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watercare services limited

Hunua Ranges Dams

Freshwater Fish Survey, 2008

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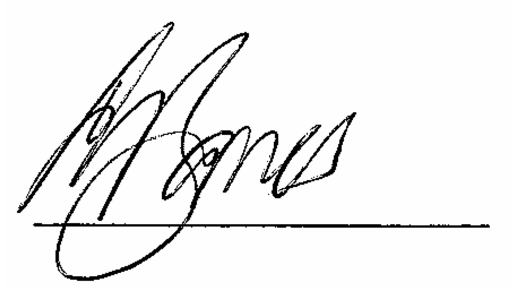

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Hunua Ranges Dams – Freshwater Fish Survey, 2008

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1 Executive Summary

Watercare Services Limited own and operate four water supply reservoirs (Cosseys, Wairoa, Upper Mangatawhiri and Mangatangi) within the upper Hunua Ranges, which maintain the majority of Auckland's water supply. The construction of dams can impact heavily upon the freshwater fish present in the headwater streams above the dam, as close to half of New Zealand's freshwater fish species are diadromous and undergo migrations between fresh and salt water during their life cycle. The four Hunua water supply dams were built between 1955 and 1977, but since construction no provision for fish passage has been made at any of the reservoirs. Since construction of the dams, only one fish survey has been undertaken (in 1989) and the results of this suggested that unique fish assemblages had developed within the reservoirs. To confirm the presence of such fish communities, NIWA were contracted to conduct a freshwater fish survey of the four Hunua reservoirs and their associated headwater streams.

Six native fish species (longfin eels, shortfin eels, banded kokopu, koaro, shortjaw kokopu and Cran's bullies) and three introduced species (rainbow trout, perch and rudd) were recorded within the four Hunua reservoirs. Longfin and shortfin eels were the only fish present in all reservoirs. For all other species, a heterogenous distribution existed. Banded kokopu and koaro were found above all reservoirs except Mangatangi, and shortjaw kokopu were only found above Mangatawhiri Reservoir. Cran's bully and trout were only found at Mangatangi and Mangatawhiri reservoirs. Invasive fish species (perch and rudd) were only found at Cosseys Reservoir. Mangatawhiri Reservoir contained the highest diversity of all sites with all six native fish species and trout recorded.

The results of the present survey have confirmed that unique and rare fish communities exist above the Hunua dams. The high densities of banded kokopu above the dams, and in particular Wairoa Reservoir, are significant at both a regional and national scale. Land locked populations of banded kokopu are absent in most North Island lake systems, and with the exception of some Nelson lakes, no other New Zealand lake system contains a fish community where banded kokopu are the dominant species. As with banded kokopu, the koaro populations above the Hunua dams are also significant at both a regional and national scale. Within the Auckland region, koaro are rare with few records outside of the Hunua and Waitakere Ranges. Within the North Island, lake populations have declined greatly with koaro extinct in some of the central North Island lakes and scarce in others. Of particular significance is the presence of shortjaw kokopu above Mangatawhiri Dam. Shortjaw kokopu are the rarest of the five galaxiid species that comprise our whitebait fishery and this is the first record of a land-locked population for this species.

Based on these survey results, installing fish passage provisions is not the most appropriate management plan for all dam sites. Although implementing a Trap and Transfer programme may increase species richness within reservoirs, this is only one measure of biodiversity and increasing the diversity of lake ecosystems at a national scale should be considered. Given the significance of the fish communities above the

dams, the native fisheries management plan for consents should consider all four dams as a whole. As such, we recommend the following native fisheries management plans:

- Wairoa Reservoir

Implement a downstream Trap and Transfer programme for migrant eels to allow breeding, and protect banded kokopu populations.

- Mangatangi Reservoir

Translocate eels to allow breeding, discontinue trout releases, and stock and protect koaro and shortjaw kokopu populations. Examine the degree of natural recruitment of eels above the dam.

- Mangatawhiri Reservoir

Implement a downstream Trap and Transfer programme for migrant eels to allow breeding, and protect the rare population of shortjaw kokopu. Further investigate the degree of natural recruitment of galaxiids above the dam.

- Cosseys Reservoir

Implement an upstream and downstream Trap and Transfer programme for native fish species (eels, koaro and banded kokopu) assessing the effectiveness through further fish surveys. Monitor perch and rudd populations.

2 Introduction

The Hunua Range lies south-east of metropolitan Auckland, within the Hunua Ecological District. The park is approximately 17 500 ha in area, containing the largest tract of indigenous forest on the mainland within the Auckland Region (Barnes 2004). Watercare Services Limited own and operate four water supply reservoirs (Cosseys, Wairoa, Upper Mangatawhiri and Mangatangi) within the upper Hunua Ranges, which maintain the majority of Auckland's water supply.

The construction of dams can impact heavily upon the freshwater fish present in the headwater streams above the dam. Close to half of New Zealand's freshwater fish species are diadromous and undergo migrations between fresh and salt water during their life cycle. Aside from the loss and degradation of habitat, one of the most significant causes of the decline in freshwater fish populations in New Zealand are anthropogenic migration barriers, such as dams, culverts and weirs. Some indigenous fish species can withstand periods out of water and possess the ability to 'climb' the wetted margins of in-stream obstacles. However, dams are only passable if they contain a spillway or structure that maintains continuity of the reservoir water with the stream below the dam. Additionally, dams present a far greater challenge for climbing fish compared to natural obstacles such as waterfalls, even at a similar height. This is because the wetted margin present on most spillways is less suitable, lacking resting areas and increasing the risk of desiccation through exposure to the sun and wind. The increased exposure also results in increased predation risk. Because of these effects, resource consents given for the construction of dams generally include conditions relating to the provision of fish passage to maintain biodiversity of fish populations above the impoundment. Since construction of the Hunua dams, no provision for fish passage has been made at any of the reservoirs.

The four dams were built between 1955 and 1977 and Mangatawhiri Reservoir is the only dam that has an external spillway, providing a potential passage way for sea-run fish to recruit to the headwater streams. The other three dams appear impassable to climbing fish. Therefore it is likely that the fish communities above Cosseys, Wairoa, and Mangatangi dams have formed land-locked populations.

Since construction of the dams, only one fishing survey (Slaven 1990) has been undertaken within the four reservoirs and associated headwater streams. Results from this survey suggested that above the dams, unique fish assemblages, significant at both a regional and national scale, may exist. However, this is not conclusive based on only the data collected in 1989. In order to determine whether installing fish passage provisions is the most appropriate management plan, the current fish communities that exist above the reservoirs need to be determined. As such, NIWA were contracted to undertake a freshwater fish survey of the four Hunua reservoirs and their associated headwater streams. This report presents the results of this survey and provides recommendations pertaining to the most appropriate environmental remediation and mitigation for the absence of fish passage provisions at each reservoir.

3 Methods

3.1 Sampling sites

In total, 250 sites were sampled within the four reservoirs and headwater streams (Figures 1 – 4). Sites within each reservoir were sampled using a variety of set nets, whilst tributary streams were electric fished. To ensure the fish communities in tributaries were sampled effectively, both semi-quantitative and spot electric fishing was undertaken within each stream (Figures 1 – 4). All sampling was conducted between the 10th and 28th March 2008.

3.2 Methodology

3.2.1 Reservoirs

Within each reservoir the following types of nets were set. All nets were left overnight and lifted the following morning:

- 10 Panel gill nets. 3 x 10 m panels of 60, 80 & 110 mm mesh, were set at tributary mouths and along lake margins in quiet waters.
- 40 Fykes nets. 20 Fine mesh (5 mm) and 20 coarse mesh (20 mm) single leader nets baited with sardines were set along shallow lake margins in quiet pools or backwaters.

The locations of nets for each reservoir are shown in Figures 1 – 4 (site co-ordinates are given in Appendix I).

3.2.2 Tributary Streams

Tributary streams were sampled using an EFM 300 battery powered back-pack electric fishing machine. Fishing was always undertaken in an upstream direction. When fishing in pools or backwaters, stunned fish were captured in small wire-mesh dip nets. When fishing within a run or moving water, a hand-held seine net was placed downstream of the anode to capture stunned fish carried downstream by the flow.

For each reservoir between 10 and 15 sites were electric fished semi-quantitatively (site co-ordinates are given in Appendix I). Sites included those sampled by Slaven (1990) as well additional sites to expand on the distribution of habitat sampled within the catchment. At each site a 30 m stretch of water was sampled using single pass electric fishing. At the end of the pass all fish captured were identified to species, measured (total length) and then released. At sites where *Gobiomorphus* sp. were captured, a sub-sample was brought back to the laboratory to confirm identification.

Additionally, streams were spot fished as comprehensively as resources allowed to ensure all fish species potentially present in the catchment had been identified. Spot fishing covered all habitats present but concentrated on the habitat of fish species that had not previously been recorded in each catchment. All fish captured were recorded and lengths were determined.

3.2.3 Determining the Life History and Age of Fish

As Mangatawhiri Reservoir is the only dam to contain a spillway, and therefore a potential migratory pathway for diadromous climbing fish species, an assessment of diadromy was undertaken in koaro (*Galaxias brevipinnis*), the most adept climber of the galaxiid species. Additionally, a shortjaw kokopu (*Galaxias postvectis*) was analysed, as a handful of shortjaw kokopu were located above the dam and presently there is no record of a land-locked population of this species within New Zealand. To determine if the galaxiids were sea-run fish, an analysis of the strontium:calcium (Sr:Ca) ratio within the otoliths (ear bones) was performed. Sr:Ca ratios are higher when fish are reared in a marine environment compared to a freshwater environment (Tzeng 1996; Shen et al. 1998) and the ratios can be used as indicators of whether fish have a diadromous life cycle with larvae reared at sea or if they have completed their life cycle in freshwater.

Otoliths were examined from 18 koaro collected above the dam (site MW 14), 15 koaro collected from below the dam (Milnes Stream, E2703898, N6452428), and one shortjaw kokopu collected from site MW8. The otoliths were removed from fish, dried, and then embedded in an epoxy resin. Abundances of strontium (^{88}Sr), calcium (^{43}Ca and ^{44}Ca), barium (^{138}Ba), magnesium (^{25}Mg) and manganese (^{55}Mn) were measured by laser ablation using an inductively coupled plasma-mass spectrometer (ICP-MS) at the Australian National University in Canberra. Otoliths were drilled through along the shortest axis, using the spike in manganese to determine when the nucleus was hit.

To determine if eels (*Anguilla* sp.) are also climbing the spillway at Mangatawhiri Dam and recruiting to the reservoir population, five eels were aged using annual growth rings present within the otoliths. Otoliths were prepared following the methods of Todd (1980). Otoliths were broken in half transversely by placing them, convex side uppermost, between the folds of a piece of thin, clear plastic, and pressing across the centre with a scalpel blade. The otolith halves were burnt by holding the broken edge against a bunsen flame until the edge turned brown. The otoliths were then embedded in clear silastic 732 RTV with the burned edge uppermost. Mounted otoliths were viewed using a Leica Wild MZ8 microscope and annual hyaline rings were then counted across the largest otolith axis. As a comparison, otoliths from 12 eels captured from Mangatangi Reservoir were also examined, as this dam does not contain a spillway and the intake valve tower is thought to be unsurpassable to climbing fish.

Figure 1:

Sites sampled within Cosseys Reservoir. Red circles signify locations of nets set within the reservoir. Green circles represent areas of tributaries that were spot electric fished and blue circles represent semi-quantitative electric fishing sites which are labelled C1 through C11.

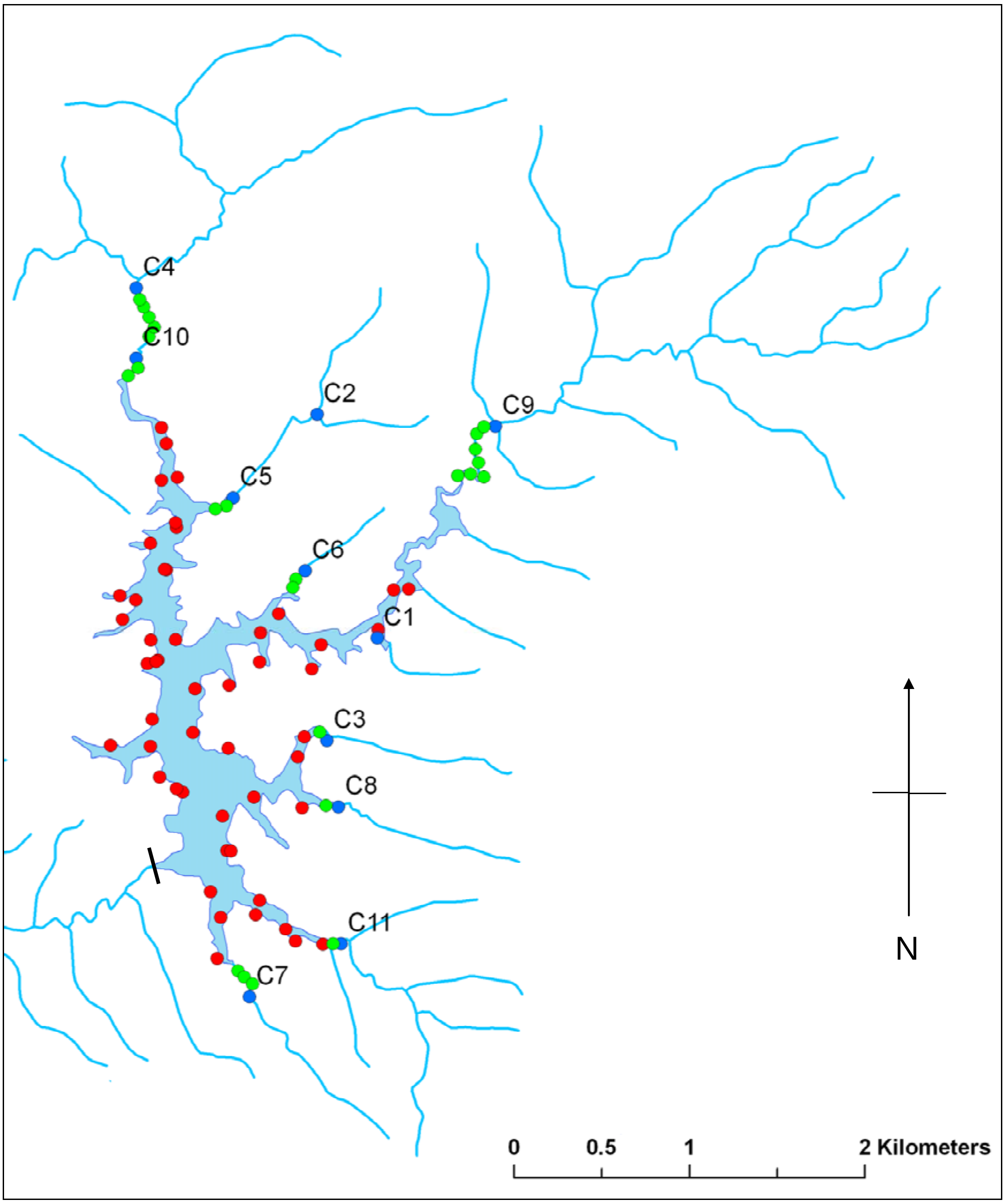


Figure 2:
Sites sampled within Wairoa Reservoir. Red circles signify locations of nets set within the reservoir. Green circles represent areas of tributaries that were spot electric fished and blue circles represent semi-quantitative electric fishing sites which are labeled W1 through W10.

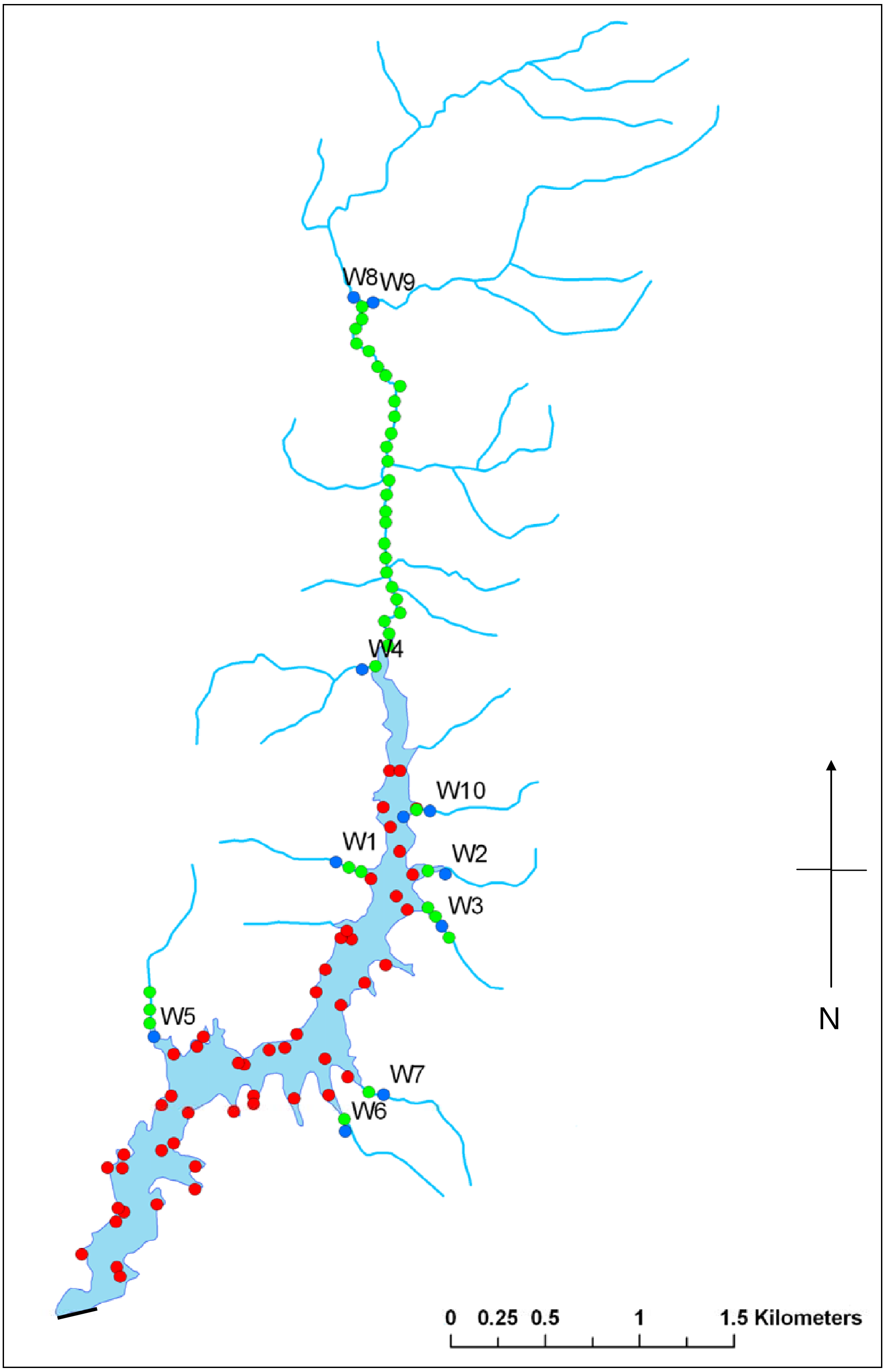


Figure 3:
Sites sampled within Mangatawhiri Reservoir. Red circles signify locations of nets set within the reservoir. Green circles represent areas of tributaries that were spot electric fished and blue circles represent semi-quantitative electric fishing sites which are labeled MW1 through MW14.

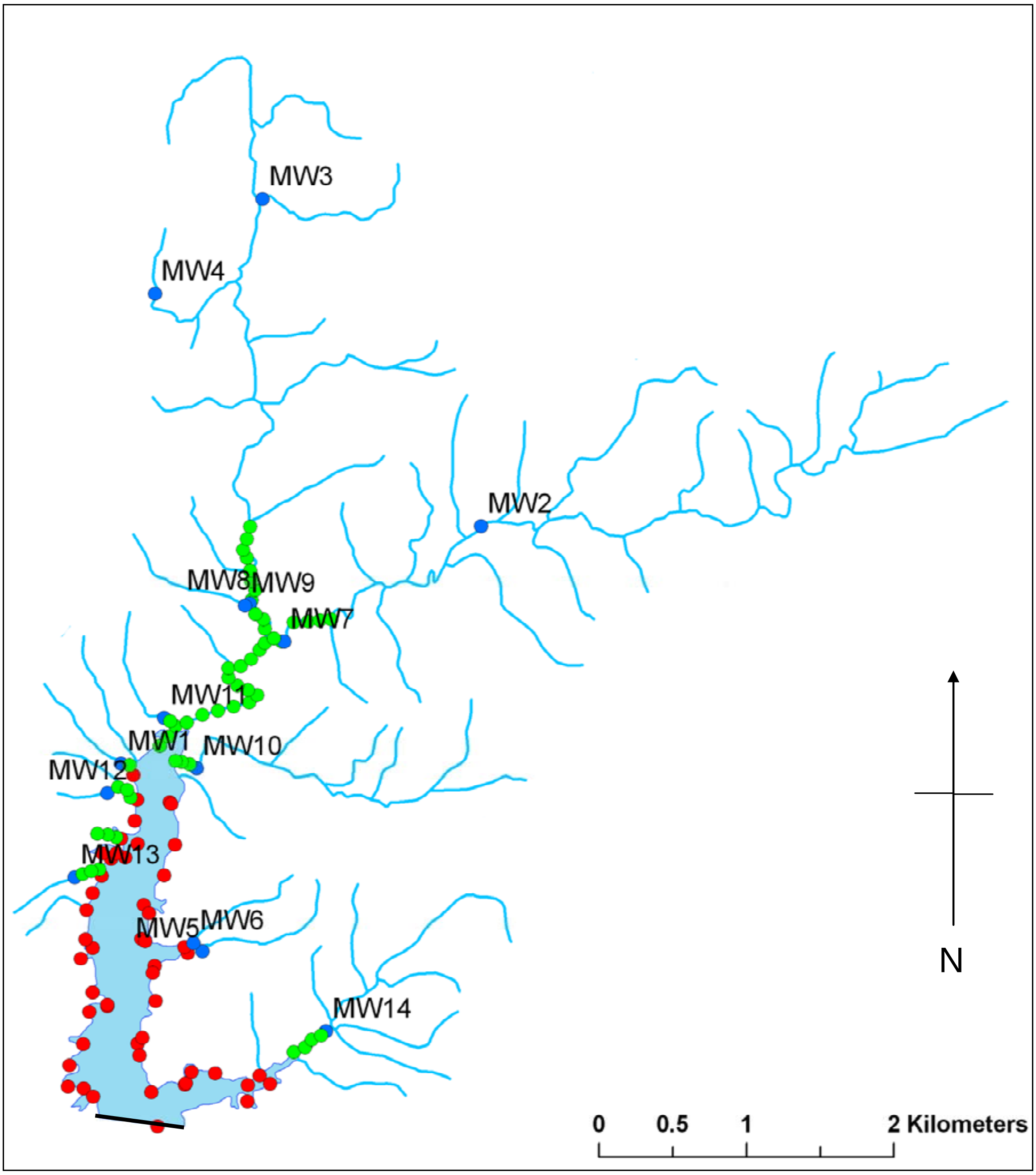
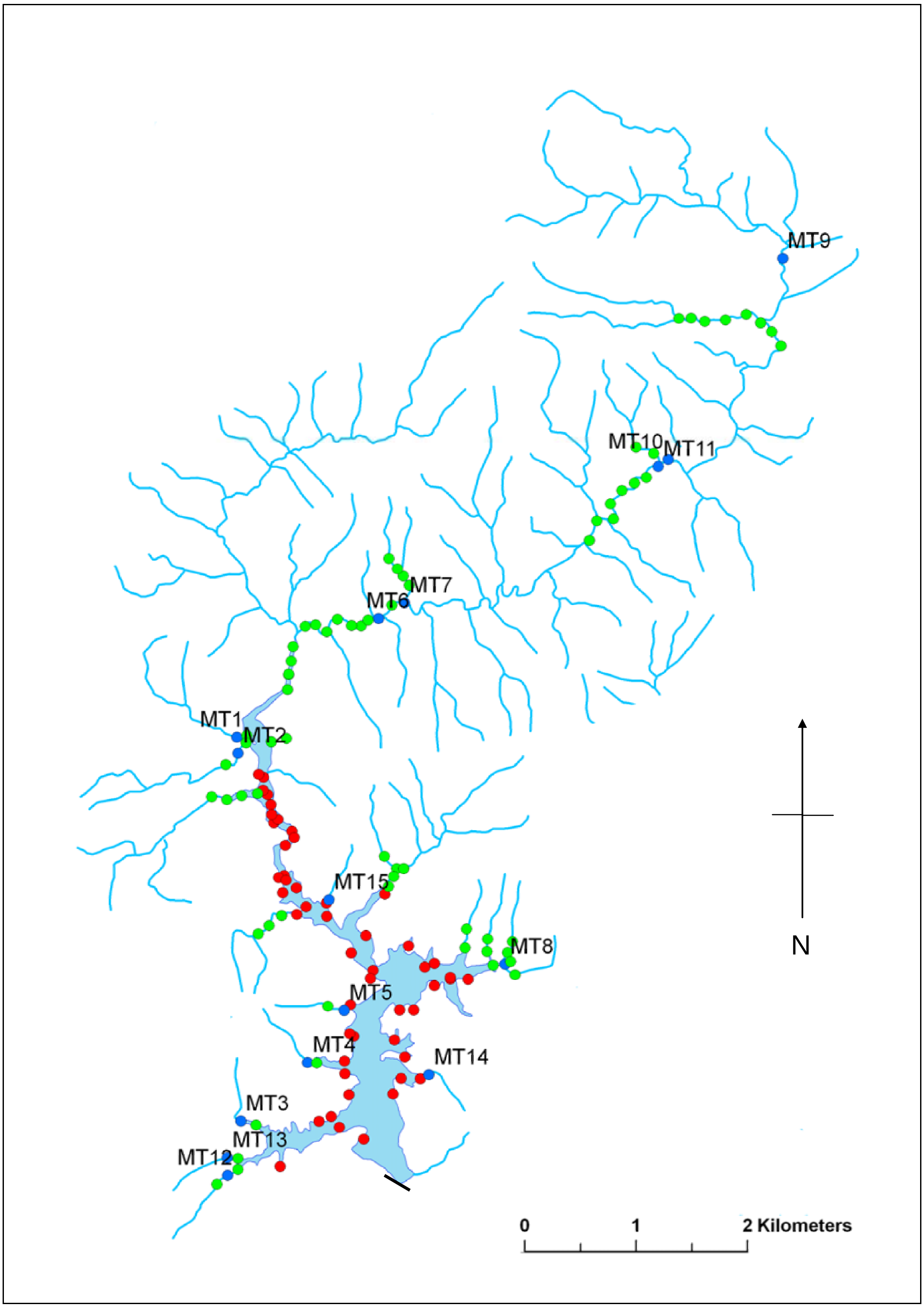


Figure 4:

Sites sampled within Mangatangi Reservoir. Red circles signify locations of nets set within the reservoir. Green circles represent areas of tributaries that were spot electric fished and blue circles represent semi-quantitative electric fishing sites which are labeled MT1 through MT15.



4 Results & Discussion

Six native fish species and three introduced fish species were recorded within the four Hunua reservoirs (Table 1). Both eel species were the only fish present in all reservoirs. For all other species, a heterogenous distribution exists between the reservoirs. Cran's bully and trout were only found above the Mangatangi and Mangatawhiri reservoirs, and no galaxiid species were found above Mangatangi Reservoir. Coarse fish species (perch and rudd) were only found at Cosseys Reservoir. Mangatawhiri Reservoir contained the highest diversity of all sites with all six native fish species and trout recorded. Koura, the freshwater crayfish, was also found and it was common in all four reservoirs.

Table 1:

Fish species recorded within the four Hunua reservoirs and headwater streams (* represents diadromous species, † signifies crustaceans).

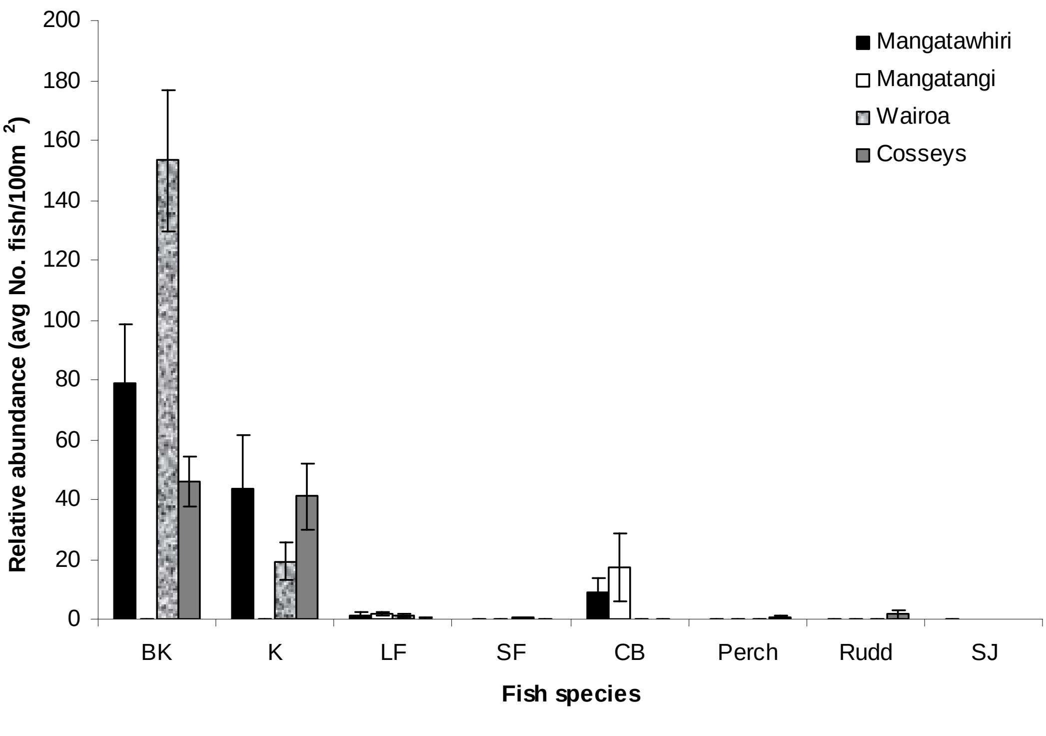
Fish & Crustacean Species		Presence/Absence			
Common Name	Scientific Name	Cosseys	Wairoa	Mangatawhiri	Mangatangi
Native Species					
Shortfin eel*	*Anguilla australis*	X	X	X	X
Longfin eel*	*Anguilla dieffenbachii*	X	X	X	X
Koaro*	*Galaxias brevipinnis*	X	X	X	
Banded kokopu*	*Galaxias fasciatus*	X	X	X	
Shortjaw kokopu*	*Galaxias postvectis*			X	
Cran's bully	*Gobiomorphus basalis*			X	X
Koura†	*Parenephrops planifrons*	X	X	X	X
Introduced Species					
Rudd	*Scardinius erythrophthalmus*	X			
Perch	*Perca fluviatilis*	X			
Rainbow Trout	*Oncorhynchus mykiss*			X	X

4.1 Native fish species

4.1.1 Galaxiids

Banded kokopu and koaro were the most abundant galaxiids above the Hunua dams and were located above Cosseys, Wairoa and Mangatawhiri dams (Figure 5). Shortjaw kokopu were also located (in low densities) above Mangatawhiri Reservoir and this is the first record for this species above the Hunua dams (Figures 5; Table 2). The absence of galaxiids, primarily banded kokopu and koaro from Mangatangi catchment appears to be an anomaly. Given that both banded kokopu and koaro have formed strong land-locked populations above the other three reservoirs, the abundance of suitable habitat, and the distance inland and altitude of Mangatangi Reservoir is comparable to Mangatawhiri, these species would have been expected to be present within the Mangatangi headwater streams. It is also interesting that banded kokopu are absent downstream of the dam, with only one record of koaro within the Mangatangi Stream below the reservoir (New Zealand Freshwater Fish Database (NZFFD)). Their absence from the Mangatangi catchment as a whole may have arisen from local extinction after construction of the dam, and subsequently migration cues such as pheromones (Baker & Montgomery 2001; Baker & Hicks 2003) were reduced compared to neighbouring catchments. As such, recruitment of these diadromous fish to streams below the dam has diminished over time. Alternatively, galaxiids may have been absent from the catchment historically and the lack of migration cues from within the catchment may still be preventing juveniles from recruiting to accessible waters below the dam.

Figure 5:
Average abundance of fish species (per 100 m^2) across all tributary sites sampled above each dam. Error bars represent ± 1 standard error. Abbreviations: BK, banded kokopu; K, koaro; LF, longfin eel; SF, shortfin eel; CB, Cran's bully and SJ, shortjaw kokopu.



4.1.1.1 Banded kokopu

Banded kokopu were the most abundant galaxiid above all reservoirs. High densities were found in streams of Mangatawhiri and Cosseys reservoirs with extremely high numbers found within the Wairoa tributaries (Figure 5). Above Wairoa Dam, all sites sampled contained banded kokopu and within some streams, densities of over 200 fish per 100 m^2 were found (Table 2). Wairoa was also the only catchment where banded kokopu were captured within the reservoir itself (Figure 6). This may reflect either the extremely high densities of this species within the catchment, or the presence of exotic piscivorous fish (such as perch and trout present in Cosseys and Mangatawhiri respectively) restricting lake-dwelling galaxiids.

The densities of banded kokopu captured in the present survey are not directly comparable to the 1989 survey as Slaven (1990) only reports an abundance scale without a known area of water fished. Slaven (1990) also undertook the fish survey over winter when galaxiids are less active diurnally (David & Closs 2003; Baker et al. in review) and harder to draw out from cover locations with electric fishing.

Table 2:

Relative abundance of fish species (per 100 m^2) at all tributary stream sites (* signifies fish species recorded during spot fishing that were not found at the semi-quantitative sites). Abbreviations: BK, banded kokopu; K, koaro; LF, longfin eel; SF, shortfin eel; CB, Cran's bully; SJ, shortjaw kokopu and RT, rainbow trout. Refer to Figures 1-4 for locations of site codes.

Mangatawhiri Reservoir															
	MW1	MW2	MW3	MW4	MW5	MW6	MW7	MW8	MW9	MW10	MW11	MW12	MW13	MW14	
BK	44.30	0	0	dry	142.86	116.84	12.60	3.77	55.07	45.27	185.71	76.56	109.45	230.53	
K	12.66	36.67	0		17.86	6.87	34.31	30.17	17.39	121.40	0	14.29	39.80	237.36	
LF	0	10	1.72		0	0	0.70	3.02	0	0	0	0	0	3.42	
SF	0	0	0		0	0	0	0	0	0	0	0	0	1.71	
CB	0	0	0		17.86	0	11.90	6.03	5.80	8.23	0	0	64.68	0	
Perch	0	0	0		0	0	0	0	0	0	0	0	0	0	
Rudd	0	0	0		0	0	0	0	0	0	0	0	0	0	
SJ	0	0	0		0	0	0	0.75	0	0	0	0	0	0	
RT*	0	0	0		0	0	0	0	0	0	0	0	0	0	
Mangatangi Reservoir															
	MT1	MT2	MT3	MT4	MT5	MT6	MT7	MT8	MT9	MT10	MT11	MT12	MT13	MT14	MT15
BK	0	0	0	dry	0	0	0	0	0	0	0	0	0	0	0
K	0	0	0		0	0	0	0	0	0	0	0	0	0	0
LF	0	0	0		0	2.26	2.56	0	1.87	2.65	0	3.14	0	9.80	0
SF*	0	0	0		0	0	0	0	0	0	0	0	0	0	0
CB	3.11	0	0		0	162.15	7.69	0	15.92	41.01	0	0	13.51	0	0
Perch	0	0	0		0	0	0	0	0	0	0	0	0	0	0
Rudd	0	0	0		0	0	0	0	0	0	0	0	0	0	0
RT*	0	0	0		0	0	0	0	0	0	0	0	0	0	0
Wairoa Reservoir															
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10					
BK	280.56	186.05	153.85	143.60	231.68	103.77	194.67	40.27	142.86	54.60					
K	27.78	7.75	3.21	30.46	0	6.35	24.00	29.08	64.94	0					
LF	0	0	0	4.35	2.36	0	0	0	2.16	2.87					
SF	0	0	3.21	0	0	0	0	0	0	0					
CB	0	0	0	0	0	0	0	0	0	0					
Perch	0	0	0	0	0	0	0	0	0	0					
Rudd	0	0	0	0	0	0	0	0	0	0					
Cosseys Reservoir															
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11				
BK	32.75	55.56	74.40	14.49	25.04	101.63	46.82	76.82	22.22	28.15	28.74				
K	14.56	124.18	20.83	62.32	62.59	8.13	16.39	2.33	43.70	72.07	24.31				
LF	0	3.27	0	0	0	0	0	0	0	0	0				
SF	0	0	0	0	0	0	0	0	0	0	0				
CB	0	0	0	0	0	0	0	0	0	0	0				
Perch	0	0	0	1.45	0	0	0	0	0	6.76	0				
Rudd	0	0	0	1.45	0	0	16.39	0	0	0	0				

Within tributary streams, the size range of banded kokopu between the three dams was similar, with multiple size classes present, ranging from young-of-the-year juveniles to adults around 200 mm (Table 3). Banded kokopu captured from within the Wairoa Reservoir consisted of smaller size classes lacking adult fish greater than 110 mm (Table 3). However, size class data shows that reliable recruitment is occurring to all populations.

The banded kokopu populations above the Hunua dams, and in particular Wairoa Reservoir, are significant at both a regional and national scale. Fish densities are higher than those recorded in streams above the water supply dams in the Waikatere Range. Between 2004 and 2008, densities of less than 5 banded kokopu per 100 m^2 were found within the Nihotupu Stream, upstream of the lower reservoir (NIWA unpublished data). Higher banded kokopu densities were recorded in the Huia Stream (between the upper and lower dams); however recruitment is inconsistent from year-to-year and densities of post-migratory fish have fluctuated from 33 to 25 and back to 57 per 100 m^2 between 2006 and 2008 (NIWA unpublished data). Size class data for the Hunua dams suggests that stable populations exist above all reservoirs.

On a larger geographic scale, banded kokopu are now absent in many North Island lake systems, and the densities recorded above the Hunua dams are higher than in most New Zealand forested streams. Jowett et al. (1998) found banded kokopu dominated some communities within unmodified forested streams of Kahurangi National Park and in most cases densities were between 10 – 20 fish per 100 m^2. Within six forested streams along the east coast of the North Island, densities of banded kokopu averaged just 6 fish per 100 m^2 (Rowe et al. 1999). It should be noted that in comparing densities, those reported for the Waitakere Range dams, Jowett et al. (1998) and Rowe et al. (1999), have utilised three pass electric fishing compared to single pass derivatives in the present survey. As such single pass fishing will underestimate densities compared with three pass estimates. Therefore, the high densities of banded kokopu above the Hunua dams represent a rare and unique occurrence for this species in New Zealand.

4.1.1.2 Koaro

Koaro were located above Cosseys, Wairoa and Mangatawhiri reservoirs. Of significance is the presence of koaro above Wairoa Dam, as Slaven (1990) failed to locate this species in 1989. It is likely that koaro were present during the 1989 survey, however, they would have been more difficult to capture when sampling during winter.

Above all dams, koaro were only found in tributary streams and at lower densities compared to banded kokopu (Figure 5; Table 2). However, some sites above Cosseys and Mangatawhiri reservoirs still contained densities of over 100 koaro per 100 m^2 (Table 2). Koaro were at their lowest densities above the Wairoa Dam and this may reflect habitat differences between the reservoirs. Of the four Hunua catchments, tributary streams above Wairoa Reservoir were gauged to have the least amount of koaro habitat. Lowland reaches of streams lacked suitable bush cover and forested streams tended to be small and contained less high gradient waters preferred by koaro (Plate 1).

For all reservoirs, a range of size classes for koaro were present from young-of-the-year juveniles to sexually mature adult fish (Table 3). Adult koaro however, tended to be smaller than banded kokopu with the largest fish of 152 mm found above Cosseys Reservoir.

Figure 6:

Average catch per unit effort (CPUE; average number of fish per net per night) of fish species captured within each reservoir (error bars represent ± 1 standard error). Abbreviations: Gill, panel gill net; FM fyke, fine mesh fyke net; CM fyke, coarse mesh fyke net; BK, banded kokopu; LF, longfin eel; SF, shortfin eel; CB, Cran's bully and RT, rainbow trout.

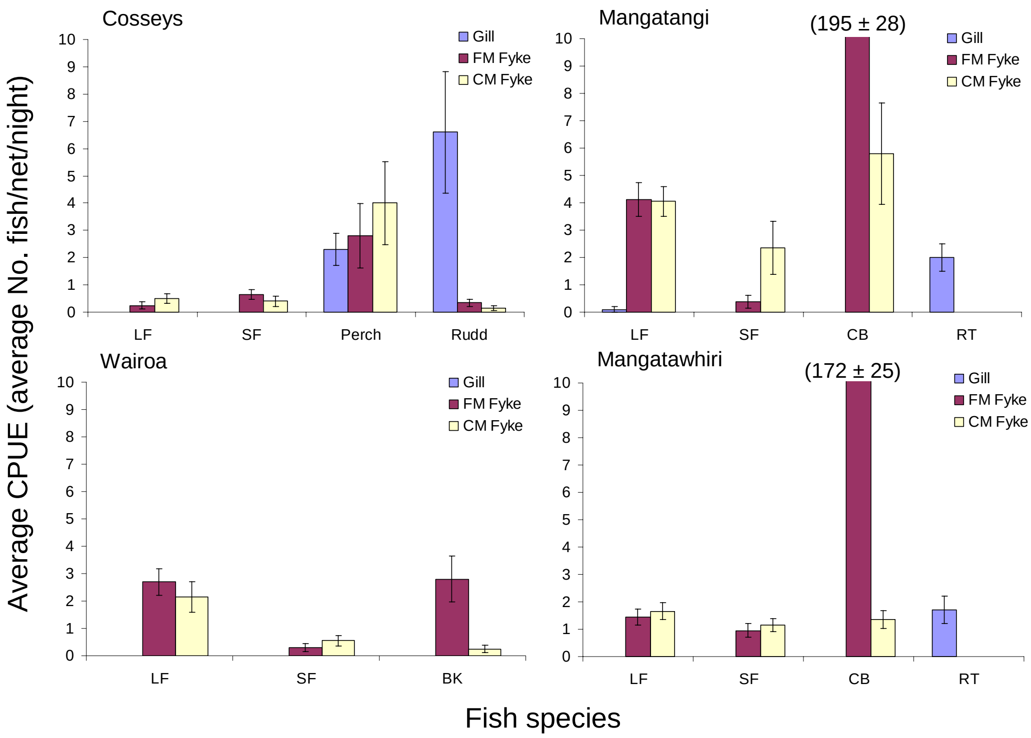


Table 3:

Size range (mm, total length) of fish species captured within tributary streams or the lake at each reservoir. Abbreviations: BK, banded kokopu; K, koaro; LF, longfin eel; SF, shortfin eel; CB, Cran's bully; SJ, shortjaw kokopu and RT, rainbow trout. A 45 mm juvenile galaxiid was found at Mangatawhiri that was thought to be a shortjaw kokopu, however it was not conclusively identified.

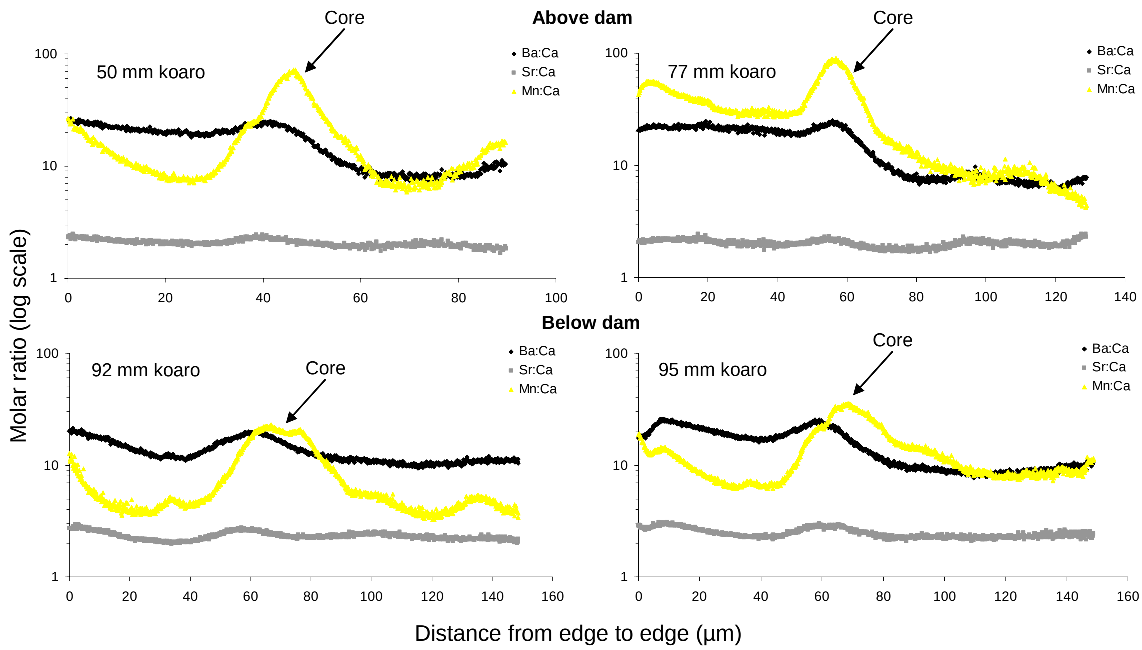
	Cosseys		Wairoa		Mangatawhiri		Mangatangi	
Species	Streams	Lake	Streams	Lake	Streams	Lake	Streams	Lake
BK	35-178	-	39-208	39-110	35-200	-	-	-
K	40-152	-	41-125	-	40-110	-	-	-
LF	800-1100	665-1340	700-1100	590-1250	500-930	470-1145	300-1150	475-1080
SF	-	645-1100	570-900	452-960	450-700	370-990	400-420	580-1040
CB	-	-	-	-	32-80	20-87	15-85	22-83
Perch	50-190	45-365	-	-	-	-	-	-
Rudd	26-65	120-260	-	-	-	-	-	-
SJ	-	-	-	-	134-210 (45?)	-	-	-
RT	-	-	-	-	60-510	270-425	126-220	275-443

As with banded kokopu, the koaro populations above the Hunua dams are significant at both a regional and national scale. Within the Auckland region, koaro are rare with few records outside of the Hunua and Waitakere Ranges. Above the lower Nihotupu Dam within the Waitakere Range, densities of less than 18 koaro per 100 m^2 have been recorded annually between 2004 and 2008 (NIWA unpublished data). Again data for the Waitakere Range report three pass fishing estimates and therefore densities for the Hunua dams will be underestimated in comparison. Within the North Island, land-locked populations have declined greatly with koaro extinct in some of the central North Island lakes and scarce in others (Rowe 1993; Rowe et al. 2002).

Plate 1:
Example of lower (bottom) and upper reaches (top) of tributary streams above Wairoa Dam.

Analysis of the otoliths from koaro captured above and below the reservoir found that all fish showed a lacustrine life-history with no evidence of a marine phase. Representative ratios of isotopes are shown in Figure 7. For all fish, the Sr:Ca ratio was similar throughout their life history. Known sea-run inanga (*Galaxias maculatus*) and koaro show a Sr:Ca ratio of 8 to 12 mmol mol^{-1} when in a marine environment (Baker & Hicks 2003; Hicks et al. 2005). Ba:Ca ratios were also similar throughout their life history, and barium abundance is known to be low in the sea compared to freshwater (Crook et al. 2006). For all otoliths, a peak in the Mn:Ca ratio was present which signifies sampling of the core. Solely lacustrine signatures were also found by Baker & Hicks (2003) when sampling the otoliths of six koaro from above Mangatawhiri Dam and six koaro captured at the base of the dam spillway.

Figure 7:
Laser ablation transects through koaro otoliths. Sr:Ca ratios given in mmol mol^{-1}. Ba:Ca and Mn:Ca ratios given as μmol mol^{-1}.



These results suggest that the koaro sampled from Milnes Stream, which is 5.5 km below the dam, belong to the landlocked population from above Mangatawhiri Dam. There is a possibility that the koaro below the dam recruited from larvae rearing in the lower Waikato River without going to sea. However, Sr:Ca and Ba:Ca ratios are similar to those exhibited from fish reared above the dam, and the Sr:Ca ratio found in otoliths of koaro from the Mangatawhiri catchment are higher than those found in galaxiids rearing in nearby freshwaters. Inanga from the Waikato River and koaro from the Oparau River both show Sr:Ca ratios of less than 2 mmol mol^{-1} (Hicks et al. 2005).

This raises the question of whether migration barriers are preventing sea-run galaxiids from penetrating within the lower Mangatawhiri River. Watercare Services Limited operates a large flow gauging weir below Milnes Stream on the Mangatawhiri River. As koaro, banded kokopu and shortjaw kokopu are recorded upstream of the weir (Barnes 2004; NZFFD) it has been assumed that sea-run fish have penetrated above the weir. Additionally, natural migration impediments (rapids and waterfalls) are present within the Mangatawhiri gorge (Barnes 2004) and based on the upstream fish communities, these have previously been thought to only prevent swimming fish passage. As all koaro captured from Milnes Stream had no evidence of a marine signature within their otoliths, such migration barriers may in fact be preventing or reducing the penetration of sea-run galaxiids. Alternatively, sea-run koaro may be in low abundance within the Mangatawhiri catchment. Analysis of the NZFFD found only a handful of records for koaro within the Waikato River catchment below Hamilton and within the Mangatawhiri River no koaro have been recorded below Milnes Stream.

As otolith microchemistry cannot discriminate koaro captured from above and below the dam, it is inconclusive as to whether juvenile koaro are capable of climbing the Mangatawhiri spillway.

4.1.1.3 Shortjaw kokopu

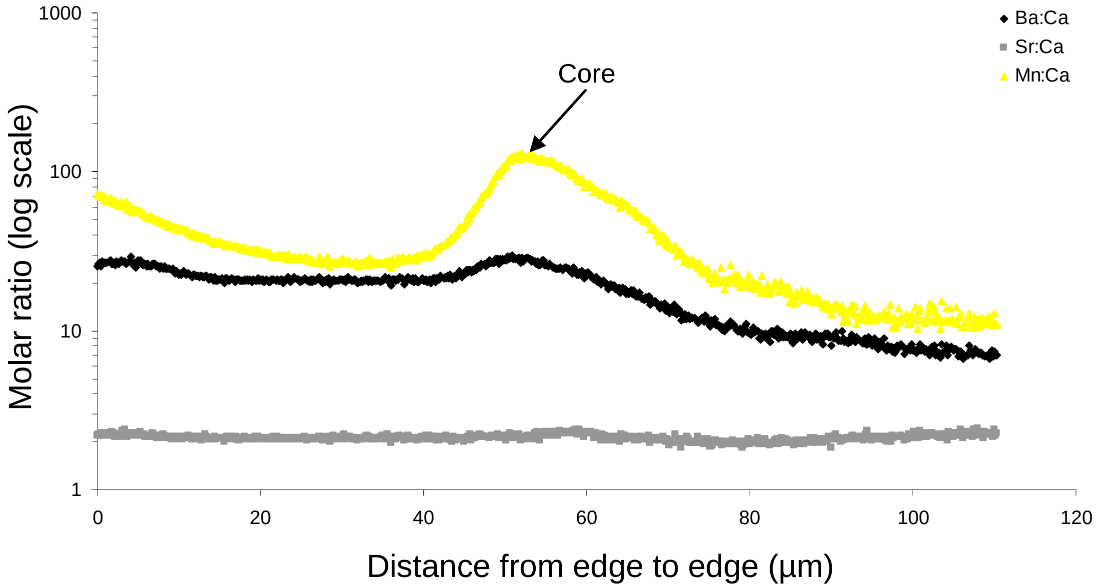
A small population of shortjaw kokopu was found in an unnamed tributary of the Mangatawhiri River. An adult fish was located at MW8 along with a 45 mm juvenile which appeared be a shortjaw kokopu but this fish was not bought back to the laboratory to confirm identification. Spotlighting of the main stem of the Mangatawhiri River on the 24th April 2008 located another adult shortjaw (210 mm; Plate 2) and a further fish that appeared to be a shortjaw was unable to be captured.

Analysis of the otolith from the 134 mm shortjaw kokopu mimicked that of koaro otoliths which suggests that the fish has reared in a lacustrine environment (Figure 8). There was no evidence of an elevated Sr:Ca ratio around the core with a corresponding reduction in Ba:Ca. The spike in the Mn:Ca ratio signifies the laser has sampled the core of the otolith. This is the first evidence of lacustrine breeding for shortjaw kokopu within New Zealand and a highly significant find.

Plate 2:
Shortjaw kokopu captured 24 April 2008 in the Mangatawhiri River.

Figure 8:

Laser ablation transects through the 134 mm shortjaw kokopu otolith. Sr:Ca ratios given in mmol mol-1. Ba:Ca and Mn:Ca ratios given as µmol mol^{-1}.



4.1.2 Cran's bully

Cran's bully was the only *Gobiomorphus* sp. found above the dams and this species was only located above Mangatawhiri and Mangatangi reservoirs. Earlier surveys by Slaven (1990) and Thompson (1977) (cited in Slaven 1990) also recorded common bullies (*Gobiomorphus cotidianus*) above Mangatawhiri and Mangatangi reservoirs. Samples of bullies captured from within Mangatawhiri and Mangatangi reservoirs, plus various rivers and streams above each lake were all identified as Cran's bullies by Dr Bob McDowall. Cran's and common bullies are remarkably similar to the naked eye, especially within the small size classes, and results of this survey suggest earlier surveys have incorrectly identified Cran's bullies as common bullies.

The absence of Cran's bully from the Cosseys and Wairoa reservoirs is perplexing as this species occurs downstream of both dams within the Wairoa River. Compared to all other native fish found above the dams, Cran's bully is the only non-diadromous species and therefore does not require access to the sea. Given that this species occurs above the Hunua Falls, it seems logical to assume that historically it would have occurred in the headwaters of the Wairoa River. However, its absence from both Cosseys and Wairoa reservoirs suggests a natural barrier has existed prior to dam construction.

Above Mangatawhiri and Mangatangi reservoirs, good populations of Cran's bully exist, with extremely high numbers of fish captured within the reservoirs themselves (Figure 6). Within tributary streams of Mangatawhiri, not all sites contained Cran's bullies (Table 2) and this distribution most likely reflects the presence of natural barriers such as waterfalls. Where Cran's bullies were located, densities are comparable to those found in other Auckland river systems. For example, between 4 and 19 fish per have been found within the Waitakere River between 2004 and 2008 (NIWA unpublished data).

Plate 3:
Examples of the waterfalls present in tributary streams of Mangatangi Reservoir.

Although similar densities of Cran's bullies were reported within tributary streams of Mangatangi Reservoir (Figure 5; Table 2), the densities reported at most of the semi-quantitative fishing sites are slightly misleading. In low gradient reaches of tributaries, extremely high numbers of Cran's bullies were located. However, most tributaries feeding into Mangatangi Reservoir were high gradient with frequent waterfalls (Plate 3). Above the waterfalls Cran's bullies were not found, and as habitat appeared well suited to galaxiids, which were previously reported absent from this catchment, many sample sites targeted prime galaxiid habitat. As Cran's bullies are non-migratory and lack climbing abilities, they have naturally been prevented from fully penetrating this catchment but are, however, abundant in low gradient streams.

The size range of bullies at both Mangatawhiri and Mangatangi reservoirs signifies that a stable population structure exists above both dams (Table 3). The increase in abundance of Cran's bullies above Mangatangi Dam compared to the Mangatawhiri population may be due to reduced competition and increased food availability. Aside from eels and rainbow trout, Cran's bullies were the only other fish species found in this catchment. As eels differ in habitat preferences to Cran's bullies, and trout are in very low densities within the catchment, bullies have little competition for habitat, and, given the low diversity of fish species present, food resources are not likely to be limiting populations.

4.1.3 Longfin and shortfin eels

Both eel species were located above all four dams. Low densities of eels were found in tributary streams for all catchments, with longfin eels the more common species (Figure 5; Table 2). No shortfin eels were located within tributaries of Cosseys Reservoir.

Within the reservoirs themselves, Mangatangi had the highest catch per unit effort (CPUE) of eels and these were predominantly longfins (Figure 6). However, the CPUE of both species within all four reservoirs is low compared to river or lake systems where recruitment is not limited. For example, within South Mavora Lake the average CPUE for longfin eels was 27 fish per net per night (± 11; 1 standard error) utilising the same fyke nets as in the present survey (NIWA unpublished data, 2003). Within the Waikato River at Ohinewai, the CPUE of longfin and shortfin eels was 16 and 15 fish per net per night respectively (NIWA unpublished data, 2007). Again, the same fyke nets as utilised in the present survey were used. It should be noted that eels are not harvested from the Hunua Lakes or South Mavora Lake, whereas commercial eel fishing occurs within the Waikato River.

The CPUE of eels in the present survey cannot be compared to the survey by Slaven (1990) as the 1989 survey was conducted during winter. In winter when water temperatures are low, eels become inactive and will bury themselves into the sediments and markedly lower CPUE results.

The size classes of eels captured within all four reservoirs shows large eels predominate (Figures 9-12). Only one eel less than 400 mm was captured and that was within the Mangatawhiri Reservoir. The netting survey undertaken can be biased in the size structure of eels captured when large eels are present in the population, as small eels avoid nets containing large eels (J. Boubée, NIWA pers. comm.). However, if smaller eels were present in these catchments, they would be easily electric fished out of tributary streams. As the size range of both eel species captured in tributaries was similar to that found in the reservoirs for all dams, it is likely that smaller eels were not present within the catchments or they were in extremely low densities.

If no recruitment had occurred to each reservoir since dam construction, assuming growth rates of eels would be similar between the reservoirs, the mean size of captured eels should reflect the age of the dam, yet this pattern was not found. Cosseys, the oldest dam does have the largest eels, however, Mangatawhiri had smaller eels than Wairoa yet the dam was built 10 years earlier (Table 4). Wairoa and Mangatangi should have a similar size class and mean size, yet smaller eels predominate at Mangatangi.

The relationship between length and age has been estimated from otolith analyses of eels captured from Mangatawhiri and Mangatangi reservoirs. As small eels were captured at Mangatangi, with only larger fish available for analysis from Mangatawhiri, the dataset was pooled for analysis. A size-at-age plot indicates the growth rate of eels within the Hunua reservoirs (Figure 13). Caution must be taken when using this relationship to estimate the age of other eels captured above the dams for several reasons. Firstly, longfin eels dominated this analysis and shortfin eels may have different growth rates (Jellyman 1997). Therefore age extrapolations have only been undertaken on longfin eels for all dams. Secondly, it is likely that this relationship will underestimate the age for eels above 1000 mm, as no large eels have been used for derivation. As both species of eel reach a finite size, growth rates can slow as fish near their maximum size. Studies have shown that as length increases, so too does the variability of age for a given length (Todd 1980; Jellyman 1997). For example, shortfin eels from a mesotrophic lake can vary up to 600 mm for a given age, and longfin eels from a high country lake have shown up to 400 mm variation per age class (Jellyman 1997). Given that large eels will be forced to remain above the intake tower dams as downstream migrations are restricted, it is possible that the larger eels above the reservoirs may have slower growth rates. Lastly, aging slow growing eels can be problematic, as otoliths contain numerous closely spaced annual rings which are difficult to distinguish and separate from false checks (Todd 1980; Jellyman 1995). The otoliths of eels from both Mangatawhiri and Mangatangi reservoirs were difficult to read (Figure 14) and therefore ages should only be taken as approximations.

Assuming the growth rate of eels from all reservoirs is similar, the derived relationship (Figure 13) suggests that recruitment of elvers may be occurring above all dams to varying degrees (Table 4). Eel ages suggest high levels of recruitment has occurred at Cosseys and Mangatawhiri dams, with little to no recruitment above Wairoa and low recruitment above Mangatangi (Table 4). As aging is only an approximation, it is likely that all eels above Wairoa Reservoir will be from before dam construction, as the age of the smallest eel captured was estimated at 30 years. Given the variability that can occur in growth rates of large eels, it is likely that the age of eels from Cosseys Reservoir has been underestimated, as this reservoir contained proportionately more eels in the larger size classes than the other three reservoirs. Overall, the results suggest that recruitment above Mangatawhiri Dam is higher than for the other reservoirs. This suggests that some eels are capable of climbing the spillway. However, given the range of ages estimated, with the youngest eel captured being 18 years (Table 4), recruitment is low for all dams, and not occurring regularly, with large piscivorous eels predominating in each reservoir.

As Mangatawhiri Dam is the only dam to contain a spillway, and therefore a feasible structure for elver passage above the dam, it is surprising that recruitment appears to have occurred at reservoirs containing only an intake tower. The intake towers remove water via a vertical shaft, and flow released downstream of the dam is maintained through a system of pipes and valves. The air intake associated with this type of spillway produces very strong winds and this, coupled with the raised pipes, valves and vertical shafts, would suggest fish passage through this system is next to impossible. As the Hunua dams are earth dams, it is plausible that elvers may climb the dam face following high rain events. Dead elvers have not been reported on the dam faces by caretakers, and Slaven (1990) undertook night searches of the dam faces under suitable conditions but also did not observe any elvers. However, given that recruitment is occurring above the dams, elvers may indeed be capable of scaling the dam faces, although in our opinion, this seems unlikely.

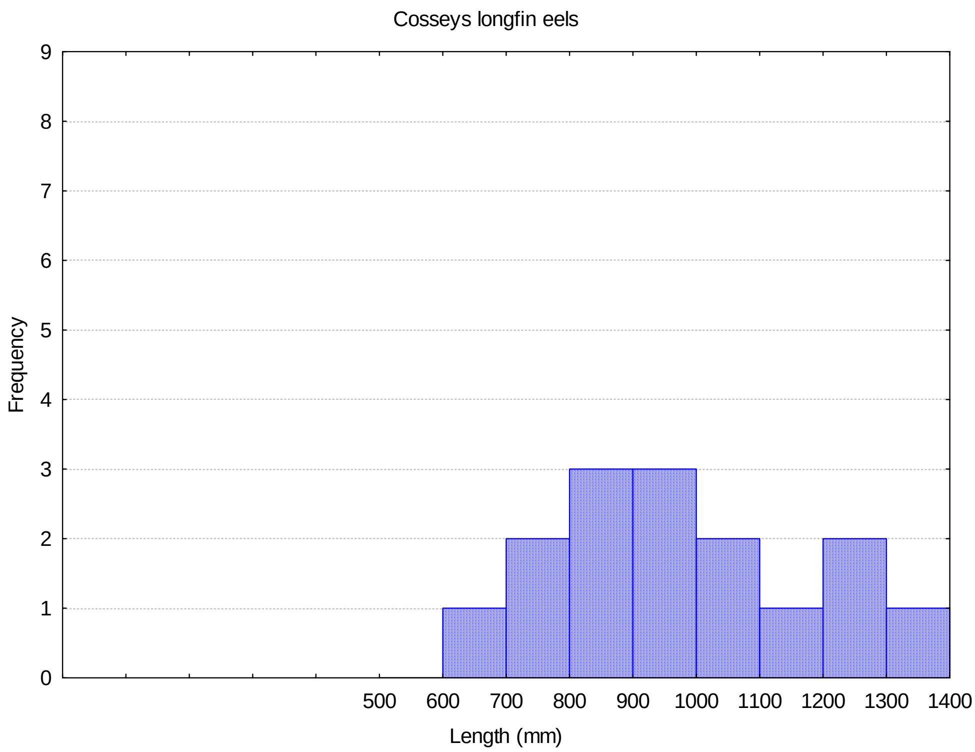
There are also anecdotal reports of dam caretakers occasionally bucketing fish from below the dams although this was unable to be substantiated. Trevor Marrett (Wairoa Caretaker), who has been with Watercare for 27 years has never heard of, or undertaken, any transfer of fish from below to above the reservoirs. David Oliver, the caretaker for Mangatangi, has worked for Watercare for 14 years and does not know of any releases other than trout above the reservoir. This, however, does not preclude interference from the general public. Given the nature of the intake tower dams, passage by elvers seems next to impossible and we cannot rule out human transfer as a method of recruitment.

Table 4:

Mean length of longfin and shorfin eels captured from within the reservoir of each dam. Based on the length-at-age relationship derived from otoliths, the minimum estimated size of longfin eels for fish to be present before the construction of each dam, along with the percentage of longfin eels captured during the survey that are estimated to be older than each dam, and estimated age range for all eels captured is also given. Abbreviations: LF, longfin eel; SF, shortfin eel; Min., minimum and se, standard error.

		Mean length (mm)		Mean length (mm)		Age estimate of longfin eels captured		
Dam	Built	LF	(se)	SF	(se)	Min. size (mm) for pre-dam	% Pre-dam	Age range (years)
Cosseys	1955	987	53.30	865	24.18	1310	20	32-54
Mangatawhiri	1965	840	22.07	703	20.18	990	21	26-48
Wairoa	1975	861	10.90	832	32.53	680	97	30-51
Mangatangi	1977	727	10.43	788	16.44	620	76	18-46

Figure 9:
Size frequency histogram of longfin and shortfin eels captured in fyke nets within Cosseys Reservoir.



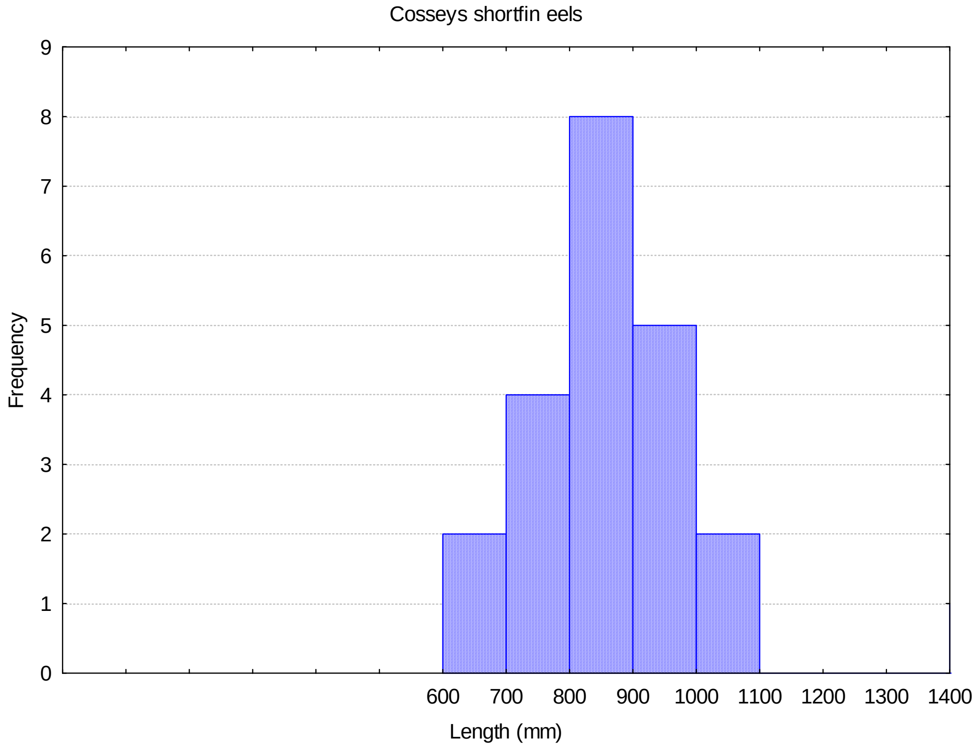
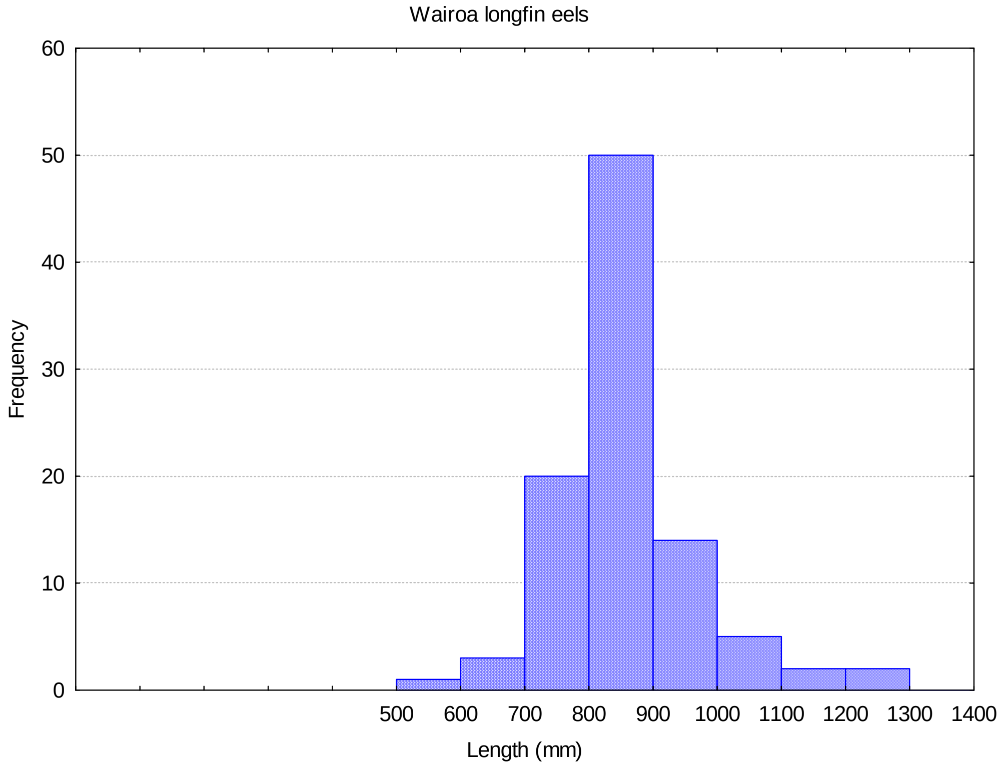


Figure 10:
Size frequency histogram of longfin and shortfin eels captured in fyke nets within Wairoa Reservoir.



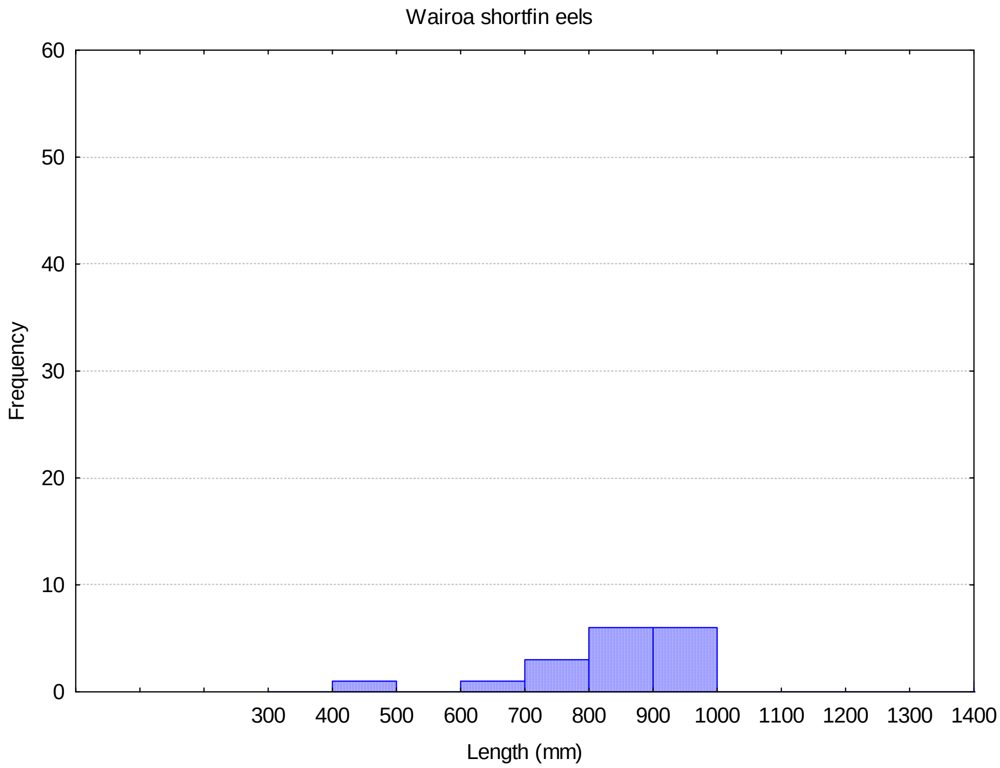
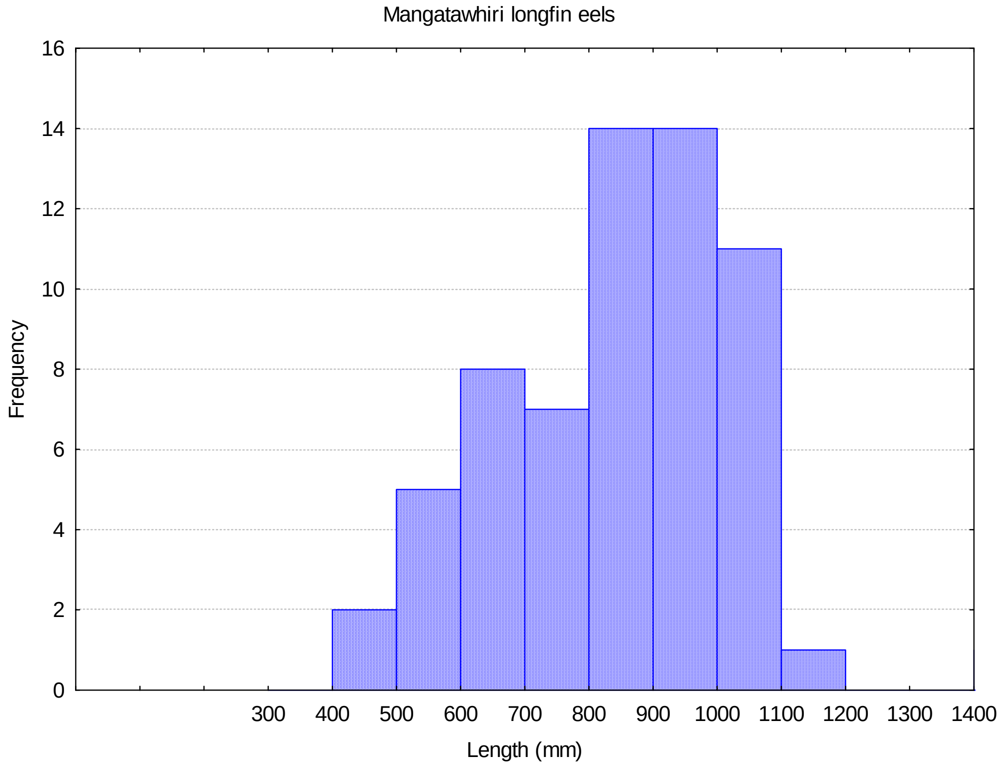


Figure 11:

Size frequency histogram of longfin and shortfin eels captured in fyke nets within Mangatawhiri Reservoir.



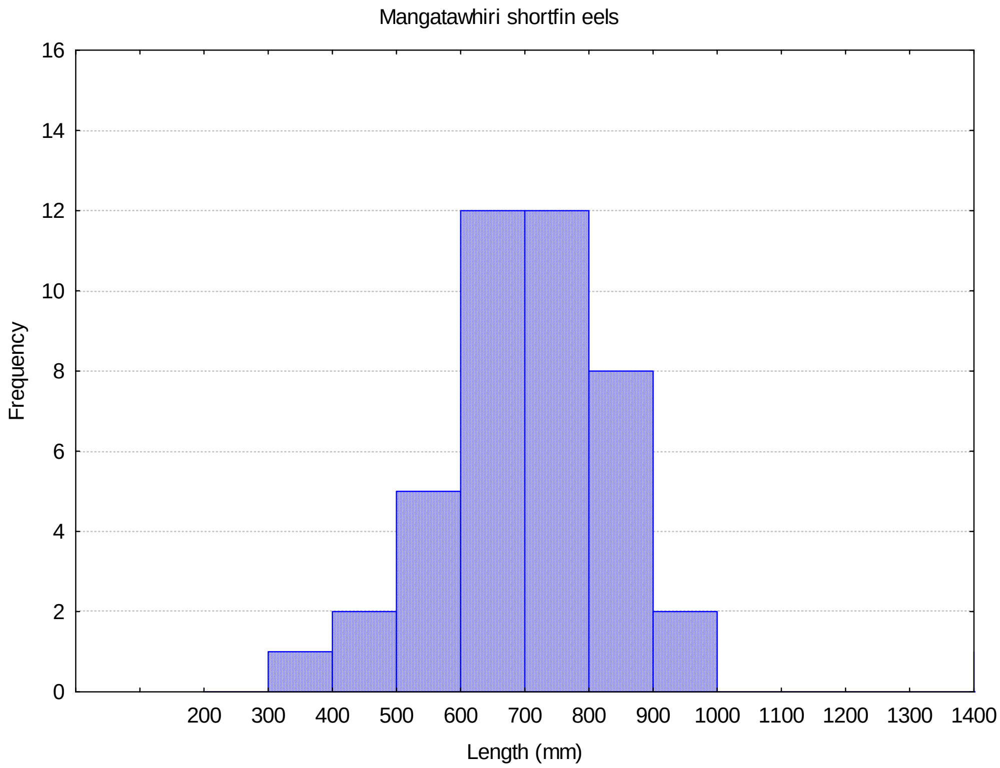
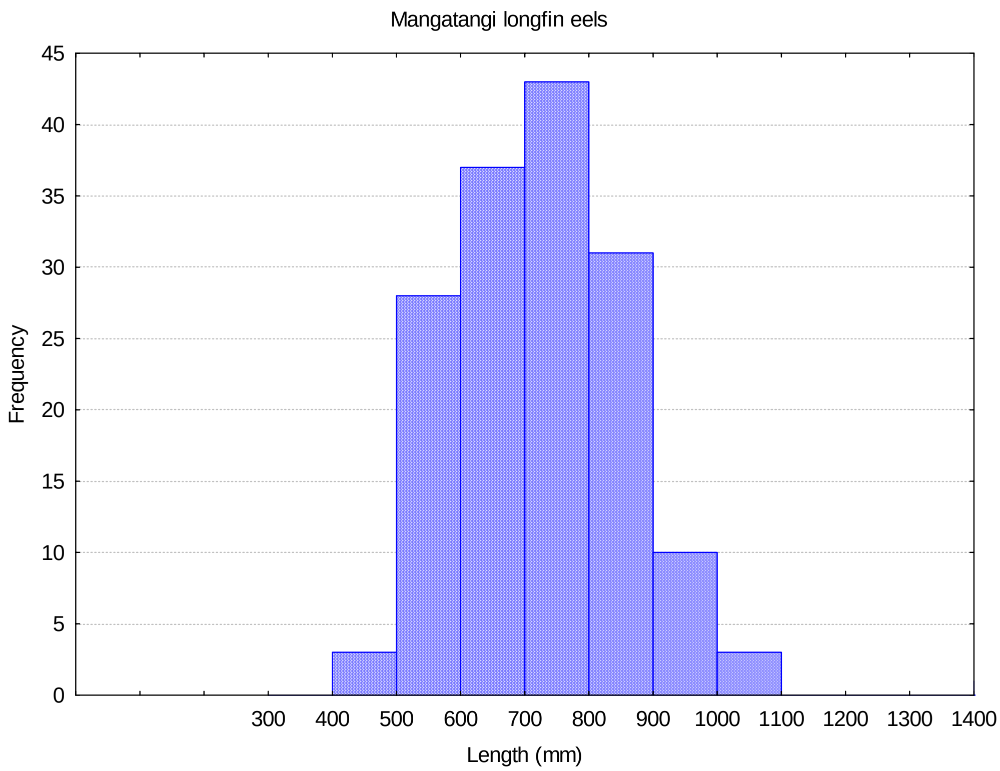


Figure 12:
Size frequency histogram of longfin and shortfin eels captured in fyke nets within Mangatangi Reservoir.



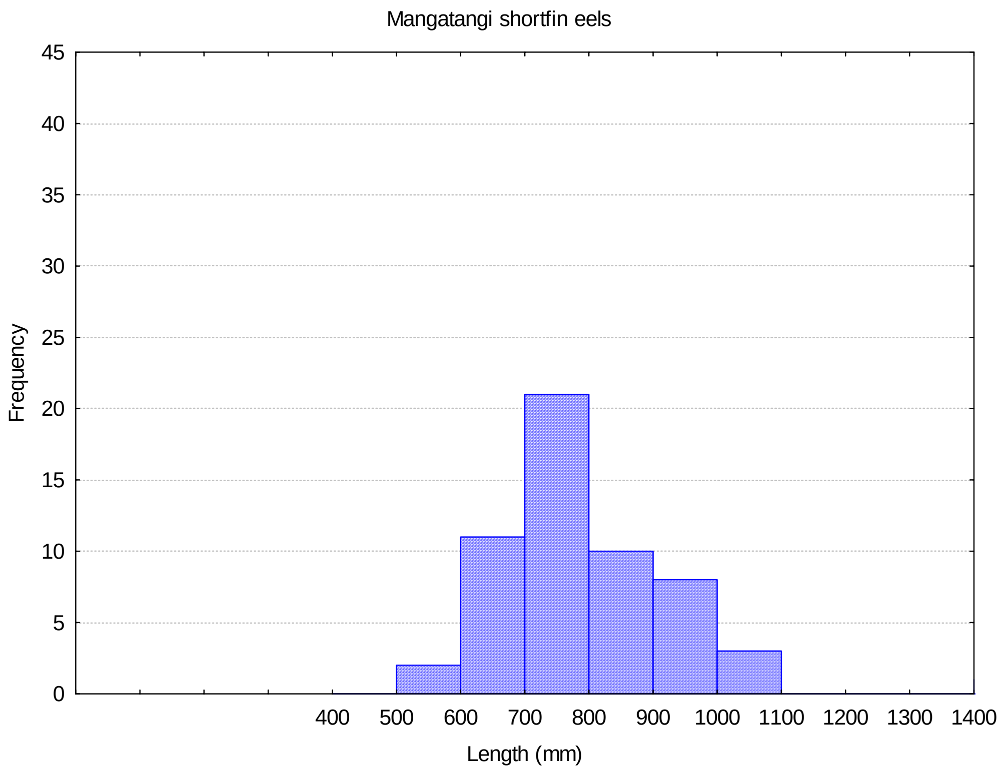


Figure 13:

Size-at-age relationship of longfin and shortfin eels captured in fyke nets within Mangatangi and Mangatawhiri reservoirs ($Y = 0.0319x + 11.112$. $R^2 = 0.7687$), compared to those captured from Waikato Hydro Lakes (NIWA 2008, unpublished data).

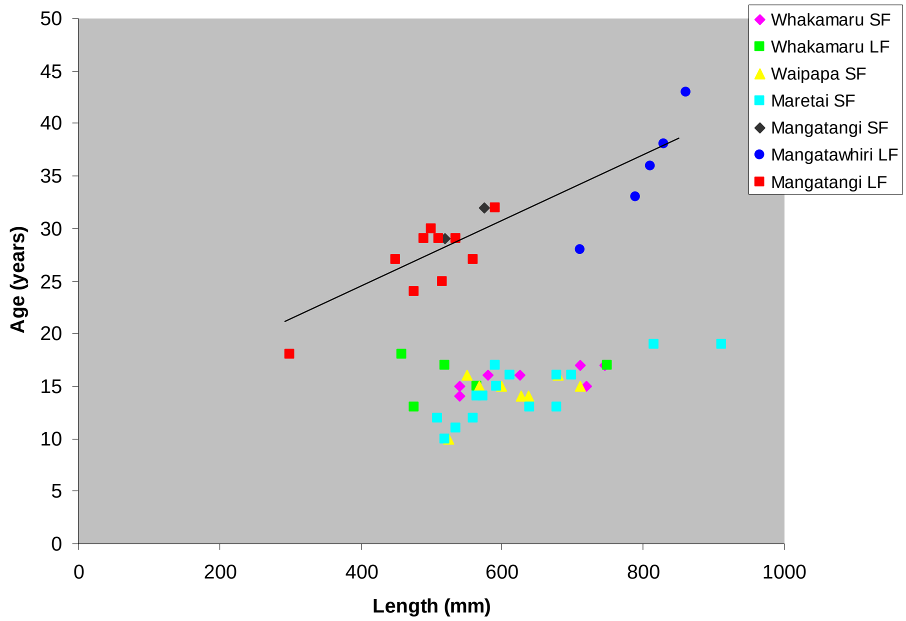
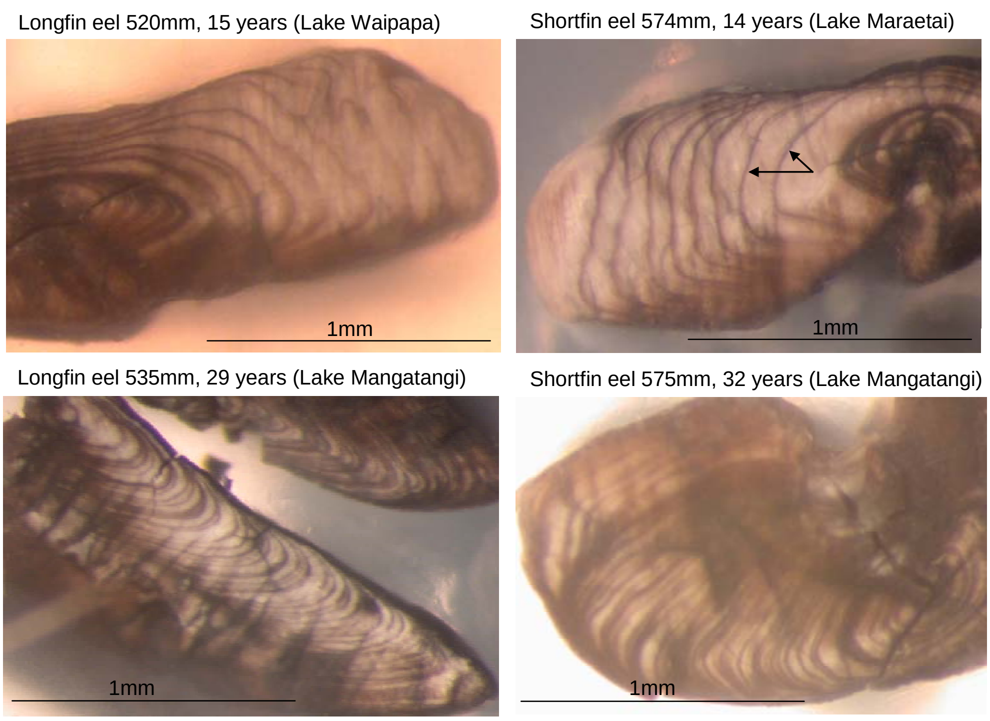


Figure 14:

Comparison of otoliths from eels captured above the Hunua dams to those from Waikato Hydro lakes (NIWA 2008, unpublished data). Arrows indicate annual growth rings.



Another anomaly with the Hunua reservoirs is the slow growth rate of eels captured. Recently stocked shortfin and longfin eels from the Waikato River hydro lakes are markedly younger at a similar size compared to those from Mangatawhiri and Mangatangi reservoirs (Figures 13 & 14). The 2008 data reported for lakes Waipapa, Maraetai and Whakamaru are on par with that found by Chisnall & Hicks (1993) for lakes Karapiro and Matahina. An analysis of length-at-age relationships for both eel species from various studies within New Zealand (Jellyman 1997) shows that for most lakes, the length of the Hunua eels tends to be at the lower end of the range for a given age. As eels are at low densities within the Hunua reservoirs, and an abundant food supply is present within each reservoir, growth rates on par with Waikato hydro lakes would be expected.

4.2 Introduced fish species

4.2.1 Rainbow trout

Rainbow trout were only recorded above Mangatawhiri and Mangatangi reservoirs (Figure 6; Tables 2 & 3). These are the only two Hunua reservoirs for which Auckland/Waikato Fish and Game undertake regular stockings (B. Wilson, Auckland/Waikato Fish and Game pers. comm.). Liberations of rainbow trout into the Hunua waterways have been undertaken historically by the Auckland Acclimatisation Society (AAS) since 1877. In 1976, a survey of Wairoa, Cosseys and Mangatawhiri reservoirs by AAS only found a self-sustaining population of trout occurring above Mangatawhiri Dam (Slaven 1990). Slaven (1990) also only captured trout in Mangatawhiri and Mangatangi reservoirs so it appears trout populations liberated into waters above Cosseys and Wairoa dams have long become extinct.

Although regular liberations of trout occur at both Mangatawhiri and Mangatangi reservoirs, the present survey suggests that of the two reservoirs, a self-sustaining population of rainbow trout only occurs above Mangatawhiri Dam. Whilst spot fishing tributary streams of Mangatawhiri Reservoir, good numbers of parr were captured, with a good size range of adult fish found in both river and lake habitats (Table 3). Although a similar CPUE of trout was found within the Mangatangi Reservoir (Figure 6), only one fish smaller than 200 mm was found within tributaries (Table 3). Slaven (1990) also failed to find fry or parr during the 1989 survey above Mangatangi Reservoir.

4.2.2 Perch and rudd

Perch and rudd were only located above Cosseys Reservoir. Although low numbers of both species were recorded from tributary fishing sites (Table 2), schools of juvenile fish were located whilst spot fishing tributary streams. Below sites C7 and C10 over 200 juvenile rudd were spot fished from approximately 30 m of stream. A school of juvenile perch was also located in the lower reaches of Cosseys Creek above the reservoir. Within the tributaries only small rudd (<65 mm) were found, whereas both juvenile and adult perch were present.

Within the reservoir itself, rudd and perch were more abundant than eels (Figure 6). Only adult rudd were captured within the nets, whereas a broad range of size classes of perch, from young-of-the-year to large adult fish were captured (Table 3).

Of the two exotic species, perch, which is a predatory piscivore, is the greatest threat to the galaxiid populations above the reservoir. It is difficult to assess whether the perch population has expanded since 1989, as the winter sampling undertaken by Slaven (1990) prevents direct comparisons of CPUE. However, given that perch were liberated into the reservoir in 1978, and only a limited number of sites within tributaries now contain perch, plus the distribution and density of galaxiid populations are still high, it appears that perch have not expanded into an unmanageable population.

5 Recommendations

The results of the present survey have confirmed that unique and rare fish communities do exist above the Hunua dams. As such, installing fish passage provisions may not be the most appropriate management plan for all dam sites. Although implementing a Trap and Transfer programme may increase species richness within the reservoirs, this is only one measure of biodiversity and increasing the overall diversity of New Zealand lake ecosystems should also be considered.

Galaxiid fishes are believed to have had an origin some 70-80 million years ago in Gondwanaland and are therefore akin to the ratite birds, tuatara and podocarp trees (McDowall 1990). As such, rare galaxiid populations deserve as much protection as the more well-known flora and fauna of New Zealand forests. In pre-European times, koaro populations dominated most of New Zealand's inland lakes, especially the North Island lakes around Taupo and Rotorua where eels are not present, but today, koaro are extinct in some of the central North Island lakes and are rare in others, being restricted to relict populations in the few streams still retaining a bush canopy (Rowe 1993; Rowe et al. 2002). Koaro are now common in only two North Island lakes (Lake Rotoaira and Lake Waikare-iti), so the conservation of lake-dwelling populations is essential for the conservation of koaro as well as for maintaining ecosystem diversity within our lakes. As with koaro, high densities of banded kokopu are rare in North Island lake systems and with the exception of some Nelson lakes, no other New Zealand lake system contains a fish community where banded kokopu are the dominant species. Shortjaw kokopu are the rarest of the five galaxiid species that comprise our whitebait fishery and this is the first record of a land-locked population for this species. Based on the abundance of banded kokopu and koaro above the Hunua dams, and the presence of shortjaw kokopu, our recommendations for establishing a native fisheries management plan are as follows:

5.1 Wairoa Reservoir

Wairoa Reservoir was the only site to contain both eel species, banded kokopu and koaro, with no introduced species present. The majority of habitat above the reservoir appeared suited to banded kokopu and this is reflected in the extremely high densities of this species within tributary streams. The high density population of banded kokopu above this dam is significant at both a regional and national scale, and the Wairoa Reservoir and headwater streams should therefore be protected as a banded kokopu sanctuary. In our opinion, a Trap and Transfer programme should not be implemented at this site.

As the Wairoa Reservoir is situated above the Hunua Falls, the diadromous fish species capable of reaching the base of the dam are restricted to climbing galaxiids and eels. Hence a Trap and Transfer programme will not add biodiversity above the dam, but can only enhance the abundance of resident species. Presently strong land-locked populations of galaxiids exist above the dam and the stocking of eels could result in a decline in galaxiid abundance. Eels have been found to prey on adult galaxiids during their spawning in the inlet streams of water reservoirs (Mitchell & Penlington 1982), and there is some evidence that stocked populations of eels were responsible for the decline of lake-dwelling galaxiids in northern dune lakes (Rowe & Chisnall 1995). In streams, large eels and banded kokopu are rarely found in the same pool indicating spatial segregation based on competition or aggression (Rowe & Smith 2003; West et al. 2005). Preserving the high density of galaxiids within this reservoir, in particular banded kokopu, should be a priority, as few North Island lakes remain with abundant banded kokopu populations.

To further enhance banded kokopu populations above the dam, as well as allow the resident eels access to breeding grounds, a programme to relocate the migrant eels downstream of the dam should be undertaken. Eels are an obligatory catadromous species and require access to the sea in order to complete their lifecycle. Because of the intake tower and spillway design, eels above Wairoa Dam are prevented from migrating downstream of the dam and therefore completing their lifecycle. The majority of eels migrate to spawning grounds during autumn, and the Trap and Transfer programme should be conducted during this season. The programme should target migrant fish only and any feeder eels captured should be retained above the dam. Relocating the migrant eels from above Wairoa Dam would be advantageous to the Wairoa galaxiid populations as well as enhancing the viable longfin eel populations of the Auckland region.

5.2 Mangatangi Reservoir

Mangatangi Reservoir and associated tributaries was the only catchment that did not contain banded kokopu or koaro. Also of significance is the absence of banded kokopu below the dam and the fact that there is only one record of koaro downstream of the reservoir. The only species currently recorded reaching the base of the dam are Cran’s bullies and both eel species, with torrentfish recorded further downstream. As Cran’s bullies are non-migratory and are unlikely to enter a trap, a Trap and Transfer programme at this reservoir would most likely only enhance eel populations above the reservoir. Increasing eel populations would add very little biodiversity value to this reservoir as these species do not form self-sustaining land-locked populations. In our opinion, the appropriate management action is to enhance the diversity of New Zealand lake ecosystems by seeding koaro and shortjaw kokopu populations above the reservoir.

Above Mangatangi Dam there are large quantities of habitat devoid of fish, owing largely to the restricted distribution of Cran’s bullies and the low densities of eels. Mangatangi Reservoir is the highest altitude Hunua dam, with an almost entirely forested catchment. Due to its higher elevation, many tributaries contain steep gradients and riffle habitat that is preferred by koaro (Plate 4). Lower sections of some tributaries and the main stem of the Mangatangi Stream contain larger pools and backwaters preferred by shortjaw kokopu (Plate 5). As these two species occupy different ecological niches, stream resident fish will not be in direct competition for habitat.

Plate 4:
Examples of koaro habitat present within the tributary streams of Mangatangi Reservoir.

To maximise the development of self-sustaining koaro and shortjaw kokopu populations, we recommend translocation of the eel populations and discontinuing the stocking of trout above the dam. Although the present abundance of eels and trout above the Mangatangi Dam would not in itself prevent self-sustaining galaxiid populations from developing, they would reduce the abundance of both species and slow the growth of the populations. As previously discussed, eels are known to prey upon and compete for habitat with galaxiids, and given that the eels above the dam are unable to breed, relocating the eel populations would be beneficial for enhancing longfin eel spawning stocks within the Auckland region. Trout do not appear to be breeding within this system and although Auckland/Waikato Fish and Game undertake regular stockings of the lake, the rainbow trout population remains in low abundance. Given that a self-sustaining population of rainbow trout occurs above Mangatawhiri Reservoir, and the fact that a gut analysis of trout captured from Mangatawhiri Reservoir showed many trout were feeding on galaxiid whitebait (Slaven 1990), the stocking of trout should be discontinued in this reservoir.

The aging of eels undertaken in the present study raises concerns regarding the degree of artificial recruitment of eels above the reservoir. To improve the efficiency and effectiveness of stocking galaxiid populations above the reservoir, it is important that the Mangatangi Reservoir and headwater tributaries be left as a natural system. Therefore a programme to try and prevent public interference should be considered. After translocation of the eel populations, the degree of natural elver recruitment above the dam should be investigated through surveys at five-yearly intervals.

Plate 5:
Example of shortjaw kokopu habitat present within streams above Mangatangi Reservoir.

5.3 Mangatawhiri Reservoir

The Mangatawhiri Reservoir and its headwater streams have the highest diversity of native fish species of all the Hunua dams. Populations of banded kokopu, koaro, shortjaw kokopu, Cran's bully, longfin eels and shortfin eels were found. The only introduced fish species is rainbow trout, with no invasive species liberated into the reservoir.

Both koaro and banded kokopu were widely distributed above the dam and in high densities. This shows that the present density of eels and rainbow trout is not detrimental to the annual recruitment of these galaxiids. Although the spillway appears to allow limited recruitment of eels above the dam, recruitment does not occur regularly and the population is remaining in low abundance. Implementing a Trap and Transfer programme at this site will undoubtedly increase the population of eels above the reservoir, which could result in a decline in galaxiid abundance. Of particular significance is the population of shortjaw kokopu. Currently the resource consent is in draft form and therefore subject to change. Preserving the galaxiids within this reservoir should be a priority and an upstream Trap and Transfer programme could disrupt the status quo. The current level of rainbow trout stocking appears sustainable with respect to the galaxiid populations and therefore if the presence of a rainbow trout population above the Hunua dams is deemed important, stocking could continue at the same frequency. However, it is important that the current stocking rate is not increased. Given that adult trout are known to feed on galaxiids, we recommend consulting with Auckland/Waikato Fish and Game regarding the importance of a trout fishery within the Hunua dams.

Although an upstream Trap and Transfer programme is not recommended at this dam site, to allow eels to complete their lifecycle, a downstream Trap and Transfer programme for migrant eels should be included as part of the native fisheries management plan. As with the Wairoa Reservoir, the transfer programme should be conducted during autumn each year, and target migrant eels only. Any feeder eels captured should be retained above the dam.

5.4 Cosseys Reservoir

Although populations of koaro, banded kokopu, shortfin eels and longfin eels occur above the dam, the catchment also contains established populations of rudd and perch which changes the fishery values of this reservoir and headwater streams. In our opinion there is no unique feature to the fish community above this impoundment and a Trap and Transfer programme could benefit the native fish communities at this site.

At present both galaxiid species occur at high densities above the dam which suggests that the perch populaton is not greatly affecting them. Currently little scientific (cf. anecdotal) data exist on the impacts of the different exotic fish species on biodiversity in lakes. However, current NIWA research has highlighted perch as a key species that poses a significant threat to native biodiversity. There is now clear evidence that common bully populations are significantly reduced in lakes containing perch (Ludgate & Closs 2003) and some studies suggest perch have decimated populations of smelt, inanga and possibly banded kokopu in North Island West Coast dune lakes.

Although eels were only captured in low numbers within this reservoir, most eels of both species were over 800 mm and these predatory fish may presently be one factor restricting perch populations above Cosseys Dam. Large eels are piscivorous, above 450 mm shortfin eels will feed mainly on fish and once over 700 mm, they feed exclusively on fish and crayfish (Chisnall 1987; Jellyman 1989). In comparison, longfin eels will feed predominantly on fish from 400 mm (Jellyman 1989) and are more aggressive piscivores when over 700 mm. Within Lake Pounui, perch constituted 86% and 58% of shortfin and longfin eel diets respectively (Jellyman 1989). Enhancement of top-down predators such as eels through the Trap and Transfer programme may be beneficial in further limiting the expansion of perch and rudd.

However, as discussed above, eels are not selective feeders and they also prey upon and compete for habitat with galaxiids. Therefore enhancing the eel population above Cosseys Dam will most likely also reduce the abundance of banded kokopu and koaro. But this effect needs to be considered in the context of the four Hunua dams as a whole. Koaro and banded kokopu populations will be protected and enhanced above the three other dams and enhancing eels above Cosseys Dam will increase the native biodiversity of the Hunua waterways. Furthermore, high densities of perch could have a far greater effect on the reduction of galaxiids.

As eels cannot form land-locked populations, the Trap and Transfer programme will need to provide both upstream and downstream passage to allow migrant fish access to the sea. In this regard, downstream passage should target migrant fish only and any feeder eels captured should be retained above the dam. In order for eel populations to be effective as top-down predators, it is imperative that no fishing occurs within the reservoir, as fishing will exploit the large piscivorous eels within the population. The programme should also ensure that only native species are transferred above the reservoir, namely eels, banded kokopu and koaro. It should be noted that implementing a trap and transfer programme at Cosseys Dam not only meets requirements of resource consent condition 4 (ii) for this dam site (permit numbers 15841, 15842 & 15843) but also for Wairoa (permit numbers 15838, 15839 & 15840) as condition 4 (ii) provides the option of transferring eels and galaxiids at either reservoir in both consents.

The present fish survey provides a baseline of fish densities above Cosseys Dam and after implementing a Trap and Transfer programme at this site, we recommend a follow-up fish survey be undertaken after five years to assess the effectiveness of the programme. The results of the survey will determine the need for further monitoring. As perch and rudd can impact on native fish populations, we also recommend surveying the abundance of these species after five years to ensure their populations do not expand and become detrimental to galaxiid abundance. Should these exotic species become dominant within the reservoir and tributary streams, a control programme will be necessary.

5.5 Further investigations

To ensure the management plans described above are efficient and effective, further investigations are necessary. Given the national significance of the freshwater fish populations above the Hunua dams, such studies should not be fully covered under the resource consents native fisheries management plans. It is expected that supplementary funding would be sought from central government funds as well as regional rate payers.

5.5.1 Mangatawhiri Reservoir

The present study was unable to determine the degree of natural recruitment of sea-run koaro above this dam. Currently, no NZFFD records of koaro occur below Milnes Stream within the lower Mangatawhiri River. However, sampling sites mostly occur in low elevation habitat of tributary streams. We recommend surveying high gradient sections of tributary streams within the lower Mangatawhiri River for koaro. For any population found, the otoliths from a sub-sample of koaro should be analysed to assess the degree of sea-run versus lacustrine recruitment within the lower river and determine if migration barriers are preventing penetration of sea-run recruits or whether sea-run koaro are just rare within the system. Banded kokopu and shortjaw kokopu are also recorded in the NZFFD below the dam down to Milnes Stream. As both of these species occur above the dam and can potentially climb the spillway, we recommend otolith analyses also be undertaken on select populations of these galaxiids from the lower river to examine sea-run versus lacustrine recruitment.

5.5.2 Mangatangi Reservoir

Creating a land-locked population of koaro and shortjaw kokopu above Mangatangi Dam may also enhance lowland fisheries by drawing whitebait of these species into the Mangatangi Stream below the dam. Recent investigations suggests juvenile banded kokopu and koaro use adult pheromones as a cue for stream and habitat selection (Baker and Montgomery 2001; Baker and Hicks 2003). Seeding koaro and shortjaw populations above the Mangatangi Reservoir could determine whether adult pheromones are the primary cue driving stream selection in galaxiid whitebait. Presently galaxiids are all but absent within the lower Mangatangi catchment with only two koaro recorded at one site. Analysis of whitebait entry into the lower Mangatangi Stream both before and after stocking koaro and shortjaw kokopu above the dam, can determine the importance of adult pheromones as a migration cue for juvenile fish. Given the presence of lacustrine koaro below the Mangatawhiri Dam, otolith analyses of fish captured below the dam will be necessary to determine the degree of sea-run recruitment.

In order for this investigation to be effective, a comparative untouched system is needed. Therefore, maintaining the status quo at Mangatawhiri Reservoir and headwater streams is essential in providing a control site. In this regard, understanding the current level of sea-run recruitment of galaxiids into the lower Mangatawhiri River is essential.

5.5.3 Research opportunities

Mangatangi Reservoir and its associated headwater streams are one of few mid-elevation landlocked systems within New Zealand with such low diversity and abundance of fish species. Before seeding fish populations above the dam, a rare opportunity exists to examine the community composition and abundance of invertebrates in areas where predation by fish is low. Additionally, high density populations of Cran's bullies have developed in some sections of streams and a rare opportunity exists to examine habitat selection by Cran's bullies where minimal competition and predation has occurred from other fish species, and therefore food resources would be the main factor limiting populations.

5.6 Summary

Consents given for construction of dams generally include conditions relating to the provision of fish passage to maintain biodiversity; however increasing species richness is only one measure of biodiversity. Fish surveys of the four Hunua reservoirs and headwater streams show unique fish communities have developed since dam construction, which are rare at both a regional and national scale. Given the significance of the fish communities above the dams, the native fisheries management plan for consents should consider all four dams as a whole. As such, we recommend the following native fisheries management plans:

- Wairoa Reservoir

Implement a downstream Trap and Transfer programme for migrant eels to allow breeding, and protect banded kokopu populations.

- Mangatangi Reservoir

Translocate eels to allow breeding, discontinue trout releases, and stock and protect koaro and shortjaw kokopu populations. Examine the degree of natural recruitment of eels above the dam.

- Mangatawhiri Reservoir

Implement a downstream Trap and Transfer programme for migrant eels to allow breeding, and protect the rare population of shortjaw kokopu. Further investigate the degree of natural recruitment of galaxiids above the dam.

- Cosseys Reservoir

Implement an upstream and downstream Trap and Transfer programme for native fish species (eels, koaro and banded kokopu) assessing the effectiveness through further fish surveys. Monitor perch and rudd populations.

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8 Appendix I – Site Co-ordinates

Easting	Northing	Waterway	Reservoir	SITE
2697870	6457752	Lake	Cosseys	
2697939	6458185	Lake	Cosseys	
2697782	6458912	Lake	Cosseys	
2697712	6458321	Lake	Cosseys	
2697528	6458584	Lake	Cosseys	
2697571	6459074	Lake	Cosseys	
2697444	6459418	Lake	Cosseys	
2697618	6459590	Lake	Cosseys	
2697591	6460401	Lake	Cosseys	
2697676	6459831	Lake	Cosseys	
2698300	6457539	Lake	Cosseys	
2698355	6457471	Lake	Cosseys	
2697928	6457607	Lake	Cosseys	
2697509	6459055	Lake	Cosseys	
2697972	6458571	Lake	Cosseys	
2698366	6458523	Lake	Cosseys	
2698118	6458292	Lake	Cosseys	
2697963	6457989	Lake	Cosseys	
2697301	6458587	Lake	Cosseys	
2697676	6458340	Lake	Cosseys	
2698825	6459249	Lake	Cosseys	
2697672	6459191	Lake	Cosseys	
2698447	6459024	Lake	Cosseys	
2697561	6459067	Lake	Cosseys	
2698151	6459064	Lake	Cosseys	
2697680	6460116	Lake	Cosseys	
2697590	6460101	Lake	Cosseys	
2698915	6459476	Lake	Cosseys	
2697369	6459308	Lake	Cosseys	
2697527	6459741	Lake	Cosseys	
2698404	6458635	Lake	Cosseys	
2698393	6458233	Lake	Cosseys	
2698511	6457453	Lake	Cosseys	
2697581	6458406	Lake	Cosseys	
2697538	6458737	Lake	Cosseys	
2697986	6457986	Lake	Cosseys	
2698151	6457702	Lake	Cosseys	
2697909	6457372	Lake	Cosseys	
2697770	6458662	Lake	Cosseys	
2698127	6457623	Lake	Cosseys	
2698999	6459482	Lake	Cosseys	
2698155	6459230	Lake	Cosseys	
2697609	6459591	Lake	Cosseys	
2697975	6458932	Lake	Cosseys	
2697354	6459443	Lake	Cosseys	
2698501	6459163	Lake	Cosseys	
2697617	6460311	Lake	Cosseys	

2697530	6459187	Lake	Cosseys	
2698259	6459340	Lake	Cosseys	
2697670	6459858	Lake	Cosseys	
2698820	6459200	stream	Cosseys	C1
2698477	6460476	stream	Cosseys	C2
2698534	6458617	stream	Cosseys	C3
2697447	6461197	stream	Cosseys	C4
2698000	6460000	stream	Cosseys	C5
2698410	6459585	stream	Cosseys	C6
2698092	6457152	stream	Cosseys	C7
2698600	6458238	stream	Cosseys	C8
2699495	6460410	stream	Cosseys	C9
2697447	6460796	stream	Cosseys	C10
2698615	6457455	stream	Cosseys	C11
2702018	6456479	Lake	Mangatawhiri	
2702195	6457176	Lake	Mangatawhiri	
2701893	6456800	Lake	Mangatawhiri	
2701672	6456188	Lake	Mangatawhiri	
2702000	6456249	Lake	Mangatawhiri	
2702090	6456066	Lake	Mangatawhiri	
2701977	6455539	Lake	Mangatawhiri	
2702296	6455260	Lake	Mangatawhiri	
2701609	6455233	Lake	Mangatawhiri	
2701770	6455793	Lake	Mangatawhiri	
2702028	6456233	Lake	Mangatawhiri	
2701975	6456894	Lake	Mangatawhiri	
2701797	6456792	Lake	Mangatawhiri	
2702156	6456678	Lake	Mangatawhiri	
2701669	6456559	Lake	Mangatawhiri	
2701623	6456246	Lake	Mangatawhiri	
2701972	6457191	Lake	Mangatawhiri	
2701669	6455885	Lake	Mangatawhiri	
2701830	6456830	Lake	Mangatawhiri	
2702205	6457164	Lake	Mangatawhiri	
2701513	6455392	Lake	Mangatawhiri	
2702805	6455321	Lake	Mangatawhiri	
2701649	6455755	Lake	Mangatawhiri	
2702503	6455336	Lake	Mangatawhiri	
2701990	6455457	Lake	Mangatawhiri	
2702098	6455826	Lake	Mangatawhiri	
2702317	6456153	Lake	Mangatawhiri	
2701674	6455177	Lake	Mangatawhiri	
2702722	6455145	Lake	Mangatawhiri	
2702303	6455268	Lake	Mangatawhiri	
2701732	6456674	Lake	Mangatawhiri	
2701957	6457047	Lake	Mangatawhiri	
2702292	6456193	Lake	Mangatawhiri	
2701739	6456829	Lake	Mangatawhiri	
2702229	6456887	Lake	Mangatawhiri	
2701862	6456929	Lake	Mangatawhiri	
2702053	6456421	Lake	Mangatawhiri	
2701589	6456113	Lake	Mangatawhiri	

2701630	6456444	Lake	Mangatawhiri	
2701947	6457358	Lake	Mangatawhiri	
2701771	6455800	Lake	Mangatawhiri	
2701607	6455536	Lake	Mangatawhiri	
2702875	6455266	Lake	Mangatawhiri	
2701502	6455246	Lake	Mangatawhiri	
2702009	6455576	Lake	Mangatawhiri	
2702077	6456018	Lake	Mangatawhiri	
2702069	6455207	Lake	Mangatawhiri	
2702343	6455346	Lake	Mangatawhiri	
2702724	6455254	Lake	Mangatawhiri	
2702110	6454975	Lake	Mangatawhiri	
2701864	6457438	stream	Mangatawhiri	MW1
2704308	6459050	stream	Mangatawhiri	MW2
2702825	6461269	stream	Mangatawhiri	MW3
2702093	6460626	stream	Mangatawhiri	MW4
2702415	6456165	stream	Mangatawhiri	MW5
2702356	6456220	stream	Mangatawhiri	MW6
2702970	6458265	stream	Mangatawhiri	MW7
2702738	6458524	stream	Mangatawhiri	MW8
2702704	6458508	stream	Mangatawhiri	MW9
2702376	6457404	stream	Mangatawhiri	MW10
2702156	6457748	stream	Mangatawhiri	MW11
2701771	6457238	stream	Mangatawhiri	MW12
2701547	6456666	stream	Mangatawhiri	MW13
2703254	6455621	stream	Mangatawhiri	MW14
2699476	6454407	Lake	Wairoa	
2700249	6455666	Lake	Wairoa	
2700281	6455299	Lake	Wairoa	
2700044	6455071	Lake	Wairoa	
2699902	6454440	Lake	Wairoa	
2698802	6453334	Lake	Wairoa	
2698839	6453627	Lake	Wairoa	
2698830	6453861	Lake	Wairoa	
2699089	6454243	Lake	Wairoa	
2699039	6453953	Lake	Wairoa	
2698797	6453577	Lake	Wairoa	
2699225	6454503	Lake	Wairoa	
2698752	6453862	Lake	Wairoa	
2700023	6454344	Lake	Wairoa	
2699013	6453668	Lake	Wairoa	
2699039	6454193	Lake	Wairoa	
2699179	6454153	Lake	Wairoa	
2699444	6454416	Lake	Wairoa	
2699216	6453870	Lake	Wairoa	
2699420	6454160	Lake	Wairoa	
2700338	6455229	Lake	Wairoa	
2700147	6455392	Lake	Wairoa	
2699740	6454229	Lake	Wairoa	
2700114	6454841	Lake	Wairoa	
2699691	6454498	Lake	Wairoa	
2699857	6454792	Lake	Wairoa	

2699988	6455078	Lake	Wairoa	
2700299	6455536	Lake	Wairoa	
2700245	6455964	Lake	Wairoa	
2700300	6455964	Lake	Wairoa	
2698819	6453286	Lake	Wairoa	
2698839	6453931	Lake	Wairoa	
2699525	6454242	Lake	Wairoa	
2699103	6454463	Lake	Wairoa	
2698808	6453647	Lake	Wairoa	
2698616	6453404	Lake	Wairoa	
2699525	6454200	Lake	Wairoa	
2700226	6454935	Lake	Wairoa	
2700318	6455720	Lake	Wairoa	
2699102	6453991	Lake	Wairoa	
2699754	6454569	Lake	Wairoa	
2699260	6454555	Lake	Wairoa	
2700369	6455414	Lake	Wairoa	
2699215	6453748	Lake	Wairoa	
2699988	6454724	Lake	Wairoa	
2700020	6455116	Lake	Wairoa	
2699609	6454486	Lake	Wairoa	
2699906	6454911	Lake	Wairoa	
2700212	6455772	Lake	Wairoa	
2699923	6454247	Lake	Wairoa	
2699962	6455480	stream	Wairoa	W1
2700541	6455415	stream	Wairoa	W2
2700522	6455142	stream	Wairoa	W3
2700100	6456500	stream	Wairoa	W4
2698997	6454556	stream	Wairoa	W5
2700010	6454055	stream	Wairoa	W6
2700214	6454250	stream	Wairoa	W7
2700055	6458471	stream	Wairoa	W8
2700159	6458442	stream	Wairoa	W9
2700459	6455752	stream	Wairoa	W10
2705774	6454948	Lake	Mangatangi	
2705994	6454618	Lake	Mangatangi	
2705923	6454219	Lake	Mangatangi	
2706120	6453941	Lake	Mangatangi	
2706721	6453369	Lake	Mangatangi	
2707416	6453293	Lake	Mangatangi	
2707187	6453398	Lake	Mangatangi	
2706549	6452776	Lake	Mangatangi	
2706902	6452256	Lake	Mangatangi	
2706417	6451957	Lake	Mangatangi	
2705828	6454695	Lake	Mangatangi	
2705733	6454988	Lake	Mangatangi	
2706014	6454562	Lake	Mangatangi	
2706470	6452440	Lake	Mangatangi	
2705802	6454860	Lake	Mangatangi	
2706697	6453295	Lake	Mangatangi	
2706037	6453872	Lake	Mangatangi	
2706513	6452800	Lake	Mangatangi	

2705872	6454202	Lake	Mangatangi	
2706034	6454111	Lake	Mangatangi	
2707007	6452588	Lake	Mangatangi	
2707273	6453230	Lake	Mangatangi	
2706304	6453853	Lake	Mangatangi	
2705886	6451604	Lake	Mangatangi	
2706961	6453011	Lake	Mangatangi	
2706658	6453680	Lake	Mangatangi	
2706344	6452055	Lake	Mangatangi	
2706975	6452396	Lake	Mangatangi	
2707042	6453586	Lake	Mangatangi	
2707578	6453288	Lake	Mangatangi	
2705735	6455106	Lake	Mangatangi	
2705933	6454494	Lake	Mangatangi	
2706637	6451850	Lake	Mangatangi	
2706525	6453526	Lake	Mangatangi	
2706302	6453973	Lake	Mangatangi	
2705693	6455130	Lake	Mangatangi	
2706828	6454052	Lake	Mangatangi	
2707273	6453432	Lake	Mangatangi	
2706518	6453058	Lake	Mangatangi	
2705867	6454727	Lake	Mangatangi	
2705941	6454181	Lake	Mangatangi	
2707148	6452394	Lake	Mangatangi	
2707418	6453305	Lake	Mangatangi	
2705809	6454769	Lake	Mangatangi	
2706236	6452012	Lake	Mangatangi	
2705910	6454067	Lake	Mangatangi	
2706465	6452553	Lake	Mangatangi	
2706915	6452742	Lake	Mangatangi	
2706504	6452251	Lake	Mangatangi	
2707086	6453011	Lake	Mangatangi	
2705498	6455464	stream	Mangatangi	MT1
2705506	6455322	stream	Mangatangi	MT2
2705532	6452014	stream	Mangatangi	MT3
2706133	6452541	stream	Mangatangi	MT4
2706462	6453007	stream	Mangatangi	MT5
2706772	6456532	stream	Mangatangi	MT6
2707005	6456673	stream	Mangatangi	MT7
2707909	6453424	stream	Mangatangi	MT8
2710407	6459769	stream	Mangatangi	MT9
2709376	6457964	stream	Mangatangi	MT10
2709288	6457899	stream	Mangatangi	MT11
2705413	6451525	stream	Mangatangi	MT12
2705409	6451683	stream	Mangatangi	MT13
2707223	6452429	stream	Mangatangi	MT14
2706325	6454004	stream	Mangatangi	MT15