NIWA
Taihoro Nukurangi

Status of eels in the Rangitaiki River reservoirs and tributaries - 2008

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Executive Summary

Matahina and Aniwhenua hydro-electric dams on the Rangitaiki River block the passage of indigenous fish. To mitigate the effects of the dams on the upstream eel populations, a manual trap and transfer of elvers from Matahina Dam began in 1983 and an elver ladder was installed in 1992. Improved trap and transfer operations were implemented in summer 1997/1998. The total number of elvers transferred from the base of Matahina Dam to upstream habitat is now estimated to be more than 20 million elvers, with 7.7 million of these being moved within the last two seasons.

Monitoring of the eel population upstream of the dam was undertaken in 1988/1989, 1996, 1999/2000 and 2007. The present study was undertaken on behalf of Ngāti Manawa to further assess the success of elver trap and transfer activities. It includes a review of existing information and a survey of the reservoirs and tributaries of the Rangitaiki River using electric fishing, fyke nets and Gee minnow traps in summer 2008/2009.

Fish species found in the catchment included shortfin and longfin eels, rainbow and brown trout, common bully, gambusia (Aniwhenua only) and goldfish. There was also a thriving population of giant kokopu in Lake Matahina and its tributaries. Numbers of eels caught were the highest on record and a wide range of sizes of eels were found. This indicates that elvers are surviving the transfer process and that habitat upstream of the dams is capable of supporting a range of age classes of eel. The eel catch was dominated by shortfin eels but this was expected as the elvers available for transfer are predominantly shortfin. However, the last two seasons have seen a large increase in the total numbers of longfins elvers transferred and an increase in the number of longfins is expected in future eel catches.

In terms of relative abundance, eels in most tributaries were recorded as 'rare' to 'occasional' possibly because recruitment, notably for longfins, is still limited but a number of soft bottomed streams did produce good numbers of shortfin eels, indicating that there would be value in protecting and enhancing this type of habitat. Within the reservoirs, eel condition has remained stable but there are some indications that growth rate is declining possibly because the large number of eel now present are competing for food. It is therefore recommended that further monitoring is carried out at 3-5 year intervals and that stocking rates be re-assessed based upon the results of such monitoring.

Numbers of longfins in the catchment remain extremely low. Improvements in recruitment could result from further control of the harvest of longfins, notably of large female eels, but such harvest control would need to occur nation-wide as juvenile eels are not thought to "home". In the Rangitaiki catchment the chances of mature eels surviving passage over the two hydro dams are negligible, so better protection/mitigation measures at the turbine intakes need to be implemented if eel stocks from the upper catchment are to contribute to the future recruitment of longfin eels.

1. Introduction

The Rangitaiki River, at 155 kilometres, is the longest river in the Bay of Plenty region. It arises from the Taupo volcanic plateau and flows in a north-east direction into the Bay of Plenty. The mainstem is joined by streams draining the Kaingaroa plains from the west, and by the Wheao and Whirinaki Rivers which arise from the Ikawhenua and Urewera Ranges to the East. About 75% of the catchment is covered either by indigenous forest or exotic pine plantations. Riverine sections of Rangitaiki River and its tributaries provide optimal habitat for many species of freshwater fish and in particular longfin eels and rainbow trout.

There are three power schemes on the Rangitaiki River: the Wheao, Aniwhenua and Matahina (Figure 1). The Wheao Power Scheme, completed in 1982, diverts water from the upper Rangitaiki River through the Rangitaiki Canal into the Wheao power house and on to the Wheao River. This scheme is supplemented with water from the upper Wheao River and Flaxy Creek. The Aniwhenua scheme is situated in the middle of the catchment, was built in the late 1970s and, like the Wheao, is essentially a 'run-of-river' scheme. Lake Aniwhenua, the reservoir created for the scheme is shallow and has extensive shallow wetlands along its margins. Matahina, the largest of the three schemes and the lowermost in the catchment, was constructed in the early 1960s. Lake Matahina is a long, thin and deep lake formed in an incised river gorge with a limited littoral zone.

Eels, like most New Zealand indigenous freshwater fish species, are diadromous and require access to the sea to complete their life cycle (McDowall, 1990). Mature adult eels migrate from freshwater to the ocean to breed. Young eels, in the form of leptocephalus larvae, return to the New Zealand continental shelf, primarily with the aid of ocean currents. Upon encountering the continental shelf, and possibly olfactory cues from streams and rivers, the leptocephalus larvae transform into glass eels which then enter freshwater. After a period in freshwater, glass eels develop into the more familiar dark-pigmented elver stage and make their way upstream in search of suitable habitat (Jellyman, 1987).

Both Matahina and Aniwhenua dams are barriers to the upstream passage of elvers, and to the downstream passage of adult eels. It is expected that recruitment of other indigenous fish to the upper Rangitaiki catchment is also limited by these dams. Both reservoirs do, however, provide quality habitat for eels. No fish pass was installed when Matahina Dam was built but some manual transfers of elvers and other fish species across the dams were made soon after the scheme was commissioned. Regular transfer operations by the Department of Conservation (and the Department of Internal Affairs as its predecessor) began in 1983. An elver ladder was installed in 1992 and permanent trap and transfer facilities implemented in late 1997. Since then, transfer activities have been undertaken on an annual basis by the Kokopu Trust on behalf of TrustPower, the current owners of the Matahina power Station. Accurate catch and species composition records have been collected at Matahina by NIWA on behalf of the Ministry of Fisheries since summer 2001/02.

Very little information is available on the diversity, distribution and density of indigenous fish in the upper Rangitaiki catchment prior to the construction of the dams. There is, however, little doubt that the two dams have severely affected the natural recruitment of indigenous fish. For eels, at least, this adverse effect should have been alleviated by the trap and transfer operations that have now been operating for over 10 years.

According to Maori elders, historically, three to four large eels could commonly be caught in a night's fishing in the tributaries of the Whirinaki. A decade or so after construction of the dam, catches decreased markedly and although catches of shortfins have improved in recent times, there are serious concerns for the lack of longfins, a more valued food resource and also a taonga.

Fish surveys of Lake Matahina were undertaken by MAF Fisheries consultants in 1988 and 1989 as part of the Edgecumbe earthquake dam repair work (Stancliff et al. 1989). These studies indicated that eel numbers were very limited despite the transfers of elvers by Internal Affairs and other parties, and that few kokopu (whitebait) species were present above the dam. A more extensive survey of lakes Matahina and Aniwhenua was undertaken in 1996 by Beentjes et al. (1997) on behalf of the Ministry of Fisheries as part of a nationwide monitoring programme on the success of the elver transfer programme. This later survey provided some valuable background information on the eel population above the Rangitaiki dams, and concluded that eel density remained low with very few longfins present in the reservoirs. A further survey, this time focussing on tributaries of the Whirinaki River was undertaken between November 1999 and February 2000 by the Department of Conservation and NIWA (Young, 2000). Results indicated that eel numbers in the Whirinaki catchment were lower than in other Bay of Plenty Rivers and that few recruits had reached the area in recent times. Similar results were found by NIWA in April 2007 when lakes Matahina and Aniwhenua as well as tributary streams were re-surveyed (Smith et al. 2007)

The present study was undertaken on behalf of Ngāti Manawa as a follow up to the 2007 survey. The study was carried out in summer to overcome issues of low temperature which may have affected results in 2007. The aim of the survey was to provide a better understanding of the freshwater fish populations, notably eels, in the upper Rangitaiki catchment.

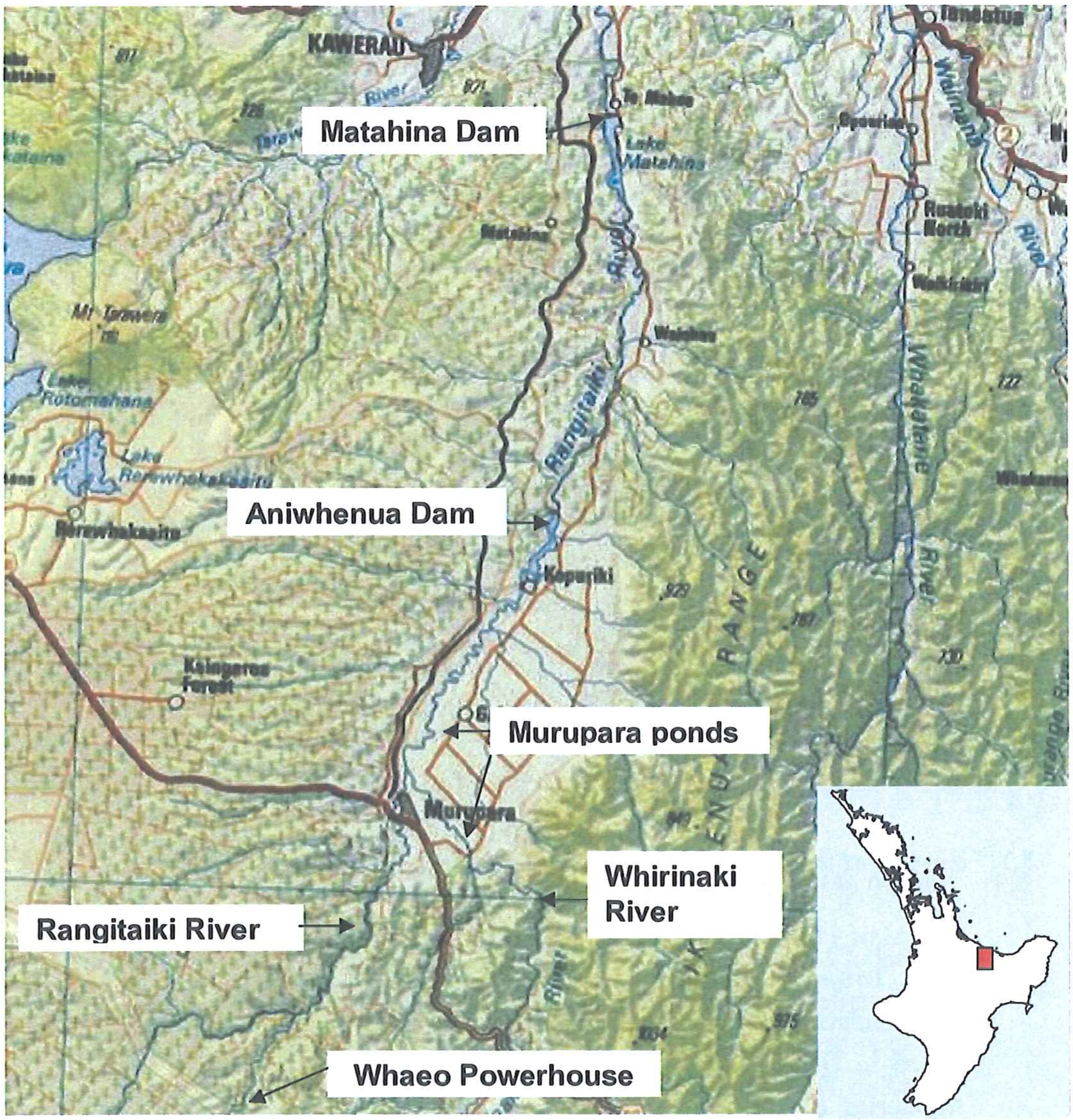


Figure 1: The Rangitaiki River mid-catchment, including Lakes Aniwhenua and Matahina.

2. Methods

2.1 Elver transfer records

A review of the information available on the elver transfer programme for the Rangitaiki was carried out to determine the number of elvers transferred upstream over time. Records examined include elver catches obtained in summer 2008-09 (Martin et al. 2009).

2.2 Elver brush traps

A variety of brush traps were developed and tested between October and December 2008 to determine if such traps could be used by Ngāti Manawa to monitor elver recruitment (Figure 2). Concurrent trials were also undertaken to determine if juvenile eels on-grown in floating flumes (Figure 3) would have better survival than juvenile eels released directly into the wild following transfer. The brush net and floating flume trials were undertaken in Lake Aniwhenua and in flooded gravel pits downstream of Murupara (Murupara ponds).

2.3 Survey of Rangitaiki River main stem and tributaries

A total of 17 sites (Figure 4), in the upper Rangitaiki River catchment were electro-fished with a battery powered back pack machine (EFM300) to provide an indication of relative eel abundance and to assess occurrence of other fish species. Fourteen of these sites were fished in December 2008 and a further five in April 2009. Sites fished were mainly tributaries of the Rangitaiki River immediately upstream and downstream of Lake Aniwhenua. The margin of the Rangitaiki River mainstem was also fished at three sites and the Wheao River at two sites.

Electro-fishing was undertaken in an upstream direction to minimise disturbance to areas not already fished. In general, each site was fished through twice to enable semi-quantitative reporting. However, in some areas, because of the large number of trout present, semi-quantitative reporting was not attempted and only the relative abundance of eels and their sizes were determined. In addition to this semi-quantitative fishing, a number of sites were spot fished, targeting likely eel habitat (e.g., undercut banks and log-jams).

Figure 2: Example of the brush trap (left) and net frame that were tested during the study.

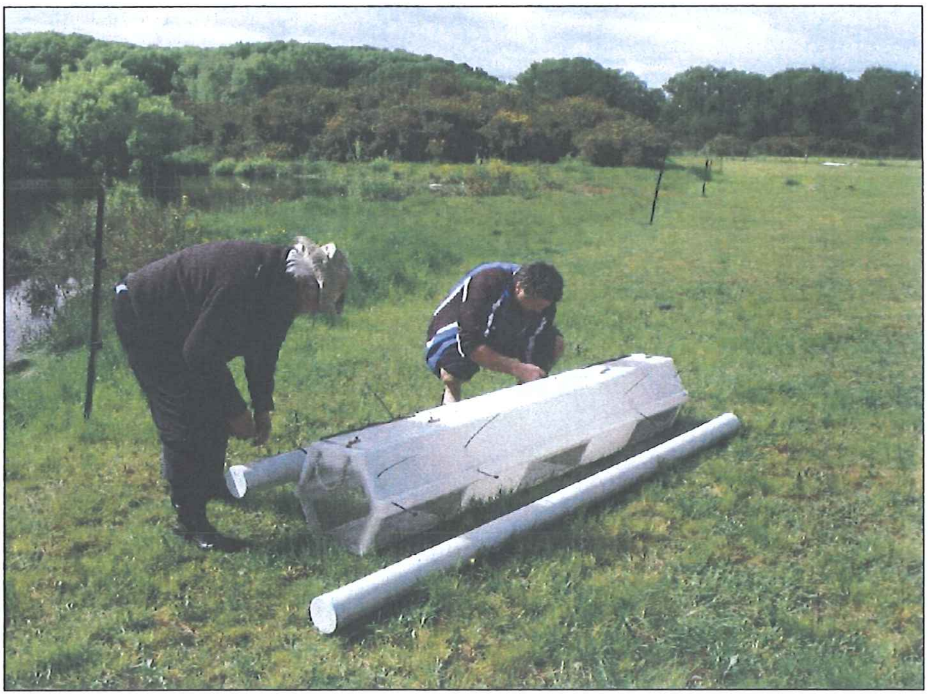


Figure 3: Preparing a floating flume used to hold eels during the study.

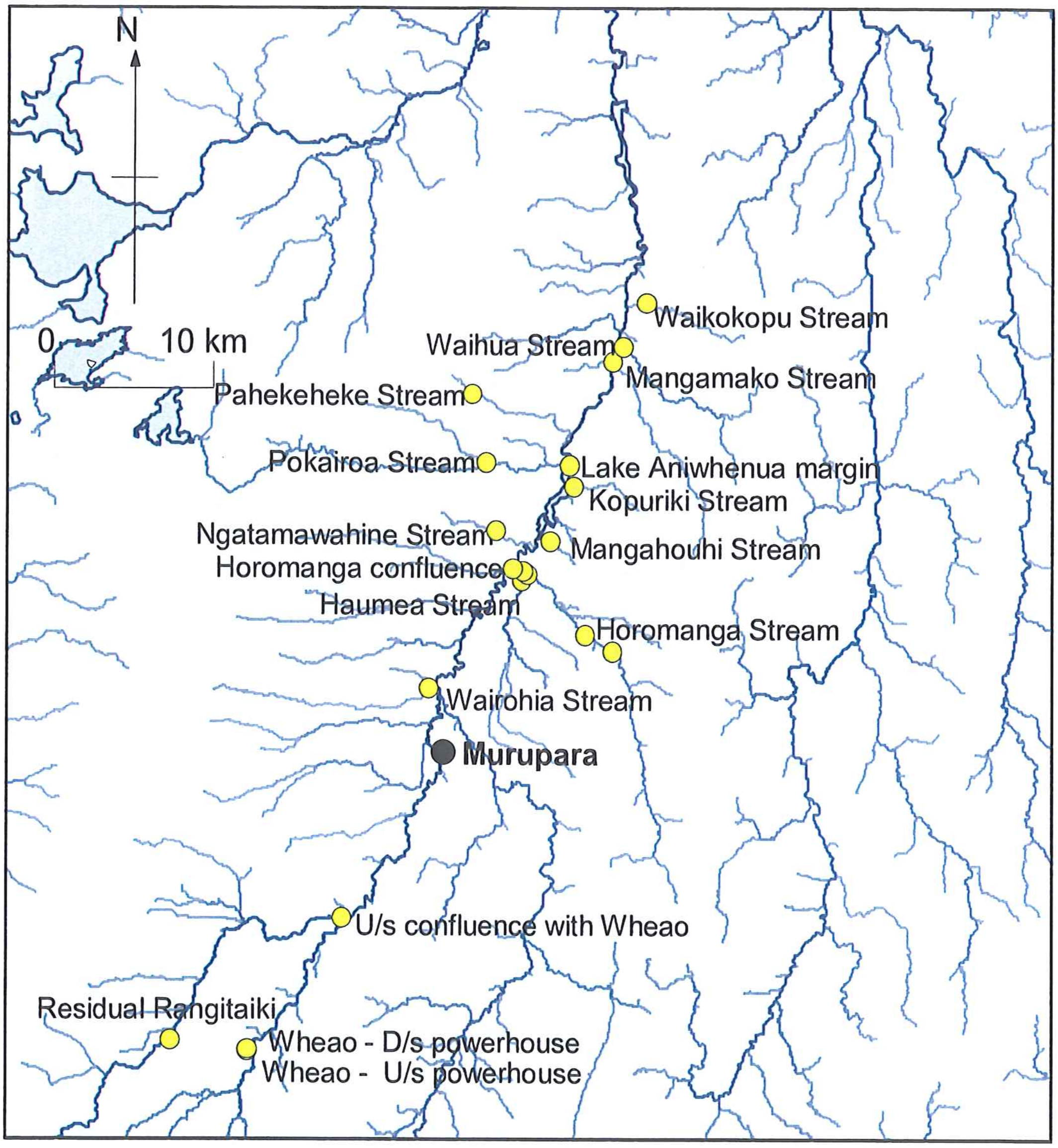


Figure 4: Electric fishing sites in the Rangitaiki River catchment, December 2008 and April 2009.

The area of the stream fished varied for the semi-quantitative reaches from 23 m^2 to 160 m^2 depending on the size of the stream and the availability of fishable water. Spot fishing reaches varied from 15 m to over 300 m in length. Fish captured were identified to species level and lengths recorded before release at the point of capture.

All fish and habitat data obtained were recorded on the New Zealand Freshwater Fish Database (http://www.niwa.co.nz/our-services/databases/freshwater-fish-database). Water temperature and conductivity were measured at key sites.

2.4 Survey of Matahina and Aniwhenua reservoirs

Lake Matahina (Figure 5) and Lake Aniwhenua (Figure 6) were surveyed using a fleet of fine mesh fyke nets (D-opening, double funnelled, 4 mm stretched mesh) and standard coarse mesh fyke nets (D-opening, double funnelled, 12 mm stretched mesh). At Matahina the nets were deployed overnight at a total five sites between 11-12 December while in Lake Aniwhenua nine sites were fished between 8-11 December). At each site three coarse mesh fykes and three fine meshed fykes were set within a 200 m reach. Nets were set primarily to fish the lake margins apart from site 4 in Lake Aniwhenua where a train of six nets (again 3 coarse and 3 fine) was set in open water at a depth of 5 m (deep set).

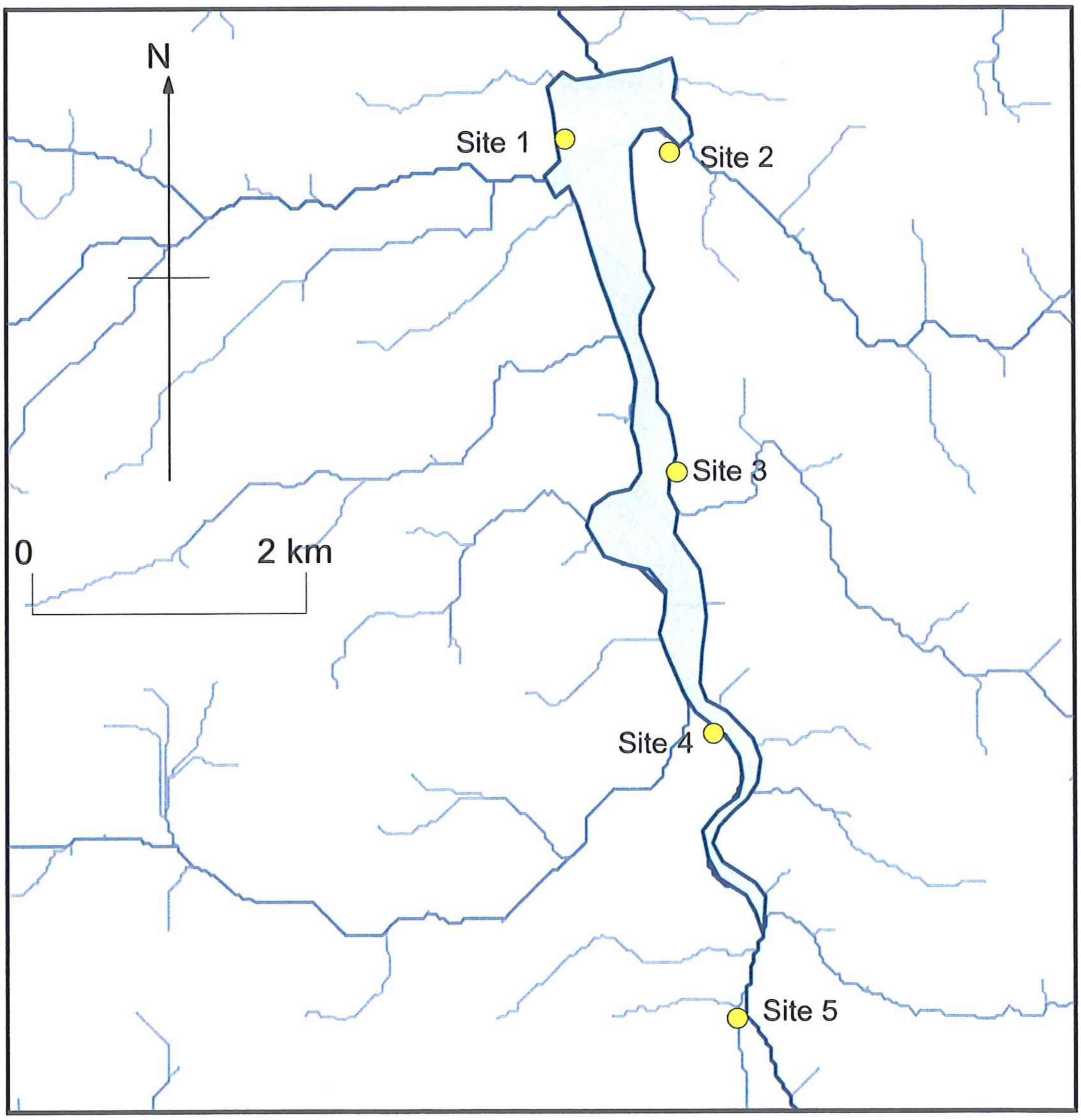


Figure 5: Lake Matahina fishing sites, 11-12 December 2008.

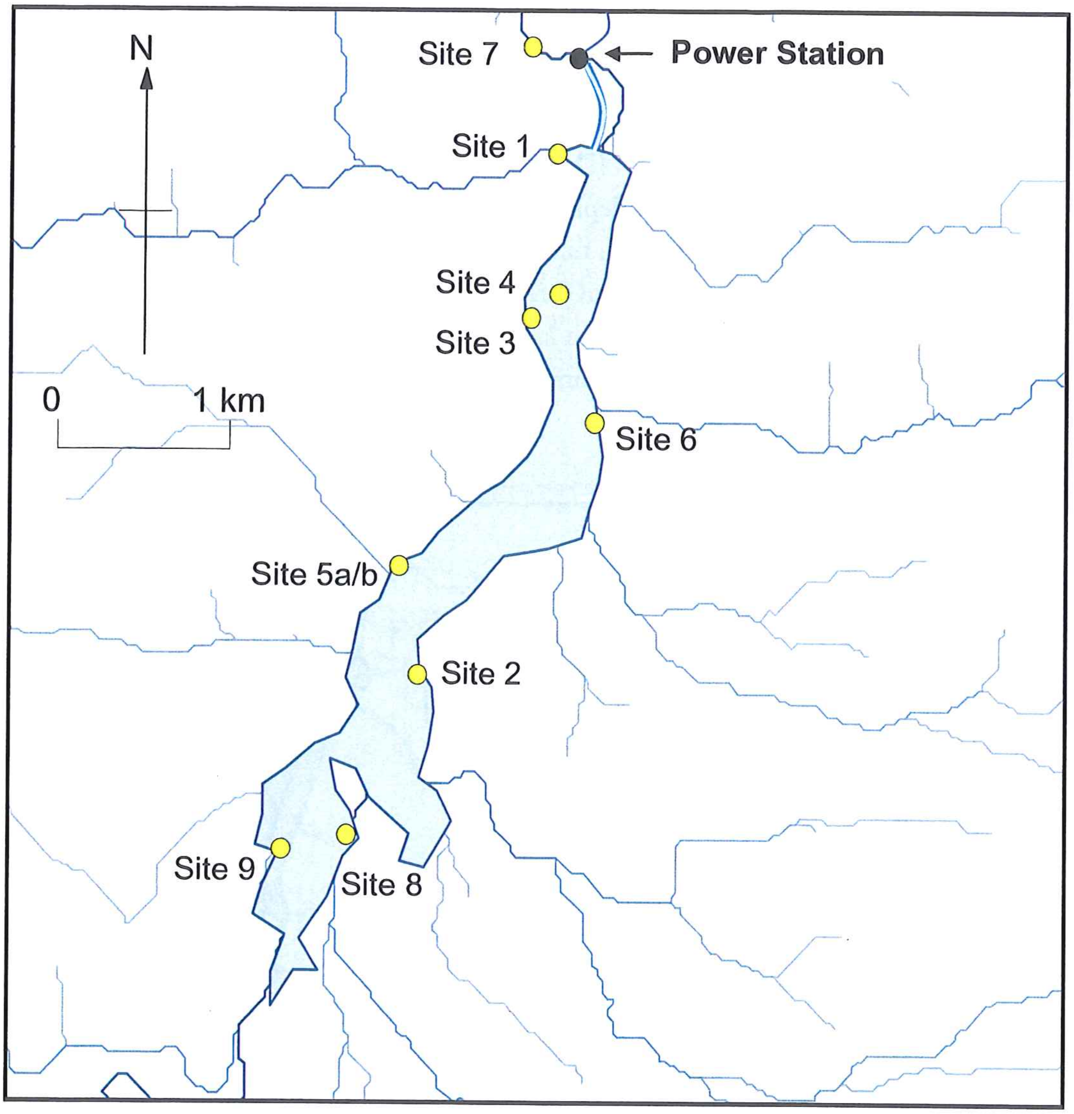


Figure 6: Lake Aniwhenua fishing sites, 8-11 December 2008.

Apart from site 4 (deep set) in Lake Aniwhenua, all the fykes nets were set in conjunction with 4 mm mesh Gee minnow traps (total of six per site). Site 5 in Lake Aniwhenua was surveyed over two nights. All fyke nets were baited with either fish or meat flavoured cat food and all Gee minnow traps were baited with crushed trout food pellets held in perforated bottles. Effort was applied consistently between sites and netting sites were chosen to represent the range of lake-margin habitats available. In the lakes the nets were set along the margins at right angles to the shoreline, cod-end outermost but at riverine sites the cod-end was placed upstream against the bank with the leader downstream. Where possible, nets were set in small clearings between aquatic macrophyte beds, however a number had to be deployed within the beds in areas where no clearings could be found. Each net location, depth, habitat type (i.e., weed/no weed), set position, time in and time out was recorded. Each net was processed separately so that catch per unit effort

(CPUE) could be recorded for each net. Length and weight measurements were obtained for most eels caught (Figure 7).

Figure 7: Processing the catch on the shore of Lake Aniwhenua. From left to right: Robert Jenner, Sacrament Jenner and Francis Mitai.

All by-catch species were counted or estimated when there were more than 500 individuals. The larger species (i.e., goldfish and giant kokopu) were also measured. For ease of processing, the eels were sedated using Aqui-S (a registered clove oil based fish anaesthetic). Fish were then identified, weighed (to the nearest g) and measured (to the nearest mm). Most eels were released after processing, with a small number retained for otolith extraction (these eels were later distributed to elders of the participating marae). Any trout present were identified, measured and released back in the water at the point of capture.

2.5 Murupara ponds and Flaxy Lake

Two small oxbow lakes known locally as the Murupara ponds (Figure 8) were also fished overnight. Two baited fine mesh fykes were set from the shore in each pond and retrieved the following morning (17 December 2008). The catch was processed on site and apart from eight shortfins retained for ageing, most fish were returned live to the ponds (again the eels retained were distributed to the local community once processed).

Four baited fine mesh fykes were also set overnight in Flaxy Lake, a small hydro reservoir located 25 km South-West of Murupara (Figure 8) on the Wheao River. These nets were retrieved the following morning (18 December 2008) and the catch processed with all fish caught returned live at the point of capture.

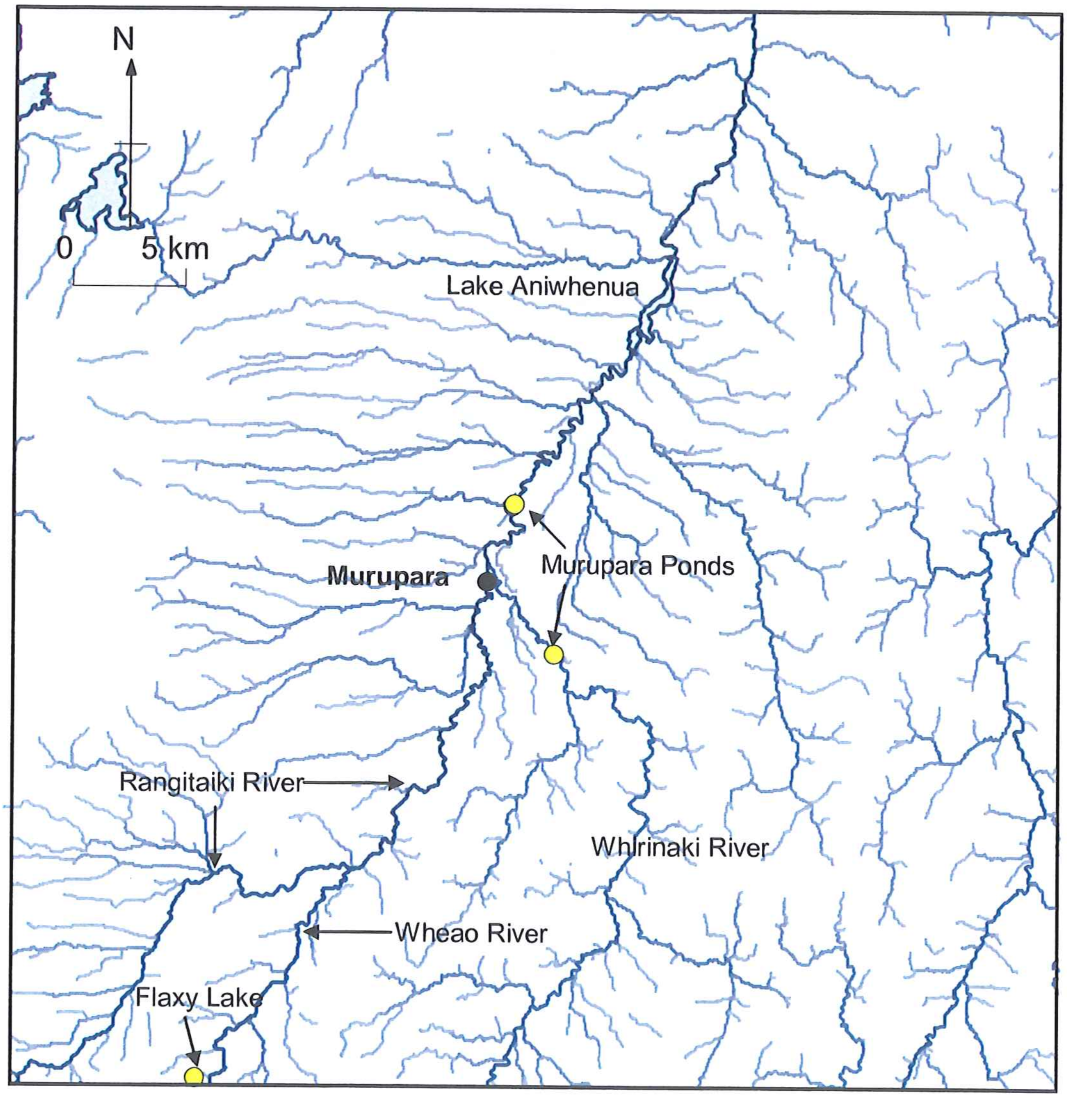


Figure 8: Murupara ponds and Flaxy Lake fyke netting sites.

2.6 Analyses of the catch

2.6.1 Relative abundance

To compare catches from the different locations during the current survey, fish abundance was expressed as catch per unit effort (CPUE) which was defined as the number of fish caught per net per overnight set. Previous surveys used nets of different mesh size and/ or used different techniques (e.g., Stancliff et al. (1989), used some double leader fykes set in mid channels and minnow trap of 7 mm, not 4 mm as per this study; Beentjes et al. (1997), used super fykes with 0.75 mm square mesh and no minnow traps). Nets of different mesh size are expected to retain fish of different lengths so comparison of catches over time was only possible for similar nets. For this reason, only coarse mesh fyke net records were used when examining trends.

2.6.2 Condition, age structure and growth

From the length and weight data collected during the survey, a linear relationship between length and weight could be determined for each species using a length-weight regression:

$$ln\ (Weight) = a + b*ln\ (Length).$$

The slope of this line (i.e., *b*) gives an indication of condition (i.e., how heavy the fish are in comparison to their length) and therefore provides a measure of fatness and hence adequacy of fish supply. This parameter is used to provide a general overview of the condition of a fish population in an area and is relatively quick and easy to calculate. However, a single parameter to describe the two dimensional length-weight relationship can result in of the loss of information on individual fish and small sample size or samples skewed by many large or small fish can produce relationships that do not accurately represent the sites. To avoid this, fish can be examined on an individual basis with each fish treated as a cylinder to calculate a condition factor i.e.:

$$Condition\ factor = Weight\ /\ (Length)^3 * 100$$

where *Weight* is in g and *Length* in cm. This condition factor can then be used to compare individual and/or groups of eels captured at different location r time. During the current survey, both techniques were used but are identified when the results are discussed.

Otoliths were prepared using the crack-and-burn method (Hu & Todd 1981). Otolith halves were mounted in silicone rubber sealant on microscope slides and examined at 10-50x magnification under a stereo-microscope using transmitted light. Hyaline zones or winter rings were counted and age expressed as years spent in fresh water, ignoring the central area of larval growth (Jellyman 1979). Narrow central growth bands previously observed in most eels taken from hydro lakes (Chisnall & Hicks 1993) were considered to correspond to time spent below the Matahina Dam. Therefore, where appropriate, eels were given three counts: 1/ narrow central growth bands counted as the "elver age"; 2/ subsequent uniform wide growth bands along the caudal radius counted as the "lake age"; and 3/ all growth bands making up the "total age" (Beentjes et al. 1997). Once eels were aged, length-at-age regressions were constructed.

Mean annual length increments were also derived assuming a recruitment length of 95 mm (the average length of elvers at Matahina) as per Jellyman (1977).

3. Results

3.1 Elver transfer records

The majority of elvers arrive at the base of Matahina Dam between December and April with a peak usually in January. Water temperature dictates the start and end of the migration and 18 °C appears to be the trigger (Martin et al. 2008).

Elver stocking levels increased dramatically in 1997 when trap and transfer operations were implemented. The number released increased from an average of about 78,000 elvers per year between 1991 and 1997 to an average of 1,144,000 elvers from 1997 to 2007. In the 2007-08 season, 3,378,000 elvers were transferred and in the 2008-09 season 4,307,000 elvers (Figure 9). In the last two seasons elver transfers of both species at Matahina have been the highest in New Zealand, when compared to other dams including Karapiro. Total transfer from the base of Matahina Dam to upstream habitat since the trap and transfer operations began in 1982 is estimated at more than 20 million elvers, with 7.7 million of these occurring in the last two seasons (Martin et al. 2009).

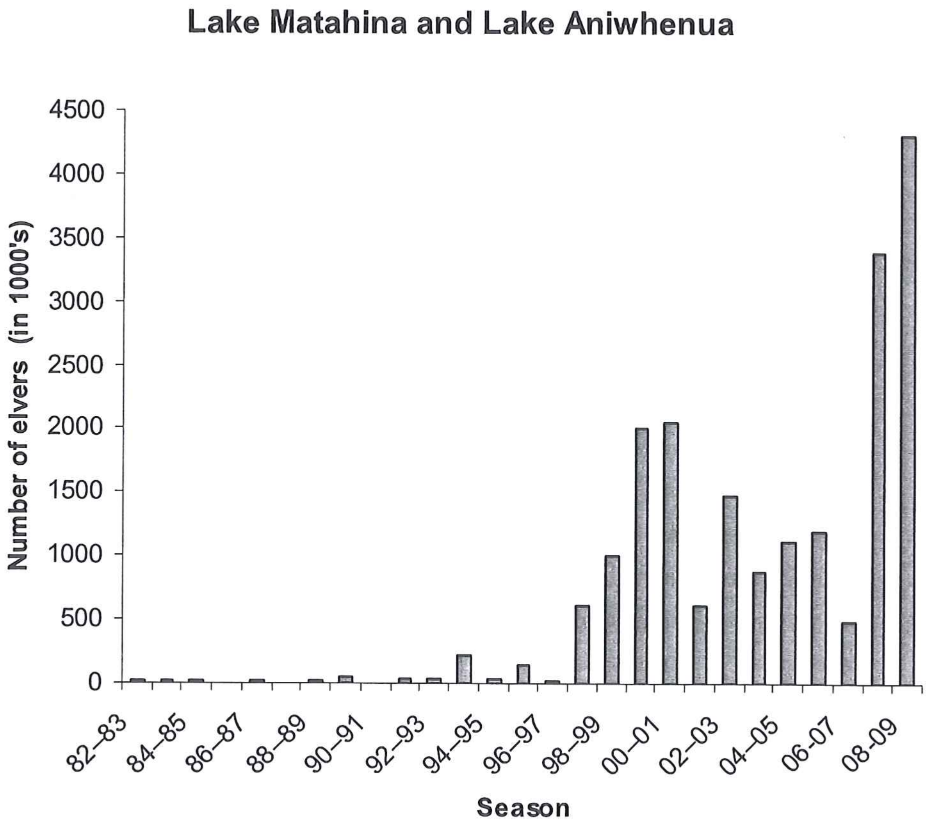


Figure 9: Total number of elvers known to have been transferred from Matahina Dam to upstream habitat.

Over time, Lake Aniwhenua and upstream habitats have received the bulk of the elvers transferred (Figures 10 & 11). The majority of the elvers transferred were shortfins, with longfins constituting only 8.5% of total elvers estimated to have been transferred between 2001 and 2006. Since 2006, longfin numbers have increased and at the end of summer 2008/09 it was estimated that 11% of the total number of elvers transferred were longfins. The total number of longfins released in the 2007-08 season (929,000) was more than the total combined number of longfin released since records began (791,000 elvers, 1982 to 2006). Most (96%) of the 2007-08 longfin elvers were released into or above Lake Aniwhenua and the remainder into Lake Matahina.

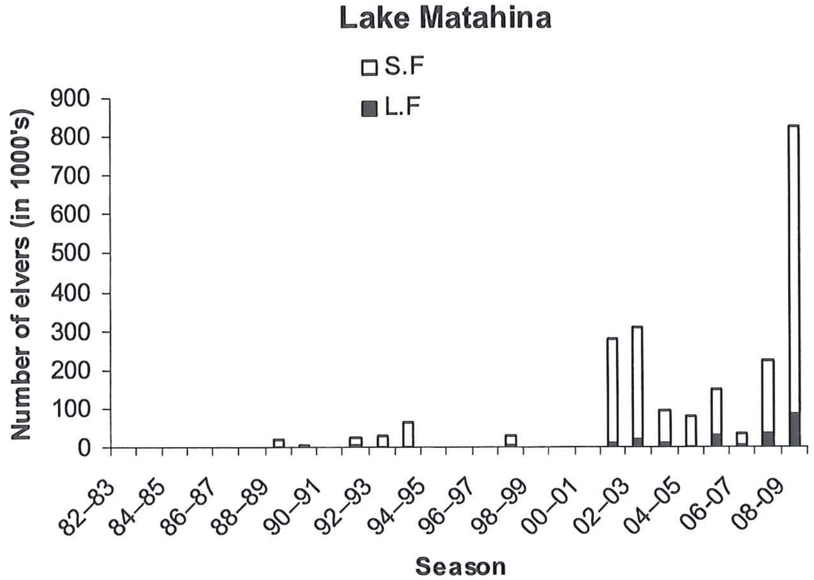


Figure 10: Total numbers of elvers known to have been transferred into Lake Matahina (species composition not available for 1982-83, 1987-88, 1989-91, 1993-96, 1998-2001).

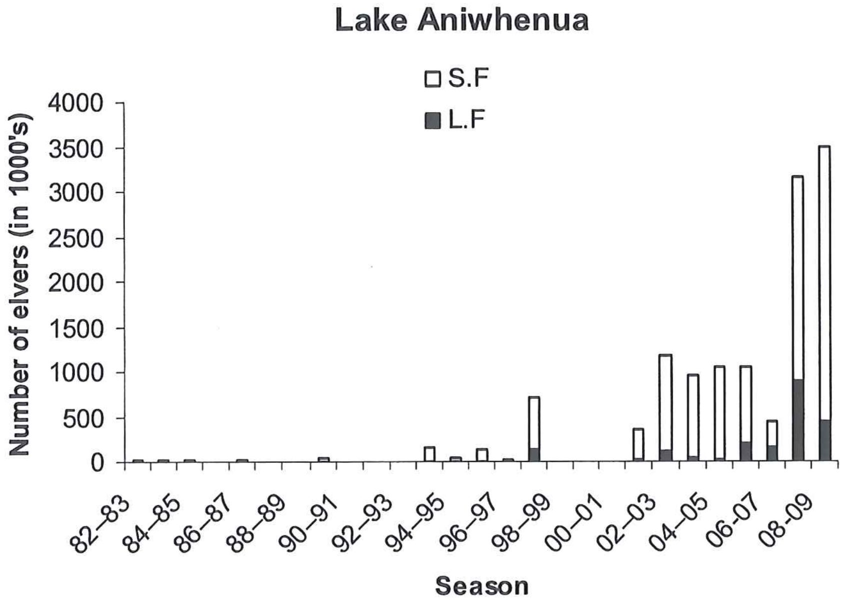


Figure 11: Total numbers of elvers transferred into Lake Aniwhenua (species composition not available for 1982-83, 1987-88, 1989-91, 1993-96, 1998-2001).

3.2 Elver brush traps

Initial trials with the brush trap (an adaptation of the method utilised to traditionally catch kōura/kēwai) indicated that eels would use the artificial habitat but that, unless a means of retaining them could be devised, it would not be possible to use the method to assess the population. Steel frames onto which fine mesh net was attached were constructed so that any eels present in the brush would be trapped upon retrieval. Although several eels and elvers were caught in this way, it soon became apparent that the method would be impractical for a catchment-wide population study by Ngāti Manawa. Smaller artificial substrate traps (i.e., plastic mesh) were more successful for elvers but again proved very difficult to retrieve successfully. Given the success of electrofishing at catching a range of eel sizes and the ease with which this could be done, it was concluded that this was a more practical means of assessing the population of smaller eels.

Eels retained in the floating flume remained healthy throughout November and early December but within a few days in mid-December some eels began to develop a fungal growth. Past experience has indicated that once this occurs the infection typically spreads rapidly through all the eels in the flume. The experiment was therefore abandoned, with a decision made to promote and enhance natural juvenile eel habitat instead.

3.3 Survey of Rangitaiki River main stem and tributaries

Most of the streams were sampled using electrofishing close to their confluence with the main-stem (Rangitaiki River) mainly because access to these streams was from roads that crossed them. Other streams (Pahekeheke, Pokairoa) were accessed via forestry roads. Most streams fished were located within areas dominated by exotic forestry or farming, many of which had scrub and or native riparian margins. Average stream depths and widths ranged from 100 mm to 800 mm, and 1.5 m to 14 m respectively. The structure of most habitat fished included a run-riffle-pool sequence. The substrate varied stream to stream from boulder/cobble trout dominated streams to mud/sand eel dominated streams.

Trout (rainbow and brown) and eels (longfin and shortfin) were the only fish species found in the tributaries of the Rangitaiki in summer 2008/2009 (Tables 1 and 2). Most trout caught were juveniles. As found previously by Young (2000) and NIWA in the 1996 and 2007 surveys (Table 3), both trout species were 'common' to 'abundant' in most streams while in general, the abundance of longfins and shortfins was 'low'. However, in 2008, shortfins were recorded as 'common' at five sites (the Rangitaiki River mainstem at the Horomanga River confluence, the Rangitaiki River upstream of the Whaeo River confluence, the Haumea stream, the lower Horomanga River and the Aniwhenua Lake margin (close to boat ramp). In addition, shortfins were found to be 'abundant' (66.7 eels per $100m^2$) in the Mangahouhi Stream. The site where eels were 'common' or 'abundant' all had soft bottoms (sand or mud) and or undercut banks for cover (Figure 12). Earlier surveys of Lake Aniwhenua tributaries only recorded shortfin eels as 'occasional' to 'rare' with no elvers captured so it appears that recruitment of this species has improved as the annual transfers increase. However, longfins remain 'rare'.

Table 1: Location and area-standardised catches of fish obtained by electrofishing tributaries of the Rangitaiki River in summer 2008/2009. **Sf** = shortfin eel, **Lf** = longfin eel, **Rt**= rainbow trout, **Bt** = brown trout, **Ut** = unidentified trout, - = none caught.

Stream / River	NZ map grid ref.		Area fished (m^2)	Area-standardised catch (Fish /100m^2)				
	East	North		Sf	Lf	Rt	Bt	Ut
Waikokopu	2846425	6324040	67	-	-	26.8	5.9	14.9
Waihua	2844988	6321437	45	-	-	31.1	13.3	-
Horomanga	2839025	6307890	93	9.6	-	3.2	2.2	-
Horomanga	2844417	6303247	45	-	-	20.0	11.1	-
Horomanga	2838808	6308005	160	6.9	-	0.6	-	-
Ngatamawahine	2837047	6310474	91	2.2	1.1	-	7.7	8.8
Pokairoa	2836396	6314524	29	-	-	-	-	-
Pahekeheke	2835472	6318587	66	-	1.5	-	-	-
Wairohia	2832796	6301075	100	1	-	-	-	-
Rangitaiki	2838097	6308245	30	23.3	-	-	-	-
Haumea	2838688	6307520	23	39.1	-	-	4.3	-
Lake Aniwhenua	2841675	6314341	45	13.3	-	-	-	-
Mangahouhi	2840473	6309875	30	66.7	-	-	-	-
Kopuriki	2841900	6313131	0 (stream dry)	-	-	-	-	-
Wheao	2821539	6279328	30	-	-	12	-	-

Table 2: Location and relative abundance (with actual number captured in brackets if available) for sites spot fished with an electric fishing machine in summer 2008/2009. **Sf** = shortfin eel, **Lf** = longfin eel, **Rt**= rainbow trout, **Bt** = brown trout, **a** = abundant, **c** = common, **o** = occasional, **r** = rare, **-** = none caught.

Stream / River	NZ map grid ref.		Distance	Relative abundance and (number)			
	East	North	fished (m)	Sf	Lf	Rt	Bt
Waikokopu	2846425	6324040	90	o (5)	-	a	a
Waihua	2844988	6321437	100	r	-	a	a
Horomanga	2844417	6303247	300	-	-	a	a
Horomanga	2842652	6304256	200	o (3)	-	c (20)	-
Mangamako	2844396	6320507	400	-	r (1)	a	a
Pokairoa	2836396	6314524	15	-	-	c (2)	-
Wairohia	2832796	6301075	30	o (2)	o (1)	-	-
Wheao	2821553	6279438	30	-	-	o (3)	o (1)
Rangitaiki	2816802	6279971	40	-	-	o (3)	o (5)
Rangitaiki	2827347	6287300	100	c (18)	-	o (1)	o (5)

Table 3: Comparison of relative abundance (with actual number captured in brackets if available) of fish obtained at sites electric fished in 1996, 2007 and 2008. **Sf** = shortfin eel, **Lf** = longfin eel, **Rt**= rainbow trout, **Bt** = brown trout, **a** = abundant, **c** = common, **o** = occasional, **r** = rare, **-** = none caught.

Stream / River	NZ map grid ref.		Distance fished (m^2)	Relative abundance (Numbers)			
	East	North		Sf	Lf	Rt	Bt
Haumea (2007)	2838702	6307500	60	o (1)	-	-	o (2)
Haumea (2008)	2838688	6307520	23	c (9)	-	-	o (1)
Horomanga (1996)	2839100	6307900	120	-	o (4)	c (77)	-
Horomanga (2007)	2838996	6307946	60	c (8)	-	o (3)	o (3)
Horomanga (2008)	2839025	6307890	93	c (9)	-	o (3)	o (2)
Horomanga (2008)	2838808	6308005	160	c (11)	-	r (1)	-
Kopuriki (1996)	2841900	6313131	150	-	-	c (12)	-
Kopuriki (2007)	2841936	6313156	30	-	-	-	-
Kopuriki (2008)	2841900	6313131	0 (stream dry)	-	-	-	-
Mangamako (2007)	2844402	6320503	25	-	-	r (1)	-
Mangamako (2008)	2844396	6320507	400	-	r (1)	a	a
Waihua (2007)	2844981	6321435	100	r (1)	-	o (7)	-
Waihua (2008)	2844988	6321437	100	r	-	a	a
Waikokopu (2007)	2846418	6334078	100	o (5)	r (1)	r (2)	r (1)
Waikokopu (2008)	2846425	6324040	90	o (5)	-	a	a

Figure 12: Mangahouhi stream where shortfin eels were abundant (note grass margin, silt bottom and undercut banks).

In total, 93 eels were caught by electric fishing. This catch was dominated by shortfins (90) with only three longfins caught. Most eels captured by electric fishing were small and shorter than 300 mm (Figure 13). The average length of all eels caught by electric fishing in 2008 was 280mm. This compares to an average of 359 mm in 2007 when 26 eels were caught by electric fishing in tributaries for both Lakes Matahina (9 sites) and Aniwhenua (5 sites). The average size at transfer for shortfins is 96 mm and 109 mm for longfins (1998/99 season) so, although some of the eels captured were from recent releases, the majority are from releases made in previous years.

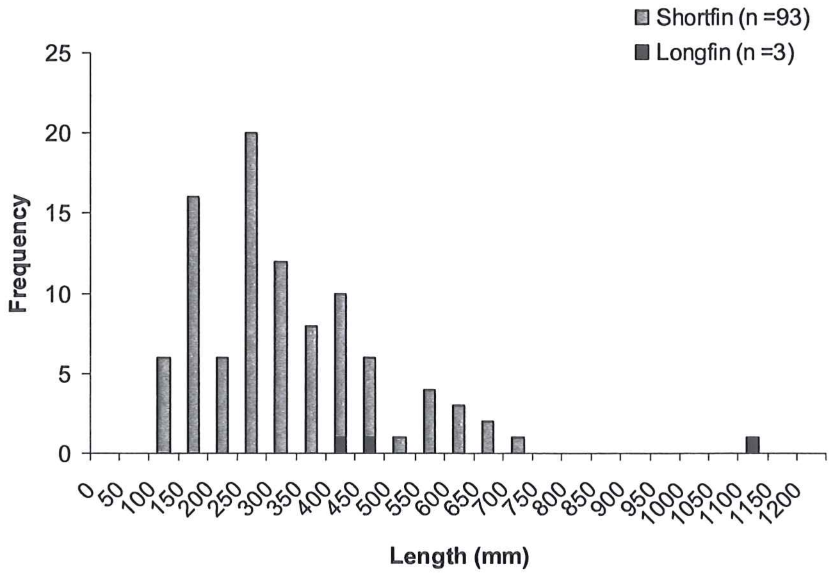


Figure 13: Length frequency for eels caught by electric fishing from Rangitaiki River and tributaries 2008.

3.4 Survey of Matahina and Aniwhenua reservoirs

3.4.1 Eel catches

Water temperature during the reservoir survey was close to 17 °C in Lake Aniwhenua and ranged from 19-21 °C in Matahina. These temperatures are some 3-4 °C higher than during the last survey in April 2007 (see Appendix 1)

A total of 52 longfins (21 in Matahina and 31 in Aniwhenua) and 947 shortfins (265 in Matahina and 682 in Aniwhenua) were captured during the December 2008 survey (Tables 4 & 5, Appendix 2). No migrant eels were captured and a single elver was captured in a fine mesh fyke set in Matahina. The fine mesh nets tended to capture more small eels that the coarse mesh fykes (Table 6).

The 15 coarse mesh fyke nets set in Matahina captured 135 shortfins and 11 longfins (Table 4). In Lake Aniwhenua 291 shortfins and 10 longfins were caught from 30 standard coarse mesh fykes set there. In terms of CPUE, shortfin catches have doubled in Lake Matahina since 1996 (4.4 eels per net in 1996 compared with 9.0 in 2008), and tripled in Lake Aniwhenua (2.6 eels per net in 1996 compared to 9.7 in 2008). CPUE for shortfins in coarse meshed fykes were also much higher in 2008 than in 2007 and a similar trend was observed with fine mesh fykes (Table 4). The longfin eel CPUE from coarse mesh fyke nets in both reservoirs was very similar in 2008 and 2007 but was higher in fine fyke nets in 2008 than in 2007.

The average weight of shortfin eels captured in the coarse mesh fyke nets was 400 g (range 20-1810 g) in Matahina and 350g (range 10-1480g) in Aniwhenua. In both Matahina and Aniwhenua there are indications that average weight of shortfins in the population is decreasing with time (Table 7). Similar trends are evident with length (Table 8). The limited records available for longfins indicate that the size structure has not changed markedly in Matahina but has declined in Aniwhenua (Tables 7 & 8).

Table 4: Total number of shortfin (Sf) and longfin (Lf), proportion of longfins in catch, and catch per unit effort for both shortfin and longfin eels captured in **coarse mesh** fyke nets set in lakes Matahina and Aniwhenua 1988 to present (12 mm mesh size used in 2008, all other years 20 mm mesh).

Site, year and number of nets	Number caught		Ratio	CPUE	
	Sf	Lf	% Lf	Sf	Lf
Matahina 1988-1989 (n = 22)	98	25	20	4.4	1.1
Matahina 1996 (n = 27)	96	14	13	3.4	0.6
Matahina 2007 (n = 20)	88	16	15	4.4	0.8
Matahina 2008 (n = 15)	135	11	7.5	9.0	0.7
Aniwhenua 1996 (n = 34)	105	5	5	3.4	0.1
Aniwhenua 2007 (n = 20)	53	4	7	2.6	0.2
Aniwhenua 2008 (n = 30)	291	10	3.3	9.7	0.3

Table 5: Total number of shortfin (Sf) and longfin (Lf), proportion of longfins in catch, and catch per unit effort for both shortfin and longfin eels captured in **fine mesh** fyke nets set in lakes Matahina and Aniwhenua 2007 & 2008.

Site, year and number of nets	Number caught		Ratio	CPUE	
	Sf	Lf	% Lf	Sf	Lf
Matahina 2007 (n = 15)	44	7	13.7	2.9	0.5
Matahina 2008 (n = 15)	130	10	7.1	8.6	0.7
Aniwhenua 2007 (n = 15)	40	2	4.8	2.3	0.1
Aniwhenua 2008 (n = 30)	391	21	5.1	13.0	0.7

Table 6: Comparison of the size of eels captured in coarse and fine meshed fyke net set in lakes Matahina and Aniwhenua 2007-2008. (Coarse mesh fykes had 12 mm mesh in 2008 but 20 mm mesh in 2007).

Location	Year	Coarse mesh fykes				Fine mesh fykes			
		Eel No.	LF (%)	Mean & (min.) length (mm)	Mean weight (g)	Eel No.	LF (%)	Mean & (min.) length (mm)	Mean weight (g)
Matahina	2007	96	16.6	623 (350)	0.62	51	13.7	568 (240)	0.51
	2008	146	7.5	549 (218)	0.45	140	7.1	542 (135)	0.41
Aniwhenua	2007	57	7.0	594 (410)	0.51	42	4.8	578 (325)	0.48
	2008	262	3.8	527 (228)	0.36	360	5.8	521 (175)	0.35

Table 7: Weight characteristics of shortfins and longfins captured in coarse mesh fyke nets (12 mm mesh in 2008 but 20 mm in other years) from the Matahina and Aniwhenua reservoirs 1988-89, 1996, 2007 and 2008.

Location	Year	Shortfin weight (g)				Longfin weight (g)			
		n	avg	min	max	n	avg	min	max
Matahina	1988-89	132	699	100	1800	42	1023	830	1300
	1996	96	570	63	3320	14	1454	147	3300
	2007	80	510	130	1830	16	1170	120	2850
	2008	135	400	20	1810	11	1000	430	2250
Aniwhenua	1996	105	656	145	1470	5	1500	400	10000
	2007	53	510	150	1470	4	460	340	600
	2008	252	350	10	1480	10	510	190	1550

Table 8: Length characteristics of shortfins and longfins captured in coarse mesh fyke nets (12 mm mesh in 2008 but 20 mm in other years) from the Matahina and Aniwhenua reservoirs 1988-89, 1996, 2007 and 2008.

Location	Year	Shortfin length (mm)				Longfin length (mm)			
		n	avg	min	max	n	avg	min	max
Matahina	1988-89	132	699	100	1800	42	900	170	2400
	1996	96	625	350	1015	14	711	375	1020
	2007	80	607	350	913	16	706	365	958
	2008	135	536	218	912	11	707	574	904
Aniwhenua	1996	105	662	435	906	5	1146	818	1430
	2007	53	591	325	880	4	561	505	600
	2008	252	526	228	872	10	563	453	798

In both Lake Matahina and Lake Aniwhenua, shortfin eels in the 350 to 450 mm length bracket were more prevalent in 2008 than in 2007 or 1996 (Figure 14). No such change was noted with longfins (Figure 15) but the population of this species remains extremely low so changes, if any, would be difficult to detect.

Electric fishing tended to capture more small eels than fyke nets and was the most efficient mean of assessing the numbers of small eels present (Figure 16).

There was no statistically significant difference (t-test, $P > 0.05$) in the mean condition of shortfinned eels between the two lakes in 2008 (mean of 0.21 in both reservoirs). Similarly there was no statistically significant difference (t-test, $P > 0.05$) in the mean condition of shortfinned eels in either reservoir between 1996 and 2007 or 2008. The slopes of the regressions between length and weight were also very similar between the lakes and between years (Table 9).

3.4.2 Murupara Ponds and Flaxy Lake

The four fine mesh fykes set in the Murupara ponds (two nets in each pond) captured a total of 68 shortfin eels (Figure 17). The CPUE was 17 eels per net, which is higher than the CPUE for the same type of nets set in the reservoirs (8.6 Lake Matahina and 13 for Lake Aniwhenua). Over 400 juvenile goldfish were also caught here indicating an abundance of food.

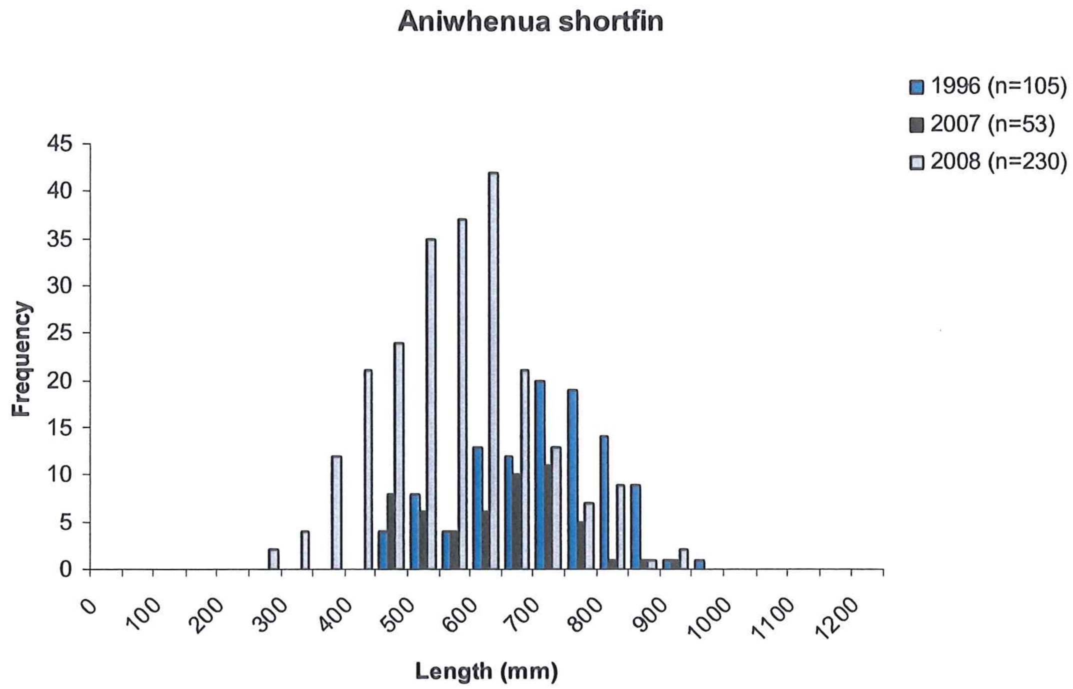
No eels were caught in Flaxy Lake from four nets set in this area which indicates that eels are not abundant there. The hydro structures are expected to prevent upstream access by eels but it is not known if elver stockings have ever been made in these upstream reaches. Juvenile trout were caught in the nets and all were released live back into the lake.

3.4.3 Age and growth of eels

Otolith pairs were extracted from eight medium sized shortfin eels (range 650-860mm) from the Murupara ponds. All of these otoliths were easy to read with clear hyaline zones visible. Growth appears to be fast with medium to wide growth bands present.

The length at age records from the Murupara ponds shortfins were comparable to those obtained in Aniwhenua in 1996 and 2007 (Figure 18). Mean annual length increment of these pond shortfins was 74 mm/year which is comparable to growth obtained for this species in the reservoirs in 1996 (Appendix 3). However, assuming consistency of methods and reporting and no change in population structure, annual growth in the reservoirs appears to be lower. If the assumption is correct[1] available figures appear to indicate reduced food availability due to an increase in the eel population in this area.

[1] (This is uncertain as, for example, differences in the intercepts (a) of the age/length regressions are unusually large between 1996 and 2007 – see Appendix 3.)



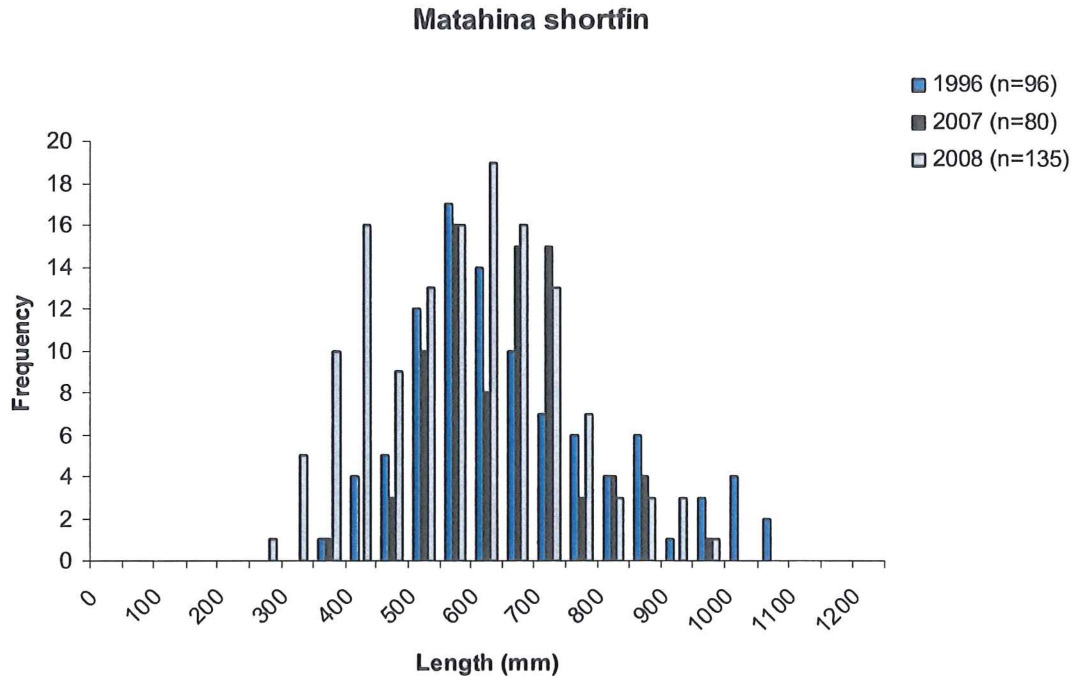
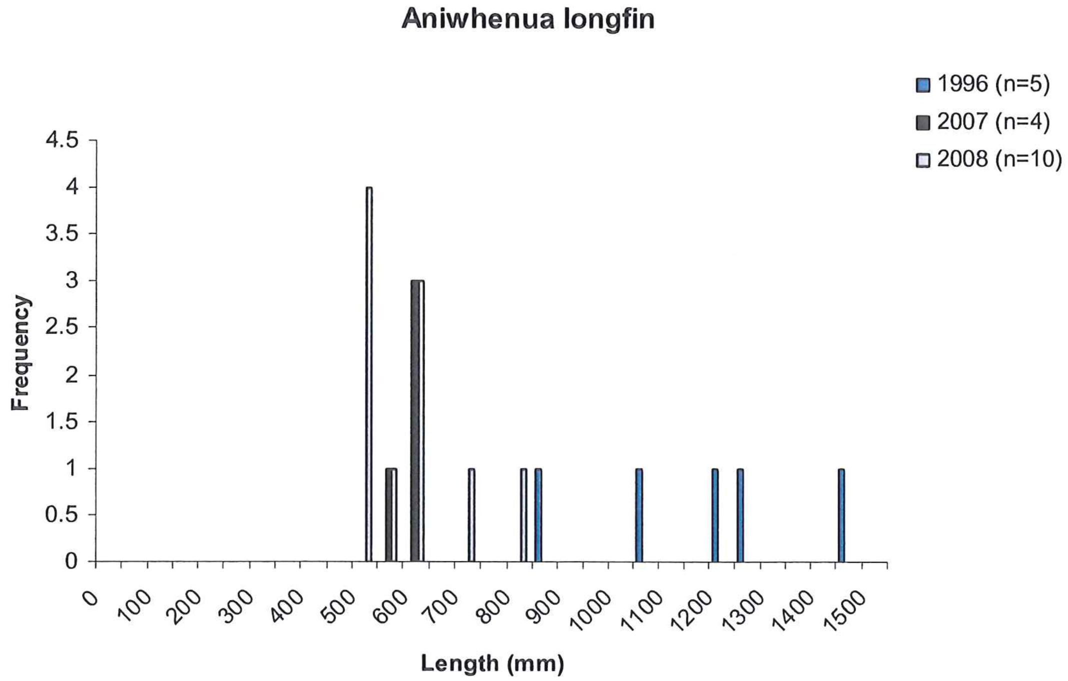


Figure 14: Length frequency distributions of shortfins caught in coarse mesh fyke nets sets in lakes Matahina and Aniwhenua in 1996, 2007 and 2008.



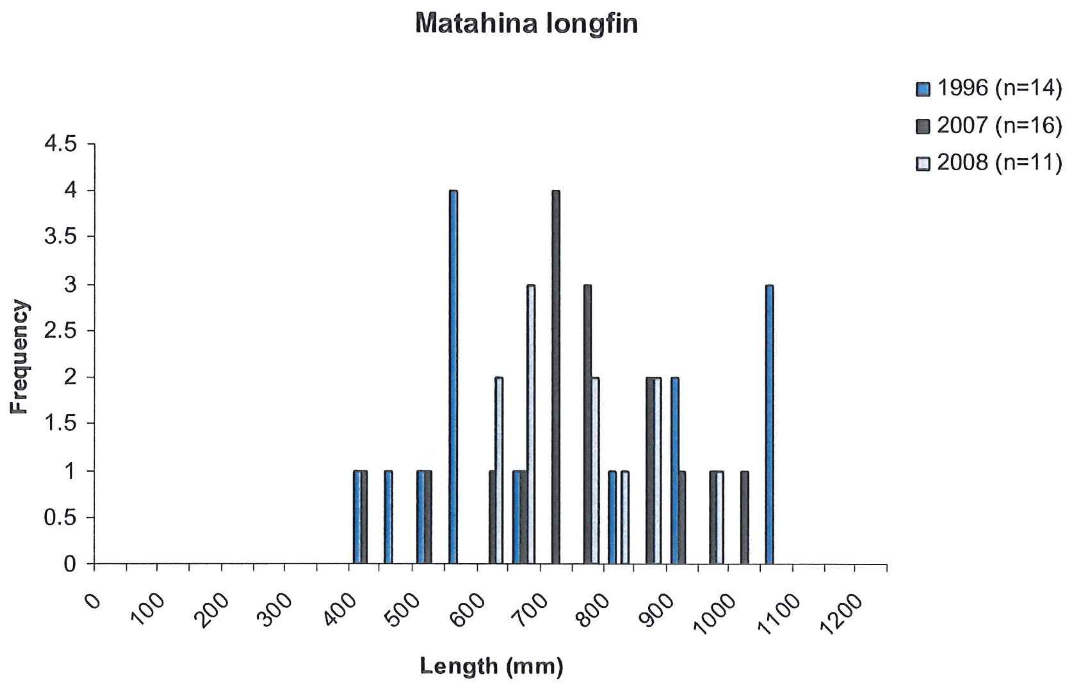


Figure 15: Length frequency distributions of longfins caught in coarse mesh fyke nets sets in lakes Matahina and Aniwhenua in 1996, 2007 and 2008.

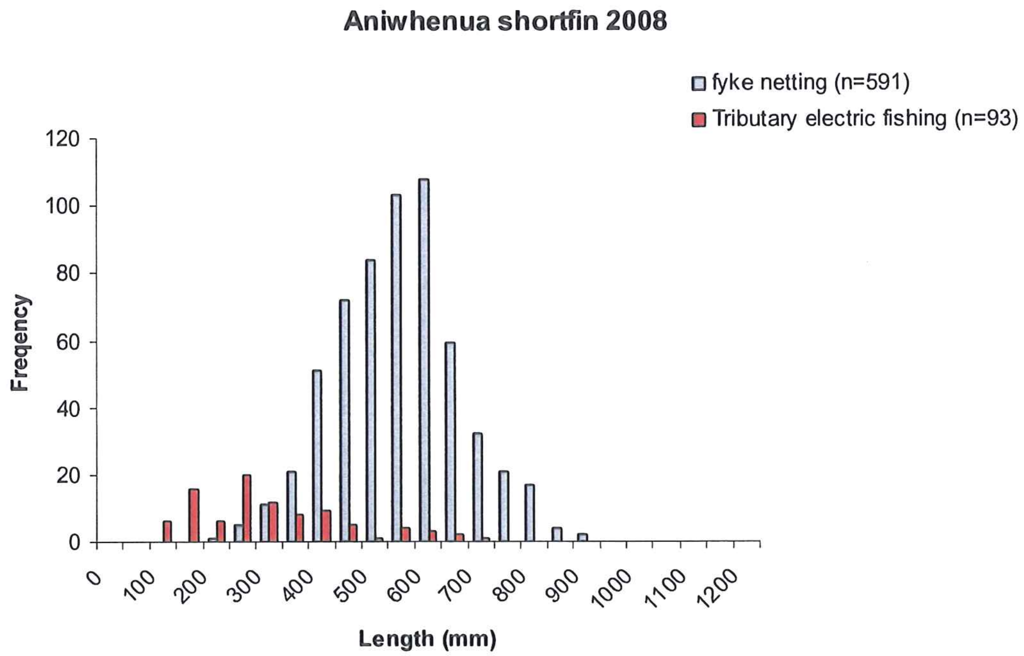


Figure 16: Length frequency distributions of shortfins caught in all fyke nets sets in Lake Aniwhenua and shortfins caught by electric fishing Aniwhenua tributaries and lake margin 2008.

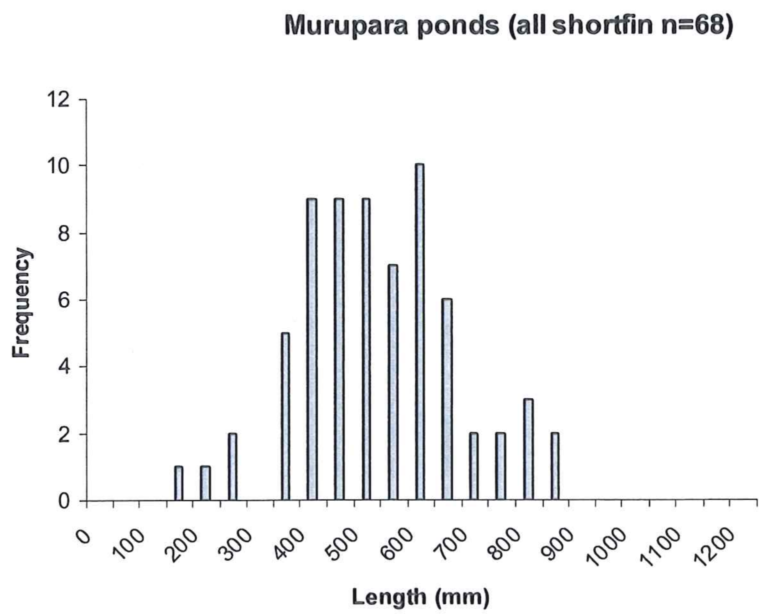


Figure 17: Length frequency distributions of eels (all shortfin) caught, in fine mesh fyke nets sets in the Murupara ponds 2008.

Table 9: Comparison of length-weight regressions for shortfin (Sf) and longfin (Lf) eels captured from lakes Matahina and Aniwhenua in 1996, 2007 and 2008. The regression is in the form: ln weight = a + b*ln length. Regression coefficient (r^2) and standard error (s.e.) on slope 'b' also shown.

		Species	*N*	Length range (mm)	Weight range (g)	*a*	*b* ± s.e.	r^2
Matahina	1996	Sf	72	350-1015	68-3320	-14.49	3.22 ± 0.06	0.98
		Lf	5	375-1020	147-3300	-13.47	3.11 ± 0.05	0.99
Matahina	2007	Sf	125	240-913	130-1835	-12.10	2.85 ± 0.07	0.94
		Lf	23	365-1180	120-3285	-13.53	3.10 ± 0.11	0.97
Matahina	2008	Sf	265	135-912	10-1810	-13.44	3.06 ± 0.04	0.96
		Lf	21	460-904	250-2250	-13.90	3.16 ± 0.16	0.95
Aniwhenua	1996	Sf	55	435-906	145-1470	-13.63	3.08 ± 0.06	0.98
		Lf	5	818-1430	1500-10000	-15.99	3.48 ± 0.18	0.99
Aniwhenua	2007	Sf	93	325-880	75-1395	-11.77	2.80 ± 0.07	0.95
		Lf	6	380-600	145-605	-12.68	2.98 ± 0.19	0.98
Aniwhenua	2008	Sf	591	175-872	10-1480	-13.80	3.11± 0.04	0.92
		Lf	31	218-1170	20-4760	-14.32	3.22± 0.07	0.99

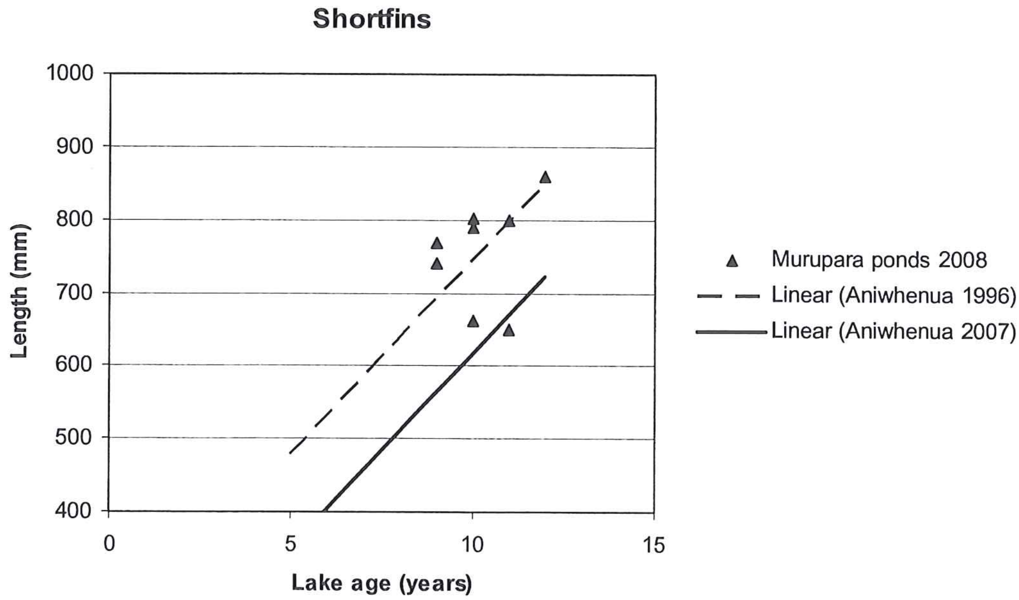


Figure 18: Length at age plot for shortfins from Murupara ponds 2008. Lake Aniwhenua length-at-age regression lines for 1996 and 2007 also shown. (See Appendix 3 for equation of lines shown).

3.4.4 Other fish species

In addition to eels, brown and rainbow trout, common bullies, goldfish and one giant kokopu (Lake Matahina) were caught during the survey (Table 10 & 11). The CPUE of common bullies was higher in Lake Matahina than in Lake Aniwhenua. This may be due to better habitat in Lake Matahina for bullies and/or lower predation by trout and eels in that reservoir. No galaxiids were caught in Lake Aniwhenua and no gambusia were caught from netting in either reservoir. However, gambusia were found to be abundant in Lake Aniwhenua when the lake margin was electric fished in December 2008. Over 400 juvenile goldfish were also caught in the Murupara ponds from four fine fyke nets.

Table 10: CPUE ± s.e. of fish other than eels caught in Lake Matahina April 2007 and December 2008.

Matahina	Nets	Common bully	Giant kokopu		Rainbow trout		Brown trout		Goldfish	
	(n)		Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult
Coarse mesh fykes 07	20	-	-	0.15 ± 0.11	0.05 ± 0.05	0.05 ± 0.05	-	0.05 ± 0.05	-	0.20 ± 0.09
Coarse mesh fykes 08	15	0.2 ± 1.15	-	0.06 ± 0.06	-	-	-	0.13 ± 0.13	0.06 ± 0.06	0.20 ± 0.10
Fine mesh fykes 07	15	85.5 ± 20.9	0.05 ± 0.05	0.15 ± 0.11	-	-	0.06 ± 0.06	-	0.26± 0.27	0.47 ± 0.27
Fine mesh fykes 08	15	6.67± 3.70	-	-	-	-	-	-	0.06 ± 0.06	0.20±0.20
G-minnows 07	21	50.1 ± 8.39	-	-	-	-	-	-	0.43± 0.20	-
G-minnows 08	30	35.6 ± 10.40	-	-	-	-	-	-	-	-
Total numbers 2007		**2267**	**1**	**6**	**1**	**1**	**1**	**1**	**13**	**11**
Total numbers 2008		**1171**	**0**	**1**	**0**	**0**	**0**	**2**	**2**	**6**

Table 11: CPUE ± s.e. of fish other than eels caught in Lake Aniwhenua, April 2007 and December 2008.

Aniwhenua	Nets	Common bully	Gambusia	Rainbow trout		Brown trout		Goldfish	
	(n)			juvenile	adult	juvenile	adult	juvenile	adult
Coarse mesh fykes 07	20	-	-	-	0.05 ± 0.05	-	0.05 ± 0.05	-	0.05 ±0.05
Coarse mesh fykes 08	30	0.03 0.03	-	-	0.03 0.03	-	0.20 0.08	0.03 0.03	-
Fine mesh fykes 07	15	3.67 ± 1.08	23.87 ± 23.87	-	-	-	-	2.47± 1.65	-
Fine mesh fykes 08	30	-	-	-	-	-	0.23 0.10	0.03 0.03	-
G-minnows 07	20	0.20 ± 0.11	-	-	-	-	-	-	-
G-minnows 08	54	0.94 0.23	-	-	-	0.02 0.02	-	0.02 0.02	-
Total numbers 2007		**58**	**358**	**0**	**1**	**0**	**1**	**38**	**1**
Total numbers 2008		**52**	**0**	**0**	**1**	**1**	**13**	**3**	**0**

4. Discussion

In excess of 20 million elvers have been transferred upstream of the two lower Rangitaiki River dams over the last two decades, with 7.7 million occurring in the last two summer migration seasons. The total number of longfins released in the 2007-08 season (929,000) is more than the 791,000 known to have been transferred between 1982 (when records began) and 2006. According to Beentjes et al. (1997) an annual stocking rate of 200 juveniles per hectare tends to be the norm for mesotrophic waters overseas. On that basis, and not taking account of tributaries and the mainstem, the two reservoirs (total surface area of about 500 ha) would only require about 100,000 elvers each year to be adequately stocked. This number, at least for shortfins, has therefore been well exceeded in past years.

The total eel catch for the 2008 survey for both lakes is the highest recorded to date with the catch per unit effort of shortfins in both fine and coarse mesh fykes double to five times that of previous surveys. Although the increase in catch between 1996 and 2008 can be attributed to increased recruitment, the dramatic increase between 2007 and 2008 is unlikely to be explained by that factor alone. Smith et al. (2007) noted that the 2007 survey was undertaken in early autumn when water temperature were between 13 and 15 °C and that at these low temperatures, eels notably juveniles, are less active and therefore less likely to be caught. Temperatures during the 2008 survey were between 17 and 23 °C so the 2008 catch records are expected to better reflect the size of the eel population now present in the reservoirs. There is, therefore, good evidence that eel numbers, at least of shortfins, have increased dramatically since 1996. This indicates that elver transfers have been successful in restoring the population of shortfins above the dams. However, the number of longfins remains low most likely because of the low number of longfin elvers available for transfer prior to 2006. To ensure that the population of longfins upstream of the dams increases, and to maintain the present populations of shortfins, the transfer of elvers needs to continue.

Smith et al. (2007) raised concerns about the lack of juvenile eels and elvers in lakes Matahina and Aniwhenua. This lack of juvenile eels and elvers recorded in 2007 now appears to be a result of sampling methods and survey timing, as the 2008 survey has produced good numbers of juvenile eels in the 350 to 450 mm bracket, notably in the fine mesh fyke nets. Small eels were also captured in brush traps but the method proved to be too labour intensive and less effective than electric fishing of streams and lake margins. Both fine mesh fykes and electric fishing thus appear the most effective methods of assessing the population of juvenile eels and could be used in future to assess the eel population upstream of the dams.

As found in 1996, 1999/2000 and 2007, both trout species were 'common' to 'abundant' in most streams surveyed in 2008. In contrast, the overall abundance of longfins and shortfins in riverine habitats of the upper catchment remains 'low'. However, there were six sites surveyed in 2008 where shortfins were found to be 'common' and one site where they were 'abundant' (Mangahouhi Stream). The majority the eels caught at these sites were juveniles and all the sites had soft bottoms (sand or mud) and/or undercut banks. As previously noted by Young (2000), shortfin eels tend to be more common in slow-flowing or static waters (see also Hanchet, 1990; Jowett & Richardson, 1995; Glova et al. 1998). Certainly, growth rates of shortfins captured in the Murupara ponds in 2008 were high indicating that the habitat was well suited to this species. Given that most recruits are currently shortfins, there is value in protecting and enhancing habitats within the catchment that suit this species.

In the current and previous surveys, eel catches were dominated by shortfin eels, with longfin eels making up only about 11% of the catch in 2007 and 2008. This was expected as the bulk of elvers transferred have been shortfins, with longfins constituting only 8.5% of total elvers estimated to have been transferred between 2001 and 2006. Such a low proportion of longfins in the population of elvers arriving at hydro dams is typical of North Island rivers. However, since 2006 longfin numbers at Matahina Dam have increased to 24% of the total catch. Hopefully this increase in the proportion of longfins will be maintained in future and will provide the necessary recruits for the excellent longfin habitat available in the upper Rangitaiki River catchment.

For longfin populations to be maintained in the long-term, a proportion of the population needs to be able to reach maturity and safely migrate out to sea. To achieve this in the Rangitaiki catchment, shortfins rather than longfins need to be targeted in future fisheries. Safe downstream passage for mature eels also needs to be provided. However, as elvers are not believed to return to rivers where their parents originated (homing), measures to increase recruitment need to occur nation-wide. Furthermore, because eels are slow growing, protection efforts need to be maintained on a long-term basis, despite taking decades to show results.

In addition to eels, a population of giant kokopu has established in Lake Matahina. Presumably this is a result of the transfer of juvenile kokopu (whitebait) across the dam as part of the current trap and transfer operations but it is possible that a self-sustaining population has established in this reservoir. Giant kokopu larvae and juveniles are now expected to be produced by the reservoir, and this could possibly increase the potential number of giant kokopu whitebait re-entering the Rangitaiki River.

5. Conclusions

The number of eels and the size distribution of the populations obtained upstream of the two lower-most hydro dams on the Rangitaiki River in 2008 indicate that elvers are surviving the transfer process and that habitat upstream of the dams is capable of supporting a range of age classes of eel.

Currently the eel catch is dominated by shortfin eels but this is to be expected as elvers available through the catch and transfer programme are predominantly shortfins. However, there has been a large increase in the number of longfin elver available for transfer in the past two seasons and increases in the number of larger specimens should occur in the near future.

The density of eels in most tributaries was low and this is attributed mainly to the habitat which was mainly fast flowing rocky water better suited to trout and longfin eels rather than to shortfin eels. An increase in longfin recruits would help to fill these relatively vacant habitats.

A number of soft bottomed streams were found to harbour good numbers of shortfin eels, indicating that there would be value in protecting and enhancing this type of habitat to ensure a wider supply of eels for harvest. An example of such habitat is the Murupara ponds where eel growth rate was high.

A harvestable population of shortfins has existed in the reservoirs for some time and although there are indications that growth rate may be slowing more data are required to check this. Consequently it is recommended that the population continues to be monitored at 3-5 years intervals so that an adjustment to the number of elvers transferred can be made should decreased growth rates be confirmed. Although larger eels can be targeted with coarse mesh fyke nets, the present study has shown that smaller eels are mostly captured with fine meshed fyke nets and by electric fishing (where suitable habitats for this method exist). Therefore, a combination of all these methods needs to be utilised in future population assessments.

Although the number of longfins transferred over the last two summers has increased and should, in time, show an improvement of the population upstream of the dams, numbers remain low. Consequently, it is strongly recommended that added protection of longfins be provided not only within the greater Rangitaiki catchment, but nation-wide. Protection measures that could be implemented within the upper Rangitaiki catchment as part of such a programme include:

- Encouraging (through an education programme) the release of all longfins captured, notably fish greater than 75 mm as they are all females.

- Enhancement of suitable shortfin habitats, to provide an alternative supply of eels for harvest.

- Better screening of the power station intakes and provision of by-passes and/or of effective truck and transfer programme for downstream migrants.

6. Acknowledgments

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8. Appendix 1

Water temperature and conductivity of waterways surveyed

Table A1: Temperature and water conductivity for some of the sites fished in April 2007 and December 2008.

Location	Water temperature (°C)	Conductivity (µs/cm)
Lake Aniwhenua boat ramp 07	14.5	94.4
Lake Aniwhenua boat ramp 08	17.1	70.0
Lake Matahina (upper) 07	13.5	91.4
Lake Matahina boat ramp 07	15.4	87.6
Lake Matahina 08	19 -21	70.0

9. Appendix 2

Eel catch records for all nets set in 1996, 2007 and 2008

Table A2: Number and type of net and trap set in Lakes Matahina and Aniwhenua 1996, 2007 and 2008 and number of eels caught. **Sf,** = shortfins, **Lf** = longfins, **Super fykes** = 0.75 mm square mesh, **Coarse fykes** = 20 mm stretch mesh (12 mm mesh 2008), **Fine fykes** = 5 mm stretch mesh, **G** minnow = 4 mm square mesh, - = method not used

	Number of nets & traps set				Number of eels captured							
	Super fyke	Coarse fyke	Fine fyke	G-minnow	Super fyke Sf	Super fyke Lf	Coarse fyke Sf	Coarse fyke Lf	Fine fyke Sf	Fine fyke Lf	G-minnow Sf	G-minnow Lf
Matahina 1996	9	27	-	-	17	-	93	20	-	-	-	-
Matahina 2007	-	20	15	21	-	-	88	16	44	7	1	-
Matahina 2008	-	15	15	30	-	-	135	11	130	10	4	
Aniwhenua 1996	10	34	-	-	-	1	106	4	-	-	-	-
Aniwhenua 2007	-	20	15	20	-	-	53	4	35	2	-	-
Aniwhenua 2008	-	30	30	54	-	-	291	10	391	21	1	-

Table A3: Catch per unit effort (CPUE) in Lakes Matahina and Aniwhenua 1996, 2007 and 2008. CPUE expressed per location, species and net type. **CPUE** = number of eels/ net; **Sf** = shortfins, **Lf** = longfins, **s.e.** = standard error, **Coarse fykes** = 20 mm stretch mesh (12 mm mesh 2008), **Fine fykes** = 5 mm stretch mesh, **G** minnow = 4 mm square mesh, - = method not used.

	CPUE ± s.e.							
	Super fyke Sf	Super fyke Lf	Coarse fyke Sf	Coarse fyke Lf	Fine fyke Sf	Fine fyke Lf	G-minnow Sf	G-minnow Lf
Matahina 1996	1.9 ± 0.3	-	3.4 ± 0.4	0.6 ± 0.1	-	-	-	-
Matahina 2007	-	-	4.4 ± 1.3	0.8 ± 0.3	3.0± 1.0	0.5 ± 0.2	0.1 ± 0.1	-
Matahina 2008	-	-	9.0 ± 1.8	0.7 ± 0.2	8.6 ± 2.3	0.7 ± 0.3	0.13 ± 0.1	-
Aniwhenua 1996	-	0.1 ± 0.1	3.4 ± 2.9	0.1± 0.1	-	-	-	-
Aniwhenua 2007	-	-	2.6 ± 0.8	0.2 ± 0.1	2.3 ± 0.9	0.1 ± 0.1	-	-
Aniwhenua 2008	-	-	9.7 ± 1.7	0.3 ± 0.1	13.0 ± 2.7	0.7 ± 0.2	0.03 ± 0.03	

10. Appendix 3

Size, age and growth records Matahina and Aniwhenua 1996 and 2007.

Table A4: Comparison of length-at-age regressions for shortfin (Sf) and longfin (Lf) eels captured from lakes Matahina and Aniwhenua in 1996 and 2007, and Murupara ponds in 2008. The regression is in the form length = a + b (lake-age). Standard error (s.e.) of regression slope (b) and mean annual length increment also shown. – = regression unable to be determined as number of records (N) is small and/or range of eel size too small.

	Species	*N*	Length range (mm)	Lake age range (y)	*a*	*b*± s.e.	r^2	Mean annual length inc. ± s.e. (mm)
Matahina (1996)	Sf	28	350-1015	3-24	312.9	31.86±4.13	0.70	75.4 ± 3.2
	Lf	3	375-520	5-9	-	-	-	56.9 ± 5.9
Matahina (2007)	Sf	20	255-810	3-12	42.4	53.55 ± 8.69	0.81	59.74 ± 1.95
	Lf	18	395-1100	6-27	254.2	29.37 ±7.05	0.52	53.8 ± 3.78
Aniwhenua (1996)	Sf	22	435-900	5-14	213.8	52.95 ± 9.87	0.63	74.0 ± 2.81
	Lf	5	818-1430	9-26	-	-	-	54.5 ± 7.8
Aniwhenua (2007)	Sf	20	420-886	4-12	85.0	57.07 ± 9.15	0.82	63.85 ± 1.90
	Lf	5	380-610	4-10	142.0	37.50 ± 9.49	0.84	57.20 ± 4.15
Murupara ponds (2008)	Sf	8	650-860	9-12				74.58 ± 3.40

Table A5: Weight, age and mean annual weight increments for shortfin (Sf) and longfin (Lf) eels captured from lakes Matahina and Aniwhenua in 1996, 2007. Number of eels aged (N), and standard error (s.e.) on mean annual weight increment also shown.

	Species	*N*	Weight range (g)	Lake age range	Mean annual weight increment ± s.e. (g)
Matahina (1996)	Sf	28	68-3320	3-24	52.79 ± 5.80
	Lf	2	147-378	5-9	35.7 ± 6.30
Matahina (2007)	Sf	20	62-945	3-12	46.75 ± 4.56
	Lf	18	115-3835	6-27	91.9 ± 16.9
Aniwhenua (1996)	Sf	22	145-1430	5-14	71.39 ± 7.57
	Lf	5	1500-10000	9-26	251.20 ± 43.67
Aniwhenua (2007)	Sf	20	175-1495	4-12	69.46 ± 6.18
	Lf	18	9-19	4-10	53.50 ± 5.80