the South Island the Grey River on the West Coast and the Waitaki River on the East Coast also showed increased recruitment of shortfins in 2012 (Figure 16). Because of the time it takes for longfins to reach these two South Island dams it is still too early to know if longfin recruitment also increased in 2012.

Two rivers, the Wairoa and Waiau do not follow the general patterns shown by the other sites although it is still too early to be certain, as the 2011–12 peak in catches may have well have occurred in the Wairoa. Issues with effort have most likely disguised the actual recruitment trend in the Waiau (Figure 16).

Combining the recruitment indices for all the sites and comparing these records to the SOI trends does not indicate a consistent link in elver recruitment to either La Niña or El Niño phases but there does seem to be a relationship between the recruitment trends of the two species (Figure 17). Since the early 1990s there have been four peaks of the average recruitment index for shortfins (1996, 2001, 2006 and 2013) and longfins (1996, 2000, 2006 and 2012) (Figure 17). The time between these peaks is from four to seven years, indicating a short-term cycle that appears to be sustaining recruitment in the medium term for both species.

5. DISCUSSION

5.1 Limitations of data

Reliable results require consistent and accurate data collection and analysis. In particular, trapping methods (especially trap design and location) and fishing effort (e.g., period of trap deployment and frequency of trap clearance) must remain consistent over time at each site. Since 1995 consistent methods have been in use to monitor seasonal catches of elvers in trap and transfer programmes at most hydro-electric dams and power stations around New Zealand. This data provides a valuable tool for estimating the relative abundance of migrating elvers at each location.

The MPI Medium Term Eel Research Plan (MPI 2012) and the 2013 Independent Expert Panel Report (Haro et al. 2013) support the use of data from trap and transfer programmes at hydro-electric dams and power stations in New Zealand to develop an index of elver abundance. These indices provide critical recruitment signals for the species, and are part of a suite of information used to assess the relative status of eel stocks.

Although trapping methods and effort has been consistent since 1995, at a number of sites there have been the inevitable exceptions. At Mararoa, for example, fishing effort has been inconsistent and this may have contributed to the significant changes in catches that have been observed there (Martin et al.

2013). For this site it is not possible to determine if the catch increases that have been recorded are due to increased recruitment, increased fishing effort, or a combination of factors.

Similarly, at Waitaki re-configuration of the traps, equipment damage by floods and inconsistent trap clearing frequencies have no doubt been responsible for the catch fluctuations. Despite these issues it is very clear that catches at this site are extremely small for the size of the catchment and that based on anecdotal evidence, recruitment has declined markedly over time.

At Arnold Dam, major dam repair work affected trap operations in 2009–10 while slips disrupted the traps and access at other times. At newly established sites, such as currently at Wairua, the traps and their operations sometimes require modifications, expansion and relocation until the right combination is discovered and catches are maximised. Such improvements can take several years to implement.

Even at sites where little or no change in the type and period of trap operation have occurred, there may be operational factors that affect the catch. At Patea, for example, a correlation between seasonal catch and the number of days the traps have been operated each season has been found (Martin et al. 2013). At this site the trap design could make it possible for elvers left in the trap for extended periods to return to the tail race. Conversely, it is likely that trap clearance frequency simply reflect catches with daily clearance occurring when the catch is high, but with less frequent clearance necessary as catches diminish.

With all these limitations it is inevitable that collecting robust and consistent recruitment records has been and will continue to be challenging. The alternative approach of fishing at the river mouth while having the benefit of monitoring migration at the entry point would no doubt be just as challenging. It would certainly be more expensive than collecting data from trapping operations, especially if migration of glass eels from the sea, as it is now suspected, is extended and sporadic. Collection of records from commercial glass eel harvest operations is used in Europe and North America to monitor migration, but remains impractical in New Zealand as there is no commercial harvesting of glass eels.

The present project utilises information gathered as part of operations with the main purpose of enhancing eel populations upstream of migration barriers at minimum cost. As discussed above, data limitations are inevitable in an "add on" study, but this does not diminish the value of the records as long as potential issues that may affect the catches are well described. For this reason it is essential that a yearly summary of trap and transfer operations at each monitoring site continues to be added to existing records (see Appendix B).

5.2 Total elver catches and enhancement implications

The total catch from the 17 monitored sites in 2012–13 was 10.4 million elvers, which is the largest catch ever recorded. That season, over half of this total was from Wairua Falls in Northland (5.5 million elvers). In the 2013–14 season data was received from 16 sites, and the total catch was 7.4 million elvers, the fifth largest catch since monitoring began in 1995. Eighteen sites were monitored in 2014–15 and 10.3 million elvers recorded (Table 5).

Since reliable and accurate monitoring of elver recruitment at hydro dams began in 1995, the number of sites included has varied, mainly due to supplementary sites no longer providing catch data, discontinuation of operations, and inclusion of new supplementary sites. For example, in 2012–13 a trapping operation at Turitea Dam in the Manawatu commenced but was not continued in 2013–14 or 2014–15. In 2014–15 also, two new supplementary sites were included in the records, Mataura Falls on the Mataura River in Southland and Lake Otamangakau in the Upper Whanganui River in the Central North Island. Elver catches at these supplementary sites are relatively small compared to the main sites, and variability in reporting for these sites does not significantly influence the total national catch. Changes in operational procedures at the main sites have the potential to significantly affect the total elver catches and need to be considered when examining overall trends in recruitment.

Karapiro and Matahina were the two main sites monitored when elver recruitment monitoring began in 1995. Waitaki was added as a main site in 2002–03, Arnold in 2004–05 and finally Patea and Wairua in 2013–14 (Figure 18). These records show that the total catch from Karapiro and Matahina peaked between 2007 and 2009, declined to a relatively low catch in the 2011–12 season, but then increased again with the catch in 2014–15 almost as large as that obtained between 2007 and 2009.

In contrast the total catch from Patea which peaked between about a year before Karapiro and Matahina (i.e. 2006) has been decreasing ever since, although there are signs of a recovery in the last three years (Figure 15).

At Waitaki elver catches have fluctuated markedly over time with large gaps in the records that make trends difficult to discern. Arnold catches show a gradual decline since the 2007–08 (shortfins) and 2008–09 (longfins) seasons, but numbers of both species increased in 2014–15 (Figure 15).

Since 1982, we estimate that at least 95 million elvers have been captured at the monitored sites and transferred to habitats upstream of the barriers. The catch has included at least 73 million shortfin and 9 million longfin elvers. Summary tables of the elver catches and transfers (where recorded) are included in Appendices C and D.

The success of these transfers has been surveyed in the upper Rangitaiki River (Smith et al. 2009), Waikaremoana Power Scheme (Bowman et al. 2007, Boubée et al. 2014, Boubée et al. 2015) and Arapuni Reservoir (NIWA unpublished data). However, effects on the eel fisheries of other catchments that have received eels from trap and transfer operations mostly remain unknown.

Commercial eel fishers have expressed disappointment with their catches from the Waikato hydro reservoirs (Boubée & Jellyman 2009). A study on eel populations from elver transfers in the Waikato hydro reservoirs which has been co-funded by MPI (EEL201101) is nearing completion with results indicating low survival rates and much lower growth rates than reported by Beentjes et al. (1997) during the early part of the programme.

5.3 Effect of environmental variables on catches

Studies of factors affecting elver migrations in tidal estuaries and rivers in England indicate that each catchment should be considered separately (White & Knights 1997). According to the same authors two threshold temperatures have key influences on elver migration: temperature at the start of migration and the temperature at the catch maxima. Once these thresholds have been achieved then other factors such as discharge or water level may act synergistically or antagonistically to influence the migration. On a daily catch basis multiple regression models on the English records accounted for up to 82.6% of the total variation of nightly elver catches using temperature, flow, trap type and time of the year (White & Knights 1997).

Elvers have a relatively low swimming ability in comparison to salmonids and preferentially use areas of low water velocities along the substrate and banks to progress upstream. They ascend major obstacles by climbing the wetted margins rather than swimming in the main flow. It is therefore unlikely that river flow has a major influence on elver migration over the entire season although a high incidence of flood flows could conceivably influence attraction and recruitment at entry from the sea. What is certainly clear, however, is that elvers migrate upstream in spring and summer when water temperatures are warm and the weather is settled and anticyclonic conditions associated with low flows predominate (e.g. Solomon & Beach 2004).

To determine what environmental factors affected the elver migration in New Zealand catch records obtained at each site were examined against river water temperature and flow. The effect of the Southern Oscillation Index (SOI) was also considered. For this analysis the elver migration was deemed to have commenced when the first significant elver catch occurred at each site and ended when 95% of the catch for the season had been obtained. Migration peaks were also considered as well as the time when 50% of the seasons catch had been obtained.

5.3.1 Temperature

Based on previous records, Martin et al. (2009a) concluded that in New Zealand the start of the migration occurred when water temperatures reached about 17–18 °C. Re-examination of the start of migration and water temperatures from six sites in the North Island and three sites in the South Island shows that the range may be wider than previously described and may be site specific. At Wairua in Northland, there are four seasons with catch records and the temperature at the start of the migration has ranged from 16.0 to 19.5° C (Figure 19). In contrast at Piripaua the water temperature range at the start of the migration has only been about 15 to 16° C, while in the South Island at Mararoa the range was 16 to 17.5° C (Figure 19).

Relationships between downstream water temperatures and the magnitude of elver catches at five of the main sites was explored using data from past seasons. Wairua was not included as there are temperature records for only three seasons at this site. To examine the relationship, average daily temperature was converted to degree-days using the following calculation:

T_0 = base temperature, 16 ^{O}C for Karapiro, Matahina and Patea; 14 ^{O}C for Arnold and Waitaki

$T_1 \ldots T_n$ average daily water temperature

$\Delta T_1 = T_1 - T_0$; $\Delta T_2 = T_2 - T_0$; $\Delta T_n = T_n - T_0$

Degree days = $\Delta T_1 + \Delta T_2 \ldots + \Delta T_n$

The median average daily temperature from 1 December to 31 March and the degree-days from 1 January to 28 February gave the strongest correlations with the total elver catches (Figure 20). However there was only one site (Matahina) with a statistically significant correlation with degree-days (α=0.05, n=10). Total elver catches at Patea showed very poor correlation with either parameter. At Karapiro, Arnold and Waitaki elver catches were weakly correlated with both parameters. At four sites degree-days showed stronger correlation than the median temperature with total elver catches (Figure 20).

5.3.2 Discharge

Comparison of daily catch records with river discharge at all sites each season has so far shown poor to no correlation. To some extent this lack of a relationship may be because flow at most of the sites examined is controlled by generation demands and storage capacity upstream. There is however no doubt that flood flows adversely affect elver catches not necessarily because they supress migration but because they also affect the ability to capture the elvers safely at some sites. The average Waikato River discharge at Huntly in the migration season over twenty years did not correlate with annual elver catches.

5.3.3 Southern Oscillation Index

The Southern Oscillation Index (SOI) is calculated using the atmospheric pressure differences between Tahiti and Darwin, and indicates the development and intensity of El Niño or La Niña events in the Pacific Ocean. These events affect ocean currents and temperatures that may have an influence on elver larval dispersal and recruitment.

Sustained negative values of the SOI below −8 often indicate El Niño episodes. Typical features are warming of the central and eastern tropical Pacific Ocean and a decrease in the strength of the Pacific Trade Winds.

Sustained positive values of the SOI above +8 are typical of a La Niña episode. They are associated with stronger Pacific Trade Winds and warmer sea temperatures to the north of Australia and New Zealand. Waters in the central and eastern tropical Pacific Ocean become cooler during this time.

To examine the potential effect of the SOI on elver recruitment, monthly average values were downloaded from the Australia Bureau of Meteorology website and smoothed using a five point moving average. These records show that in the last 10 years there were La Niña conditions in early 2005, early 2007 and 2008. There was also a very strong La Niña in 2010, but this dissipated about mid-2011. Another small La Niña occurred from about mid-2012 to early 2013, and since then the SOI has been declining and by about mid-2013 with an El Niño persisting since about mid-2013 (Figure 21).

Combining the recruitment indices for all the sites and comparing these records to the SOI does not indicate a consistent link between elver recruitment to La Niña or El Niño phases but there does seem to be a relationship between the recruitment trends of the two species (Figure 17).

Chisnall et al. (2002) suggested that the La Niña phase has more persistent north-easterlies winds that enhance elver recruitment along the east coast. In contrast, when the SOI is negative (El Niño) westerly winds favour recruitment along the west coast.

The elver recruitment data that has been collected to date does not support the Chisnall et al. (2002) hypothesis consistently. For example, the last three main La Niña phases occurred in 2007, 2008, and 2010. Based on the Matahina records there was an increased in recruitment for the Rangitaiki on the east coast between 2007 and 2008 but certainly not in 2010. However, based on the Mararoa Weir records, on the Waiau River on the east coast peak recruitment appear to correspond with the last three La Niña phases both in terms of amplitude and timing (Figure 17).

For west coast catchments, if Chisnall et al. (2002) are correct, there should have been increased recruitment during the El Niño peaks in 2006, 2009 and 2011–12. There were indeed recruitment peaks in the Waikato, Patea and Grey rivers in 2006 and 2011–12 but not in 2009 (Figure 17).

In contrast to all the other sites, for Piripaua (Wairoa River, East Coast) there is no match between the SOI value and the recruitment index for longfins or shortfins (Figure 17). Therefore, other factors must be affecting catches at this site and increasing attraction odours since the implementation of the catch and transfer program is but one possibility.

Sea currents and ocean productivity (phytoplankton biomass) may also influence elver recruitment. The SOI influences ocean currents and therefore maybe a factor affecting larval dispersal and recruitment while ocean productivity provides food for larvae during their migration to New Zealand. In 2005 ocean productivity was reported as relatively high (Pinkerton et al. 2015) and there was certainly an overall increase in recruitment of both species in 2006 that could be linked to increased productivity at sea (Figure 17).

Information available at present indicates that SOI does not consistently affect elver recruitment but may exert influence in combination with other factors and in a location specific manner. A better understanding of sea currents along the coastline of New Zealand and their responses to the SOI and the longer term Interdecal Pacific Oscillation may contribute to understanding the factors that control elver recruitment in New Zealand.

5.3.4 Conclusions on environmental factors affecting the catch

Overall the results indicate that water temperature, river discharge and the SOI on their own were not significantly correlated with annual elver catches. The weak correlations with temperature and river flows indicate that the timing and magnitude of elver migrations may be site-specific and influenced by multiple environmental factors. River flows at most of the sites are also influenced by station discharges responding to electricity demand and upstream storage requirements. Clear relationships are difficult to quantify because multiple environmental factors occur simultaneously and vary with time, local conditions, hydrological factors and power station operational decisions. Nevertheless further examination, using multiple regression and multivariate analysis, of the influence of all factors that could potentially affect the catch should be undertaken in the future.

5.4 Recruitment

While elver catches at individual sites may be influenced by local conditions such as river flow and temperature, recruitment strength would also be a major influence on the magnitude of catches. Annual recruitment is more likely to be influenced by larger scale factors such as the Southern Oscillation Index (SOI) affecting larval dispersal and survival. However, a relationship between recruitment and the SOI was not evident. The average recruitment indices for both species indicate a four to seven year short term recruitment cycle has been occurring since the early 1990s, and there has been no decline of recruitment over this period.

5.5 Elver Ageing

In the Northern Hemisphere, in addition to crack and burn, a variety of other methods, including staining procedures are in use, each with their attributes and issues (e.g., ICES 2009). The toluidine blue otolith staining method has not been extensively used in New Zealand and not yet been validated for New Zealand eels. However toluidine blue staining has been calibrated with crack and burn methods for Atlantic eels (ICES 2009).

The April 2014 NIWA workshop found that the two otolith preparation methods had about similar agreement with reference ages, but the crack and burn method had better readability. This finding is contrary to ICES (2009) which recommended the crack and burn method for older eels, and staining on the sagittal plane as the best method for elvers. Based on the workshop conclusions, the crack and burn method was superior for aging elvers and preferred for elvers collected in the 2013–14 season.

Age frequency distributions derived from age length keys show that age zero elvers are the dominant class for shortfins at Patea and Wairua. Either site would be useful for undertaking future research to accurately determine the age distribution and ultimately recruitment of shortfins into freshwater. There are relatively few age zero longfins at any site compared to Patea and Wairua age zero shortfins. The low number of age zero longfins indicates a slower migration upstream than shortfins. Age 1 is the dominant class for longfins at Karapiro and Patea, and either site would be suitable for future elver age research. In the South Island at Arnold and Waitaki age two and four are the dominant size classes for longfins respectively.

The age length keys from each site in this study were based on about 25 aged elvers, using fixed length sampling. Fixed length sampling can introduce bias in the length at age estimates. The sampling design used in 2013–14 was chosen by the Eel Fishery Assessment Working Group (EEL FAWG) to maximise the number of elvers aged from five sites. However, larger random sample sizes of 500–1000 with at least 10 fish aged per size class can achieve the best possible accuracy (Coggins et al. 2013).

Nevertheless, combined age length keys produced comparable results to similar sites where the age length key was based on elvers aged from that site and may a useful approach for some sites. However site specific age length keys with larger sample sizes would provide more robust and reliable data.

Consideration should also be given to the long term storage options for mounted otoliths. ICES (2009) reported that some otoliths mounted with super glue type media may detach from slides after two years. They also noted similar problems for Crystal Bond and epoxy resin. Otoliths prepared using crack and burn method are mounted in clear silicone, and may have better long term storage performance than Crystal bond mounted otoliths.

5.6 Future monitoring

An international review panel was convened in December 2013 to assess methods and information used by MPI to monitor and manage the eel fishery. The panel recommended continuation of monitoring elver catches at hydro dams but with the addition of information on the age structures of the elvers at each site so that the absolute numbers of younger age classes could be derived and followed in subsequent years (Haro et al. 2013).

Continued collection of robust data from the main trap and transfer sites (Karapiro, Matahina, Patea, Wairua, Arnold and Waitaki), with the inclusion of some supplementary sites (Piripaua, Mararoa, and if possible Roxburgh[4]) is essential in providing an understanding of the drivers of freshwater eel recruitment. In this respect, enforcement of minimum standards for data collection and reporting through the transfer permit system issued by MPI is crucial.

Based on this advice the Eel Fishery Assessment Working Group (EEL FAWG)) endorsed continued monitoring of elver catches at the current six main sites and also at two supplementary sites (Piripaua and Mararoa) which have yielded useful records so far.

Furthermore, the EEL FAWG has recommended that until contrary information is obtained, in future studies, elver ages at each site should be determined from a random sample of elvers collected through the season and only be used to assign age of the elvers collected that year and at that specific site.

Improved knowledge of the age of elvers collected at each location is essential to try to align recruitment at each site with date of entry in freshwater and also to compare trends between sites. The ageing undertaken in 2013–14 has indicated that elvers arriving at the hydro dams are younger than previously determined by Martin et al. (2013). The difference may be in part due to different ageing techniques and interpretation of the otoliths but most likely reflects the huge variability in growth rate of eels.

A standard ageing protocol for future studies has been published (Walsh et al. 2016) and this will hopefully eliminate otolith interpretation issues in future. The otoliths that have been previously aged should be re-read to determine if interpretation of the otoliths has been inaccurate in the past.

In addition to endorsing the new eel ageing protocols the EWG recommended that the following guidelines be implemented when sampling elvers for aging from 2015–16:

- A total of 400 otoliths should be aged each year to determine the age composition of elvers at key dam sites

- Owing to growth within the migratory season, a random sampling approach covering the entire season should be used for determining age composition.

- It is critical that samples be collected randomly with regards to length, and that the research provider pay careful attention to developing site specific sampling protocols.

[4] Roxburgh was a monitoring site intermittently from 1996 to 2004.

- Initially the 400 otoliths to be aged should be collected from two sites (Wairua Falls and Karapiro Dam) so that an optimal sampling and analysis design can be devised.

- The EEL FAWG recommended that in 2015–16 otoliths from elvers selected randomly each month during the main migration period (i.e. December, January and February) at both Karapiro and Wairua Falls be examined. Since most elvers at Wairua are consistently small and few longfin elvers are captured there, it was agreed that only 30 shortfins be sampled and examined at this site each month (total 90 shortfins). Further, that the number of elvers sampled at Karapiro where the size of elvers is more variable be set to 50 per species per month (total 150 shortfins and 150 longfins). Monthly samples at both sites should be taken on two separate dates, around the 10th and 20th of each month.

- Equivalent numbers of elvers should be collected through the season at the remaining four main sites, but otoliths need not be extracted or aged. Owing to freeze related shrinking, all fish should be measured and individually packed prior to freezing.

- Appropriate analysis should be completed and discussed with the EEL FAWG at the end of the first year in order to determine optimal sampling designs for the future. If more than 400 otoliths are required per year for all six sites, the EEL FAWG would make a decision on the subset of sites to be sampled.

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Table 1: List of supplementary monitoring sites and seasons 2012 to 2015 (– = traps not installed). See Figure 1 for locations.

Station	Catchment or River	Data received		
North Island:		2012–13	2013–14	2014–15
Waitakere Ranges	Huia, Nihotupu, Waitakere	Yes	Yes	No
Hunua Ranges	Cosseys Stream, Hays Creek	Yes	Yes	No
Wairere Falls Power Station	Mokau River	Yes	Yes	Yes
Mokauiti Power Station	Mokauiti Stream	Yes	Yes	Yes
Piripaua Power Station	Wairoa River	Yes	Yes	Yes
Lake Otamangakau Valve	Upper Whanganui River	–	–	Yes
Mangorei Power Station	Waiwakaiho River	Yes	Yes	Yes
Motukawa Power Station	Waitara River	Yes	Yes	Yes
Turitea Dam	Turitea Stream	Yes	No	No
Wilson's Dam	Waiwarawara Stream	No	No	No
Morrinsville	Topehaehae Stream	No	No	No
Lake Waikare fish pass	Lake Waikare outlet	Discontinued monitoring 2004		
South Island:				
Roxburgh Dam	Clutha River	Yes	Yes	Yes
Mataura Falls	Mataura River	–	–	Yes
Waihopai Dam	Waihopai River	Yes	Yes	Yes
Mararoa Weir	Waiau River	Yes	Yes	Yes

Table 2: Elver monitoring sites operating dates for 2012–13, 2013–14 and 2014–15 seasons (M = Main site; S = supplementary site).

Season	Island	Site type	Site	Monitoring period Start	End	Duration Days	No. days trap was cleared	No. of samples
2012–13	North	M	Karapiro	24-Nov	2-Apr	129	129	33
		M	Matahina	1-Nov	3-Mar	122	76	12
		S	Patea	1-Nov	12-Mar	131	16	14
		S	Wairua Falls	26-Sep	4-Mar	159	92	27
		S	Piripaua	7-Nov	1-May	175	60	8
		S	Wairere Falls	25-Oct	10-Apr	167	58	2
		S	Mokauiti	25-Oct	6-Feb	104	11	2
		S	Mangorei	1-Nov	12-Apr	162	16	0
		S	Motukawa	1-Nov	12-Apr	162	6	0
		S	Turitea	27-Nov	23-Feb	88	21	0
		S	Waitakere	1-Oct	30-Apr	211	9	0
		S	Hunua	1-Oct	30-Apr	211	21	0
	South	M	Arnold	8-Dec	4-Apr	117	82	17
		M	Waitaki	19-Nov	25-Mar	126	22	7
		S	Mararoa[a]	17-Nov	19-Mar	97	95	48
		S	Roxburgh	1-Dec	22-Mar	111	41	5
		S	Waihopai	1-Dec	15-Mar	104	15	5
2013–14	North	M	Karapiro	28-Nov	13-Apr	136	122	29
		M	Matahina	1-Nov	15-Mar	134	71	16
		M	Patea	1-Nov	27-Apr	177	19	12
		M	Wairua Falls	6-Aug	7-Mar	213	78	21
		S	Piripaua	23-Nov	1-Apr	129	39	8
		S	Wairere Falls	1-Nov	12-Mar	131	79	0
		S	Mokauiti	1-Nov	12-Mar	131	68	0
		S	Waitakere	1-Oct	30-Apr	211	12-13[b]	0
		S	Hunua	1-Oct	30-Apr	211	14-17[b]	0
	South	M	Arnold	6-Dec	18-Mar	102	87	16
		M	Waitaki	7-Dec	31-Mar	114	30	5
		S	Mararoa	3-Dec	31-Mar	118	87	87
		S	Roxburgh	20-Jan	21-Mar	60	13	1
2014–15	North	M	Karapiro	27-Nov	6-Apr	130	126	30
		M	Matahina	1-Nov	1-Mar	120	78	10
		M	Patea	1-Nov	13-Apr	163	19	14
		M	Wairua Falls	4-Sep	16-Mar	193	70	14
		S	Piripaua	27-Nov	8-Apr	132	35	10
		S	Wairere Falls	25-Oct	26-Mar	152	108	2
		S	Mokauiti	1-Nov	28-Feb	120	70	0
		S	Waitakere	1-Sep	22-May	263	7-26[b]	0
		S	Hunua	1-Sep	22-May	263	9	0
		S	Mangorei	1-Nov	30-Apr	181	12	0
		S	Motukawa	1-Nov	30-Apr	181	13	0
		S	L. Otamangakau	11-Jan	1-Apr	80	26	2
	South	M	Arnold	15-Dec	24-Mar	99	80	11
		M	Waitaki	31-Oct	16-Mar	136	52	6
		S	Waihopai	6-Dec	2-Apr	118	16	5
		S	Mataura Falls	1-Feb	26-Feb	26	9	9
		S	Roxburgh	1-Dec	23-Feb	85	16	3

[a] Trapping stopped for 25 days in January 2013.

[b] Range as several traps in place.

Table 3: Average elver weights at monitored sites for 2012–13, 2013–14 and 2014–15 (SFE = shortfins; LFE = longfins). Main sites (*) are listed above supplementary sites for the North Island and South Island.

Season	Island	Site	SFE			LFE		
			N	Average (g)	Range (g)	N	Average (g)	Range (g)
2012–13	North	Karapiro*	3378	0.9	1.3–0.7	226	1.6	3.3–1.6
		Matahina*	2181	1.0	1.2–0.9	307	1.8	2.1–1.2
		Patea	645	0.5	0.8–0.4	129	0.7	1.3–0.4
		Wairua Falls[a]	1593	0.3	0.5–0.12	22	0.2	0.4–0.1
		Piripuau	771	1.1	1.3–1.0	90	2.1	2.4–1.8
		Wairere	122	0.8	1.1–0.6	14	1.4	1.4–1.1
		Mokauiti[a]	105	1.2	1.2–0.9	9	1.6	3.0–1.2
	South	Arnold*	1109	1.0	1.47–0.8	604	1.6	2.2–1.0
		Waitaki*	162	2.9	6.6–2.5	632	11.6	13.1–6.3
		Mararoa	0			1452	4.2	6.9–2.5
		Roxburgh	0			274	3.0	4.8–2.3
		Waihopai[b]	36	1.34	±0.11 (se)	11	2.94	±0.42 (se)
2013–14	North	Karapiro*	2921	0.8	0.9–0.8	254	1.5	2.8–1.0
		Matahina*	2584	0.9	1.2–0.8	284	2.1	6.6–1.1
		Patea*	1241	0.5	1.1–0.4	130	0.6	0.9–0.4
		Wairua	2249	0.3	0.5–0.3	17	0.5	1.0–0.2
		Piripuau	1027	1.0	1.2–0.9	166	1.8	2.1–1.4
	South	Arnold*	1122	1.1	1.5–1.0	714	2.0	2.6–1.5
		Waitaki*	127	2.7	4.6–2.1	56	10.4	11.6–4.0
		Mararoa	15	1.4	3.3–0.7	1465	4.5	12.9–3.2
		Roxburgh	0			16	4.4	7.5–2.3
2014–15	North	Karapiro*	3057	0.9	1.1–0.7	256	1.3	5.8–1.0
		Matahina*	1764	1.0	1.2–0.9	119	1.5	2.1–1.0
		Patea*	1261	0.6	0.9–0.5	105	0.7	1.1–0.6
		Wairua	546	0.4	0.6–0.2	40	0.6	0.6–0.3
		Piripuau	711	1.2	1.6–0.8	56	1.6	1.9–1.0
		Wairere	34	0.8	0.9–0.8	3	1.2	
		L.	30	1.4	1.5–1.4	2	1.71	
	South	Arnold*	690	1.1	1.2–1.0	540	1.8	2.4–1.5
		Waitaki*	271	2.6	3.0–2.0	698	11.7	13.4–10.0
		Mararoa	0			2168	4.8	5.8–2.56
		Waihopai	25	1.2	1.3–0.7	22	2.9	3.29–1.8
		Mataura Falls	7	2.4	3.7–1.1	173	2.9	17.9–0.9
		Roxburgh	0			168	2.8	3.0–2.0

[a] Frozen samples adjusted for weight loss using factors of 1.4 (Wairere and Mokauiti) and 1.3 (Wairua Falls).

[b] Waihopai average elver weights were reported as mean and standard error (se).

Table 4: Summary of elver catches at monitored sites for 2012–13, 2013–14 and 2014–15 seasons. Main sites (*) are listed above supplementary sites for the North Island and South Island.

Season	Site	Shortfin elvers		Longfin elvers		Total	
		No.	Weight	No.	Weight	No.	Weight
2012–13	Karapiro*	1 632	1 404.0	139	224.0	1 771	1628.0
	Matahina*	2 104	2 209.3	317	554.8	2 421	2764.1
	Patea[a]	183	26.2	51	9.6	234	35.8
	Wairua Falls[a]	5 389	1 600.0	99	21.0	5 488	1621.0
	Piripaua	28	29.5	5	10.7	33	40.2
	Mangorei					13	13.3
	Motukawa					13	14.2
	Turitea					1.0	1.0
	Wairere Falls					182	154.5
	Mokauiti					3	3.9
	Waitakere					0.2	0.2
	Hunua					0.8	0.8
	Arnold*	55	54.5	36	54.9	91	109.4
	Waitaki*	2	5.4	7	83.7	9	89.1
	Roxburgh			14	36.2	14	36.2
	Waihopai	1	1.2	0.3	0.8	1	2.0
	Mararoa Weir			128	448.5	128	448.5
	Total elvers	9 394	5 330.1	796	1 444.2	10 403	6 962.2
2013–14	Karapiro*	1 683	1 419.2	160	257.9	1 843	1 677.1
	Matahina*	1 848	1 775.4	220	351.4	2 068	2 187.7
	Patea*	170	80.2	24	14.9	194	95.1
	Wairua Falls*	2 764	930.7	16	6.6	2,780	937.3
	Piripaua	61	62.2	8	13.6	69	75.8
	Mangorei					17	16.4
	Motukawa					8	8.6
	Wairere Falls					193	167.7
	Mokauiti					25	29.9
	Waitakere					1	0.6
	Hunua					2	2.0
	Arnold*	36	40.9	29	54.2	65	95.1
	Waitaki*	0.1	0.4	0.1	0.5	0.2	0.9
	Roxburgh			0.8	2.2	1	2.2
	Waihopai	2	3.0	1.1	3.0	3	6
	Mararoa Weir	0.04	0.04	145.3	508.3	145.4	508.4
	Total elvers	6 563	4 312.0	604	1,212.6	7,413	5,811.1
2014–15	Karapiro*	1 444	1 205.7	160	206.2	1 604	1
	Matahina*	4 460	4 426.7	275	411.3	4 736	4 838.0
	Patea*	237	131.3	23	14.5	261	145.9
	Wairua Falls*	2 893	911.9	118	35.8	3 011	947.7
	Piripaua	56	60.6	5	7.7	61	68.3
	Mangorei					11	11.0
	Motukawa					16	17.2
	Wairere Falls					242	203.0
	Mokauiti					46	54.4
	Waitakere					2.3	2.3
	Hunua					0.9	0.9
	L.Otamangakau	5	6.4	1	0.9	5	7.3
	Arnold*	87	95.0	65	110.8	152	205.8
	Waitaki*	1	3.9	5	56.4	6	60.3
	Roxburgh			1	3.7	1	3.7
	Waihopai	1.2	1.3	0.5	1.2	1.7	2.5
	Mararoa Weir	0.1	1.3	135.5	745.7	135.6	745.8
	Mataura	0.1	0.2	3.1	8.9	3.2	9.1
	Total elvers	9 186	6 844.3	792	1 603.0	10 296	8 734.9

[a] Patea and Wairua Falls were designated main sites in 2013–14.

Table 5: Total elver numbers recorded at trap and transfer sites nationally from 1995 to 2015.

Season	All monitored sites			Main monitored
	No. of elvers (1000s)	No. of sites	Rank	No. of elvers (1000s)
1995–96	>1 299	2	20	
1996–97	1 776	5	19	
1997–98	2 673	4	17	
1998–99	2 153	5	18	
1999–00	3 613	6	11	
2000–01	3 556	6	12	
2001–02	3 104	6	16	
2002–03	4 141	11	8	
2003–04	4 081	11	10	
2004–05	3 260	11	15	2 479
2005–06	4 256	13	7	3 390
2006–07	3 262	13	14	1 892
2007–08	7 577	11	4	6 296
2008–09	7 744	12	3	6 783
2009–10	3 310	12	13	2 732
2010–11	4 129	12	9	3 392
2011–12	5 465	13	6	1 767
2012–13	10 403	17	1	4 291
2013–14	7 413	16	5	6 950
2014–15	10 296	18	2	9 769

[a] The four main sites that have been monitored from 2004–05 are: Karapiro Dam, Matahina Dam, Arnold Dam and Waitaki Dam. Patea Dam and Wairua Falls Power Station were designated main sites in 2013–14.

Table 6: Dates for when 50% of the elver catches occurred at monitored sites between 1995 and 2015 (Note: the year when monitoring began varies with site). Main sites (*) are listed above supplementary sites for the North Island and South Island.

Site	Region	Date range 1995 to 2015	2012–13	2013–14	2014–15
Wairua*	Northland	27 Dec–3 Jan	29-Dec	27-Dec	27-Jan
Matahina*	Bay of Plenty	19 Dec–3 Feb	16-Jan	12-Jan	18-Jan
Karapiro*	Waikato	6 Jan–9 Feb	6-Jan	6-Jan	24-Jan
Patea*	Taranaki	2 Feb–3 Mar	11-Feb	28-Jan	11-Jan
Wairere	Waikato	3 Jan–12 Feb	31-Jan	27-Jan	29-Jan
Mokauiti	Waikato	7 Jan–16 Feb	12-Jan	14-Jan	7-Jan
Mangorei	Taranaki	10 Jan–10 Feb	26-Jan	10-Jan	30-Jan
Motukawa	Taranaki	4 Jan–11 Feb	4-Jan	17-Jan	4-Jan
Piripaua	East Coast NI	10 Jan–26 Feb	4-Feb	27-Jan	21-Jan
Arnold*	West Coast SI	24 Jan–10 Feb	2-Feb	5-Feb	31-Jan
Waitaki*	East Coast SI	16 Jan–14 Feb	16-Jan	3-Feb	21-Jan
Mararoa	West Coast SI	7 Jan–3 Feb	3-Feb	30-Jan	29-Jan

Table 7: Dates for start and end of the 2012–13, 2013-14 and 2014–15 elver migrations and respective average daily water temperatures. Main sites (*) are listed above supplementary sites for the North Island and South Island.

Season	Island	Site	Start date	Temperature (°C)	End date	Temperature (°C)	Duration of run (weeks)
2012–13	North	Wairua	15-Nov	no data	3-Mar	no data	15.3
		Karapiro*	4-Dec	18.7	20-Mar	17.8	15.1
		Matahina*	13-Dec	17.5	1-Mar	18.6	11.1
		Patea*	15-Dec	20.2	25-Feb	21.4	10.3
		Wairere	17-Dec	no data	14-Mar	no data	12.4
		Piripaua	18-Dec	14.8	15-Apr	no data	16.9
	South	Arnold*	20-Dec	18.3	15-Mar	16.7	12.1
2013–14	North	Wairua*	8-Oct	16	2-Mar	20.1	20.7
		Karapiro*	28-Nov	19.77	13-Mar	20.9	15.0
		Matahina*	26-Nov	18	1-Mar	18.5	13.6
		Patea*	27-Dec	20.0	6-Apr	19.6	14.3
		Wairere	14-Dec	no data	1-Mar	no data	11.0
		Piripaua	29-Nov	14.9	11-Mar	16.2	14.6
	South	Arnold*	21-Dec	18.1	17-Mar	16.7	12.3
		Mararoa	6-Dec	16	28-Feb	13.0	12.0
2014–15	North	Wairua*	22-Nov	19.48	13-Mar	22.06	15.9
		Karapiro*	29-Nov	18	28-Mar	20.6	17.0
		Matahina*	9-Dec	17.6	18-Feb	18.1	10.1
		Patea*	15-Dec	18.2	23-Mar	19.8	14.0
		Wairere	22-Dec	no data	22-Mar	no data	12.9
		Piripaua	5-Jan	17	20-Mar	14.9	10.6
	South	Arnold*	26-Dec	19.2	22-Mar	17.7	12.3
		Waitaki*	15-Jan	17.7	11-Feb	17.7	3.9
		Mararoa	16-Jan	17.5	3-Mar	15.8	6.6

Table 8: Summary of estimated number (in 1000s) of total elvers and longfin elvers (in brackets) captured in the 2012–13, 2013–14 and 2014–15 seasons at the main (*) and significant supplementary sites. Inaccurate annual records for individual sites are shaded.

Year	Wairua*	Karapiro*	Matahina*	Wairere	Patea*	Piripaua	Arnold*	Waitaki*	Roxburgh	Mararoa
1992–93		92	> 32							
		(31)	(>2)							
1993–94		518	> 215							
		(176)	(NA)							
1994–95		282	> 39							
		(96)	(NA)							
1995–96		1 155	> 144							
		(333)	(NA)							
1996–97		1 220	14			2.1			0.3	
		(246)	(4)			(1)				
1997–98		2 040	615			7.3			11	
		(510)	(136)			(NA)				
1998–99		1 097	1 002			3.1			7.4	44
		(341)	(NA)			(0.4)				(43)
1999–00		892	2 001	166	461	2.6				90
		(94)	(NA)	(NA)	(NA)	(<0.1)				(90)
2000–01		782	2 054	191	495	6				28
		(155)	(NA)	(NA)	(NA)	(0.2)				(28)
2001–02		1 596	619	130	754	4.1			1	NA
		(246)	(27)	(NA)	(48)	(0.4)				
2002–03		1 942	1 484	289	380	10.2		<0.1	0.1	36
		(176)	(124)	(22)	(8)	(0.2)		(<0.1)		(36)
2003–04		2 131	945	330	391	4.9		4.6	1.4	98
		(200)	(64)	(NA)	(1)	(0.2)		(4.6)		(98)
2004–05		1 333	1 117	155	450	8.1	27	1.5		64
		(132)	(15)	(13)	(NA)	(0.5)	(7)	(1.5)		(64)
2005–06		2 178	1 193	163	562	2.8	14	4.7		46
		(483)	(228)	(28)	(87)	(0.1)	(8)	(4.7)		(46)
2006–07		1 296	485	294	896	4.2	107	3.3		118
		(179)	(159)	(25)	(53)	(0.3)	(52)	(3.3)		(118)
2007–08		2 728	3 378	204	857	5.7	186	4.1		133
		(701)	(928)	(57)	(98)	(1.1	(78)	(4.1)		(133)
2008–09		2 288	4 307	216	480	9.5	183	4.7		81
		(298)	(517)	(16)	(82)	(2.2)	(87)	(3.5)		(81)
2009–10		1 708	1 002	146	309	10.3	20	2.4		71

Year	Wairua*	Karapiro*	Matahina*	Wairere	Patea*	Piripaua	Arnold*	Waitaki*	Roxburgh	Mararoa
		(232)	(78)	(7)	(20)	(2.9)	(5)	(2.1)		(71)
2010–11		1 434	1 841	227	247	11.8	114	2.9		198
		(175)	(84)	(NA)	(20)	(2.5)	(49)	(2.4)		(198)
2011–12	3178	1 003	641	119	72	15.6	76	7	NA	266
	(10.6)	(36)	(15)	(0.5)	(6.8)	(3.1)	(26)	(5.8)	(NA)	(266)
2012–13	5 488	1 771	2 421	182	234.1	32.9	90.4	8.9	13.8	128.4
	(97.8)	(139)	(317)	(NA)	(50.8)	(5.2)	(35.6)	(7.1)	(13.8)	(128.4)
2013–14	2780	1843	2068	193.1	193.7	68.7	65.3	0.2	0.8	145.4
	(16.2)	(160)	(220)	(NA)	(23.7)	(7.9)	(29.4)	(0.1)	(0.8)	(145.3)
2014–15	3010.6	1604	4736	241.9	260.6	61.2	152.5	6.0	1.3	135.6
	(118)	(160)	(275)	(NA)	(23.1)	(4.7)	(65)	(4.6)	(1.3)	(135.5)

Table 9: Summary of elver lengths and estimated median ages at sites where individual weights and lengths of 100 shortfin (SFE) and 100 longfin (LFE) if available were measured monthly during 2013–14. Main sites (*) are listed above supplementary sites for the North Island and South Island.

	No. days	Species	Number	Length (mm)			Median
North			N	Mean	Median	Range	Y
Wairua	214	LFE	7	60	59	55-66	–[a]
		SFE	1 318	63	61	48–130	0
Karapiro*	139	LFE	140	106	104	75–157	1
		SFE	295	93	91	74–153	1
Matahina*	135	LFE	272	111	110	86–152	1
		SFE	750	97	96	75–133	1
Patea*	178	LFE	124	80	79	59–124	1
		SFE	1 247	74	73	57–121	0
Piripaua	130	LFE	166	115	112	90–188	2
		SFE	497	101	100	85–142	1
South							
Arnold*	103	LFE	400	130	126	101–202	2
		SFE	418	111	108	90–175	1
Waitaki*	174	LFE	53	196	200	118–260	4
		SFE	103	132	130	102–203	2
Roxburgh	61	LFE	16	159	163	120–210	–[a]
Mararoa	119	LFE	1 591	152	137	92–240	2
		SFE	15	108	104	92–150	–[a]

[a] An accurate age distribution could not be determined, an insufficient number of elvers were measured.

Table 10: Summary of age class mean lengths, median lengths and median ages derived from age length keys for the 2013–14 migration season (SFE = shortfins; LFE = longfins). Shaded cells indicate site where a combined age length key was applied. Elvers over age four years not included for Arnold, Waitaki and Mararoa.

Site		Species	Mean Length (mm) at age					Median Length	Median age
			0	1	2	3	4	mm	Y
North Island	Wairua	SFE	62	71	95			63	0
	Karapiro	SFE	81	90	98			90	1
		LFE	75	100	111	117		102	1
	Matahina	SFE*	83	95	99	117	125	92	1
		LFE*	85	104	115	116	135	107	1
	Patea	SFE	69	80	98			72	0
		LFE	65	83	118			75	1
	Piripaua	SFE*	85	100	102	117	125	98	1
		LFE*		105	116	120	135	111	2
South Island	Arnold	SFE		106	118	121	161	106	1
		LFE		105	120	128	143	123	2
	Waitaki	SFE*		117	130	134	145	124	2
		LFE			125	169	203	192	4
	Mararoa	LFE*		109	127	145	164	132	2

*Ages calculated using 2013–14 combined age length key

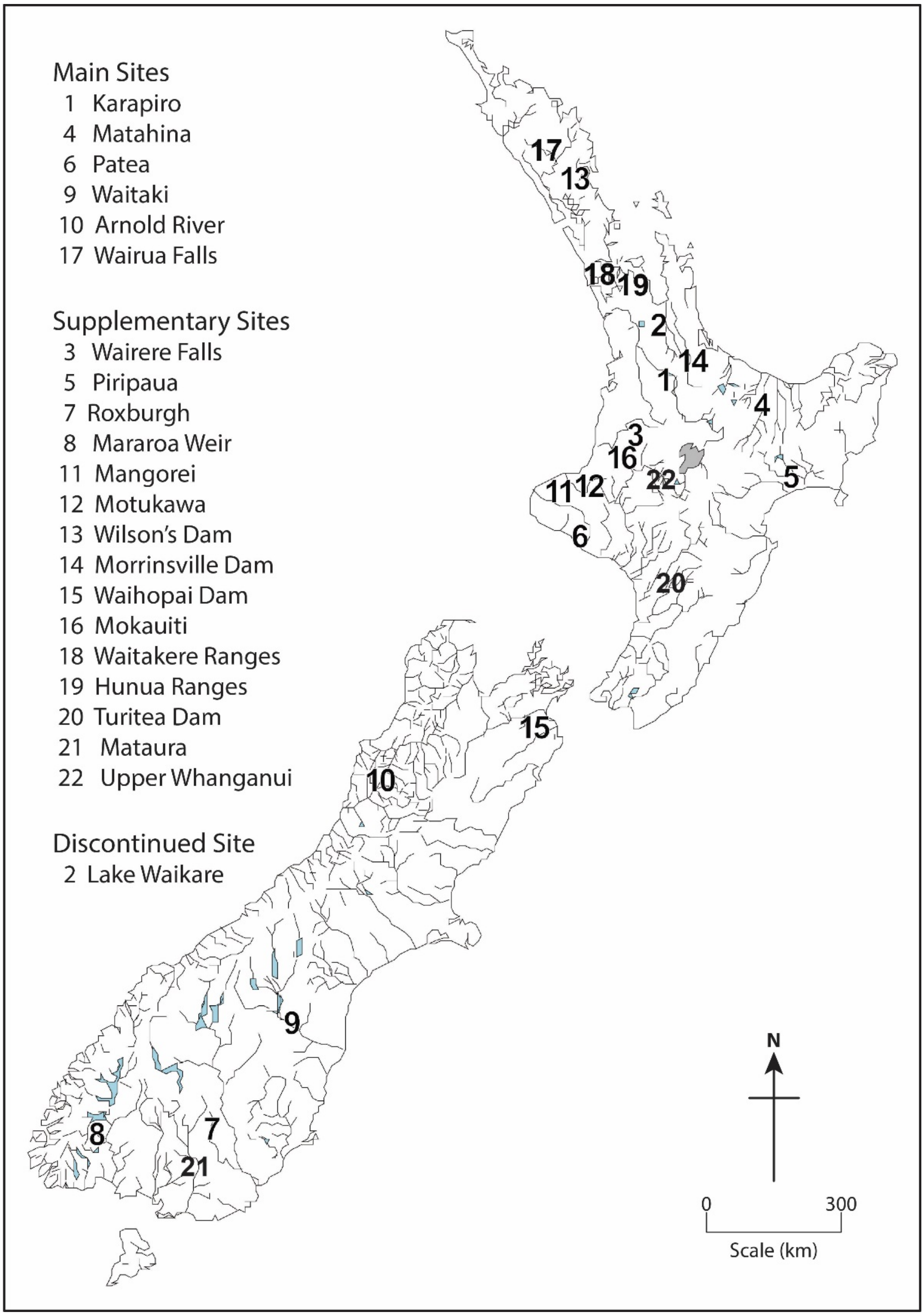


Figure 1: Main and supplementary elver catch monitoring sites.

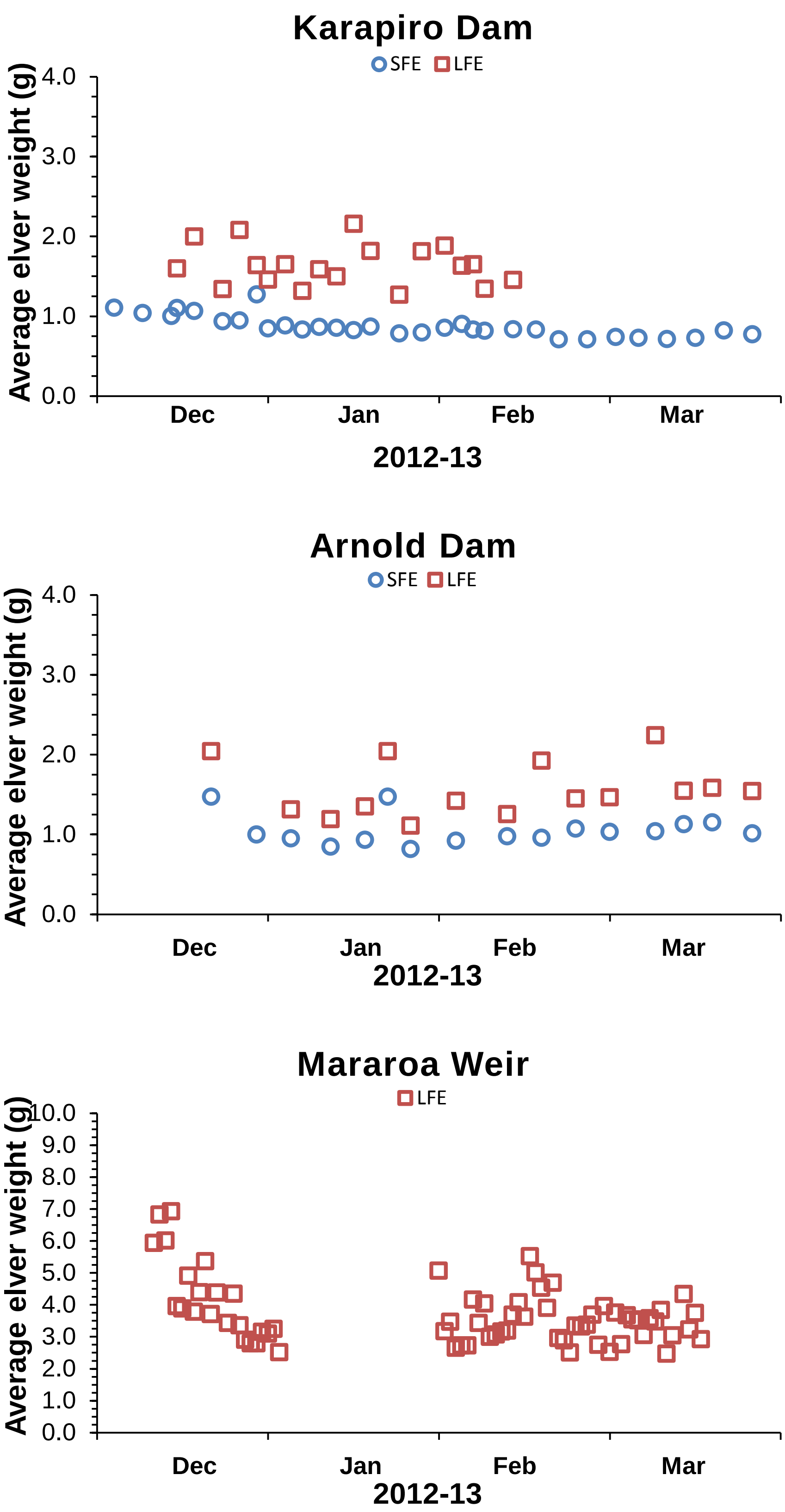
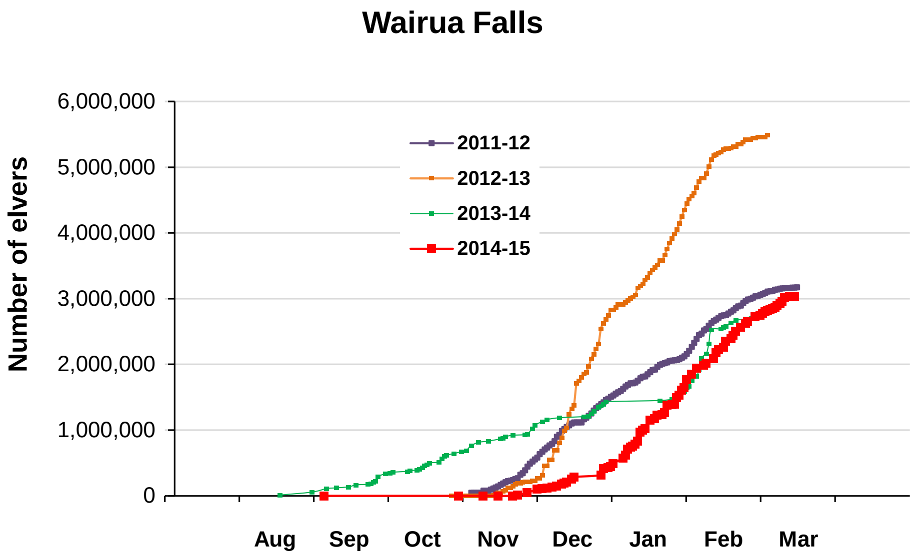
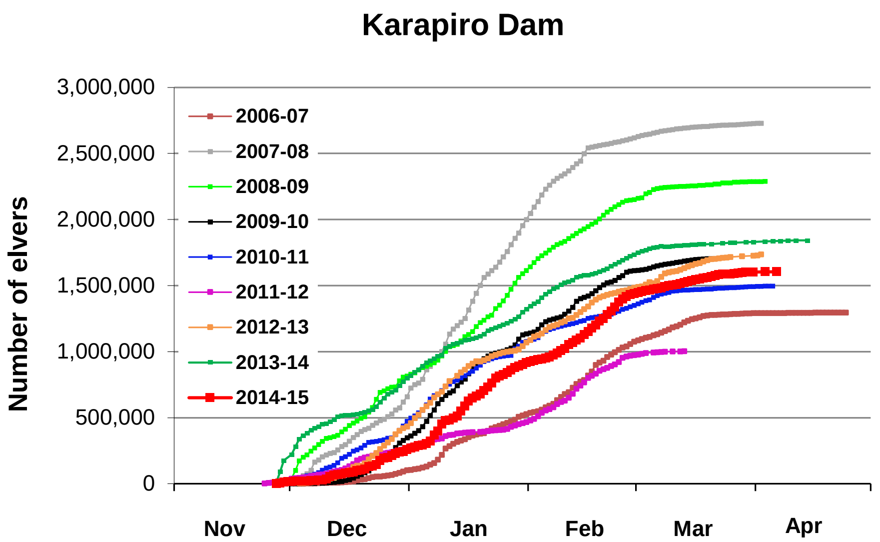


Figure 2: **Average elver weights determined by dividing the total sample weight by the number of elvers for 2012–13 season. SFE = shortfins, LFE = longfins.**





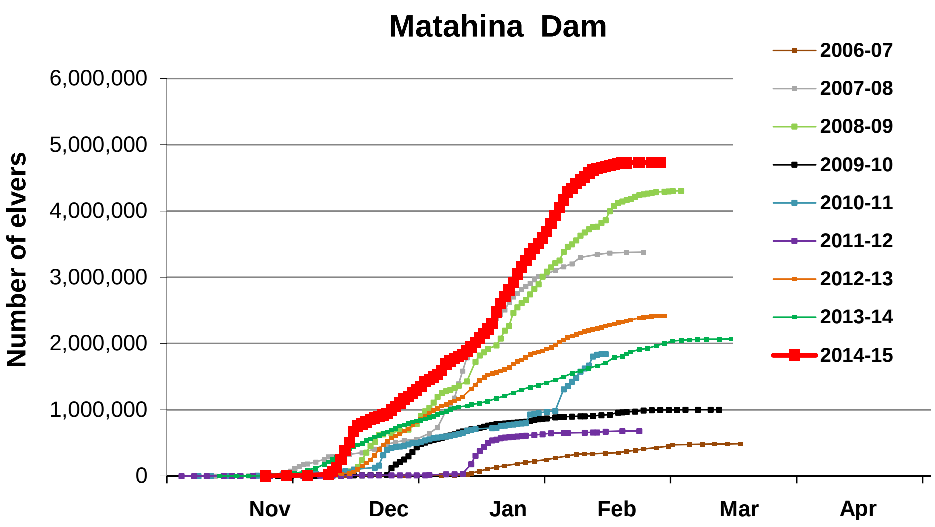
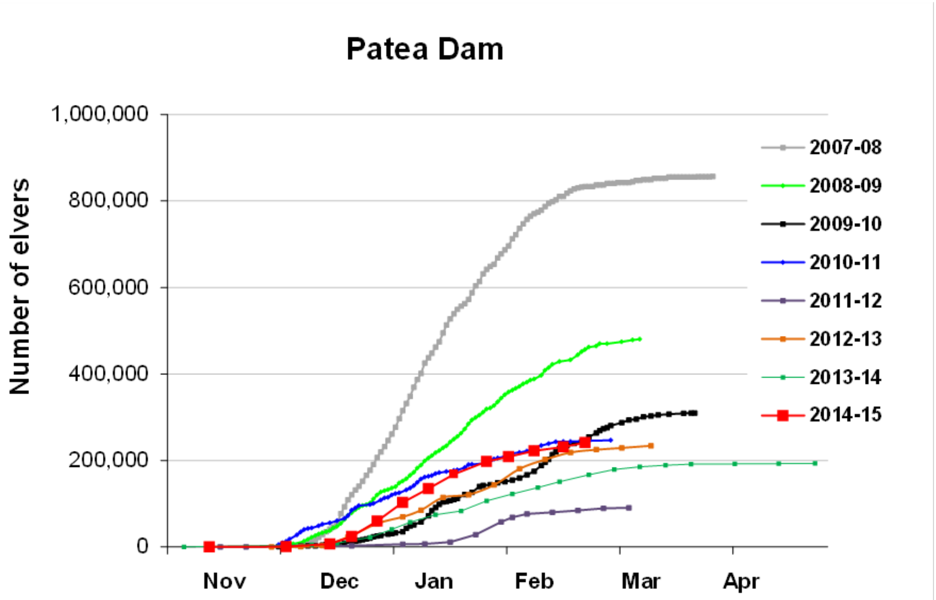


Figure 3: Annual cumulative elver catch records for Wairua Falls, Karapiro Dam and Matahina Dam.



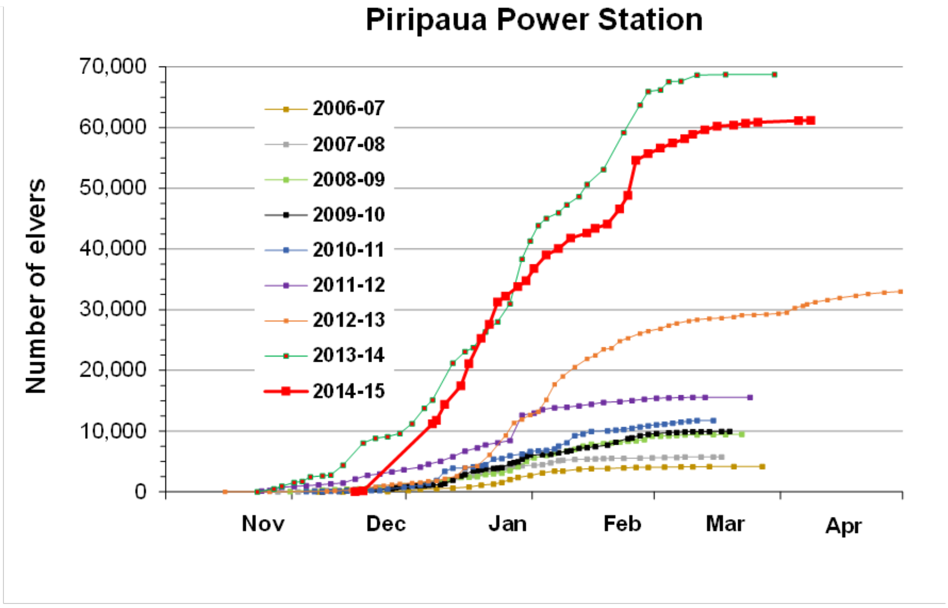


Figure 3 (continued): Annual cumulative elver catch records for Patea Dam and Piripaua Power Station Dam.

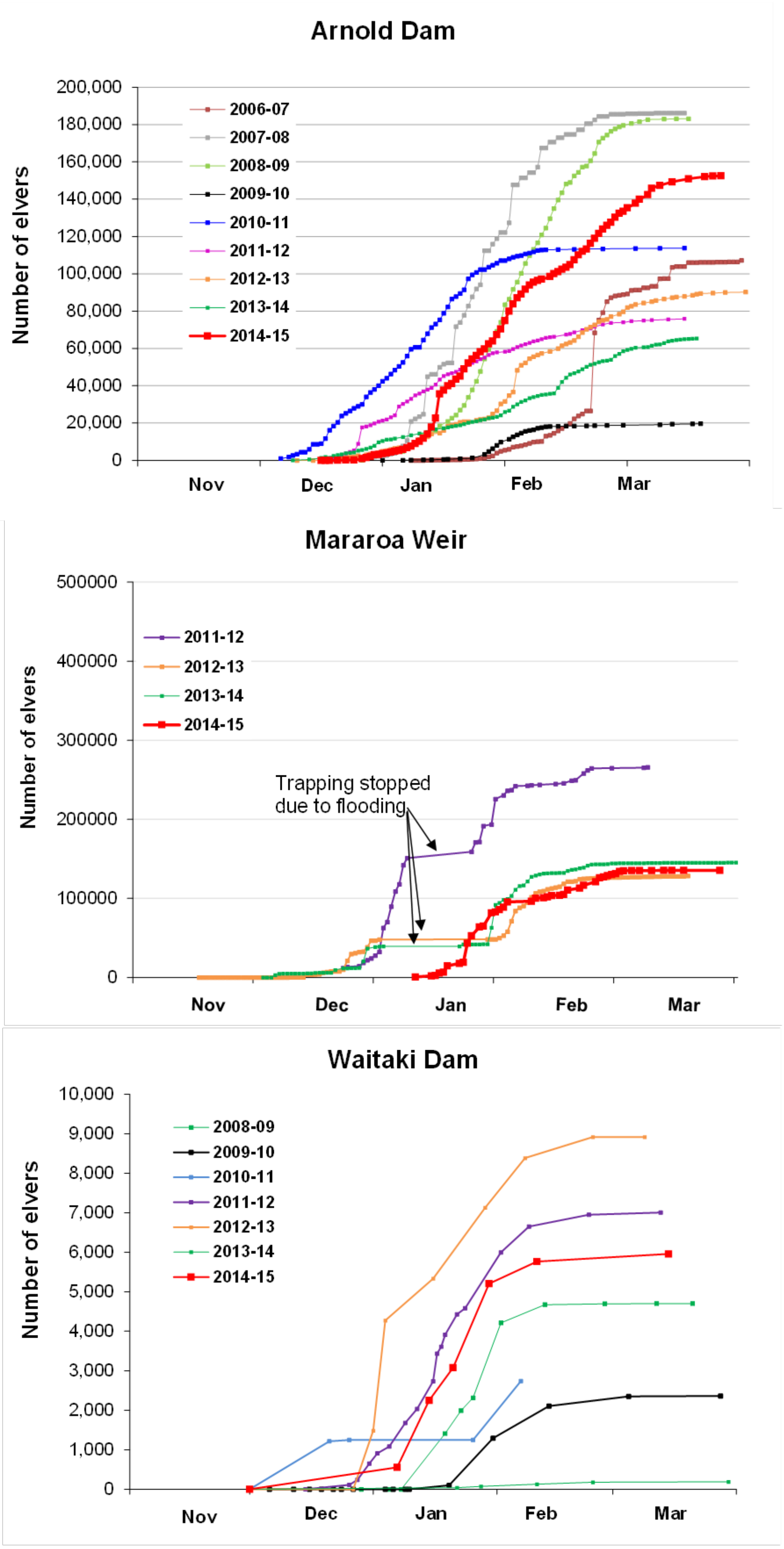


Figure 3 (continued): Annual cumulative elver catch records for Arnold Dam, Waitaki Dam and Mararoa Weir (Note trapping at Mararoa Weir in 2014–15 only started in mid. January).

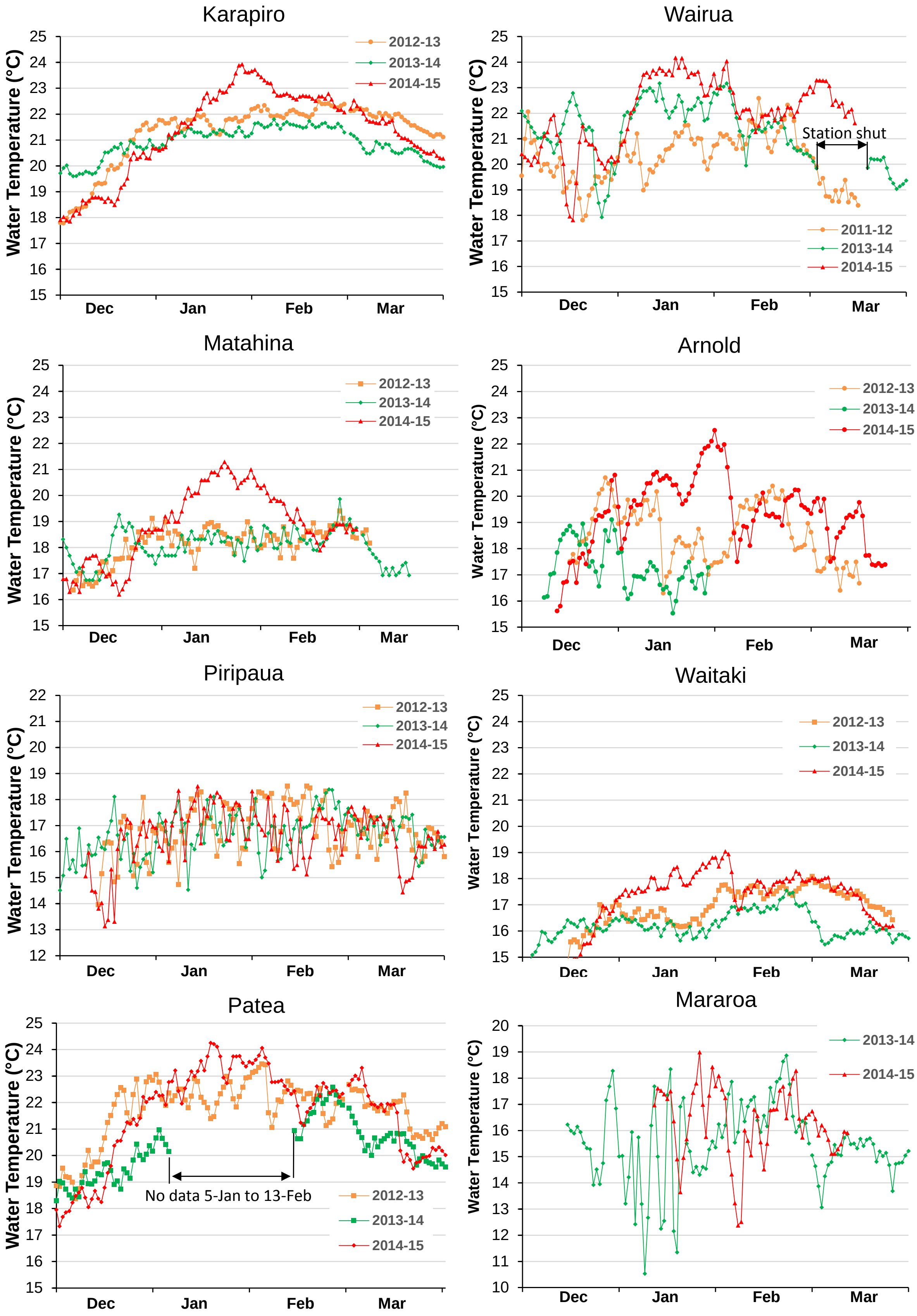


Figure 4: Mean daily water temperature for monitored sites 2012–13, 2013–14 and 2014–15.

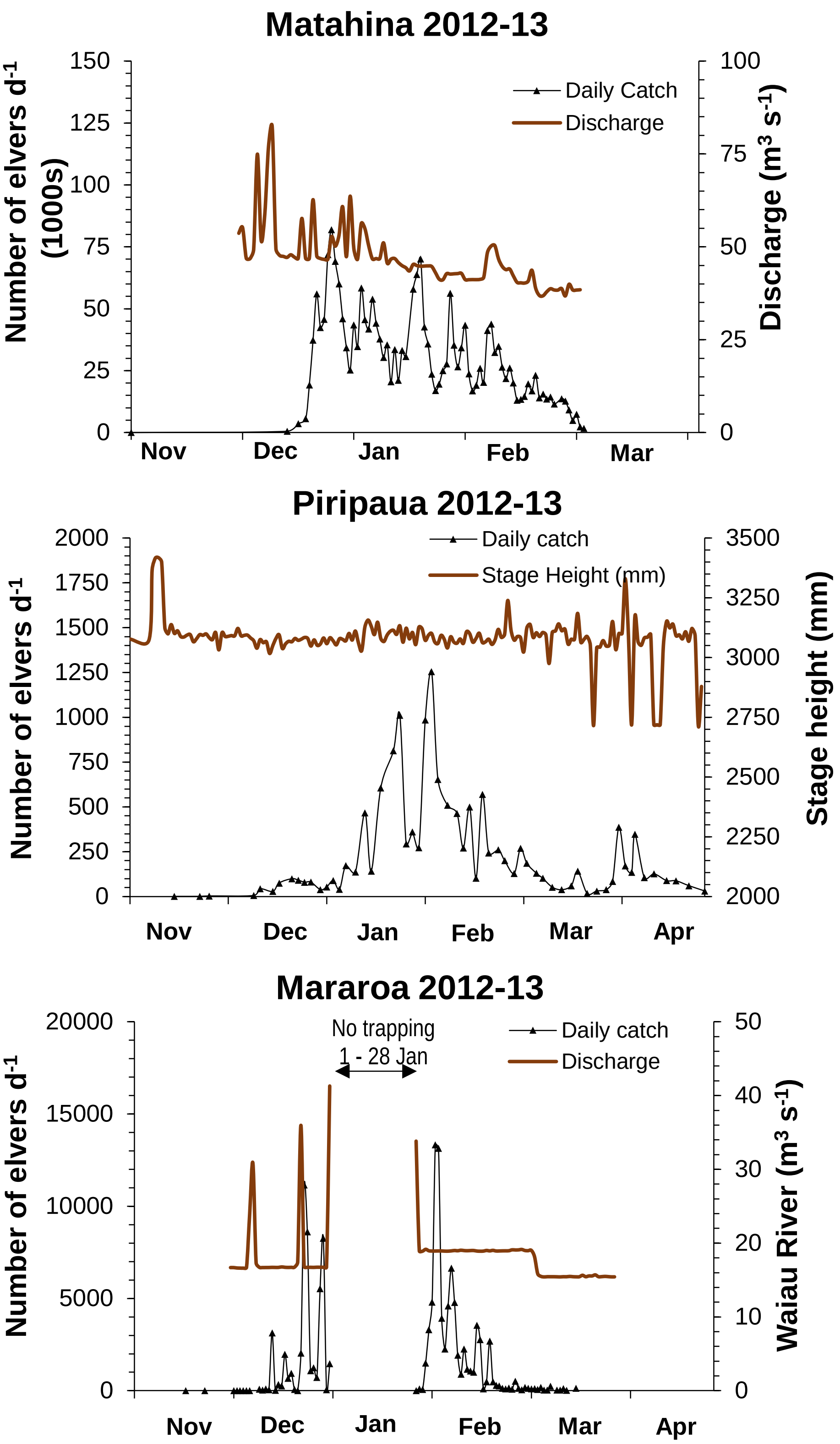


Figure 5: Daily elver catches and average daily flow elver catches for three sites monitored in 2012–13. Note: Flow records for Matahina from Rangitaiki River at Te Teko, Piripaua from Waikaretaheke River, Mararoa from Waiau River at Manapouri Stucture.)

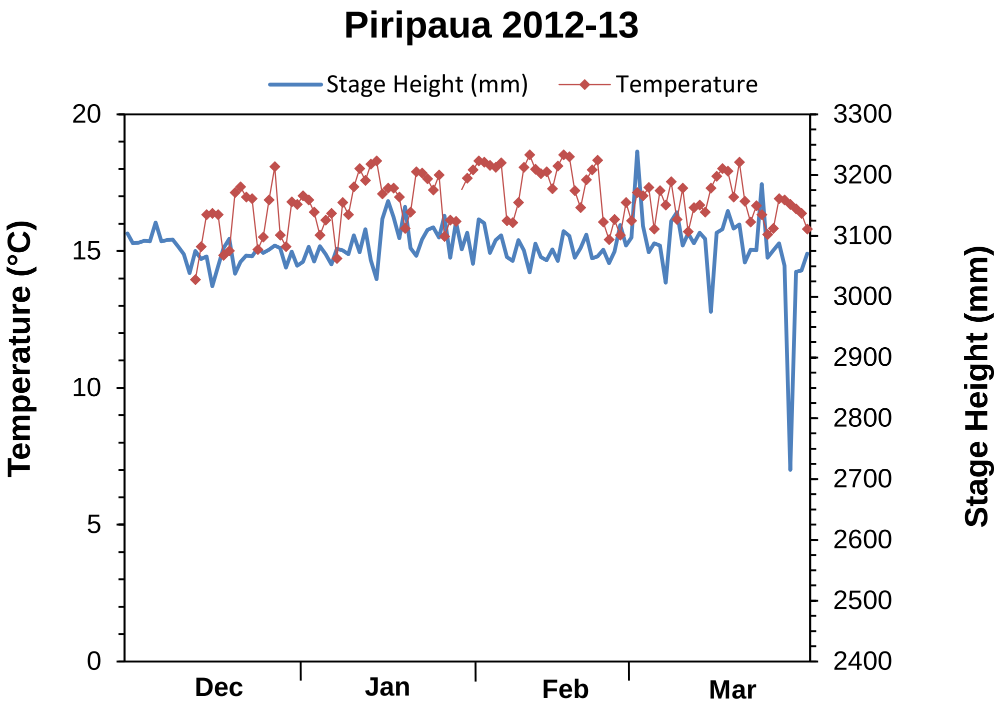


Figure 6: Waikaretaheke River stage height and tailrace water temperature in the Piripaua Power Station tailrace during the 2012–13 elver migration season.

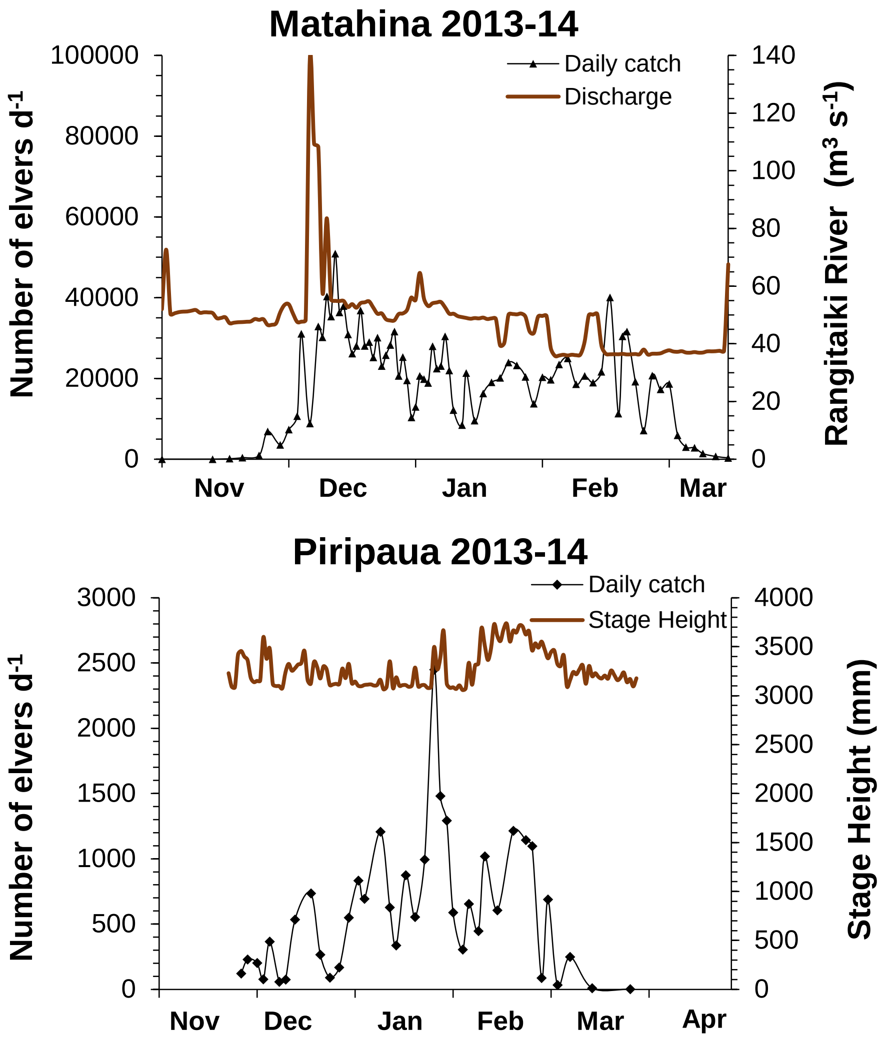


Figure 7: Daily elver catches and downstream river flows for Matahina and Piripaua in 2013–14 (Note flow records for Matahina are from the Rangitaiki River at Te Teko and for Piripaua the stage height from the Waikartaheke River).

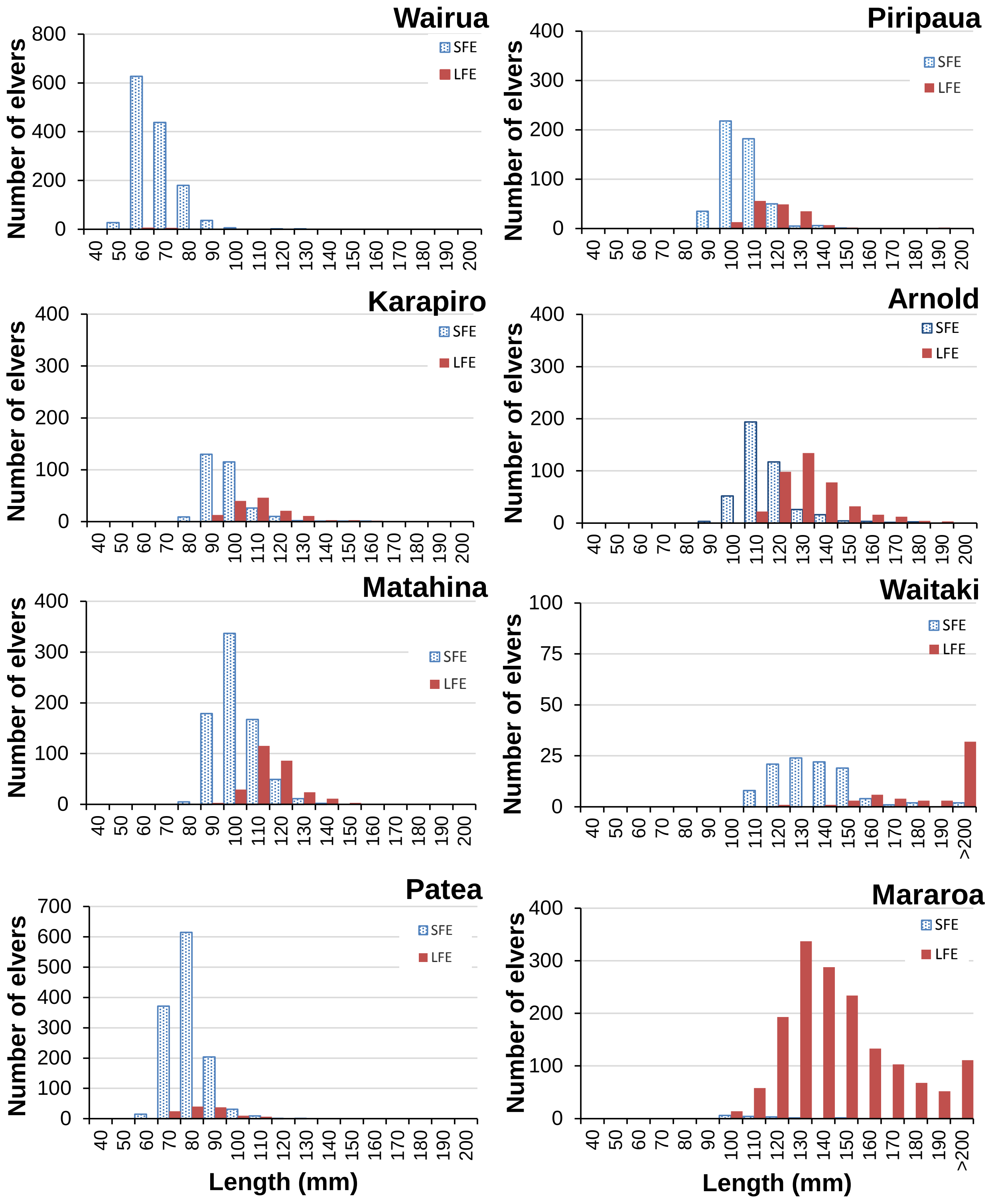


Figure 8: Length distributions of individually measured elvers in the 2013–14 season. Elvers greater than 200 mm are grouped in the >200 class for Waitaki and Mararoa (SFE = shortfins; LFE = longfins). See Table 9 for summary of elver measurements.

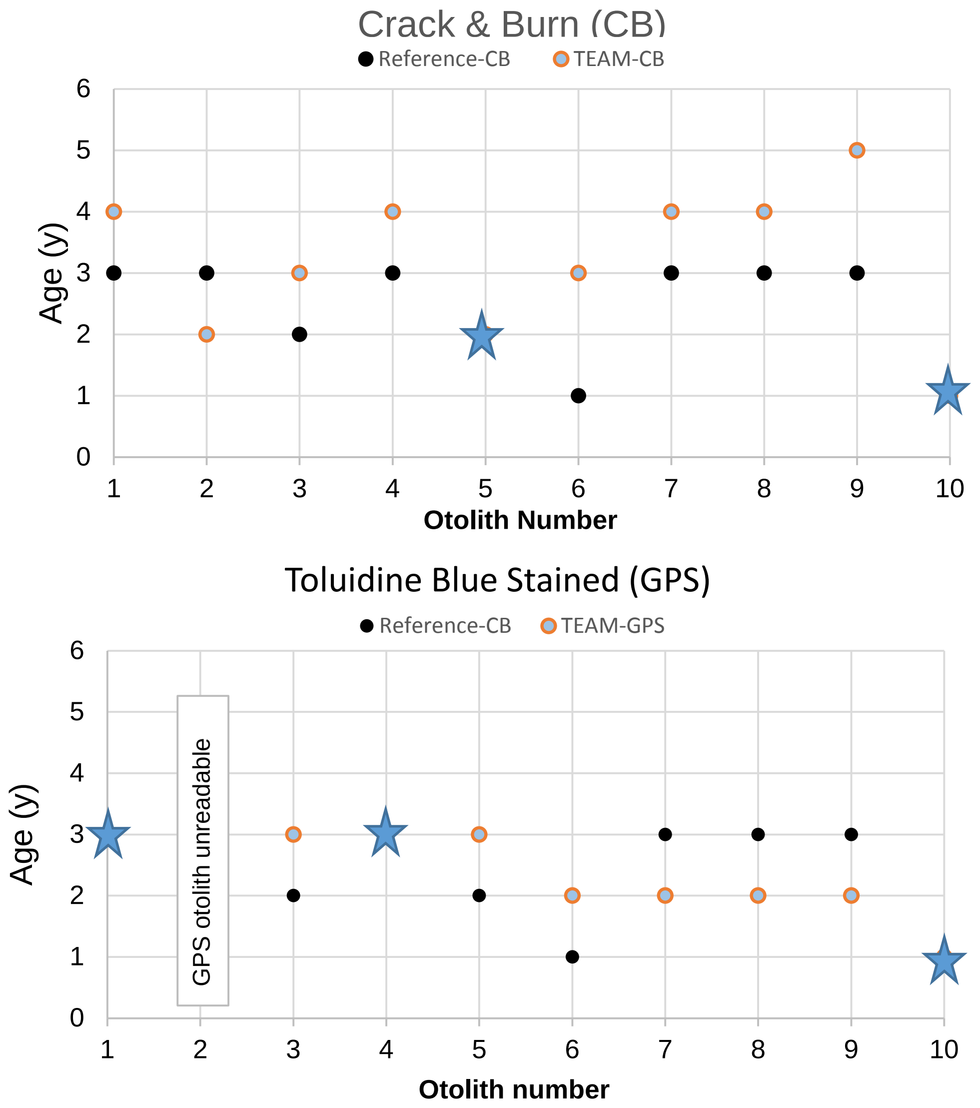


Figure 9: Comparison of ages of ten elver otoliths (20122202, 1–10) using crack and burn (CB) and polishing with EDTA, etching and toluidine blue staining (GPS) preparation methods (Reference=NIWA Principal Scientist ages for crack and burn otoliths). A blue star indicates agreement between reference reader and workshop team.

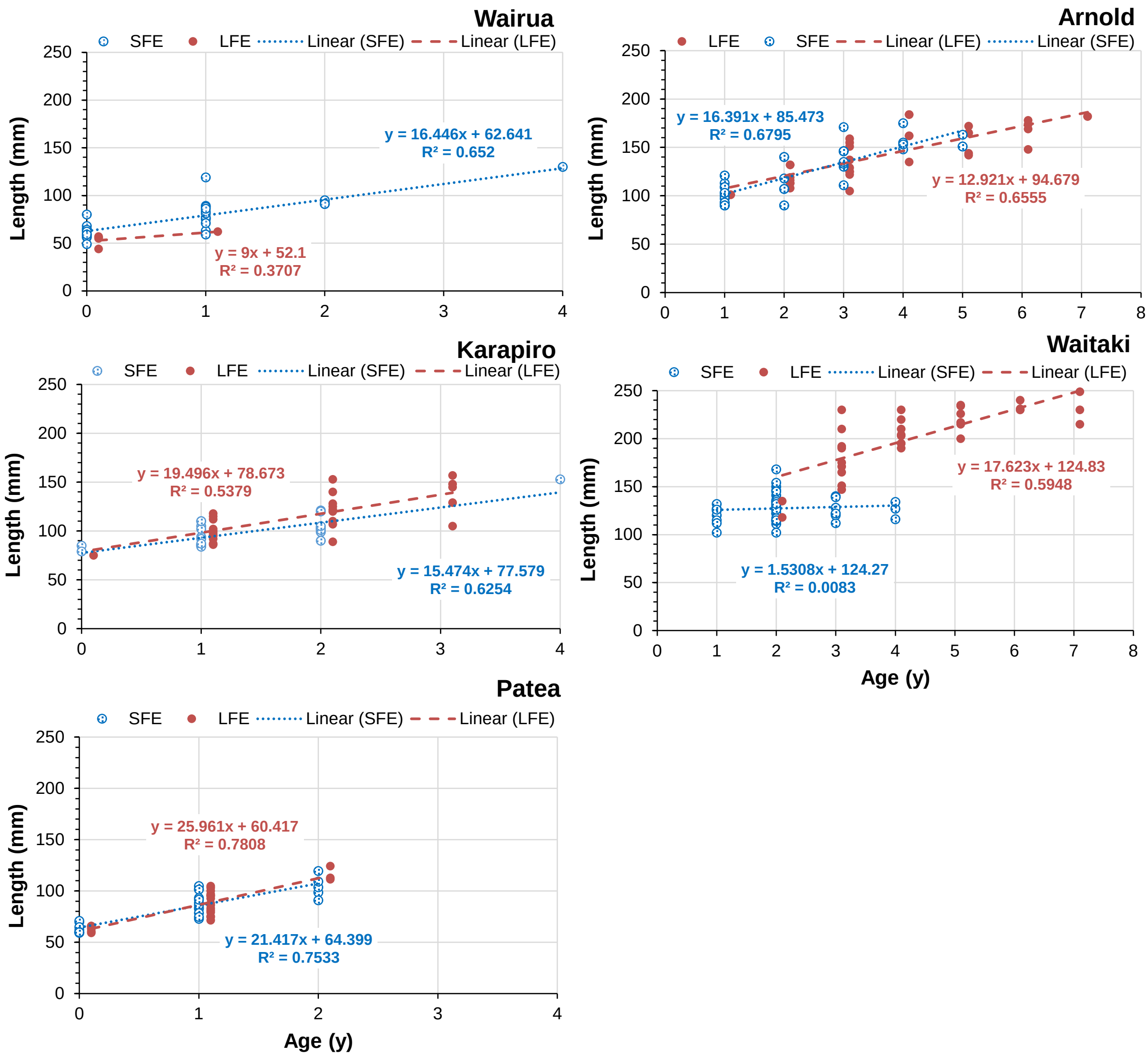


Figure 10: Length–age regressions for elvers collected during the 2013–14 season (SFE = shortfins; LFE = longfins). Small eels greater than 250 mm and/or 20 g not included in regressions.

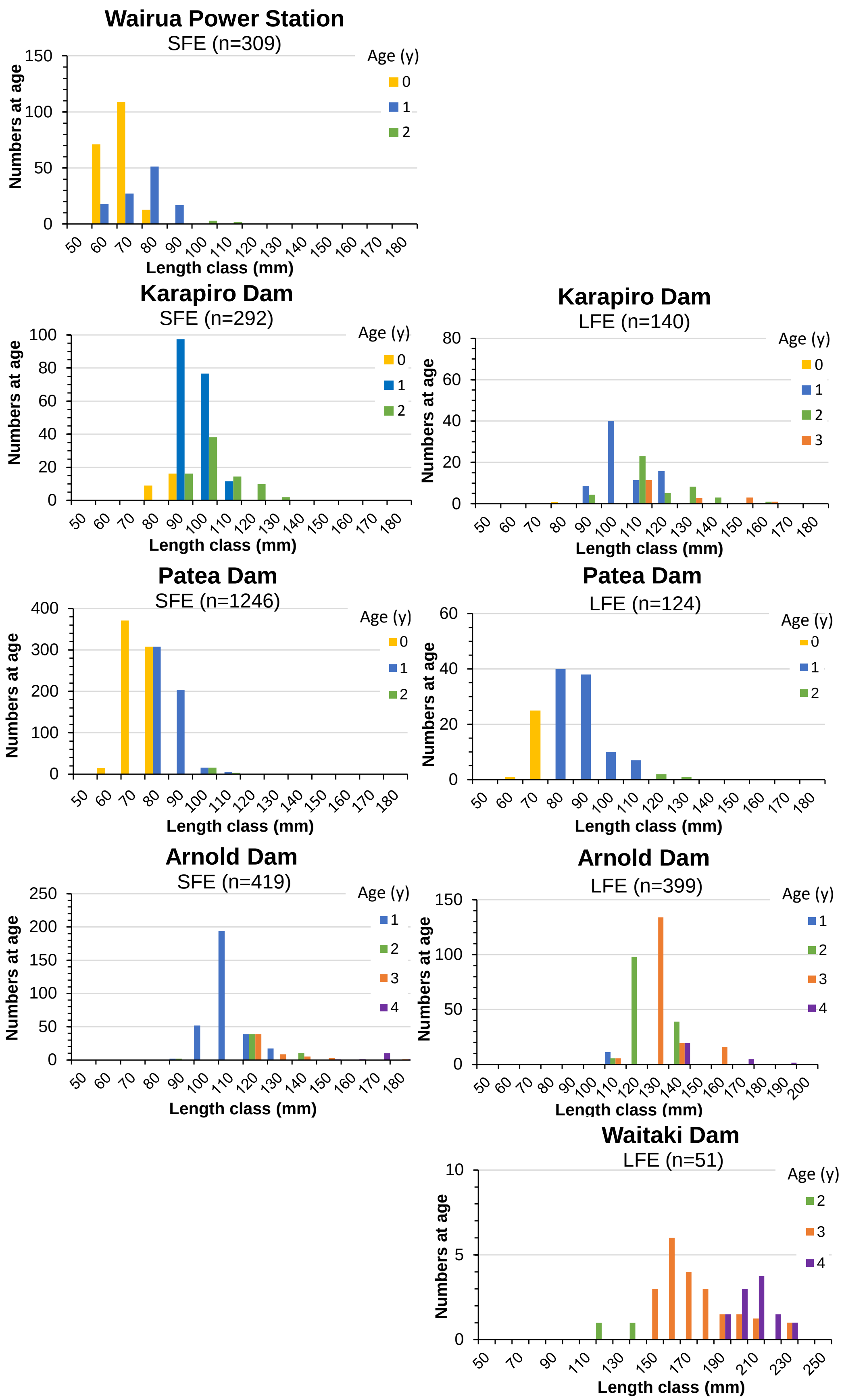


Figure 11: Age distributions of elvers measured in the 2013–14 season derived from age-length keys (SFE = shortfins; LFE = longfins). Elvers over age 4 not plotted for Arnold and Waitaki.

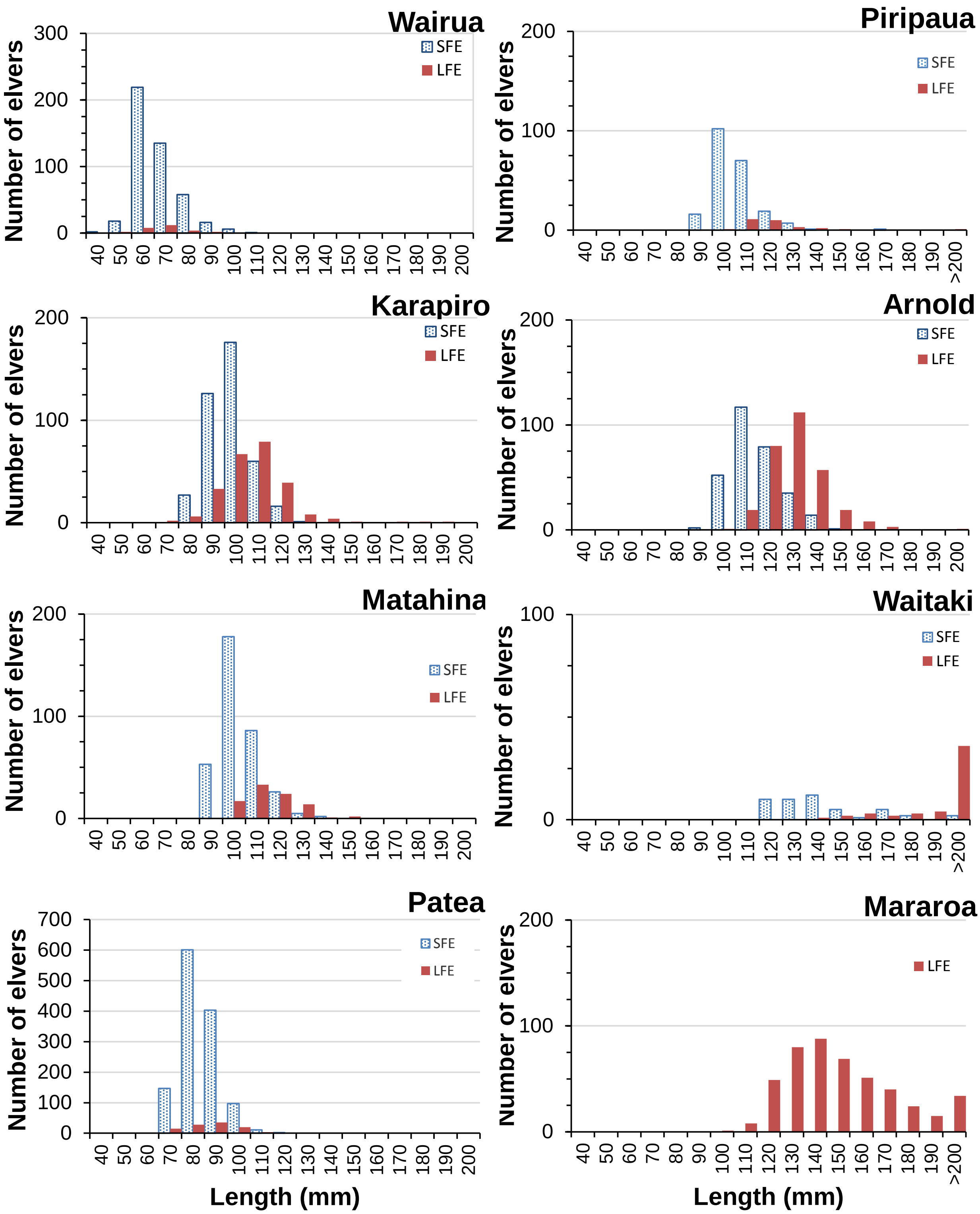


Figure 12: Length distributions of individually measured elvers in the 2014–15 season. Elvers greater than 200 mm are grouped in the >200 class for Waitaki and Mararoa (SFE = shortfins; LFE = longfins).

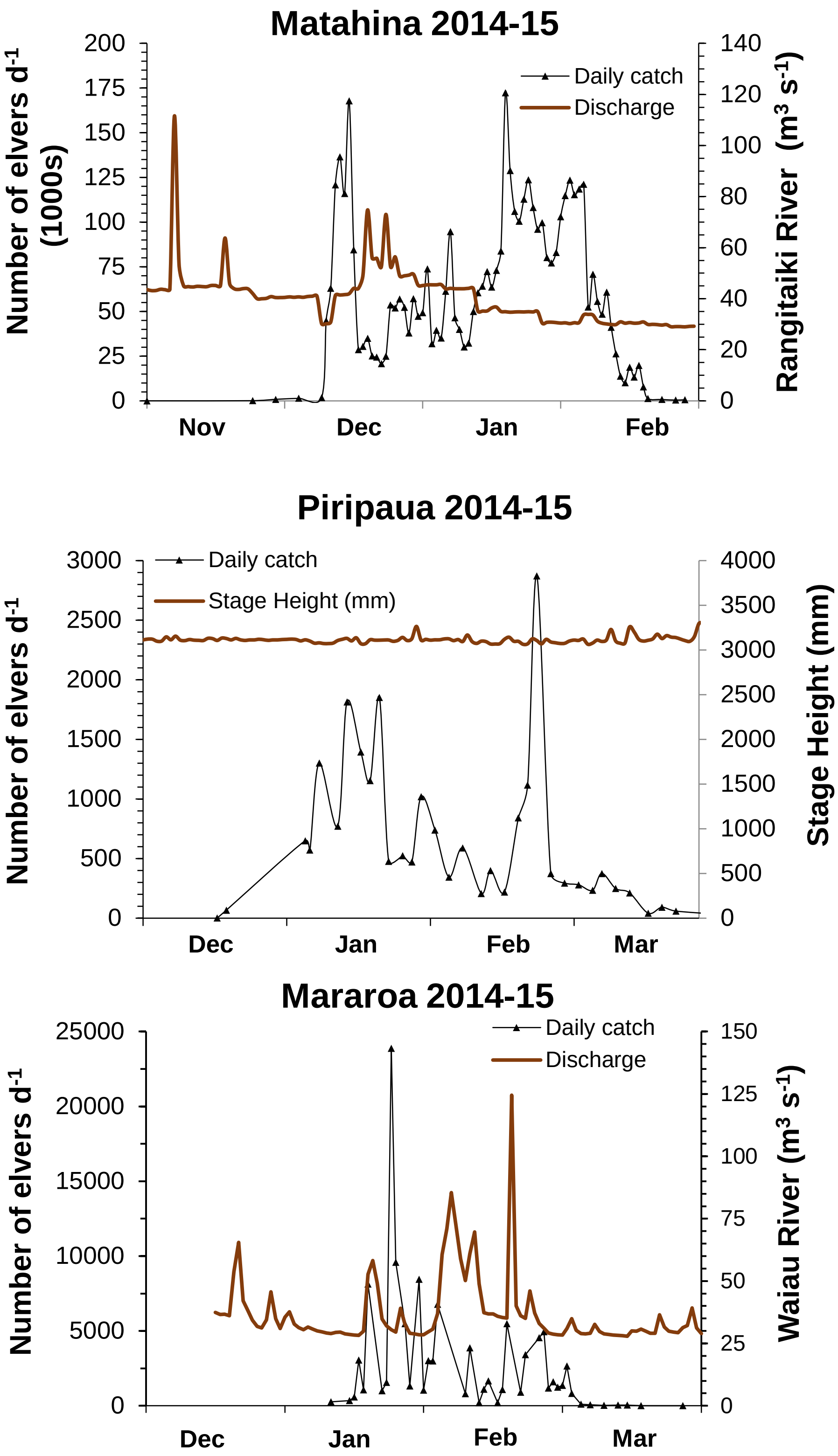
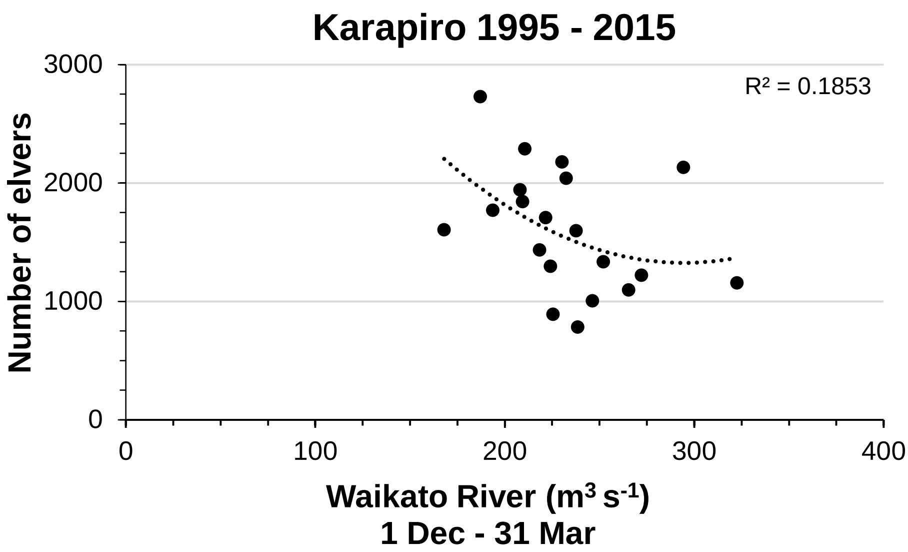


Figure 13: Elver catches and river flow for three of the sites monitored in 2014–15. Flow records for Matahina are from the Rangitaiki River at Te Teko, Piripaua stage height from Waikaretaheke River, Mararoa from Waiau River at Sunnyside.



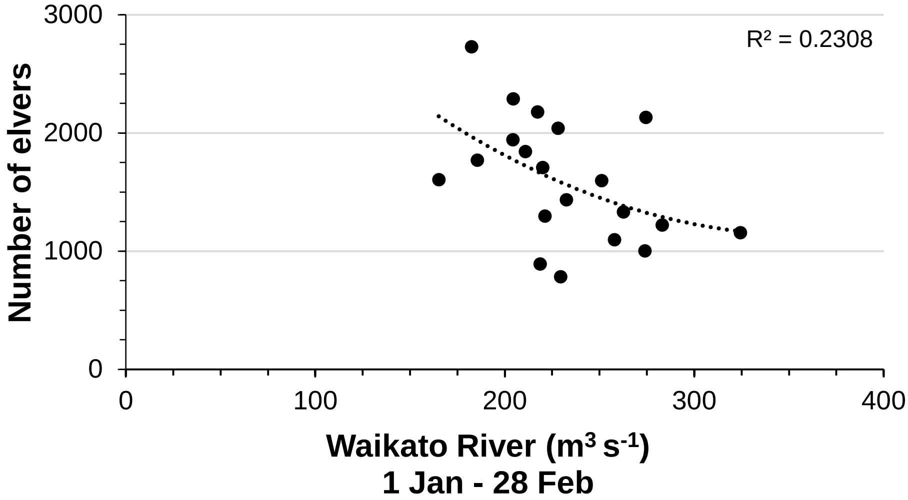


Figure 14: Plot of total annual elver catches against average river flow for the period shown. Records are from 1995 to 2014. The period 1 Dec to 31 March covers the entire migration season while the 1 Jan to 28 Feb period is for the main migration. Flow records are from the Hamilton City flow recording station.

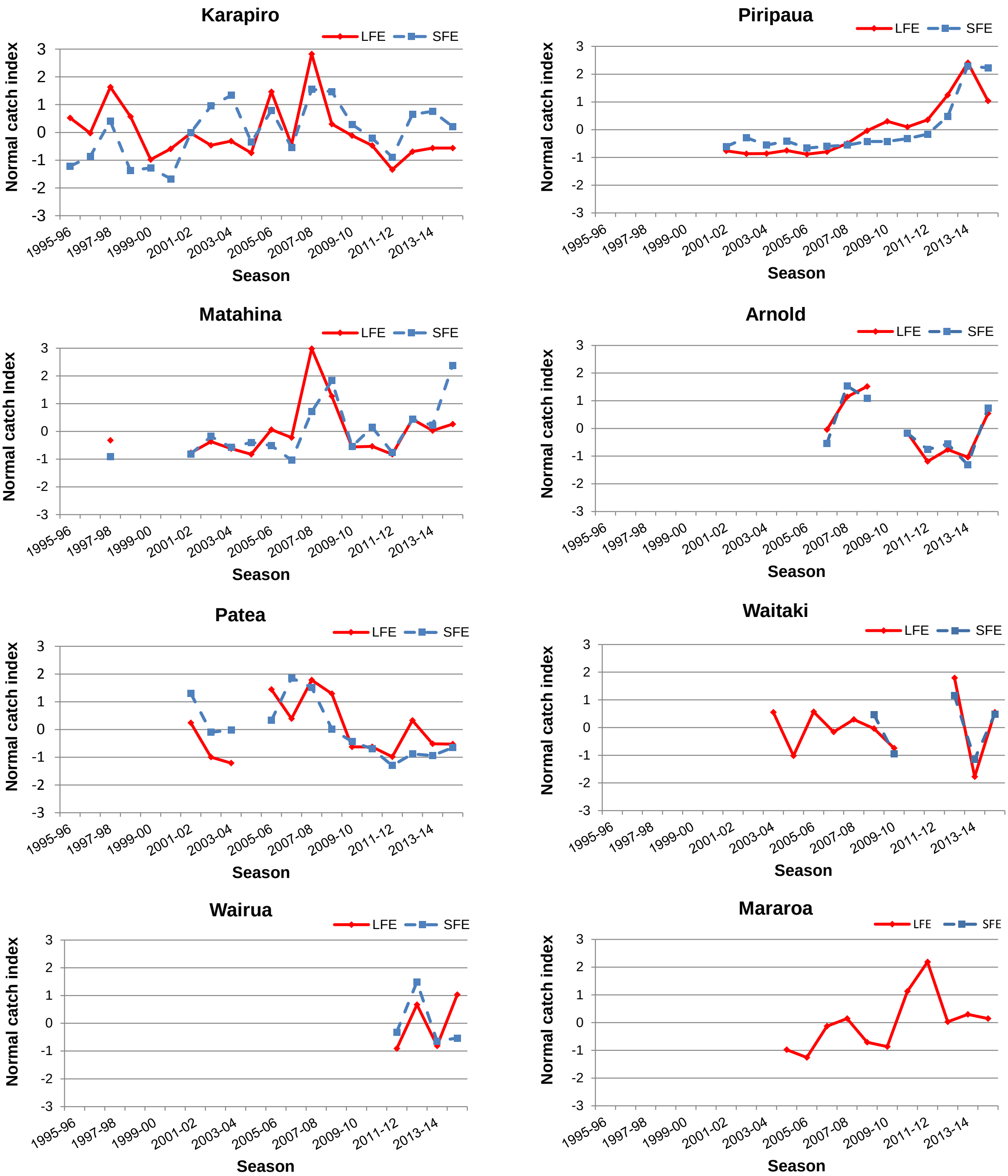


Figure 15: Normal catch indices for longfin and shortfin elvers at monitored sites 1995–96 to 2014–15. (0 = average catch for entire monitoring period for each site).

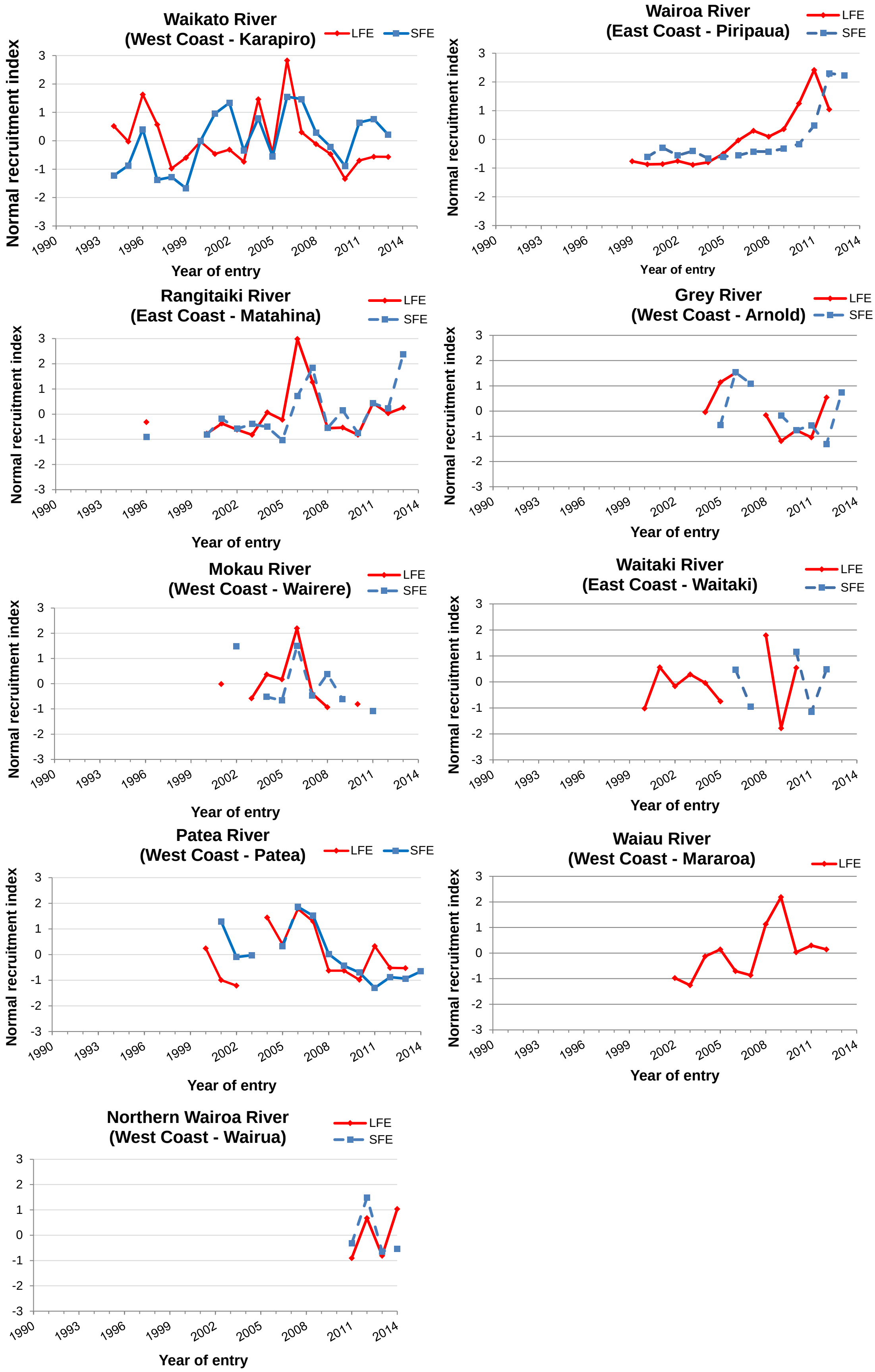


Figure 16: Normalised recruitment indices for longfin and shortfin elvers at entry into freshwater (0 = average for entire monitoring period for each site). These records are obtained by adjusting the normal catch indices by the estimated median age of the elvers at each site.

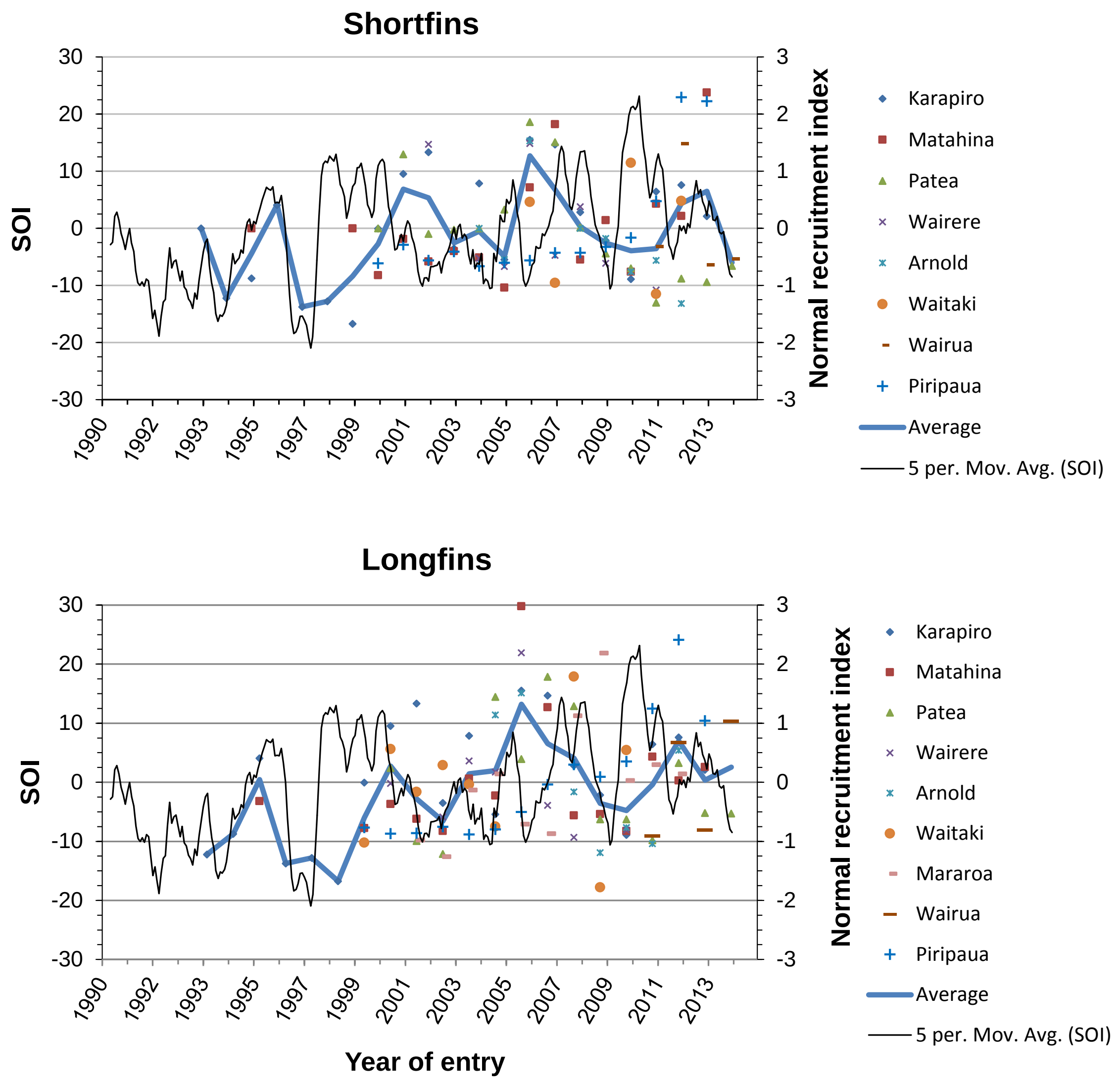


Figure 17: Southern Oscillation Index (SOI) and normalised recruitment indices for longfin and shortfin elvers for all sites monitored up to 2014–15. (SOI data from Australian Bureau of Meteorology).

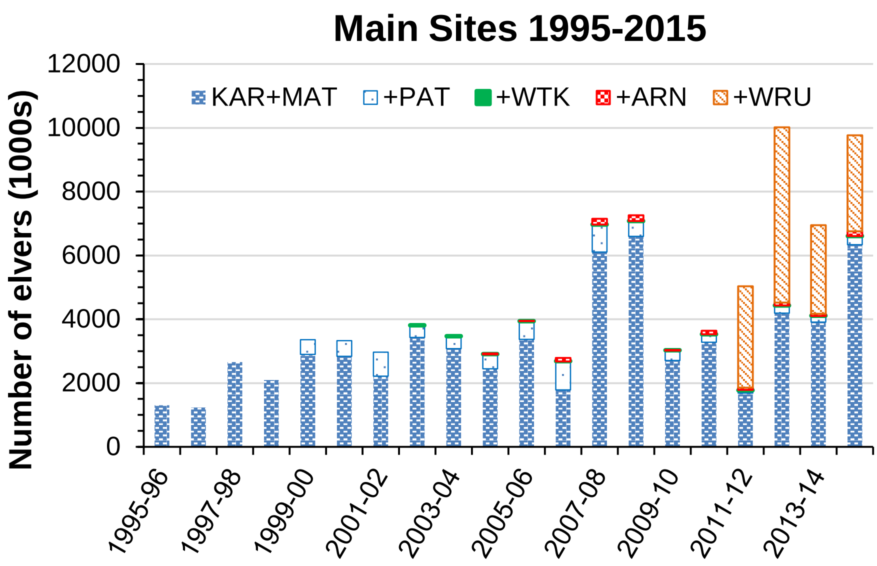


Figure 18: Total elver catches for main sites 1995 to 2015 (KAR = Karapiro; MAT = Matahina; PAT = Patea; WTK = Waitaki; ARN = Arnold; WRU = Wairua).

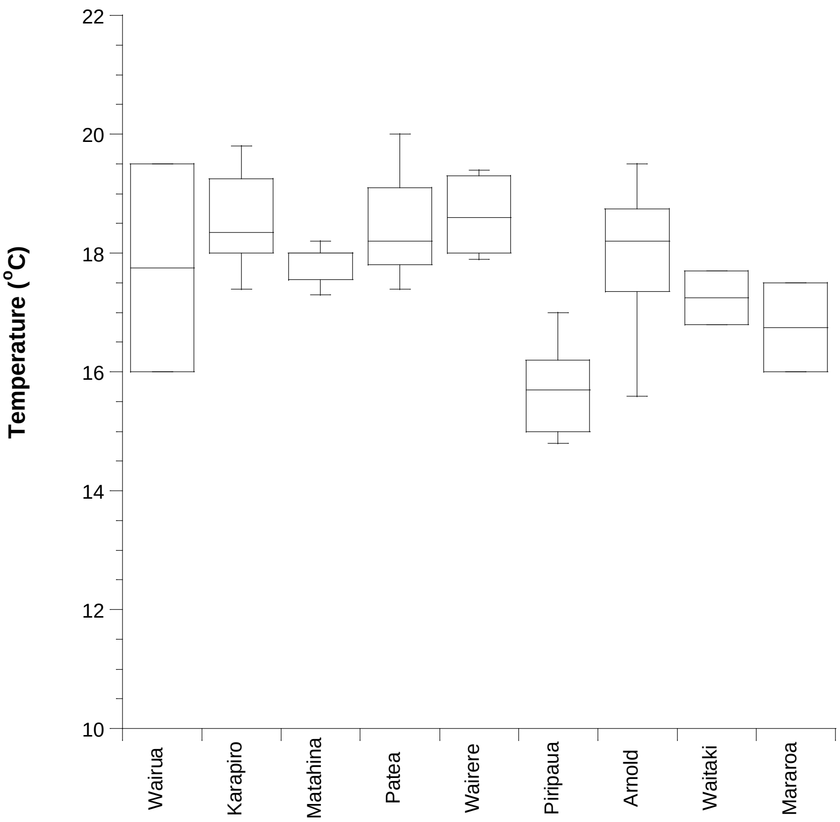


Figure 19: Water temperature ranges at the start of the elver migrations. Boxes show 50% of the data with the median value of the variable displayed as a line. The top and bottom of the box mark the limits of ± 25% of the variable population. The lines extending from the top and bottom of each box mark the minimum and maximum values within the data set that fall within an acceptable range. Any value outside of this range, called an outlier, is displayed as an individual point.

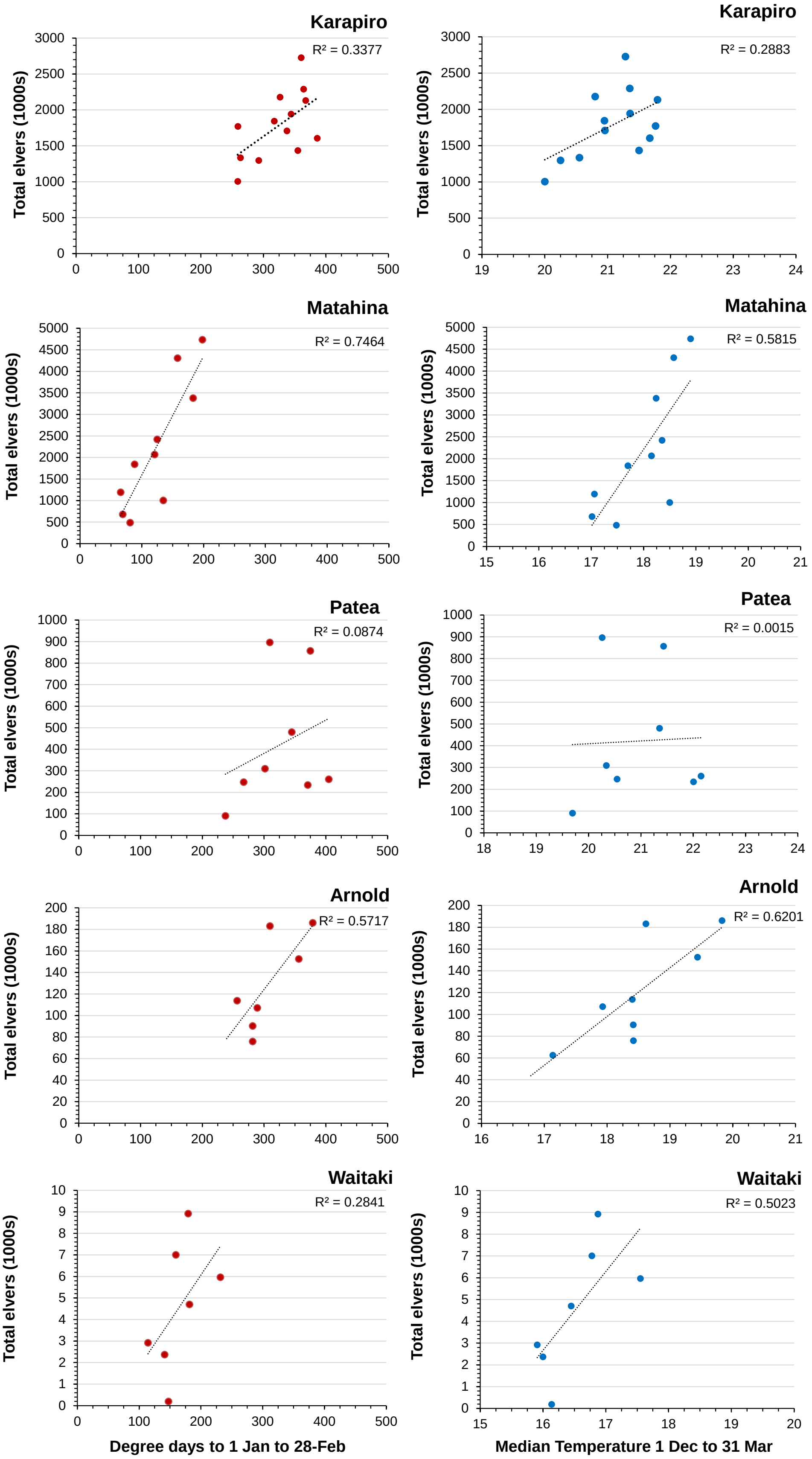


Figure 20: Relationships between total elver catches and degree-days (left) and, total elver catches and median temperature (right) for main sites. (Wairua has been omitted as it has only three years of records).

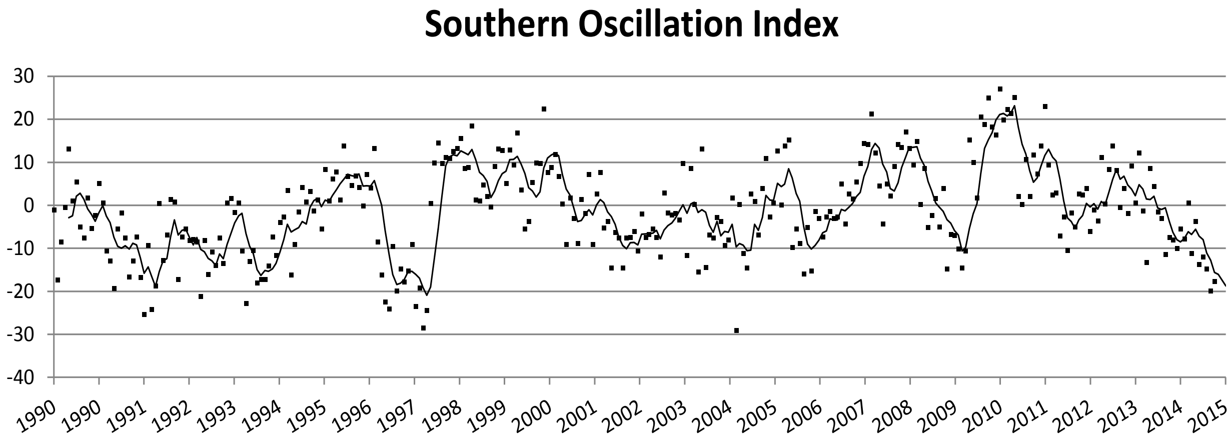
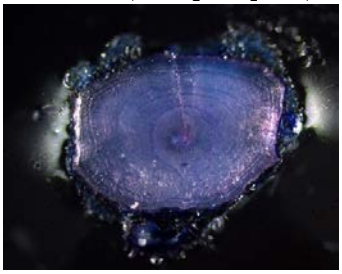
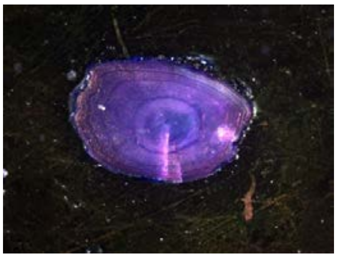
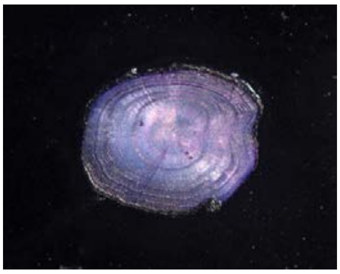


Figure 21: Southern Oscillation Index (SOI) five point moving average for 1990 to 2015 (From Australia Bureau of Meteorology http://www.bom.gov.au/climate/glossary/soi.shtml**).**

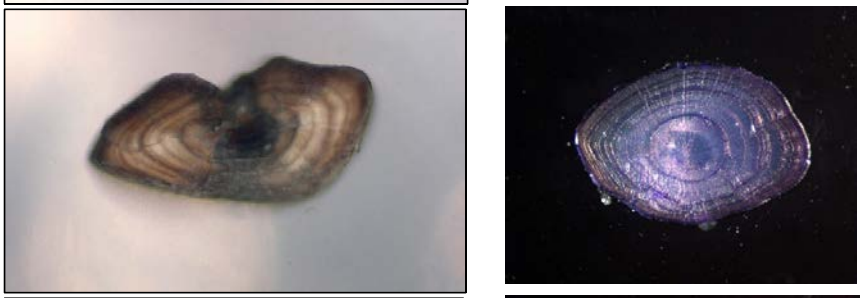
8. APPENDIX A: Workshop otolith images

Photos: Greg Kelly, NIWA. Descriptions of otolith orientations are from Panella (1980).

Otolith ID	Crack & burn, otolith cut through nucleus (i.e. half transverse plane).	Grinding, polishing, toluidine blue stain (i.e. sagittal plane)
20122202#1 (Age 3 years)		
20122202#2 (Age 3 years)		
20122202#3 (Age 2 years)		
20122202#4 (Age 3 years)		
20122202#5 (Age 2 years)		
20122202#6 (Age 1 year)		

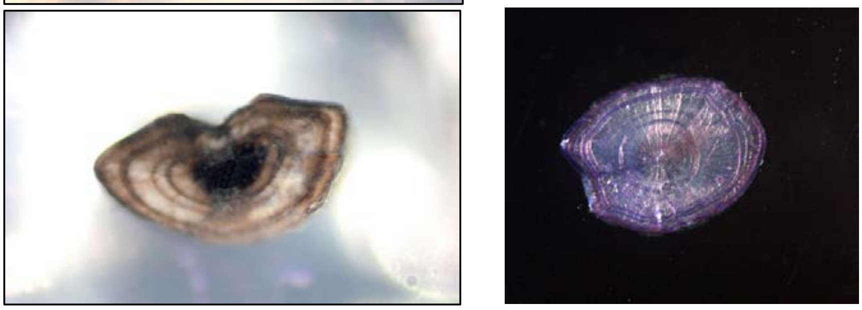
20122202#7
(Age 3 years)

20122202#8
(Age 3 years)

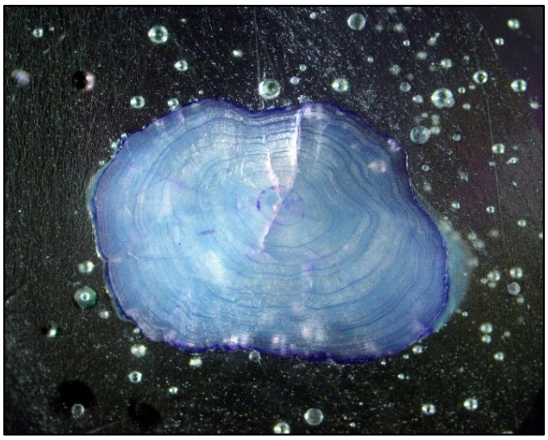


20122202#9
(Age 3 years)

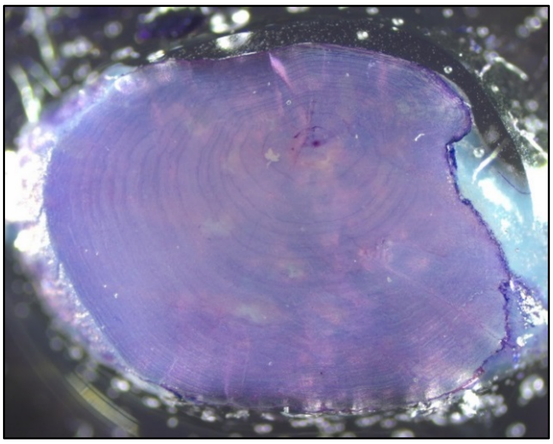
20122202#10
(Age 1 year)



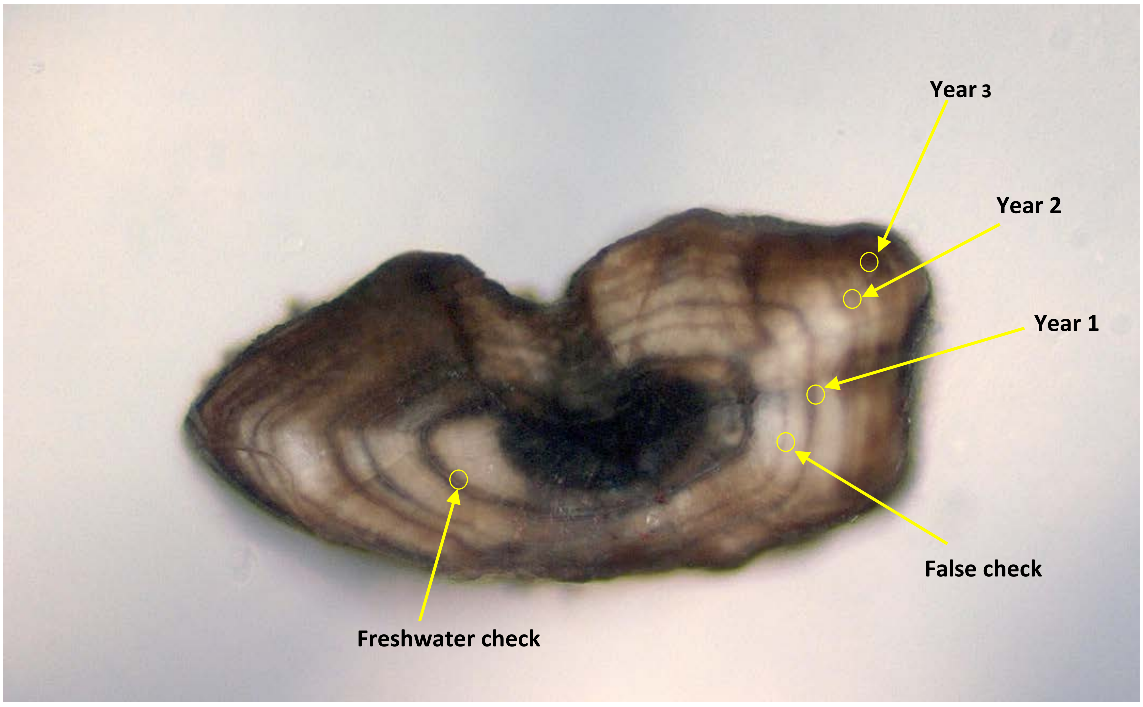
Juvenile eel L=214 mm

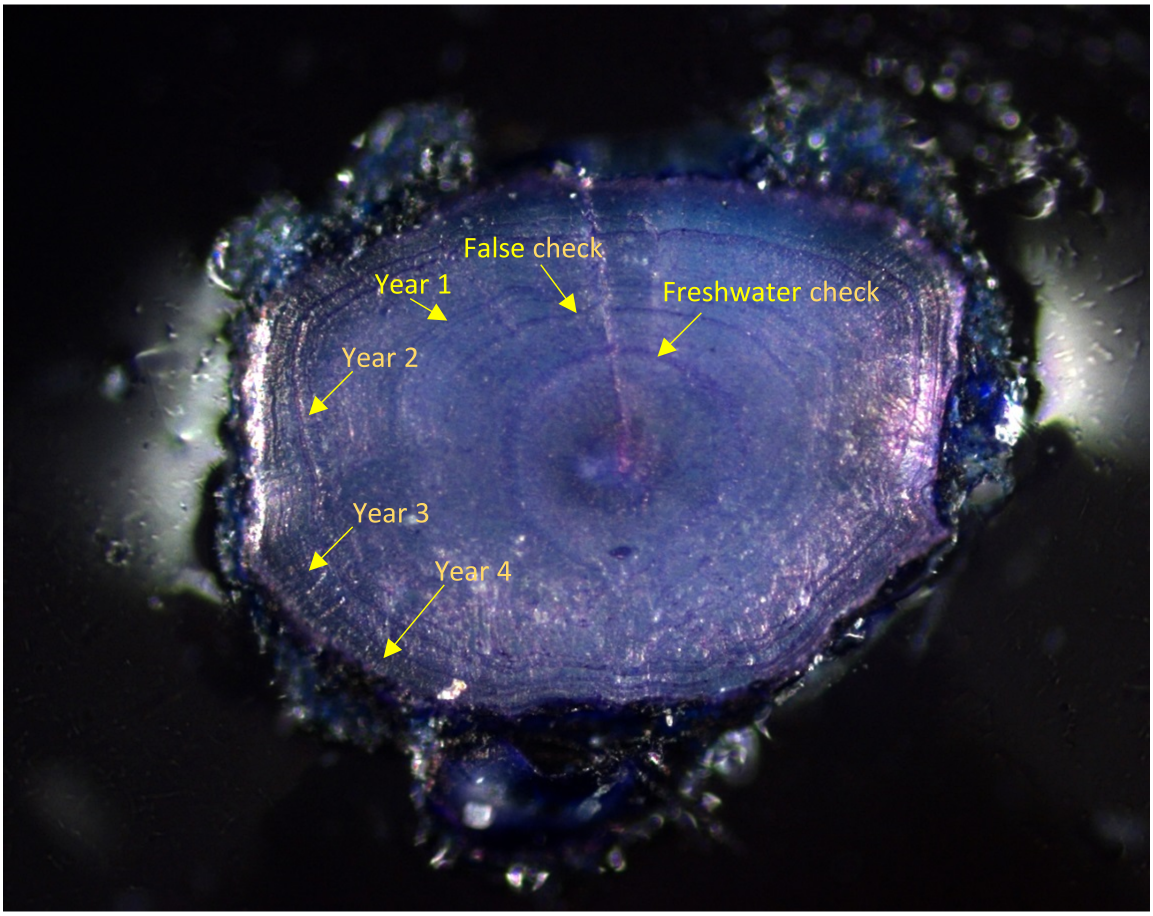


Juvenile ee; L>250 mm



Elver otolith 20122202#1 showing growth rings using crack and burn (upper) and grinding, polishing, etching and toluidine blue staining (lower).





9. APPENDIX B: Site timelines

Summary of historical elver passage operations at monitored sites

Note: 1. Location and site numbering are as shown in Figure 1.

2. References are shown in square brackets and given in full at the end of this Appendix.

3. Highlighted dates are considered unsuitable for trend analysis.

4. Underlined dates indicates a minor problem with species identification.

Main Sites

Karapiro Dam (1)

Pre 1983–84 Dam completed in 1948. Elvers able to climb spillway and siphons overflow when wet. Electric barrier initially installed on spillway to stop elvers climbing but no longer in use by the 1980s [Ref 2]. Some monitoring of elver was made at Karapiro in the 1970s [Ref 3, 23].

1984 to 1992 Some monitoring of elvers made by the dam operator but records are unsuitable for use in trend analysis [Boubée pers. obs.].

1992–93 Dip netting at various location by eels fishers. Development and testing of a floating trap concept. Some records are available but not suitable for use in trend analysis [Ref 2].

1993–94 Further capture trials undertaken. Transfer made to lakes Karapiro, Arapuni and Waikare. Some records are available but not suitable to use in trend analysis [Ref 2].

1994–95 Further capture trials were undertaken with traps also installed on the spillway and tailrace embankments. Transfer to lakes Karapiro, Arapuni, Waikare, Waipapa and Maraetai. Some catch records available but these are considered unsuitable for any trend analysis [Ref 2].

1995–96 Permanent trap installed consisting of two ramps and traps attached to a pontoon moored near the transformer cooling water outlet. A ramp and trap also installed on the stop log platform. A trap was still in operation on the spillway and abutment but caught very few elvers. A spray of water was introduced at the crest of one of the spillway siphons to see if elvers would use such a “natural route” but performance proved very poor. A transfer permit was issued by the Ministry of Fisheries and this stipulated the maximum weight of elvers able to be released in each reservoir up to and including Maraetai. Extensive monitoring was undertaken by NIWA under contract to ECNZ. Result provided in a NIWA report and summarised under MFish contract INEE01. Records usable for trend analysis from this date [Ref 1, 2].

1996–97 No change from 1995–96 except that the abutment trap was removed because of low catches obtained there in the previous season. Most of the catch was obtained on the pontoon traps [Ref 31]

1997–98 Pontoon traps operating. Stop log trap rebuilt to make it easier to operate. Spillway ramp damaged by winter spills and not repaired as overall this trap caught very few elvers in the past. Species composition reported as 50% longfins but as this was markedly different from any other records this was adjusted using the mean of records from the previous and following years [Ref 28, 11].

1998–99 Lift trap installed to replace pontoon that broke away during winter floods. Stop log trap operating. [Ref 29].

1999–00 No change to trapping and monitoring operations. Samples of the catches were not analysed for elver weights and lengths.

2000–01 Lift trap and stop log trap operated by Tainui Tuna (Eel) Working Group and monitored by NIWA. No Change in mechanism except that the trap access ramps were lined with brushes instead of gravel [Ref 13].

2001–02 Lift trap and stop log trap operated by Tainui Tuna (Eel) Working Group and monitored by NIWA [Ref 33].

2002–03 Lift and stop log traps operated by the eel enhancement Company (EECo). All monitoring undertaken by EECo under NIWA's supervision [Ref 24].

2003–04 Lift and stop log traps operated by EECo. All monitoring undertaken by EECo under NIWA's supervision [Ref 24].

2004–05 Lift and stop log traps operated by EECo. All monitoring undertaken by EECo under NIWA's supervision [Ref 25].

2005–06 Lift and stop log traps operated by EECo. All monitoring undertaken by EECo under NIWA supervision [Ref 25].

2006–07 Lift trap and stoplog trap operated by EECo and monitored by NIWA [Ref 11].

2007–08 Lift trap and stoplog trap operated by EECo and monitored by NIWA [Ref 11].

2008–09 Lift trap and stoplog trap operated by EECo and monitored by NIWA [Ref 8].

2009–10 Lift trap and stoplog trap operated by EECo and monitored by NIWA. [Ref 26]

2010–11 Lift trap and stoplog trap operated by EECo and monitored by NIWA [Ref 27].

2011–12 Lift trap and stoplog trap operated by EECo and monitored by NIWA [Ref 34].

2012–13 Lift trap and stoplog trap operated by EECo and monitored by NIWA [this study].

2013–14 Lift trap and stoplog trap operated by EECo and monitored by NIWA. Video monitoring of lift trap [this study].

2014–15 Lift trap and stoplog trap operated by EECo and monitored by NIWA. Video monitoring not commissioned [this study].

Matahina (4)

Pre 1983–84 Matahina Dam completed in 1967. No fish pass included in original design.

1983–84 Collection of elvers from the transformer cooling water outlet made by the then Internal Affairs (now DoC) from about 1982. Transfers made to upper catchment and some transfer records are available [Ref 2].

1984–85 Some transfer made by various groups but limited records available [Ref 2].

1985–86 Some transfer as per previous years by various groups. Limited transfer records available [Ref 2].

1986–87 Some transfer as per previous years by various groups. Limited transfer records available [Ref 2].

1987–88 Some transfer probably done as per previous years by various groups. No records available [Ref 2].

1988–89 Some transfer as per previous years by various groups. Limited transfer records available [Ref 2].

1989–90 Some transfer as per previous years by various groups. Limited transfer records available [Ref 2].

1990–91 Elver ladder installed. No records available [Ref 2].

1991–92 Elver ladder operating. Estimates of elver usage made [Ref 4].

1992–93 Elver ladder operating. Estimates of elver usage made [Ref 4.]

1993–94 Elver ladder operating. Estimates of elver usage made [Ref 4].

1994–95 No monitoring of elver ladder. Some manual transfers made but limited records available [Ref 2].

1995–96 No monitoring of elver ladder. Some manual transfers made but limited records available [Ref 2].

1996–97 Reservoir lowered so the earthquake damaged dam could be repaired. Elver ladder not usable. Temporary traps installed on each bank of the tail race and monitored by NIWA under contract to ECNZ [Ref 15, 16 and 22].

1997–98 Elver ladder still not usable because of on-going dam repairs. Temporary trap on right bank of tail race (at outlet of transformer cooling water outfall) replaced by a permanent structure and monitored by NIWA under contract to ECNZ. First set of records usable for trends analysis [Ref 17].

1998–99 Existing trap at transformer cooling water outlet operated by Kokopu Trust on behalf of TrustPower. Records incomplete [Ref 33].

1999–00 Trap operated by Kokopu Trust but records incomplete [Ref 33] .

2000–01 Trap operated and monitored by Kokopu Trust. No subsamples analysed and reported elver catch weight probably included eels as well as elvers [Ref 33].

2001–02 Trap operated and monitored by Kokopu Trust using standardised monitoring procedures. Records from this date usable for trend analysis [Ref 33].

2002–03 As above [Ref 24].

2003–04 As above [Ref 24].

2004–05 Trap damaged by winter flood but repaired in time for start of season [Ref 25].

2005–06 Trap operated by Kokopu Trust on behalf of TrustPower and species composition monitored by NIWA [Ref 25].

2006–07 Trap operated by Kokopu Trust on behalf of TrustPower and species monitored by NIWA [Ref 11].

2007–08 Trap operated by Kokopu Trust on behalf of TrustPower and species monitored by NIWA [Ref 11].

2008–09 Trap operated by Kokopu Trust on behalf of TrustPower and species monitored by NIWA [Ref 8].

2009–10 Normal operation continues [Ref 26].

2010–11 Normal operation continues [Ref 27].

2011–12 Normal operation continues but unusually low catch early in season. Season also ended early. Reason(s) for these unusual records is unclear [Ref 34].

2012–13 Trap operated by Kokopu Trust on behalf of TrustPower and species compositions analysed by NIWA on site [this study].

2013–14 Trap operated by Kokopu Trust on behalf of TrustPower and species compositions analysed by NIWA on site [this study].

2014–15 Trap operated by Kokopu Trust on behalf of TrustPower and species compositions analysed by NIWA on site [this study].

Patea (6)

Pre 1983–84 Patea Dam completed in 1984. Fish pass retrofitted once dam built.

1984–85 Brush elver ladder installed and began to operate in Jan 1985 [Ref 2].

1985–86 Estimate of elver ladder passage per hour made [Ref 2].

1986 to 1992 No monitoring or maintenance made and by 1992 the brush core had rusted away making the pass un-usable.

1992–93 Brush removed from elver ladder and pipe lined with gravel [Ref 2].

1993–94 Estimate of elver ladder usage made [Ref 2].

1994–95 No records available [Ref 2].

1995–96 Estimate of elver ladder usage made [Ref 2].

1996–97 Elver pass operating but attempt to monitor passage with an electronic counter failed [Ref 16].

1997–98 Elver ladder in operation but multiple water supply failures is known to have occurred.

1998–99 A temporary trap installed at the edge of the tailrace by Grant Williams a commercial eel fisher that operated in the Taranaki area. Elver ladder still operating but usage relative to the trap found to be minimal [Ref 33].

1999–00 Tailrace elver trap improved [Ref 33].

2000–01 Elver trap further improved and standard monitoring procedures implemented. Records usable for trend analysis from this date [Ref 18, 33].

2001–02 Trap and transfer as well as standardised monitoring procedures operated by station staff [Ref 33].

2002–03 The elver ladder no longer functioning but trap and transfer operations fully implemented [Ref 24].

2003–04 Trap and transfer operations. Subsample of catch retained for NIWA to analyse [Ref 24].

2004–05 Trap and transfer operations. No subsample of catch retained for analysis through the season but Taranaki RC did analyse one sample [Ref 25].

2005–06 Trap and transfer operations. Twelve frozen sub-sample of catch provided to NIWA for analysis [Ref 25].

2006–07 Trap operated over entire season by TrustPower and eight frozen sub-samples of the catch analysed by NIWA [Ref 11].

2007–08 Trap operated over entire season by TrustPower and five frozen sub-samples of the catch analysed by NIWA [Ref 11].

2008–09 Trap operated over entire season by TrustPower and six frozen sub-samples of the catch eventually sent to NIWA for analysis [Ref 8].

2009–10 Trap operated over entire season by TrustPower and six frozen sub-samples of the catch analysed by NIWA [Ref 26].

2010–11 Trap operated over entire season by TrustPower and five frozen sub-samples of the catch analysed by NIWA [Ref 27].

2011–12 Monitoring undertaken by Ryder Consulting Ltd under contract to TrustPower. Some catch records obtained at the end of the season, but no details were forwarded to NIWA until 2013. Trap clearance effort has substantially declined in the last two years [Ref 34].

2012–13 Monitoring of traps and daily operations undertaken Trustpower staff and supervised by Ryder Consulting Ltd. New transfer permit received late January 2013, records received late in season [Ref 36].

2013–14 Monitoring of traps and daily operations undertaken Trustpower staff and supervised by Ryder Consulting Ltd. Data received throughout the season [Ref 38].

2014–15 Monitoring of traps and daily operations undertaken Trustpower staff and supervised by Ryder Consulting Ltd. Data received throughout the season. Final reporting not yet received from Trustpower [Ref 47].

Wairua (17)

pre 1983–84 Power Station built in the early 1900s but revamped a number of times since. No fish passage provisions included in original design.

1994–95 About 1 kg of elvers transferred from the power station tailrace to upstream habitat by eel industry [Ref 2].

2010–11 Equipment and instruction provided to stakeholders by NIWA but flooding prevented any trapping. No records obtained [Ref 27].

2011–12 Temporary trap installed and operating over summer. A number of subsamples examined by NIWA [Ref 32].

2012–13 Trap operated by Hoori George Tuhiwai. Canal dewatering 30 October to 9 November. Used pump from tailrace to operate the tailrace trap. Spillway trap non-functional over repair period. Repair to penstock, elvers attracted to penstock leakage during repairs. Trap and netting carried out to save elvers attracted there. Recorded as trap 2 or penstock trap and were mostly larger elvers. Severe drought country wide. By mid-February virtually no water to run the station except at peak time. Tailrace mostly dry. Catch data received late May and not included in MPI progress report [this study].

2013–14 Trap operated by Hoori George Tuhiwai. Canal dewatered 3 March 2014, no further operations [this study].

2014–15 Trap operated by Hoori George Tuhiwai [this study].

Waitaki (9)

Pre 1983–84 Dam completed in 1935. A pool and weir salmon pass was installed when the dam was constructed but was abandoned when the station was revamped in 1951. Report of high numbers of elvers present below the dam in the 1980s [Ref 5, 23].

1992–93 An elver ladder installed on dam face [Ref 2].

1993–94 Elver ladder operating but only six elvers used it [Ref 2]. Unlike previous years very few elvers seen in the stop-log area [Ref 24].

1994–95 Elver ladder operating but only one elver used it [Ref 24].

1995–96 Elver ladder operating but only three elvers used it [Ref 24].

1996–97 Elver ladder operating but only three elvers used it [Ref 24].

1997–98 Elver ladder operating and six elvers used it. Considerably more elvers seen in the transformer cooling water outlet than in the last few years [Ref 24].

1998–99 Two elver traps installed in the stop-log area of tailrace. No catch records available.

1999–00 No records available.

2000–01 No records available.

2001–02 A total of 2061 eels reported as caught but most of the catch appear to be eels rather than elvers so records not usable for trends analysis [Ref 24].

2002–03 Access ramps to traps upgraded. Full season monitoring undertaken but records not judged suitable for trend analysis [ref 24].

2003–04 Two traps were again operated and monitored for the full season. Total catch records usable for trend analysis but it is possible that the contractor did not recognise that a small proportion of the catch were shortfins [Ref 24].

2004–05 Oil interceptor (Trap 2) and auxiliary traps (Trap 1) operating. Monitoring undertaken by local contractor with assistance from Meridian Energy. Presence of shortfins in the catch may have been missed [Ref 25].

2005–06 Traps operated from turbine 1 outlet (Trap 1) and oil interceptor (Trap 2). A floating trap also operated in Turbine 3 outlet. Presence of shortfins in the catch may have been missed [Ref 11, 25].

2006–07 Trap 1, and floating trap in Turbine 3 outlet operated. Oil interceptor (trap 2) decommissioned as it no longer receives flows from transformer cooling system (now air cooled). Presence of shortfins in the catch may have been missed [Ref 11].

2007–08 Trap 1, and floating trap in Turbine 3 outlet operated. New fixed trap installed in decommissioned Turbine 3 outlet. Presence of shortfins in the catch may have been missed [Ref 11].

2008–09 The elver ladder over the dam was decommissioned and modified to provide a pathway for elvers between the spillway and the tailrace where Trap 1 is located. Small modifications to Trap 3 outflow made. Floating trap decommissioned. Operation and monitoring by G Hughes under contract to Meridian [Ref 8].

2009–10 Normal operation continued by G Hughes under contract to Meridian [Ref 26].

2010–11 Floods damaged the traps. Records available are not for the entire migration season [Ref 27].

2011–12 Normal operation continued by G Hughes under contract to Meridian. However, no species composition was collected in January which is normally the peak of migration season. Omit record for trend analysis [Ref 34].

2012–13 Normal operation continued by G Hughes under contract to Meridian. Operations adversely impacted during February 2013 when high river flows flooded the platform where the traps were located, and damaged the traps. Video monitoring of holding tank G3 commissioned [this study].

2013–14 Normal operation continued by G Hughes under contract to Meridian. Video monitoring of holding tank G3. Video monitoring of salmon ladder 21 January 2014 no elvers were seen [this study].

2014–15 Normal operation continued by G Hughes under contract to Meridian. Video monitoring not commissioned. It was not possible to assemble and operate G1 elver ramp and trap due to construction work on the sluice gate pier [this study].

Arnold (10)

Pre 1983–84 Dam commissioned in 1932. A fish pass was included in the original design but this was closed when the dam was raised in 1938.

2004–05 Trapping trials begin December 2004. Upgrades made Feb. 2005. Samples of the catch analysed by NIWA. Omit records for trend analysis as further trap modifications were made in 2006 [Ref 25].

2005–06 Trap and transfer operations continue. Omit records for trend analysis as further trap modifications were made in 2006 [Ref 25].

2006–07 Trap installed below flow measuring weir and monitored over entire season but water supply problem found and considerable number of elvers were found to bypass the trap and accumulated in a leakage pool below the dam wall. These were manually collected by NIWA in February 2007 and number collected added to the trap records. Sub–samples examined by NIWA. Records are considered comparable to those obtained in following years [Ref 11].

2007–08 Trap below the flow measuring weir operated and monitored regularly over entire season. Sub-samples analysed by NIWA [Ref 11].

2008–09 Land slip over winter destroyed the existing trap. A trap with a different configuration was re-installed in this area. A second trap was also installed at a higher level on the dam. This later was also damaged by a further land slip in December and had to be moved. This new trap proved to be more attractive to elvers than the lower trap. Subsamples of catch analysed by NIWA. [Ref 8].

2009–10 Major repairs to dam in progress and this affected trapping operations. Records not usable for recruitment trend analysis [Ref 26].

2010–11 Return to normal trapping and monitoring operation for the entire migration season [Ref 27].

2011–12 Normal trapping and monitoring undertaken through entire migration season [Ref 34].

2012–13 Normal trapping and monitoring undertaken by NIWA staff through entire migration season [this study].

2013–14 Normal trapping and monitoring undertaken by NIWA staff through entire migration season [this study].

2014–15 Normal trapping and monitoring undertaken through entire migration season [this study].

Supplementary sites

Waikare gates (2)

Pre 1983–84 Flood control gates installed in 1963 with no fish passage provision included in design. Elvers and other fish congregated below the weir in large numbers.

1983–84 Brush elver ladder installed on dam face in 1984 but this was poorly maintained. No monitoring results available [Ref 2].

1984 to 1994 Elver ladder not maintained and eventually breaks apart over this decade.

1994–95 Gravel lined elver ramp installed but no monitoring undertaken [Ref 2].

1995–96 Elver ladder possibly working but no records available.

1996–97 Trap installed on outlet of fish ladder and catch monitored January through to March [Ref 16].

1997–02 Unclear if elver ladder in operation but little or no appear to have been made over this period.

2002–03 Manual trap and transfer undertaken by members of the eel industry and a local farmer. Some monitoring records made available by EW. [Ref 24].

2003–04 “Nature like” fish pass installed. Monitoring results made available by EW. [Ref 24].

2004–05 No further monitoring undertaken.

Wairere Falls (3)

Pre 1983–84 Power Station commissioned in 1925. No fish pass included in original design but some passage of elvers likely over falls and weir during spills and rain events. Station operated by King Country Energy (KCE).

1994–95 Some manual transfer made but no monitoring records available. [Ref 2]

1995–96 Some manual transfer made but no monitoring records available. [Ref 2]

1996–97 Possibly as above but no confirmed records available.

1997–98 Semi permanent traps installed on banks of both tail races. An elver ramp was also installed on the weir at top of the falls but this was destroyed by a flood soon after installation [Ref 24].

1998–99 Possibly as above but no confirmed records available [KCE staff pers. comm.].

1999–00 Traps operated and some records made available by King Country Energy. No species composition available so records not suitable for trend analysis [KCE staff pers. comm.].

2000–01 Traps operated and some records made available by King Country Energy. No species composition available so records not suitable for trend analysis [KCE staff pers. comm.].

2001–02 Traps operated and some records made available by King Country Energy. No species composition available so records not suitable for trend analysis [KCE staff pers. comm.].

2002–03 Catch records obtained from the two tailrace traps by KCE. Subsamples of catch analysed by NIWA [Ref 24].

2003–04 Catch records obtained from the two tailrace traps by KCE. Only one subsamples of the catch provided to NIWA for analysis [Ref 24].

2004–05 New elver ladder installed on weir at top of Falls. Two tailrace traps continue to be operated. Sub-samples of catch analysed by NIWA [Ref 25]

2005–06 Elver ladder installed on weir at top of falls operating but used by very few elvers. Two tailrace traps in operation and catching well. Sub-samples of catch analysed by NIWA [Ref 25].

2006–07 Elver traps operated on each of the two tailraces by KCE. Elver ladder also present on weir at top of falls. Sub-samples of catch analysed by NIWA [Ref 11].

2007–08 Elver traps operated on each of the two tailraces by KCE. Elver ladder also present on weir at top of falls. Sub-samples of catch analysed by NIWA [Ref 11].

2008–09 An elver trap operated on each of the two tailraces by KCE. Elver ladder at the weir operated by KCE and elver passage over weir also facilitated by spraying water over the abutments. Monitoring by NIWA under contract to KCE [Ref 8 and 10].

2009–10 Tailrace traps operating on each of the tailraces. Elver ladder on weir at top of falls monitored with a video camera that indicate low usage compared to tailrace traps. Sub-samples of catch analysed by NIWA [Ref 26].

2010–11 Tailrace traps operating on each of the tailraces. No sub-samples of catch provided for species composition [Ref 27].

2011–12 Tailrace traps operating on each of the tailraces. A small number of sub-samples provided to NIWA for analysis. [Ref 34].

2012–13 Traps operated by KCE staff. Few details of catch provided, 2 samples of catch frozen and retained for analysis [this study].

2013–14 Traps operated by KCE staff. Few details of catch provided, No samples of catch frozen and retained for analysis [this study].

2014–15 Traps operated by KCE staff. Few details of catch provided, No samples of catch frozen and retained for analysis [this study].

Piripaua (5)

Pre 1983–84 Piripaua Power Station is part of the Waikaremoana Power Scheme and was commissioned between 1943–44. No fish passes were included in the scheme's original design but staff did collect elvers from the turbine well during maintenance and transferred these to the upper catchment. Early publications claim that that there were no eels in Lake Waikaremoana but this view has since been challenged and the pre-scheme status of the eel population remains unclear. Evidence of the presence of a few large eels within the system start to emerge by 1984.

1996–97 Elver traps installed in the tailrace and stop log but system not operated for full season. NIWA contracted by Genesis to oversee monitoring [Ref 19].

1997–98 Traps operated in tailrace and stop log. NIWA contracted by Genesis to assist with monitoring. Species composition information possibly inaccurate and verified only once by NIWA. Only total catch records suitable for trend analysis for this season [Ref 20].

1998–99 Traps operated in tailrace and stop log. NIWA contracted by Genesis to assist with monitoring. Only small number of elvers checked for species composition. [Ref 20].

1999–00 Traps operated in tailrace and stop log. NIWA contracted by Genesis to assist with monitoring Thirteen samples analysed by Genesis contractor, but not verified by NIWA. Only total catch records suitable for trend analysis for this season [Ref 21].

2000–01 Ramp to tailrace trap lined with brushes. Stop log trap dismantled as it never caught many elvers [Ref 21].

2001–02 Tailrace trap operated by Genesis and monitoring checks made by NIWA [Ref 33.]

2002–03 Tailrace trap operated by Genesis and monitoring checks made by NIWA [Ref 24].

2003–04 Tailrace trap operated by Genesis and monitoring checks made by NIWA [Ref 24].

2004–05 Tailrace trap operated by Genesis and monitoring checks made by NIWA [Ref 25].

2005–06 Tailrace trap operated by Genesis and monitoring checks made by NIWA [Ref 25].

2006–07 Tailrace trap operated by Genesis and monitoring checks made by NIWA [Ref 11].

2007–08 Tailrace trap operated by Genesis and monitoring checks made by NIWA [Ref 11].

2008–09 Tailrace trap operated by Genesis contractor and monitored by NIWA under contract to Genesis [Ref. 8 and 9].

2009–10 No changes to trap and transfer operations made [Ref 26].

2010–11 No changes to trap and transfer operations made [Ref 27].

2011–12 No changes to trap and transfer operations made [Ref 34].

2012–13 No changes to trap and transfer operations made [Ref 46]].

2013–14 No changes to trap and transfer operations made [Ref 46].

2014–15 No changes to trap and transfer operations made. Trapping ceased over Christmas – New Year period for 12 days [this study]. Survey of eel populations in catchments completed [Ref 48].

Roxburgh (7)

Pre 1983–84 Dam completed in 1956. No fish pass installed to protect "lake [trout] fisheries from contamination by eels and salmon' [Ref 27]. No elver reported in tailrace in 1960 [Ref 6]. Some elvers reported from the tailrace in 1971 [Ref 6,7].

1983–84 No elver run observed [Ref 8].

1994–95 Evidence of elvers in various galleries of the station reported [Ref 2.]

1995–96 Floating trap trials at base of spillway but only 40 elvers collected.

1996–97 Elver ramps and traps installed by South Island eel industry and the Araiteura Eel Management Area Committee with help from NIWA and co-funding from MFish 325 elver (1.5kg) captured and transferred to L Dunstan [Ref 22].

1997–98 Elver traps operated with 22 kg captured and transferred into Lake Dunstan and Wanaka. Large numbers of lampreys used the ramps and overwhelmed the system so the traps closed down by Runanga representative because of adverse effects on lamprey.

1998–99 Traps not operated.

1999–00 Traps not operated but between January 28 and 1 April 225 kg of eels and elvers collected in No. 2 turbine sump during maintenance work. All catch transferred to L Roxburgh [Greg Ryder email to Daniel Druce of CONTACT 7 Feb 2012Traps not operated.

2000–01 Traps not operated.

2001–02 Trap repaired and operated by NIWA and eel industry. Samples of the catch analysed. Approx 1000 (2.5kg) LFE captured over season. 333 transferred to L Dunstan, 70 to L Roxburgh, rest retained as sample [Ref 33].

2002–03 Traps operated through season by NIWA and eel industry 127 LFE (0.39 kg captured and transferred to L Roxburgh.

2003–04 Ramps and traps operated through season by NIWA and Hokonui Runanga 1,380 (3.82 kg) LFE captured.

2004–05 Trapping discontinued because of uncertainties over responsibilities [Ref 25].

2011–12 Upstream and downstream traps recommissioned and some trials undertaken. No details provided.

2012–13 Trapping reinstated, and daily catch data received from Contact Energy. Two frozen samples analysed by NIWA. Three samples retained for aging if required [this study].

2013–14 Traps operating from early February 2014, 1 sample analysed 16 elvers [this study].

2014–15 Trap operating January, February 2015, 3 samples analysed.New trap not commissioned [this study].

Mararoa Weir (8)

pre 1983–84 Dam completed in 1976 with a borda orifice fish pass installed but this soon filled with gravel [Ref 30].

1995–96 Mass mortality of elvers reported below the weir. Sample of elvers measured and aged [Ref 16].

1996 to 1998 No records.

1998–99 Vertical slot fish pass completed but use by elvers unknown. Some trapping and netting attempted.

1999–00 Limited elver capture and transfer operation continue.

2000–01 Some catch records available.

2001–02 No records.

2002–03 Some trapping and dip netting carried out below the gates [Ref 24].

2003–04 Some trapping and dip netting carried out below the gates [Ref 24].

2004–05 Two floating traps operated when condition permitted by Runanga representatives with the support of Meridian Energy. Some species composition record available but as effort changes over time the data collected is of limited value for recruitment trend analysis [Ref 25].

2005–06 Two floating traps operated when condition permitted by Runanga representative with support of Meridian Energy [Ref 25].

2006–07 Trap only operated for short periods each months Dec. to Feb. A small number of elvers were weighed and measured individually through the season [Ref 11].

2007–08 Trap only operated for short periods each months Dec. to Feb. A small number of elvers were weighed and measured individually through the season [Ref 11].

2008–09 Trap operated by Meridian and contractor. Floods limited deployment of trap to 16 nights [Ref 8].

2009–10 Trapping interrupted by Health and Safety concerns in mid Feb. Records not continuous [Ref 26].

2010–11 Trapping not continuous through season but more extensive than in the past [Ref 27].

2011–12 Most extensive trapping to date. Catches highest on records but results may have been partially affected by the extra effort made [Ref 34].

2012–13 Trap deployed November 2012, monitored throughout season. Interrupted by flood flows 1st to 27th Jan 2013 [this study].

2013–14 High rainfall 3rd to 20th January 2014 and flood flows interrupted operations. Greater catch effort, daily trapping [Ref 39].

2014–15 New contractors Gail and William Thompson and whanau from Te Runanga o Awarua. Traps deployed 9 January [this study].

Mangorei (11)

pre 1983–84 Power scheme constructed around 1904 with subsequent upgrades notably in the 1930s. No fish pass provision included in the original design.

2003–04 Trap installed Jan 2003. Some analysis of catch made by Taranaki RC [Ref 24].

2004–05 Trap and transfer operation by station staff. No subsample retained for analysis [Ref 24].

2005–06 Trap and transfer operation by station staff. No samples retained for analysis [Ref 25].

2006–07 Trap operated by TrustPower. No subsample of the catch obtained [Ref 11].

2007–08 Trap operated by TrustPower. One subsample of the catch obtained [Ref 11].

2008–09 Trap operated by TrustPower. No subsamples obtained but Taranaki Regional Council did analyse one sample [Ref 8].

2009–10 Trap operated by TrustPower. No subsample of the catch obtained [Ref 26].

2010–11 Trap operated by TrustPower. No subsamples of the catch obtained [Ref 27].

2011–12 Trap operated by TrustPower. No subsample of the catch obtained [Ref 34]

2012–13 Trap operated by TrustPower. No subsample of the catch obtained [Ref 37].

2013–14 Trap operated by TrustPower. No subsample of the catch obtained [Ref 40].

2014–15 Trap operated by TrustPower. No subsample of the catch obtained [Ref 43].

Motukawa (12)

pre 1983–84 Power scheme commissioned in 1927 with subsequent upgrades. Last turbine installed in 1939. No fish passage provision included in original design.

2002–03 Trap and transfer operated by local fisherman with support from Trust Power. Some analysis of catch made by Taranaki RC. No catch records provided [Ref 24].

2003–04 No catch records provided [Ref 24].

2004–05 Trap and transfer operated by eel industry with support from Trust Power. No subsamples retained for analysis [Ref 25].

2005–06 Trap and transfer operated by eel industry with support from Trust Power. No subsamples retained for analysis [Ref 25].

2006–07 Trap operated by TrustPower. No subsample of the catch obtained but one sample counted and weighed by TrustPower in Jan 2006 [Ref 11].

2007–08 Trap operated by TrustPower. No subsample of the catch obtained but one sample counted and weighed by TrustPower in Jan 2006 [Ref 11].

2008–09 Trap operated by TrustPower. No subsample of the catch obtained [Ref 8].

2009–10 Trap operated by TrustPower. No subsample of the catch obtained [Ref 26].

2010–11 Trap operated by TrustPower. No subsample of the catch obtained [Ref 27].

2011–12 Trap operated by TrustPower. No subsample of the catch obtained [Ref 34].

2012–13 Trap operated by TrustPower. No subsample of the catch obtained [Ref 37].

2013–14 Trap operated by TrustPower. No subsample of the catch obtained [Ref 40].

2014–15 Trap operated by TrustPower. No subsample of the catch obtained [Ref 43].

Wilson’s Dam (13)

Pre 2003 Water supply dam completed around 2003. Fish ladder installed as part of Consents requirements by Whangarei District Council (WDC) but the exact monitoring requirements are unclear.

2004–05 Fish pass operated and monitored by WDC. Species composition provided by the dam owner could not be confirmed [Ref 25].

2005–06 Fish pass operated and monitored by WDC. Species composition provided could not be confirmed [Ref 25].

2006–07 Elver pass monitored by Whangarei DC. Catch records provided but no species composition available [Ref 11].

2007–08 No further monitoring records made available [Ref 11].

Morrinsville Dam (14)

Pre 2001 Water supply dam for Morrinsville township. Initial construction date unknown but the dam has been upgraded a number of times over its life. Various attempts to pass elvers and other fish have been made in last two decades but no confirmation of what was tested is available.

2001–02 Temporary trap installed at base of dam [Ref 33].

2002 to 2005 Unclear if the trap was operated over this period but by 2005 the trap had fallen into disrepair.

2005–06 New trap installed in Feb. 2006. No species composition available [Ref 25].

2006–07 Trap operated by Kaimai Valley services. Only total catch records obtained [Ref 11].

2007–08 Trap operated by Kaimai Valley services. No catch records obtained [Ref 11].

2008–09 No further records obtained [Ref 8].

Upper Whanganui (22)

2014–15 Manual collection of elvers from the from the Otamangakau Valve at the bases of the Otamangakau Reservoir and transferred to above the power scheme structures. A permanent trap is proposed for installation at this site for the 2015-16 season. Collection, transfers and data from John Morgan, Lena Bell (Ngāti-Hikairo-ki Tongariro) and Genesis [Ref 44].

Waihopai Dam (15)

Pre 1983–84 Power scheme constructed 1925–27. No fish pass included in original design.

2005–06 Trap installed by TrustPower and monitored visually by Golder as part of a five year requirement of Consents [Ref 11, 12].

2006–07 Trap operated by TrustPower and monitored by Golder as part of consenting [Ref 11, 12].

2007–08 Basic records obtained [Ref 11].

2008–09 Basic records obtained [Ref 8].

2009–10 Basic records obtained [Ref 26].

2010–11 No records obtained.

2011–12 No records obtained [Ref this study].

2012–13 Data received from Golders, including total catch for previous seasons [Ref 35].

2013–14 Data received from Golders, species composition data as proportion of catch [Ref 41].

2014–15 Raw data sheets received [this study].

Mokauiti Dam (16)

Pre 1983–84 Mokauiti Power Station was commissioned in 1963. No fish pass included in original design.

2008–09 Temporary elver trap installed and monitored by NIWA under contract to King Country Energy (KCE) [Ref 8, 10].

2009–10 “Nature like” fish pass constructed. Monitoring of fish passage undertaken but only one sample retained for analysis [Ref 26].

2010–11 Fish pass modification completed in mid-January and no further monitoring done after that [Ref 27].

2011–12 Monitoring re-instated but only a few samples were provided to NIWA for species composition analysis [Ref 34].

2012–13 Monitoring ceased early February 2013, two frozen samples retained and and analysed by NIWA [this study].

2013–14 Monitored for whole season by KCE staff. No samples of catch analysed [this study].

2014–15 Traps operated by KCE staff. Few details of catch provided, No samples of catch retained for analysis [this study].

Waitakere Ranges (18)

2008–09 Traps installed no elvers captured.

2009–10 Watercare Services reported that the first elvers were recorded at Nihotupu on 7 September. Trapping was discontinued on 25 February. The total catch for the three traps was 3.5 kg, which was estimated to be 3041 elvers. The size range was 70 to 100 mm (Watercare Services Ltd (2010). The largest proportion of the catch was made at the Lower Nihotupu Dam trap (75%, 2269 elvers). The trap at the Huia Stream captured 411 elvers (0.6 kg), and the Waitakere River trap caught 361 elvers (0.4 kg). In addition to elvers, a single juvenile eel, 31 bullies and 3355 shrimp were also captured (Watercare Services Ltd 2010).

2010–11 No data.

2012–13 Traps operated 1 Oct to 30 Apr, about 200 elvers captured [Ref 49].

2013–14 Elvers captured in Nihotupu and Watercare Dam sites. Received data from Watercare [Ref 42].

2014–15 Traps operated 1 Sep to 22 May, about 2300 elvers captured [Ref 50].

Hunua Ranges (19)

2009–10 Elvers were not captured in the two traps in the Hunua Ranges.

2010–11 No data.

2012–13 Traps operated 1 Oct to 30 Apr, about 800 elvers captured [Ref 49].

2013–14 Elvers captured at Cosseys Dam and Hays Creek Dam. Received data from Watercare [Ref 42].

2014–15 Traps operated 1 Sep to 22 May, about 900 elvers captured [Ref 50].

Turitea Dam (20)

2012–13 Monitoring from late November 2012 to late February 2013 by Palmerston North CC [Ref 51].

2013–14 Traps not operating.

2014–15 Traps not operating.

Mataura (21)

2014–15 Trials using spat ropes and an existing trap in previous seasons. Elvers captured using hand nets from pools until new trap commissioned 23 February 2015, and modified with brush ramps [Ref 45].

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10. APPENDIX C: Historial elver catches

Summary of historical elver catches and migration timing

Table C1: Wairua Falls Power Station estimated elver catches (in 1000s) (SFE = shortfin; LFE = longfin).

	Season				
	2011–12	2012–13	2013–14	2014–15	Total
Total elvers	3 178	5 488	2 780	3 011	14 457
50% of total	3-Jan	29-Dec	27-Dec	27-Jan	
95% of total	26-Feb	12-Feb	17-Feb	8-Mar	
Total SFE	3 167	5 389	2 764	2 893	14 213
50% of SFE	3-Jan	30-Dec	27-Dec	28-Jan	
95% of SFE	26-Feb	12-Feb	19-Feb	8-Mar	
Total LFE	11	98	16	118	243
50% of LFE	22-Dec	13-Dec	26-Nov	31-Dec	
95% of LFE	26-Feb	16-Dec	5-Feb	23-Feb	
% LFE	0.3	1.8	0.6	3.9	1.7

Table C2: Karapiro Dam estimated elver catches (in 1000s). Shaded cells indicate years with inaccurate data (SFE = shortfin; LFE = longfin).

	Season										
	1995–96[a]	1996–97	1997–98[b]	1998–99	1999–00	2000–01	2001–02	2002–03	2003–04	2004–05	2005–06
Total elvers	1 155	1 220	2 039	1 097	892	782	1 596	1 942	2 131	1 333	2 177
50% of total	20–22 Jan	26-Jan	6-Jan	14-Jan	29 Jan–3 Feb	14-Jan	28-Jan	19-Jan	21-Jan	5-Feb	1-Feb
95% of total	1–5 Mar	6-Mar	26-Feb	10-Mar	5–10 Mar	28-Feb	25-Feb	9-Mar	27-Feb	22-Mar	24-Feb
Total SFE	822	974	1 529	756	798	627	1 351	1 766	1 931	1 201	1 695
50% of SFE	25-Jan	27-Jan	9-Jan	19-Jan	3–8 Feb	11-Jan	26-Jan	21-Jan	21-Jan	6-Feb	5-Feb
95% of SFE	1–5 Mar	6-Mar	28-Feb	16-Mar	5–10 Mar	22-Mar	3-Mar	11-Mar	29 Feb	23-Mar	27-Feb
Total LFE	333	246	510	341	94	155	245	176	200	132	482
50% of LFE	13–15 Jan	22-Jan	4-Jan	11-Jan	7–11 Jan	14-Jan	28-Jan	7-Jan	25-Jan	3-Feb	20-Jan
95% of LFE	9–12 Feb	10-Feb	23-Feb	9-Feb	12–19 Feb	9-Feb	13-Feb	6-Feb	9-Feb	24-Feb	5-Feb
% LFE	29	20	25	31	11	20	15	9	9	10	22
	2006–07	2007–08	2008–09	2009–10	2010–11	2011–12	2012–13	2013–14	2014–15		Totals
Total elvers	1 296	2 728	2 288	1 708	1 434	1 003	1 771	1 843	1 604		32 039
50% of total	9-Feb	17-Jan	17-Jan	18-Jan	11-Jan	3-Feb	16-Jan	6-Jan	24-Jan		
95% of total	14-Mar	25-Feb	3-Mar	6-Mar	6-Mar	25-Feb	15-Mar	2-Mar	13-Mar		
Total SFE	1 117	2 027	1 990	1 476	1260	967	1 632	1 683	1 444		27 046
50% of SFE	12-Feb	20-Jan	18-Jan	18-Jan	15-Jan	4-Feb	17-Jan	8-Jan	26-Jan		
95% of SFE	15-Mar	29-Feb	3-Mar	6-Mar	7-Mar	26-Jan	15-Mar	3-Mar	14-Mar		
Total LFE	179	701	298	232	175	36	139	160	160		4 994
50% of LFE	31-Jan	11-Jan	11-Jan	13-Jan	31-Dec	4-Jan	8-Jan	26-Dec	17-Jan		
95% of LFE	18-Feb	4-Feb	14-Feb	9-Feb	3-Feb	15-Feb	11-Feb	1-Feb	25-Feb		
% LFE	14	26	13	14	12	4	8	9	10		16

[a] Transferred elvers only as total catch data not recorded.

[b] 1997–98 data revised (Martin et al. 2009a).

Table C3: Matahina Dam estimated elver catches (in 1000s). Shaded cells indicate years with inaccurate data (SFE = shortfin; LFE = longfin).

	Season										
	1996–97[a]	1997–98[b]	1998–99[c]	1999–00[c]	2000–01[c]	2001–02	2002–03	2003–04	2004–05	2005–06	2006–07
Total elvers	14	615	1 002	2 001	2 054	619	1 484	945	1 117	1 193	485
50% of total	7–10 Feb	30-Jan	–	–	–	8-Jan	10-Jan	19-Dec	3-Feb	28-Jan	30-Jan
95% of total	10–13 Mar	23-Feb	–	–	–	16-Feb	19-Feb	28-Jan	24-Feb	19-Feb	1-Mar
Total SFE	10	478	–	–	–	592	1 360	881	1 102	965	326
50% of SFE	12–16 Feb	23-Feb	–	–	–	8-Jan	10-Jan	19-Dec	3-Feb	28-Jan	4-Feb
95% of SFE	10–13 Mar	26-Feb	–	–	–	16-Feb	19-Feb	28-Jan	24-Feb	19-Feb	1-Mar
Total LFE	4	136	–	–	–	27	124	64	15	228	159
50% of LFE	3–7 Feb	5-Jan	–	–	–	24-Dec	12-Jan	20-Dec	29-Jan	27-Jan	23-Jan
95% of LFE	28 Feb–3 Mar	13-Feb	–	–	–	6-Feb	13-Feb	5-Jan	17-Feb	15-Feb	22-Feb
% LFE	29	22	–	–	–	4	8	7	1	19	33
	2007–08	2008–09	2009–10	2010–11	2011–12	2012–13	2013–14	2014–15			Total
Total elvers	3 379	4 307	1 002	1 842	681	2 421	2 068	4 736			24 279
50% of total	11-Jan	20-Jan	1-Jan	26-Jan	14-Jan	16-Jan	12-Jan	18-Jan			
95% of total	7-Feb	15-Feb	16-Feb	10-Feb	31-Jan	19-Feb	25-Feb	8-Feb			
Total SFE	2 450	3 791	924	1 758	666	2 104	1 848	4 460			17 474
50% of SFE	11-Jan	20-Jan	2-Jan	28-Jan	14-Jan	14-Jan	12-Jan	18-Jan			
95% of SFE	7-Feb	16-Jan	16-Feb	10-Feb	31-Jan	20-Feb	25-Feb	8-Feb			
Total LFE	928	516	78	84	15	317	210	275			3 180
50% of LFE	12-Jan	20-Jan	30-Dec	24-Jan	13-Jan	16-Jan	12-Jan	10-Jan			
95% of LFE	3-Feb	15-Feb	1-Feb	5-Feb	23-Jan	2-Feb	17-Feb	2-Feb			
% LFE	27	12	8	5	2	13	11	6			13

[a] An additional 84.5 kg of eels and elvers were caught but proportions were not recorded and data omitted.

[b] A further 107 kg of elvers and eels were caught but proportions were not recorded and data omitted.

[c] Kokopu Charitable Trust Inc. reported catching 2001 kg of elvers in 1999–00 and 2045 kg in 2001 (Bill Kerrison, Murupara, pers. comm.). Estimated number shown is based on an average weight of 1 g. It is possible that the catches include juvenile eels.

Table C4: **Patea Dam estimated elver catches (in 1000s). Shaded cells indicate years with inaccurate data (SFE = shortfin; LFE = longfin).**

	Season									
	1999–00	2000–01	2001–02	2002–03	2003–04	2004–05	2005–06	2006–07	2007–08	2008–09
Total elvers	461	495	754	380	391	450	562	896	857	480
50% of total	–	9–11 Jan	22-Jan	23-Jan	19-Jan	3-Feb	2-Jan	27-Jan	4-Jan	17-Jan
95% of total	–	27–30 Mar	8-Mar	10-Mar	12-Feb	21-Feb	21-Feb	19-Mar	20-Feb	23-Feb
Total SFE	–	–	707	372	390		475	843	759	398
50% of SFE			22-Jan	23-Jan	19-Jan		4-Jan	26-Jan	3-Jan	12-Jan
95% of SFE			8-Mar	10-Mar	12-Feb		24-Feb	19-Mar	21-Feb	23-Feb
Total LFE	–	–	48	8	1		87	53	98	82
50% of LFE			14-Jan	23-Jan	25-Jan		25-Dec	15-Feb	11-Jan	30-Jan
95% of LFE			25-Feb	10-Mar	25-Feb		30-Jan	18-Mar	5-Feb	27-Feb
% LFE			6	2	0.3		15	6	11	17
	2009–10	2010–11	2011–12	2012–13	2013–14	2014–15				Total
Total elvers	310	247	91	234	194	261				6 802
50% of total	3-Feb	2-Jan	31-Jan	21-Jan	28-Jan	11-Jan				
95% of total	9-Mar	11-Feb	28-Feb	25-Feb	11-Mar	2-Mar				
Total SFE	289	227	82	183	170	237				4 895
50% of SFE	7-Feb	2-Jan	31-Jan	21-Jan	28-Jan	11-Jan				
95% of SFE	9-Mar	11-Feb	28-Feb	18-Feb	6-Apr	2-Mar				
Total LFE	20	20	9	51	24	23				500
50% of LFE	15-Jan	7-Jan	31-Jan	21-Jan	14-Jan	18-Jan				
95% of LFE	26-Feb	11-Feb	21-Feb	25-Feb	25-Feb	23-Feb				
% LFE	7	8	9	22	12	8				7

Table C5: Piripaua Power Station estimated elver catches. Shaded cells indicate years with inaccurate data (SFE = shortfin; LFE = longfin).

											Season
	1996–97	1997–98[a]	1998–99	1999–00	2000–01[b]	2001–02	2002–03[c]	2003–04[c]	2004–05	2005–06	2006–07
Total elvers	2 100	7 339	3 141	2 577	5 964	4 084	10 185	4 886	8 127	2 760	4 180
50% of total	26-Feb	5-Feb	19-Jan	21–28 Jan	21–28 Jan	21-Jan	3-Feb	10-Jan	4-Feb	30-Jan	26-Jan
95% of total	11-Mar	18-Mar	18-Mar	21–25 Feb	24-Feb	27-Mar	4-Mar	20-Feb	28-Feb	22-Feb	24-Feb
Total SFE	2 100	–	2 732	2 529	5 432	3 656	10 001	4 685	7 669	2 613	3 832
50% of SFE	26-Feb		19-Jan	21–28 Jan	21–28 Jan	21-Jan				30-Jan	24-Jan
95% of SFE	11-Mar		18-Mar	21–25 Feb	22-Feb	4-Apr				2-Mar	21-Feb
Total LFE	0	–	409	48	224	428	184	201	458	147	348
50% of LFE	–		19-Jan	14–21 Jan	19-Feb	14-Jan				3-Feb	7-Feb
95% of LFE	–		7-Feb	21–28 Jan	7-Mar	8-Mar				7-Mar	7-Mar
% LFE	0		13	1.9	3.7	10.4	1.8	4.1	5.6	5.3	8.3
	2007–08	2008–09	2009–10	2010–11	2011–12	2012–13	2013–14	2014–15			Total
Total elvers	5 736	9 472	10 226	11 779	15 573	32 986	68 734	61 186			271 035
50% of total	17-Jan	28-Jan	24-Jan	23-Jan	21-Jan	4-Feb	27-Jan	21-Jan			
95% of total	16-Feb	28-Feb	25-Feb	4-Mar	20-Feb	12-Apr	27-Feb	8-Mar			
Total SFE	4 685	7 319	7 279	9 320	12 498	27 818	60 798	56 490			231 456
50% of SFE	15-Jan	30-Jan	24-Jan	26-Jan	18-Jan	6-Feb	27-Jan	21-Jan			
95% of SFE	14-Feb	28-Feb	20-Feb	4-Mar	20-Feb	12-Apr	27-Feb	8-Mar			
Total LFE	1 051	2 153	2 947	2 459	3 075	5 168	7 936	4 696			31 932
50% of LFE	21-Jan	26-Jan	24-Jan	19-Jan	27-Jan	25-Jan	10-Jan	17-Jan			
95% of LFE	2-Mar	9-Feb	27-Feb	12-Feb	16-Feb	20-Feb	7-Feb	5-Mar			
% LFE	18.3	23.0	28.8	20.9	19.7	15.5	11.5	7.7			13.2

[a] % longfin based on one sub-sample.

[b] Species composition information available for transferred catch only.

[c] Dates not shown for shortfin or longfin or LFE as less than 5 sub-samples analysed over entire season.

Table C6: Taranaki Power Stations (Mangorei and Motukawa) estimated elver catches.

	Season						
	2002–03	2003–04	2004–05	2005–06	2006–07	2007–08	2008-09
Mangorei:							
Monitoring period	9/1/02-11/4/03	1/12/03-10/6/04	13/01/05-21/3/05	30/11/05-20/3/06	19/10/06-26/4/07	25/11/07-26/3/08	1/12/08-20/03/09
Total elvers[a]	18 000	19 600	9 800	20 208	24 000	33 000	32 651
50% of total	27-Jan	19-Jan	24-Jan	3-Feb	2-Feb	16-Jan	23-Jan
95% of total	25-Mar	17-Feb	2-Mar	24-Feb	30-Mar	11-Mar	4-Mar
Motukawa:							
Monitoring period	1/12/02-22/2/03	15/11/03-19/2/04	1/12/04-30/4/05	8/12/05-17/2/06	1/12/06-20/4/07	13/12/07-25/3/08	1/12/08-21/03/09
Total elvers[b]	45 500	64 400	94 000	57 800	21 000	45 000	56 101
50% of total	13-Jan	24-Jan	11-Feb	5-Jan	29-Jan	16-Jan	26-Jan
95% of total	22-Feb	13-Feb	16-Mar	7-Feb	23-Feb	3-Mar	26-Feb
Total	63 500	84 000	103 800	78 008	45 000	78 000	88 752
	2009–10	2010–11	2011–12	2012–13	2013–14	2014_15	Totals
Mangorei:							
Monitoring period	18/12/09-25/2/10	1/12/10-28/2/11	27/1/11-23/2/2012	1/11/12-12/4/13	1/11/13-30/4/14	1/11/14-30/4/15	Total
Total elvers	7 500	7 640	549	12700	16 900	11 300	213 848
50% of totalh	15-Jan	24-Jan	10-Feb	26-Jan	10-Jan	10-Jan	
95% of total	5-Feb	18-Feb	23-Feb	28-Mar	13-Mar	13-Mar	
Motukawa:							
Monitoring period	11/12/09-31/1/10	1/12/10-28/2/11	9/12/11-3/2/2012	1/11/2012-12/4/13	1/11/12-30/4/14	1/11/12-30/4/14	
Total elvers	9 000	42 330	6 799	13 000	8 000	15 938	478 868
50% of total	7-Jan	20-Jan	27-Jan	4-Jan	17-Jan	17-Jan	
95% of total	22-Jan	22-Feb	3-Feb	15-Feb	20-Feb	20-Feb	
Total	16 500	49 970	7 348	25 700	24 900	27 238	692 716

[a] Mangorei: total number of elvers calculated using 1030 elvers/kg (Martin et al. 2009b).

[b] Motukawa; total number of elvers calculated using 925 elvers/kg (Martin et al. 2008).

Table C7: Wairere Falls estimated elver catches. Shaded cells indicate years with inaccurate data (SFE = shortfin; LFE = longfin).

							Season
	1999–00[a]	2000–01	2001–02	2002–03	2003–04	2004–05	2005–06	2006-07
Monitoring period	20/12/99-16/3/00	22/11/00-22/3/01	8/12/01-10/5/02	1/12/02-19/4/03	2/1/03-11/2/04	6/1/04-22/3/05	14/11/05-1/5/06	6/11/06-28/3/07
Total elvers	166	191	130	289	330	155	163	294
50% of total	29-Jan	17-Jan	31-Jan	2-Feb	19-Jan	2-Feb	3-Jan	26-Jan
95% of total	10-Mar	11-Mar	13-Mar	4-Mar	8-Feb	8-Mar	6-Feb	27-Feb
Total SFE	–	–	–	268	–	144	135	269
50% of SFE						2-Feb	28-Dec	25-Jan
95% of SFE						8-Mar	7-Dec	22-Feb
Total LFE	–	–	–	22	–	13	28	25
50% of LFE						1-Feb	29-Jan	14-Feb
95% of LFE						8-Mar	4-Feb	13-Mar
%LFE	–	–	–	8	–	9	17	9

	2007-08	2008-09	2009-10	2010-11[b]	2011-12[b]	2012-13[b]	2013-14[b]	2014-15[b]	Total
Monitoring	14/11/07-	13/10/08-	1/11/09-	14/10/10-	1/11/11-	25/10/12-	1/12/13-	25/10/14-	
Total elvers	204	216	146	228	119	182	193	242	3 247
50% of total	25-Jan	19-Jan	30-Jan	11-Jan	12-Feb	31-Jan	27-Jan	29-Jan	
95% of total	24-Feb	24-Feb	1-Mar	7-Feb	28-Feb	14-Mar	22-Feb	27-Feb	
Total SFE	147	200	138.5	203	109				1 614
50% of SFE	25-Jan	19-Jan	30-Jan		12-Feb				
95% of SFE	24-Feb	24-Feb	1-Mar		28-Feb				
Total LFE	57	16	8	25	9				203
50% of LFE	25-Jan	19-Jan	30-Jan		3-Jan				
95% of LFE	24-Feb	24-Feb	16-Feb		28-Feb				
% LFE	28	7	6	11	8				6

a Total catch data supplied in litres and converted to kg using Weight = 0.33 + 0.91 litres.

b Estimate of species composition and number of elvers based on average values from of previous seasons with accurate catch sample analyses.

Table C8: Mokauiti Power Station estimated elver catches. Shaded cells indicate years with inaccurate data (SFE = shortfin; LFE = longfin).

	Season							
	2008–09[a]	2009–10	2010–11[b]	2011–12	2012–13[c]	2013–14	2014–15	Total
Monitoring period	14/10/08-3/4/09	5/11/09-31/3/10	4/10/10-12/1/11	1/11/11-22/3/12	25/10/12-6/2/13	1/12/13-12/3/14	1/11/14-28/2/15	
Total elvers	82 187	21 157	3 350	22 860	3 244	25 118	45 705	203 621
50% of total	16-Feb	5-Feb		18-Jan	12-Jan	14-Jan	7-Jan	
95% of total	16-Mar	19-Jan		21-Feb	6-Feb	22-Feb	4-Feb	
Total SFE	77 608	21 143		22 334				121 085
50% of SFE		5-Feb		17-Jan				
95% of SFE		19-Feb		21-Feb				
Total LFE	4 579	429		527				5 535
50% of LFE		5-Feb		10-Feb				
95% of LFE		19-Feb		26-Feb				
% LFE	6	2		2				

[a] Species composition and average weight based on a single sample

[b] Monitoring ceased 12 Jan 2011

[c] Monitoring ceased 6 Feb 2013

Table C9: **Arnold Dam estimated elver catches. Shaded cells indicate years with inaccurate data (SFE = shortfin; LFE = longfin).**

	Season											
	2004–05[a]	2005–06[a]	2006–07	2007–08	2008–09	2009–10[b]	2010–11	2011–12	2012–13	2013–14	2014–15	Total
Total elvers	27 516	14 510	107 100	186 153	183 117	19 658	113 794	75 537	90 353	62 555	152 484	1 032 777
50% of catch	10-Feb	26-Jan	21-Feb	24-Jan	1-Feb	27-Jan	7-Jan	11-Jan	2-Feb	5-Feb	31-Jan	
95% of catch	18-Feb	10-Feb	12-Mar	17-Feb	24-Feb	24-Feb	1-Feb	23-Feb	10-Mar	8-Mar	7-Mar	
Total SFE	20 385	6 218	55 242	107 743	96 217	14 955	64 579	49 576	54 780	35 841	87 465	593 001
50% of SFE	10-Feb	2-Feb	21-Feb	20-Jan	29-Jan	26-Jan	6-Jan	11-Jan	2-Feb	8-Feb	26-Jan	
95% of SFE	18-Feb	10-Feb	16-Mar	8-Feb	22-Feb	28-Feb	31-Jan	25-Feb	8-Mar	11-Mar	7-Mar	
Total LFE	7 131	8 292	51 858	78 410	86 900	4 703	49 215	25 961	35 752	29 414	65 019	442 655
50% of LFE	10-Feb	3-Jan	21-Feb	31-Jan	7-Feb	27-Jan	10-Jan	14-Jan	2-Feb	4-Feb	10-Feb	
95% of LFE	18-Feb	7-Feb	7-Mar	21-Feb	26-Feb	10-Feb	1-Feb	18-Feb	12-Mar	3-Mar	7-Mar	
%LFE	26	57	48	42	48	24	43	34.4	39.4	45.1	43.0	43.0

[a] Trap setup and development.

[b] Habitat disruption from maintenance works.

Table C10: Wataki Dam estimated elver catches. Shaded cells indicate years with inaccurate data (SFE = shortfin; LFE = longfin).

	Season							
	1999–00[a]	2000–01	2001–02	2002–03[c]	2003–04	2004–05	2005–06[d]	2006–07
Total elvers	–	2 061	(65 kg[b])	56	4 652	1 559	4 683	3 252
50% of total	–	30-Jan	–	3-Feb	31-Jan	14-Feb	31-Jan	14-Feb
95% of total				13-Feb	27-Feb	3-Mar	18-Feb	18-Mar
Total SFE	–	–	–	0	9	0	0	0
50% of SFE					6-Jan			
95% of SFE	–	–	–		7-Jan			
Total LFE	–	–	–	56	4 643	1 559	4 683	3 252
50% of LFE	–	–	–	3-Feb	31-Jan	14-Feb	31-Jan	14-Feb
95% of LFE	–	–	–	13-Feb	27-Feb	3-Mar	18-Feb	18-Mar
% LFE				100	99.8	100	100	100

	2007–08[e,f]	2008–09	2009-10	2010-11[g]	2011-12[h]	2012-13[h]	2013-14[h]	2014-15	Total
Total elvers	4 140	4 701	2 363	2 940	7 004	8 917	188	5 959	52 475
50% of total	17-Jan	26-Jan	31-Jan	26-Jan	18-Jan	16-Jan	3-Feb	21-Jan	
95% of total		13-Feb	1-Mar	7-Feb	9-Feb	8-Feb	25-Feb	11-Feb	
Total SFE	0	1237	263	520	1 182	1 801	120	1 312	6 444
50% of SFE		26-Jan -2-Feb	9-Feb		18-Jan	16-Jan	3-Feb	30-Jan	
95% of SFE		2-Feb	28-Feb		24-Feb	8-Feb	25-Feb	16-Mar	
Total LFE	4 140	3 464	2 100	2 420	5 822	7 116	68	4 647	43 970
50% of LFE	17-Jan	23-Jan	31-Jan		18-Jan	4-Jan	3-Feb	21-Jan	
95% of LFE	15-Feb	13-Feb	1-Mar		9-Feb	8-Feb	25-Feb	11-Feb	
% LFE	100	74	89	82.3	83	80	36	78	84

[a] Mostly juvenile eels (>20g).
[b] Catch was 65 kg but full season records not available and most of the catch was juvenile eels (>20 g).
[c] Traps altered including change of substrate on ramps.
[d] An additional floating trap installed in tailrace.
[e] Floating trap replaced by fixed ramp in 2007–08. Mostly large elvers (93% of elvers were > 2g).
[f] Amended to true elvers as catch reported by Martin et al. (2009) probably included many small eels.
[g] Floods damaged traps.
[h] Monitoring not continuous and few sub-samples examined.

11. APPENDIX D: Historical elver transfers

Location of known historical elver transfers in New Zealand

Table D1: Wairua Falls Power Station total elver transfers location and numbers (in 1000s) 2011 to 2015 (mostly all shortfins).

	Estimated total elver transferred (1000s)				
Location	2011–12	2012–13	2013–14	2014–15	Total
Akerama	34	32		65	130
Aponga		85			85
Ben Smith Pond		142	48		190
Boys Pond		93			93
Hibbert Pond		66			66
Karukaru	419	267	260	441	1 387
Kauritutahi 1	105	261	160	97	624
Kauritutahi 2		244	214	245	702
Kauritutahi 3			80	210	
Kokopu	96	112			208
Malone	35	171	80	275	561
Mangawhero	60		388		448
Mangahahuru		106		90	196
Mangakahia Bdg	1 151	1 672	579	725	4 126
Mangere	252	448	349	404	1 453
Okoihu	194	161	35		390
Puketitoi	109	237	20		366
Purua		115	50	195	360
Umuwhawha		254	82		336
Waipao 1	299	340	303	118	1 061
Waipao 2	394	461	134	219	1 207
Waipao 3		166			166
Wairua PS canal		4			4
Walton pond		52			52
Whakapara	49				49
Samples			2		
Total Transfers	3 196	5 488	2 778	2 993	14 455

Table D2: Wairua Falls Power Station elver transfer locations (Format: WGS84 ddd.dddddd)

Site name	Code	Longitude [E]	Latitude [S]
Ngaruawahine (Ruangawahine) Stm Haile Rd. Akerama	Akerama	174.166636	-35.487206
Aponga Stream on Aponga Rd, Hikurangi Swamp	Aponga	174.068192	-35.66133
Ben Smith Pond	Ben Smith Pond	174.223344	-35.594372
C&E Boys reservoir, Mangere stm, Kara rd	Boys Pond	174.19605	-35.702283
reservoir on M&J Hibbert, Kara Rd, Mangere stm	Hibbert Pond	174.200017	-35.704283
Karukaru Crk at Carruth Rd	Karukaru	174.106416	-35.777455
Kauritutahi Stm at Mangakahia Rd Maungatapere	Kauritutahi 1	174.17461	-35.753999
Kauritutahi Stm at Tatton Rd	Kauritutahi 2	174.175026	-35.760247
Kokopu Stream, Kokopu Rd, Shayne O'Shea's property	Kokopu	174.128549	-35.711299
Wairua River at Malone Bridge	Malone	174.118677	-35.704945
Mangahahuru Stm at Apotus Road	Mangahahuru	174.259538	-35.617854
Wairua R at Mangahia Rd Bridge	Mangahia Bdg	174.092846	-35.731779
Mangere Stm at Kara Rd	Mangere	174.192499	-35.703876
Okoihu Stm at Whatitiri Rd	Okoihu	174.096676	-35.736884
Puketitoi Stm, At Puketitoi Rd - Trevor Currents property	Puketitoi	174.123202	-35.676864
Wairua River at Lovell road, Purua	Purua	174.152083	-35.652634
Umuwhawha Stm at Waiotu Block Rd	Umuwhawha	174.22193	-35.505025
Waipao Stm at Kokopu Rd	Waipao 1	174.097997	-35.728397
Waipao Stm at Draffin Rd	Waipao 2	174.125276	-35.726161
Waipao Stm at McBeth Rd	Waipao 3	174.153724	-35.733999
Wairua Power Station canal at spillway	Wairua PS canal	174.066054	-35.756796
	Walton pond	174.195159	-35.776051

Table D3: Karapiro Dam (Waikato River) estimated total elvers and longfin (LFE) only transfers (in 1000s) to upstream hydro reservoirs 1992 to 2015. Shaded cells indicate years with inaccurate data.

	Season																							
Hydro-lake	92–93	93–94	94–95	95–96	96–97	97–98	98–99	99–00	00–01	01–02	02–03	03–04	04–05	05–06	06–07	07–08	08–09	09–10	10–11	11–12	12–13	13–14	14–15	Total
Karapiro	92	267	264	504	130	273	488	397	316	645	171	514	414	724	428	716	369	375	336	297	407	395	298	8 820
LFE	*31*	*91*	*90*	*190*	*27*	*122*	*107*	*23*	*57*	*129*	*2*	*61*	*32*	*111*	*48*	*106*	*57*	*31*	*24*	*15*	*20*	*10*	*31*	1416
Arapuni	0	251	8	459	343	389	108	119	200	379	321	396	377	395	287	468	440	242	127	101	263	234	177	6 084
LFE		*85*	*3*	*96*	*74*	*168*	*60*	*20*	*38*	*57*	*38*	*39*	*20*	*81*	*43*	*131*	*51*	*9*	*5*	*0.2*	*24*	*24*	*15*	1082
Waipapa	0	0	4	123	62	68	60	63	15	69	58	111	75	61	70	41	73	71	59	32	0	65	30	1 210
LFE			*1*	*33*	*13*	*29*	*6*	*6*	*2*	*0*	*7*	*19*	*13*	*20*	*13*	*25*	*1*	*4*	*3*	*0*	*0*	*6*	*0*	201
Maraetai	0	0	6	70	92	161	0	0	0	0	281	277	91	194	54	429	418	219	214	117	201	259	235	3 318
LFE			*2*	*14*	*28*	*81*					*16*	*14*	*10*	*46*	*16*	*140*	*34*	*45*	*28*	*6*	*10*	*17*	*17*	524
Whakamaru	0	0	0	0	173	246	109	14	97	145	453	247	63	89	62	401	301	222	237	164	230	172	242	3 667
LFE					*28*	*167*	*38*	*1*	*20*	*23*	*18*	*25*	*12*	*53*	*16*	*104*	*55*	*39*	*34*	*4*	*25*	*18*	*25*	705
Atiamuri	0	0	0	0	80	57	37	123	72	94	83	134	56	76	83	244	262	237	196	104	151	214	175	2 478
LFE					*26*	*25*	*7*	*13*	*18*	*2*	*20*	*6*	*18*	*37*	*4*	*70*	*37*	*46*	*45*	*2*	*16*	*29*	*15*	437
Ohakuri	*0*	*0*	*0*	*0*	*327*	*483*	215	153	74	261	490	352	257	459	311	419	418	341	291	151	518	504	448	6 472
LFE					*48*	*267*	*81*	*30*	*19*	*37*	*71*	*32*	*28*	*132*	*38*	*123*	*64*	*58*	*36*	*9*	*43*	*55*	*55*	1226
Total elvers	92	518	282	1156	1207	1677	1017	869	774	1593	1857	2031	1333	1998	1296	2718	2288	1708	1497	967	1771	1843	1605	32 049
Total LFE	*31*	*176*	*96*	*333*	*244*	*859*	*299*	*93*	*154*	*248*	*172*	*196*	*132*	*480*	*179*	*698*	*298*	*232*	*175*	*36*	139	160	160	5 591
% LFE	*34*	*34*	*34*	29	20	51	29	11	20	16	9	10	10	24	14	26	13	14	12	4	8	9	10	17

Table D4: Matahina Dam (Rangitaiki River) estimated total number of elvers and longfins only (LFE) transferred to upstream hydro reservoirs (in 1000s) 1982 to 2015. Shaded cells indicate years with inaccurate data.

	Season																
	82–83	83–84	84–85	85–86	86–87	87–88	88–89	89–90	90–91	91–92	92–93	93–94	94–95	95–96	96–97	97–98	98–99
Aniwhenua	20	21	23	6	19	–	–	40	–	–	–	149	39	144	14	587	–
LFE	–	*10*	*5*	*1*	*11*			–				–		–	*4*	*133*	–
													–				
Matahina	–	–	–	–	–	–	18	6	–	>24	>32	>66		–	–	28	–
LFE							*2*	–		*>7*	*>2*	–	–	–	–	*3*	–
													–				
Total elvers	20	21	23	6	19	–	18	46	–	>24	>32	>215	>39	>144	14	615	1 002
Total LFE	–	*10*	*5*	*1*	*11*	–	*2*	–	–	*>7*	*>2*	–	–	–	*4*	*136*	–

	99–00	00–01	01–02	02–03	03–04	04–05	05-06	06-07	07-08	08-09	09-10	10-11	11-12	12-13	13-14	14-15
Aniwhenua	–	–	341	1 169	945	1 036	1 045	449	3 156	3 480	229	1 418	544	2 104	1 330	3 768
LFE	–	–	*18*	*102*	*50*	*14*	*198*	*156*	*892*	*434*	*25*	*55*	*11*	*283*	*156*	*224*
Matahina	–	–	278	308	94	81	148	36	223	827	720	424	136	317	738	968
LFE	–	–	*9*	*22*	*10*	*1*	*30*	*3*	*37*	*83*	*54*	*29*	*4*	*35*	*63*	*51*
Total elvers	2 001	2 054	619	1 477	881	1 117	1 193	485	3 379	4 307	949	1 842	681	2 421	2 068	4 736
Total LFE	–	–	*27*	*124*	*60*	*15*	*228*	*159*	*928*	*517*	*78*	*84*	*15*	*317*	*219*	*275*

Table D5: Patea Dam location and estimated total elver transfers (in 1000s) 1999 to 2015. Shaded cells indicate years with inaccurate data.

	Season																
	99–00	00–01	01–02	02–03	03–04	04–05[a]	05–06	06–07	07–08	08–09	09–10	10–11	11–12	12–13	13–14	14–15	Total
Lake Rotorangi	461	495	754	380	391	450	562	896	857	664	310	247	10	0	4	2	6 482
Patea River													79	167	98	121	464
Mangaehu Stream													1	44	39	50	135
Makuri Stream														23	51	88	162
Total										664	310	247	91	234	192	261	1 997

[a] Based on 2003–04 species composition (Martin et al. 2007).

Table D6: Piripaua Power Station location and estimated total number (in 1000s) of elver transferred to upstream locations 1996 to 2015.

Location of releases											Season
	96–97	97–98	98–99	99–00	00–01	01–02	02–03	03–04	04–05	05–06	06–07
L. Whakamarino & Kahutangaroa R.	900	1 690	370	250	880	3 636	9 771	3 947	8 083	2 739	4 180
Mangaone Stm. at Miromiro	500	2 170	2 700	320	1 150						
Mangaone Stm. at Kuha Pa		1 440		390	950						
Waikaretaheke R. above Tuai	700	630		20	70						
L. Kaitawa		1 240		1 400	1 150						
Potaka Pond											
Tapui											
L. Waikaremoana[1]		160									
L kaitawa desilting pond											
Others			70		1,450	157	120				
Total	2 100	7 330	3 140	2 380	5 650	3 793	9 891	3 947	8 083	2 739	4 180

	07–08	08–09	09–10	10–11	11–12	12–13	13-14	14-15			Total
L. Whakamarino & Kahutangaroa R.	5 536			3 611	9 830	5 067	18 406	21 473			100 369
Mangaone Stm. at Miromiro		4 540	4 484				21 999	6 341			44 204
Mangaone Stm. at Kuha Pa		4 932	4 804	8 168	5 743	1 464		5 404			33 295
Waikaretaheke R. above Tuai			252			156	17 894				19 722
L. Kaitawa	44					3 256		9 432			16 522
Potaka Pond						11 234		9 767			21 001
Tapui						11 650					11 650
L. Waikaremoana[1]											160
L. Kaitawa desilting pond						157	4 575				4 732
Blues Pond							4 971				6 768
Rotokiokio								2 367			
Te Hei O Tohaka Bridge							889				54 122
Others	156		437					4 745			7 135
Total	5 736	9 472	9 977	11 779	15 573	32 984	68 734	59 528			267 016

[1] Not an approved release site.

Table D7: Waitaki Dam location and estimated total number of elvers transferred to upstream locations 2002 to 2015. Shaded cells indicate years with inaccurate data.

	Season													
Transfer Location	02–03	03–04	04–05	05–06	06–07	07–08	08–09	09–10	10–11	11–12	12–13	13–14	14–15	Total
L Waitaki	55		51		20	6	486	110	1	3 962	530	104	196	5 521
L Waitaki headwaters				14										14
L Benmore (Sailors Cutting)		4 536	57			4 134								4 191
L Benmore headwaters			1 451	4 669	3 081		4 215	2 229	2 914	2 367	8 387		5 689	35 002
Not recorded					151					672				823
Total	55	0	1 559	4 683	3 252	4 140	4 701	2 339	2 915	7 001	8 917	104	5 885	45 551

Table D8: Mararoa Weir location and estimated total number (in 1000s) of elver transferred upstream 2002 to 2015 records (all longfins except 2013–14).

	Season													
Transfer Location	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11	11-12	12-13	13-14	14-15	Total
L Manapouri			31.7		15.4		26.1	26.2	108.7	77.5	38.3	45.1	50.2	419.2
L. Te Anau	36.1	97.9	13.5		101.0		50.1	14.1	49.0	163.4	80.0	91.7	73.9	770.7
Mararoa R				49.1	1.6	122.7	4.5	0.5	1.6	1.7	5.7	4.2[a]	5.2	196.7
Home Creek						3.4								
Not recorded			18.9		0.4	7.4			7.9	4.0	0.0	0.0	0.8	39.4
Upukerora River							0.6	30.4	31.0	19.2	4.4	4.3	2.9	92.8
Total	36.1	97.9	64.1	49.1	118.4	133.5	81.4	71.1	198.2	265.8	128.5	145.3	133.0	1 518.8

[a] Total includes 40 shortfin elvers.