Fisheries assessment of waterways throughout the Kaituna-Maketu & Pongakawa-Waitahanui WMA

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Technical summary

1 A freshwater fish survey was undertaken throughout waterways in the Kaituna-Maketū and Pongakawa-Waitahanui Water Management Area (WMA) in May 2016 to help fill knowledge gaps identified in an earlier science review of the current state of waterways in this WMA. Site selection was made by examining the New Zealand Freshwater Fish Database (NZFFD) and selecting sites with either out-dated information (i.e. >16 years), or that flowed through catchments dominated by native bush or pine plantation, as these were under-represented in the NZFFD. A total of 58 sites were surveyed over a three week period from 18 April to 10 May 2016.

2 Fish communities were assessed by electric-fishing in shallow, hard-bottomed streams. Habitats in these streams where fish were likely to occur were specifically targeted. Triplicate fyke nets were used in deep, slow-flowing streams or streams with fine substrates. These nets were deployed overnight and emptied the following morning. In all cases, all fish caught were identified and measured prior to release.

3 Data from the field surveys were combined with data from the NZFFD, giving a total of 251 sites throughout the WMA with information on fish community composition. Environmental factors such as climate (temperature, rainfall) catchment factors (elevation, distance to sea, slope) flow (mean and mean annual low flow), land use and local factors (e.g. substrate and habitat) were extracted from the Freshwater Environments of New Zealand (FWENZ) database based on the individual GPS locations for each site. Ordination analysis was done to reveal any structure in the physical data and identify what the major environmental differences were between sites.

4 As expected, a wide variety of stream types existed throughout the WMA. There was a general trend of increasing altitude with increasing distance inland, although overall elevation gradients were not particularly large. Stream size was highly variable, ranging from small streams with low discharge through to large waterways such as the Kaituna River. Land cover also varied greatly between catchments, with more developed pasture than native bush or exotic plantation forest in most catchments. Overall, strong gradients existed in elevation and distance to sea, stream size, catchment slope, climatic variables, land use and local variables such as substrate and habitat.

5 A total of 16 fish species were identified in the latest survey. The communities were dominated by longfin and shortfin eels, redfin bully, unidentified small eels and koura. All of these fish (and koura) have previously been recorded in the WMA, with the exception of shortjaw kokopu. Shortjaw kokopu were found at one site in the Ohineangaanga stream, representing a new record in the WMA. This species is considered as threatened, so its presence in the Ohineangaanga is significant. Other notable findings were new populations of koaro in small streams draining the Whataroa, and in a stream in the upper Waitahanui. New populations of banded kokopu in the Waikoura Stream, the upper reaches of the Whataroa, the Mangorewa, and inland sites in the Wharere were also found. These results highlight the importance of maintaining good fish access throughout waterways within the WMA to ensure that many of the migratory native fish can complete their life cycle.

6 The results of the 2016 survey were compared to the results of previous surveys extracted from the NZFFD. A higher proportion of sites with redfin bully, giant kokopu and koaro were found in the recent survey, but this may have simply reflected differences in stream types surveyed. The 2016 survey targeted smaller streams in catchments dominated by native bush or pine forest, whereas the NZFFD had under-represented these sites. In contrast, common bully, rainbow trout and mosquito fish were less common in the contemporary survey than in the NZFFD. This may also reflect the fact that habitat conditions in the surveyed streams were unsuitable for these latter species.

7 All fish data was converted to presence-absence data, and ordination used to explore relationships and patterns in this data, and links between fish communities and environmental factors. This analysis identified that elevation and distance to sea were major drivers of fish communities. Other large scale factors such as catchment topography, climatic variables such as average summer temperature, and land cover were also implicated in structuring fish communities throughout the WMA, although to a lesser extent.

8 The health of the fish communities within the WMA was assessed by calculating the Fish Index of Biotic Integrity (IBI) at each site. This score ranges from zero (no fish present) to 60, typical of sites with excellent integrity of fish communities, characterised by a high diversity of sensitive native fish. Of the 251 sites surveyed, approximately one third had scores characteristic of poor integrity classes, 23% of sites had scores characteristic of moderate or excellent integrity, and 16% of sites had scores characteristic of sites of good integrity. Six sites had no fish. No differences were observed in Fish IBI score and dominant land cover, although streams draining urban catchments had low, but highly variable scores. Fish IBI scores also did vary greatly according to distance to sea or elevation. These results suggest that factors other than location or land use are important in determining the overall Fish IBI at a site.

9 The observed distribution patterns of the dominant fish species found throughout the WMA were described, along with brief notes on their natural history. The importance of free access between freshwater and the sea was emphasised for many species. Thus, any instream barriers such as flood gates, pump stations, road culverts or dams can prevent or restrict this natural upstream and downstream migration of fish. This means that even a small, badly designed road culvert can have huge implications to the upstream fish fauna, even though instream habitat conditions above this culvert could be ideal.

10 A number of different pressures that fish in the WMA are faced with are discussed. Such pressures include: loss of habitat as a result of land-use change; engineering works to maximise hydraulic efficiency and constrain river channels between stop banks; stabilisation of banks from erosion using hard structures such as riprap; loss of riparian vegetation that provides both shade and cover; loss of coarse stream bed habitat as sedimentation causes in-filling of spaces between cobbles and boulders; loss of hydraulic habitat arising from water abstraction.

11 Recommendations for six new studies and monitoring programmes are made, including:

- Implementation of routine fisheries surveys as part of a new module under the NERNM monitoring programme.
- Identification of barriers to fish passage, and prioritising the order to which these are remedied.
- Obtaining a better understanding of inanga spawning areas throughout the WMA.

- Creation of new inanga spawning and rearing areas using a mixture of engineering actions such as creation of “borrow pits” for adult rearing of whitebait, and use of straw hay bales within the high tide mark of inanga spawning zones.
- Creation of new fish habitat along some of the heavily modified drainage network.
- Determining the relative habitat values of riprap to different fish communities, and develop and monitor the effectiveness of different bank profiles, and planting regimes on inanga spawning.

Contents

Part 1: Introduction

The National Policy Statement for Freshwater Management (NPS-FM) requires regional councils to establish freshwater objectives and subsequently set limits to give effect to those objectives. The NPS-FM also requires that the overall quality of fresh water within a region is maintained or improved. It has identified a number of specific water quality attributes under the National Objectives Framework (NOF) that councils must monitor, and has set minimum acceptable states (i.e. 'national bottom lines') for those attributes to support the compulsory values of ecosystem health and human health for recreation.

Implementing the NPS-FW requires community discussions about both the current state of fresh water as well as the desired state. The Bay of Plenty Regional Council (BOPRC) is implementing the NPS-FW progressively by working in priority catchments, which they have called Water Management Areas (WMAs). As part of the community consultation process, Suren et al. (2015) prepared a report that summarised the current state of scientific knowledge within the Kaituna-Maketū and Pongakawa-Waitahanui WMA, and highlighted information gaps. This report briefly summarised information on:

- Freshwater quality.
- Periphyton (stream algae).
- Cyanobacteria (commonly called blue-green algae).
- Freshwater invertebrates.
- Fish communities.
- Hydrology.
- Landuse and soils.
- Groundwater.

The Suren et al (2015) report emphasised that the freshwater fish are one of the most important ecological values of waterways and have sustained iwi for centuries, who have developed close relationships with their natural life cycles. Such close relationships ensured that they could harvest this bountiful food supply. Other important freshwater fish include introduced trout, which were liberated during the 19th century throughout the country, and which form a hugely important recreational resource.

Despite their importance, both native and introduced fish are often adversely affected by human activities. For instance, channel straightening and dredging, removal of riparian vegetation, input of excess nutrients and sediments, and water abstraction all place stress on fish communities. Such stressors are particularly evident in lowland areas where agricultural development and urban activities occur. Many native fish also require free access to and from the sea, and this is often interrupted by dams (either hydroelectric or water supply), as well as structures such as poorly installed road culverts and floodgates.

The Suren et al (2015 report) made four recommendations for future fisheries work and the Kaituna-Maketū and Pongakawa-Waitahanui WMA:

1 Initiate a one-off sampling campaign to provide information on fish communities in sites where this information is lacking.

2 Consider implementation of a monitoring program for fish communities in selected sites throughout the WMA.

3 Compare observed fish distributions to those predicted in the absence of human activities.

4 Develop and maintain a database of potential fish barriers throughout the WMA to help set priorities for their removal.

Many of these recommendations were based on information extracted from the New Zealand Freshwater Fisheries Database (NZFFD). The NZFFD is a nationally significant database that is maintained by NIWA, and contains over 30,000 records of freshwater fish observations throughout the country. Examination of the NZFFD showed that fish surveys have been conducted at 198 sites throughout the WMA (Figure 1). Eight records were from sites surveyed prior to 1980, while the most up-to-date records come from eight sites surveyed in 2010 and 2011 (Table 1). Most samples (86) were collected post 2000, whilst 46 and 50 sites were collected respectively during the 80s and 90s. This means that much of the fisheries information from sites in the WMA may be out of date, and in need of reassessment.

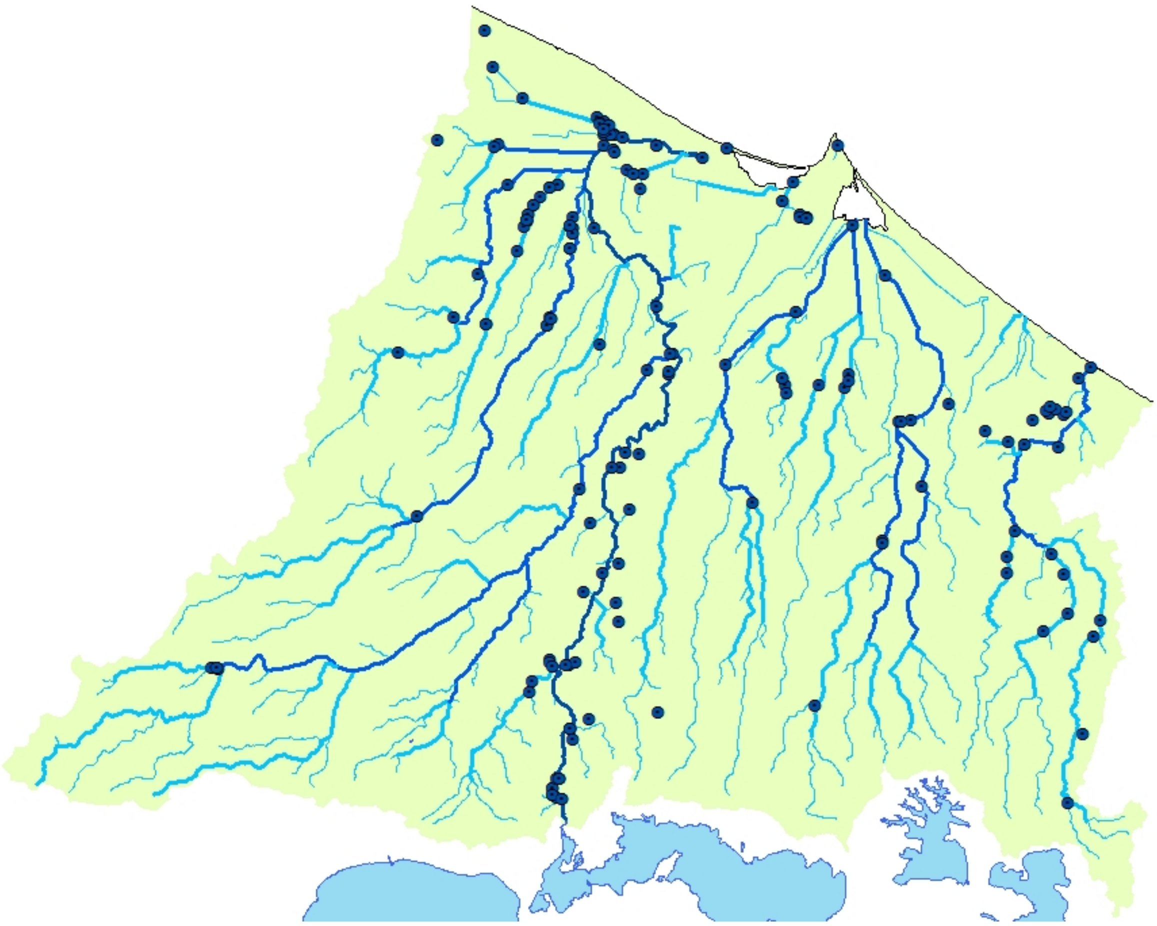

Figure 1 Map of the previous sampling sites as identified in the New Zealand Freshwater Fisheries Database showing the location of fish surveys undertaken in the WMA.

Table 1 Summary of the number of surveys conducted over approximately a 10 year interval in the Kaituna–Maketu and Pongakawa–Waitahanui WMA. All data was extracted from the NZFFD.

Decade	***No of surveys***	***Percentage of total***
Pre-1970s	2	1.0
1970s	6	3.0
1980s	46	23.2
1990s	50	25.3
2000s	86	43.4
2010's	8	4.0
Total	**198**	

1.1 Summary of current data

A number of specific fish surveys have already been conducted in the WMA. In particular, NIWA (2004) undertook a large-scale survey of fish throughout mainstem of the Kaituna, where they sampled fish from five sites in the mainstem Kaituna, and five sites in tributary streams draining into the Kaituna. Bioresearches also conducted a number of fish surveys throughout the WMA, including the lower Kaituna River as part of investigations into the AFFCO freezing works discharge at Waitangi (Bioresearches 1991, 1993), and in the Ohineangaanga in a stream as part of investigations for the Pukepine stormwater discharge (Bioresearches 1978).

Surveys have also been conducted at 30 sites in the Waitahanui Catchment since 1983, with the majority of sites (16) being surveyed in 1995 as part of investigations into minimum ecological flows for this river. Seven other surveys were done in this catchment between 2005–2008. Longfin eels were the most widely distributed species, being found at 19 sites, while shortfin eel and redfin bullies were found at 10/30 sites. Species such as torrent fish, giant bullies, inanga, yellow-eyed mullet and black flounder were only found at one or two sites - although densities of some of these fish were very high. These surveys are typical in that they show that the lower parts of the river and the estuary contained greater fish diversity than sites in the upper tributaries.

The Environmental Research Institute of the University of Waikato also surveyed the large oxbow pond in the lower reaches of the Kaituna River, as well as the mainstem of the river just upstream of the oxbow (Hicks et al 2014). This survey was done with the use of an electrofishing boat and was in response of sightings by the public of "large orange fish:" in the oxbow, and concern that they may be koi carp. This survey showed no koi carp were present; instead the large fish were goldfish. Other common fish in the oxbow included shortfin eels (the most numerous fish), redfin, giant and common bully.

Examination of the NZFFD of all surveys within the WMA revealed that 21 species of fish have been recorded, along with three unidentified species of eel, bully and galaxias (Table 2). The freshwater crayfish, or koura, were also found. Although not fish, these invertebrates are included in the NZFFD, reflecting their importance as mahinga kai species. The most commonly collected fish were longfin and shortfin eels (found at 44 and 39% of sites respectively), followed by common bully (found at 29% of sites), as well as inanga, smelt and redfin bully (collected at between 20 – 25% of sites: Table 2).

Introduced fish such as mosquito fish and rainbow trout were found at 14% of the sites sampled, while brown trout and goldfish were found at about 4% of sites. Koura were also very common at sites throughout the area.

*Table 2 List of fish species recorded within the Kaituna-Maketu and Pongakawa-Waitahanui WMA showing the number of sites each species was found at, and their percentage occurrence. Species in bold indicate introduced fish. Data from the NZFFD (downloaded October 2015). * = Introduced species.*

Common name	***Species***	***Sites***	***Percent***
Longfin eels	*Anguilla dieffenbachii*	88	44.4
Shortfin eels	*Anguilla australis*	80	40.4
Koura	*Parenephrops planifrons*	60	30.3
Common bully	*Gobiomorphus cotidianus*	59	29.8
Smelt	*Retropinna retropinna*	48	24.2
Inanga	*Galaxias maculatus*	47	23.7
Redfin bully	*Gobiomorphus huttoni*	44	22.2
Rainbow trout*	*Oncorhynchus mykiss*	29	14.6
Unidentified eel	*Anguilla* sp	29	14.6
Mosquito fish*	*Gambusia affinis*	28	14.1
Banded kokopu	*Galaxias fasciatus*	22	11.1
Giant bully	*Gobiomorphus gobioides*	19	9.6
Giant kokopu	*Galaxias argenteus*	8	4.0
Gold fish*	*Carassius auratus*	8	4.0
Torrentfish	*Cheimarrichthys fosteri*	7	3.5
Brown trout*	*Salmo trutta*	7	3.5
Koaro	*Galaxias brevipinnis*	6	3.0
Grey Mullet	*Mugil cephalus*	5	2.5
Yelloweye mullet	*Aldrichetta forsteri*	4	2.0
Lamprey	*Geotria australis*	3	1.5
Unidentified galaxid	*Galaxias* sp	2	1.0
Yellowbelly flounder	*Rhombosolea retiaria*	2	1.0
Unidentified bully	*Gobiomorphus*	1	0.5
Cran's bully	*Gobiomorphus basalis*	1	0.5
Cockabully	*Grahamina nigripenne*	1	0.5

As part of ecological investigations of waterways throughout the WMA that have been initiated to fill the gaps identified in the Suren et al (2015) report, a freshwater fish survey was undertaken in May 2016 to specifically address at least one of the recommendations to provide information on fish communities in sites where this information is lacking. A secondary, but closely aligned objective was to conduct more up-to-date surveys from sites previously examined, but where the data was greater than 20 years old. It is hoped that this information would feed into other recommendations such as implementing a fish monitoring programme throughout the WMA, and identifying priority areas where fish barriers be removed or remediated.

Part 2: Methods

2.1 Site selection

Following the recommendations made by Suren et al (2015), the NZFFD was examined and all data from the Kaituna WMA extracted. Examination of this data showed that almost half of the 198 surveys had been conducted prior to 2000, and so were 16 or more years old. Examination of these records in GIS showed that many of these sites with old surveys were clustered to one of 11 catchments (Figure 2; Table 3). Sites within these catchments where fisheries information was potentially out-dated were assessed as priority targets for repeat fishing surveys in 2016.

Table 3 Number of sites identified from the NZFFD in each of the 11 catchments where surveys were more than 16 years old. These catchments were prioritised for surveys in 2016.

Catchment		***Sites***
1	Upper Waitahanui	9
2	Lower Waitahanui below Campbell Road	3
3	Upper Pongakawa (above Old Coach Road)	5
4	Pongakawa Canal	2
5	Kaikokopu (at State Highway 2 and Little Waihī Estuary)	2
6	Ohineangaanga (lower and upper)	10
7	Raparapahoe	1
8	Whataroa	1
9	Upper Pokopoko	1
10	Upper Wairai	1
11	Upper Mangorewa	3
TOTAL		**38**

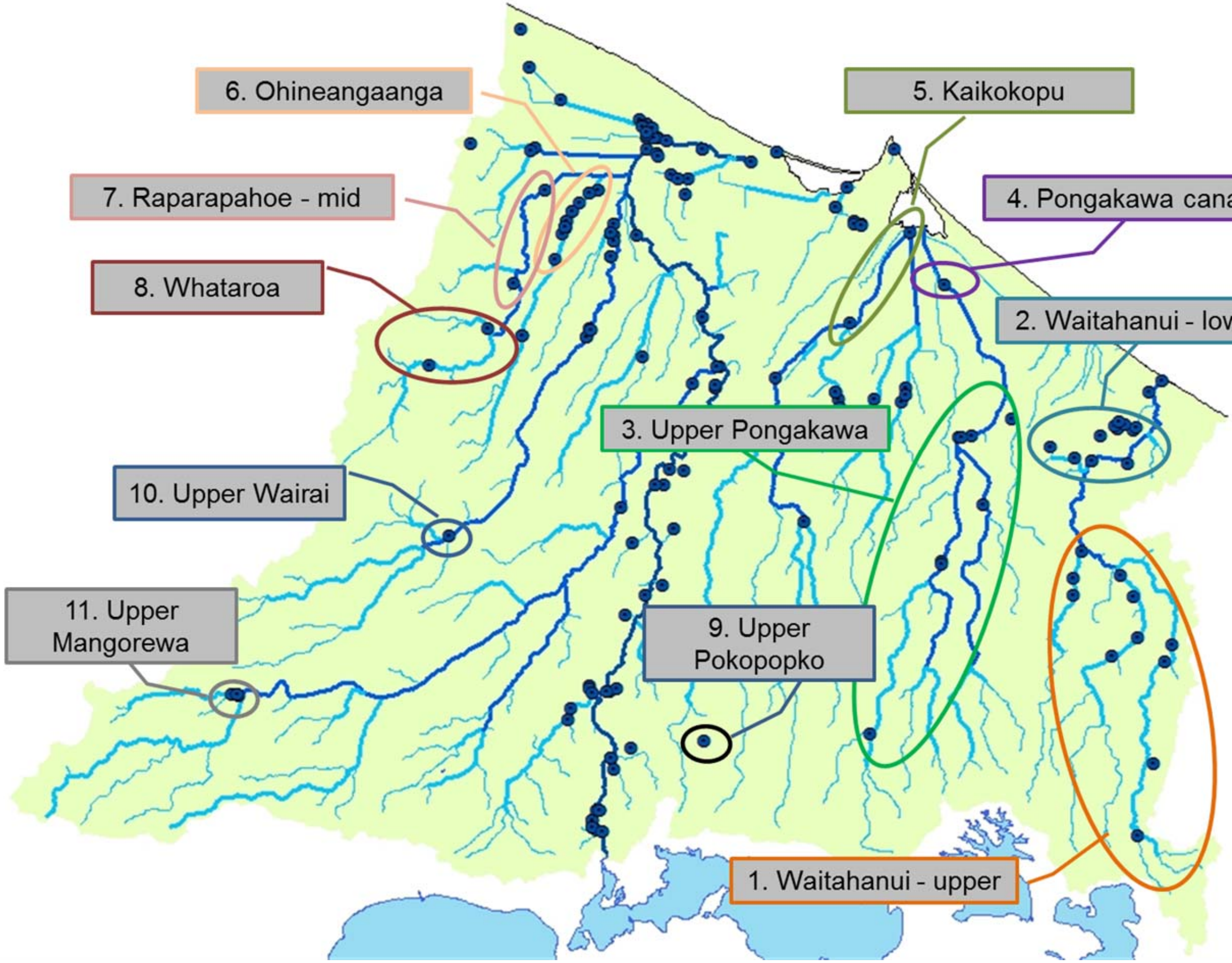

Figure 2 *Location of the 11 catchments from where surveys were conducted prior to 2000. These sites were prioritised for further follow-up survey work in 2016.*

Another priority target for fish surveys was based on further interrogation of the NZFFD to identify sites draining catchments of different land use. The River Environment Classification (REC) database was used to identify the dominant land use above each segment of the waterway network where previous surveys had been conducted. The REC provides a network "map" of all waterways throughout the country, with waterways divided into individual segments (called NZReaches): defined as a specific reach of a waterway between tributaries. Our previous analysis (Suren et al 2015) showed that catchments draining either native bush or pine plantation were under-represented in the area, so waterways draining these land use types were subsequently targeted for the 2016 survey. The REC waterway network within the WMA was first clipped to sites within 50 m of a road, as ease of access was considered an important aspect of the site selection process. This process revealed approximately 40 potential sites that could be sampled that flowed through either pine forest or native bush.

A potential short-list of about 80 sites was subsequently created throughout the WMA, some of which had been previously surveyed. However, field investigations showed that many of these sites were dry, inaccessible due to either steep topography, dense growths of blackberry or gorse, or were located on private land where access could not be arranged. These sites were subsequently omitted from the list. A total of 58 sites were finally surveyed over a three week period from 18 April to 10 May 2016.

2.2 Field assessments

Fish communities were assessed by a combination of single pass electric-fishing using a Kāinga EFM3000, or using fyke nets in deep, slow flowing streams or streams with fine substrates. Electric fishing specifically targeted habitats in streams where fish were likely to occur, instead of surveying all habitats in a reach. Thus, for example, areas of fine, highly mobile pumice sand, or cobbles in fast flowing riffles were not extensively fished, as these habitats rarely supported any fish. In contrast, undercut banks, debris jams and macrophyte beds were specifically targeted within a reach, as these habitats often supported fish. The average area fish was 80 m^2, ranging from 20 m^2 in a small narrow tributary into the Mangorewa River, to 175 m^2 in a small tributary into the Whataroa Stream. Average fishing time was nine minutes per site, although this was as high as 20 minutes at a site in the Pongokawa. Voltages used during fishing ranged from 200 – 500 volts, with the majority of sampling using 300 volts. All collected fish were kept in buckets, and anaesthetised using phenoxy-ethanol (diluted to about 5 ml per 10 litres). Fish length was measured to the nearest millimetre, identified, and replaced into a bucket containing natural stream water to recover. All fish were subsequently released back into the stream. Three unbaited replicate fyke nets (mesh size = 4 mm) were deployed overnight at sites that were unsuited for electric fishing. All nets were retrieved the following morning, and all fish caught were identified and measured prior to release.

2.3 Statistical analysis

2.3.1 Physical characteristics

A total of 58 additional sites were surveyed during April/May 2016. All this data was combined with data extracted from the NZFFD, giving a total of 251 sites. Individual GPS locations for each new site were plotted using ARC-GIS to ensure that they were located on the appropriate NZReach. Where necessary, sites were manually moved to the appropriate NZReach. This occurred mainly where sites had been surveyed close to a tributary to ensure the appropriate NZReach had been selected.

The representativeness of all surveyed sites in relation to rivers throughout the WMA was assessed using techniques outlined in Snelder and Scarsbrook (2005). Briefly, this involved calculating the proportion of survey sites of a particular REC classification class to the total number of sites of the same class throughout the WMA. The proportion of river length in each class throughout the WMA was then calculated, and expressed as a proportion to the total river length in the WMA. The ratio of the first proportion to the second proportion illustrated the representativeness of the fish survey sites to other waterways within the WMA. Numbers close to 1 suggest that the number of fish survey sites was similar to the ratio of waterway length in that class; numbers greater than 1 indicate an over representation of fish survey sites when compared to waterway length; numbers less than 1 indicate under representation. Site representativeness was calculated first for just sites extracted from the NZFFD, and secondly for all combined fishing sites.

Environmental factors such as elevation, distance to sea and slope were extracted from the Freshwater Environments of New Zealand (FENZ) database based on the NZReach identification. A total of 13 environmental factors describing each site were derived from the 251 sites. This environmental data described overall physical, climatic, and flow features at each site which may have influenced fish community composition. To reduce the inherent complexity of this data (13 factors from 251 sites), a Principal Components Analysis (PCA) was used to reveal any hidden structure in the data. In this way we could identify what the major environmental differences were between sites. Prior to the PCA, all factors were standardised so that measures with different units could be analysed together. The PCA also identified what environmental parameters were responsible for any observed gradients in the data. This was done by examining correlation coefficients between the environmental factors and the PCA axis 1 and 2 scores.

Following the PCA, a similarity matrix was calculated to show the similarity of all sites to each other based on their environmental data. The Euclidean distance measure was used for this analysis, which measures the “straight-line” distance between samples, and is appropriate for physical data. Thus, for example, consider three sites, A, B and C. If Sites A and B were generally small, far inland, and dominated by native bush, and Site C was a large river close to the coast flowing through a catchment dominated by pasture, then the Sites A and B would have a very small Euclidean distance measure as all environmental factors would be similar. However, there would be a greater Euclidean distance between sites A and C, and B and C, reflecting the fact that site C was different to the other sites. The resultant similarity matrix for all 251 sites thus summarised the similarity of all sites to each other, based on their environmental data. This similarity matrix was used to compare to a second similarity matrix that was created based on the fish survey data (see below). Having two similarity matrices allowed us to see how well relationships in the ecological data matrix match up with the patters in the environmental data matrix.

2.3.2 Fish community patterns

All fish data was converted to presence-absence, and ordination (non-metric multidimensional scaling: NMDS) used to examine and explore relationships and patterns in the fish community composition. Ordination is a statistical method used in exploratory data analysis to search for patterns in the data, such as being done here, rather than in testing specific hypothesis. It orders objects (in this case individual sampling sites) that are characterized by values of multiple variables (in this case the presence or absence of different fish at each site) so that similar sites are located near each other on an x-y graph, and dissimilar sites are located farther from each other.

The first step in an ordination is to calculate a similarity matrix of all sites to each other. The Bray-Curtis similarity measure was used for this analysis. This measure results in scores ranging from 0 (i.e. two sites having no species in composition) to 1 (i.e. two sites having exactly the same species composition). An NMDS ordination was then run on this similarity matrix to examine relationships between all the individual sites. NMDS produces a statistical score (called stress) that indicates the strength of the resultant ordination. Stress values greater than 0.3 indicate the resultant sample configurations are no better than arbitrary (i.e. there are no underlying patterns to the invertebrate community composition at each site). This would occur where the fish communities did not differ greatly between the different streams. Under such a scenario, no differences would be expected between streams flowing through native forest or through pasture. Generally speaking, sample configurations should not be interpreted unless the stress value is less than 0.2 (Clarke and Gorley 2001). The ordination thus identifies major gradients in the data, with the x-axis representing the greatest difference between samples, and the Y axis representing the second greatest difference. Analysing correlations of both species distribution and environmental variables against these axes allows us to determine which species and environmental variables were responsible for the observed gradients in the data.

The similarity matrices developed from the environmental and ecological data were examined to determine how well the relationships between sites matched each other. For this analysis we used the RELATE command in Primer (Ver 6.0), which calculates the Spearman rank correlation of the similarity matrices based on environmental or ecological data. If the fish communities were structured by the derived environmental variables, then we would expect a strong correlation between the two similarity matrices, whereas if fish communities were responding to other non-measured environmental variables, then such strong correlations would not exist. Following this analysis we examined relationships between environmental variables and fish communities using the BEST procedure. This procedure determines which environmental variables were responsible for any observed patterns to the fish data. Because of the large number of environmental variables (13), we used a stepwise approach for this analysis, whereby the BEST procedure iteratively added or removed variables and selected only those which explained the highest degree of variation to the fish communities. This analysis was complemented by a regression analysis of environmental variables against the NMDS axis scores. Both the BEST and regression analysis enabled us to determine which of the environmental variables were responsible for structuring fish communities throughout the WMA.

Following this analysis, commentary was made about selected species, including comments on their distribution throughout the WMA.

2.3.3 Assessment of fish integrity

Suren (2016) recently developed a fish index of biotic integrity (Fish IBI) to describe the ecological integrity of fish communities at sites throughout the Bay of Plenty. This Fish IBI was based on work developed by Joy and Death (2004) that examined the behaviour of six different metrics describing fish communities at sites along a gradient of elevation and distance to sea. The metrics used included the number of: native species; riffle dwelling species; benthic pool species; pelagic pool species; intolerant species; and the proportion of native species at a site. Joy (2007) demonstrated the use of quantile regression analysis that, when fitted to each metric plotted against either elevation or distance to sea, more accurately divided the data into two regression lines. The lowermost regression line was based on 33% of the data points occurring below this line, while the upper regression line was based on 66% of the data occurring below this. Where the number of species for a particular metric at a site of a given and altitude (or distance to sea) was below the 33% regression line, that site scored 1 for that particular metric. Where the number of species was above the 66% regression line, the sites were scored 5 of that metric. Sites where the number of species was between the two lines at a given altitude were scored 3. The total Fish IBI was based on the sum of the scores for the six metrics for both elevation and distance to sea.

Although Suren (2016) found slightly different relationships between some metrics and distance to sea and elevation than found by Joy (2007) in the Waikato region, the overall range of scores was very similar. Joy (2007) also developed five integrity classes based on percentile scores of the calculated Fish IBI, and Suren (2016) used a similar method in the Bay of Plenty. The range of Fish IBI scores used by Suren were very similar to those used by Joy (2007), suggesting that despite the subtle differences in the fish community composition between the regions, and differences in the behaviour of each metric against the altitudinal or distance to sea gradients, the two scores were very similar.

The Fish IBI was thus calculated for each site sampled throughout the WMA. Regression analysis assessed how the scores varied with parameters such as elevation, distance to sea, and percentage of different land cover classes. ANOVA was also used to see whether the Fish IBI differed between streams draining different land use classes.

Part 3: Results

3.1 Site representativeness

Representativeness of fishing sites extracted from either the NZFFD, or NZFFD sites combined with the 2016 survey sites was assessed in comparison to the nature of water ways throughout the WMA. For the REC Climate class, both the Cool-Wet (CW) and Warm-Dry classes were over-represented, while the Cool-Extremely Wet (CX) class was under-represented (Table 4). Both the Warm-Wet, and Warm-extremely Wet climate classes were well-represented. There was no major change in site representativeness between the NZFFD surveys and the combined surveys, although the over-representation of sites had been reduced slightly.

For source of flow, Hill country sites (H) were under represented in both datasets, whereas Lowland sites were only slightly overrepresented (Table 4). Lake-fed sites were well over-represented in the NZFFD surveys, reflecting the large number of sites from the Kaituna River. This over-representation declined slightly in the combined survey, reflecting the fact that the Kaituna River was not surveyed again in 2016.

The dominant catchment geology in the WMA was volcanic, and these were well represented in both the NZFFD and the combined data (Table 4). There as a slight over-representation of sites in non-volcanic geology in the NZFFD data, but this over-representation had declined in the combined data.

Examination of land cover data showed some differences in site representativeness between the NZFFD data and the combined data (Table 4). In particular, the proportion of streams draining native bush had increased in the combined data, while the proportion of streams draining urban catchment shad decreased slightly. This simply reflected the fact that catchments that drained native bush were in part, specifically targeted in the contemporary survey, as these had been identified previously as being under-represented (Suren et al. 2015).

Table 4 *Calculation of site representativeness of the fish sites extracted from the NZFFD, or the combined data from there and the contemporary survey when compared with streams throughout the WMA for different climate, source of flow, geology and land cover classes. Shading indicates whether particular REC classes were under represented (orange), overrepresented (green), or sampled roughly according to the proportion found in the region (blue).*

REC class	Number of NZFFD sites	Combined NZFFD + 2016 survey	Total length of class (km)	Length of class as a proportion of total river length (%)	Representation of class by NZFFD sites	Representation of class by combined sites
Climate						
CW	34	36	128.5	7.5	2.35	1.91
CX	3	3	136.4	7.9	0.20	0.15
WD	6	7	9.7	0.6	5.46	4.90
WW	130	177	1304.8	75.8	0.88	0.93
WX	21	29	141.6	8.2	1.32	1.40
Source of flow						
H	4	6	209.5	12.2	0.17	0.20
L	145	201	1461.9	84.9	0.88	0.94
Lk	45	45	49.6	2.9	8.05	6.20
Geology						
Non_Volcanic	7	7	42.2	2.5	1.47	1.14
Volcanic	187	245	1678.8	97.5	0.99	1.00
Land cover						
Agriculture	157	195	1180.4	68.6	1.18	1.13
Exotic_Forest	27	35	321.4	18.7	0.75	0.74
Native	8	20	195.4	11.4	0.36	0.70
Urban	2	2	23.7	1.4	0.75	0.58

3.2 Physical characteristics

The Kaituna-Maketu and Pongakawa-Waitahanui WMA is characterised by a dozen or so large catchments of which all but the Waitahanui drain into estuaries. Rivers such as the Kopureroa, Raparapahoe, Ohineangaanga, Waiari, Mangorewa all coalesce and drain into the Kaituna River, which flows into the Kaituna-Maketu Estuary. Other rivers such as the Pokopoko, Pongakawa, Wharere and Kaikokopu all drain into the Waihi Estuary.

As expected, a wide variety of stream types existed throughout the WMA. Streams varied greatly with respect to their location, with some streams located in low elevations close to the coast, and others more inland at higher elevations (Table 5). However, the overall elevation gradients were not particularly high, and most sites were relatively close to the coast. Stream size was also highly variable, ranging from very small streams with low discharge through to large rivers such as the Kaituna with correspondingly higher discharge (Table 5). Land cover also varied greatly between catchments, with more developed pasture than native bush and most catchments. Average modelled sediment size was also relatively small, emphasising the dominance of fine pumice substrate throughout the WMA.

Table 5 Summary of environmental factors in each of the 56 sites surveyed in 2016, showing the average, minimum and maximum values.

Environmental factor	***Average***	***Min***	***Max***
Average elevation (m ASL)	74.9	4.6	386.1
Distance to coast	18.9	0.2	63.8
Average annual January air temp	18.4	16.8	18.8
Average segment flow	6.365	0.004	49.134
Average annual segment low flow	2.963	0.001	21.973
Segment slope	0.6	0	6.3
Downstream average slope	0.2	0	3.0
Upstream average rainfall days (> 20 mm)	19.8	12.3	23.5
Upstream average slope	8.4	0.1	27.2
% Native in upstream catchment	29.1	0	100.0
% Pasture in upstream catchment	46.6	0	100.0
Sediment size (modelled)	2.6	1.0	5.9
Habitat (modelled)	3.8	1.6	4.4

Examination of relationships between distance inland and altitude showed some interesting difference between the major catchments surveyed (Figure 3). For example, streams in the Waitahanui, Waiari, and Pongakawa catchments appeared steeper than streams in the Kaituna, or Mangorewa catchments. Nevertheless, as expected, there was a general trend of increasing altitude with increasing distance inland.

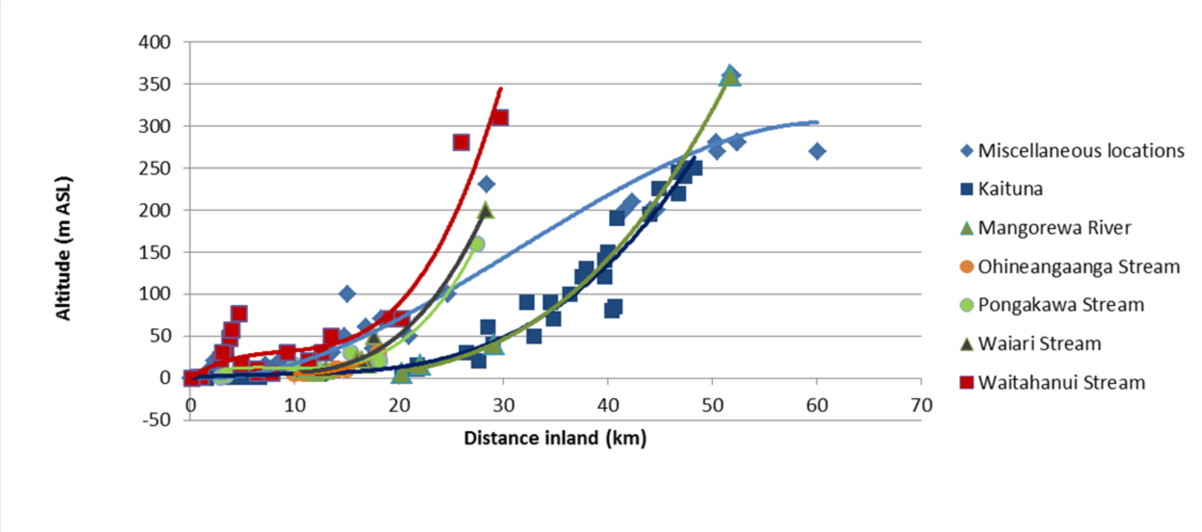

Figure 3 *Relationships between distance inland and altitude in six catchments in the Kaituna-Maketu and Pongakawa-Waitahanui WMA. Also shown is a general relationship to sites in other miscellaneous catchments in the WMA. Regression lines showing were based on a third-order polynomial, which explained the most variation for each relationship (r^2 >0.90).*

The PCA of the 13 environmental factors was used to identify any major gradients in the data, and to determine if any natural groupings could be detected according to environmental factors. The first two axes of the PCA explained a total of 48% of total variability in the data. A major gradient along the PCA axis 1 was related to distance to sea and elevation, catchment slope, climate (January Air temperature and rainfall), and land cover (native bush or pasture). PCA axis 2 appeared to represent gradients in climate, distance to sea and elevation, land cover, stream hydrology, catchment slope and habitat (Figure 4). These results suggested that physical conditions in the 251 sites were influenced by a strong gradient of physical location (elevation and distance to sea), catchment slope, climatic variables, land use and local variables such as substrate and habitat.

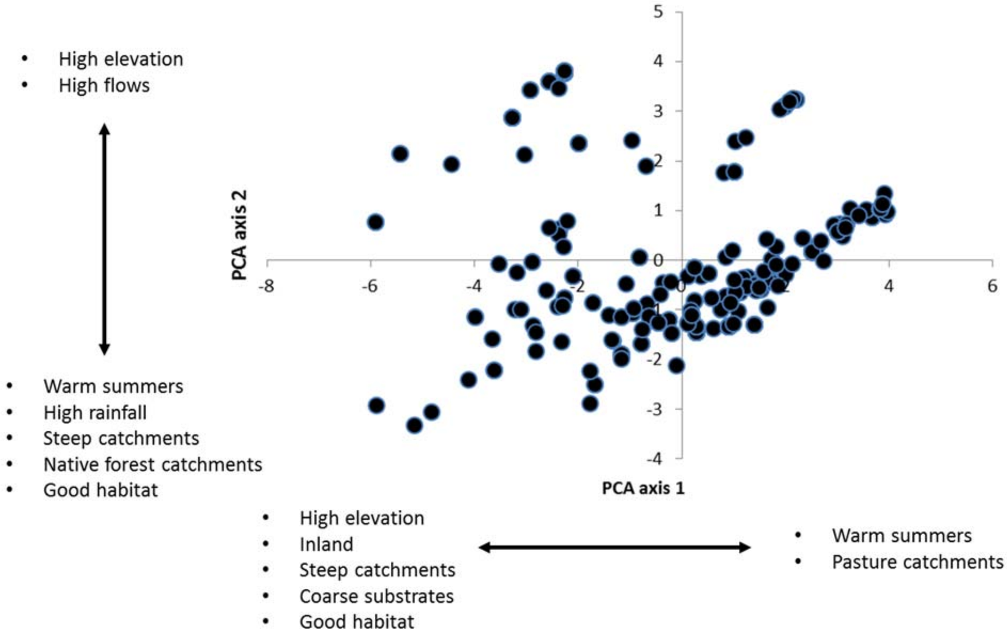

Figure 4 *Results of a principal components analysis (PCA) of environmental data collected at the 251 sites extracted from the NZFFD, and the 2016 fish survey. Also shown are specific environmental factors that displayed strong correlations in either the PCA axes 1 or 2 scores.*

3.3 The fish fauna

A total of 16 fish species were identified in the latest survey of streams throughout the WMA, along with unidentified species of eel, bully and galaxias, and koura (Table 6). The fauna was dominated by longfin and shortfin eels, redfin bully, unidentified small eels and koura. All of these fish (and koura) have previously been recorded in the WMA, with the exception of shortjawed kokopu. The finding of shortjaw kokopu at one site in the Ohineangaanga Stream represents a new record of this species in the WMA. This species is considered in the Department of Conservation threat classification ranking as being threatened. Its finding in the Ohineangaanga is therefore significant. A full list of fish species found at each site is provided in Appendix 1.

Table 6 List of fish species recorded within the Kaituna-Maketu and Pongakawa-Waitahanui WMA from the recent 2016 survey, showing the number of sites each species was found that, and their percentage occurrence. Species in bold indicate introduced fish. Species are highlighted in pink indicate those listed by the Department of Conservation as being "Threatened, nationally vulnerable"; those highlighted in orange indicate those identified as being "At risk, declining".

Common name	***Species***	***Sites***	***Percent***
Longfin eels	*Anguilla dieffenbachii*	48	82.8
Redfin bully	*Gobiomorphus huttoni*	36	62.1
Shortfin eels	*Anguilla australis*	26	44.8
Unidentified eel	*Anguilla* sp	25	43.1
Koura	*Parenephrops*	21	36.2
Inanga	*Galaxias maculatus*	14	24.1
Smelt	*Retropinna retropinna*	13	22.4
Giant bully	*Gobiomorphus gobioides*	8	13.8
Banded kokopu	*Galaxias fasciatus*	6	10.3
Giant kokopu	*Galaxias argenteus*	5	8.6
Koaro	*Galaxias brevipinnis*	5	8.6
Mosquito fish	*Gambusia affinis*	5	8.6
Common bully	*Gobiomorphus cotidianus*	4	6.9
Torrentfish	*Cheimarrichthys fosteri*	3	5.2
Unidentified galaxias	*Galaxias* sp	2	3.4
Lamprey	*Geotria australis*	2	3.4
Rainbow trout	*Oncorhynchus mykiss*	2	3.4
Brown trout	*Salmo trutta*	2	3.4
Shortjaw kokopu	*Galaxias postvectis*	1	1.7

The results of the 2016 survey were compared to the results of the fish surveys extracted from the NZFFD. In particular, the frequency of occurrence of each fish species at sites throughout the WMA was compared between the two datasets. Examination of the ratio of the frequency of occurrence in the 2016 surveys to those from the NZFFD showed that 7 fish species were more frequently encountered in the contemporary survey (Table 7). The higher proportion of sites with redfin bully, giant kokopu and koaro may reflect the differences in stream types surveyed in the more recent survey, many of which were in smaller streams in catchments dominated by native bush or pine forest. Other fish, such as common bully, rainbow trout and mosquito fish were less common in the contemporary survey. This may also reflect the fact that habitat conditions in many of the small forested streams that were surveyed were unsuitable for these species. For example, common bullies and mosquito fish prefer generally slow flowing streams with fine substrates, whereas many of the streams surveyed in 2016 were relatively fast flowing with coarser substrates. Lack of rainbow trout may also reflect the fact that many of the streams surveyed were too small to support rainbow trout.

Table 7 List of fish species recorded within the Kaituna-Maketu and Pongakawa-Waitahanui WMA showing the ratio of the frequency of occurrence of different species in the 2016 surveys and in the NZFFD data. Fish more commonly encountered in the 2016 survey highlighted in green; fish less commonly encountered highlighted in orange.

Common name	***Species***	***% NZFFD***	***% 2016***	***Ratio Contemporary: NZFFD***
Longfin eels	*Anguilla dieffenbachii*	44.4	82.8	1.86
Shortfin eels	*Anguilla australis*	40.4	44.8	1.11
Koura	*Parenephrops*	30.3	36.2	1.19
Common bully	*Gobiomorphus cotidianus*	29.8	6.9	0.23
Smelt	*Retropinna retropinna*	24.2	22.4	0.93
Inanga	*Galaxias maculatus*	23.7	24.1	1.02
Redfin bully	*Gobiomorphus huttoni*	22.2	62.1	2.80
Rainbow trout	*Oncorhynchus mykiss*	14.6	3.4	0.24
Unidentified eel	*Anguilla* sp	14.6	43.1	2.95
Mosquito fish	*Gambusia affinis*	14.1	8.6	0.61
Banded kokopu	*Galaxias fasciatus*	11.1	10.3	0.93
Giant bully	*Gobiomorphus gobioides*	9.6	13.8	1.44
Giant kokopu	*Galaxias argenteus*	4	8.6	2.16
Brown trout	*Salmo trutta*	3.5	3.4	0.99
Torrentfish	*Cheimarrichthys fosteri*	3.5	5.2	1.48
Koaro	*Galaxias brevipinnis*	3	8.6	2.87
Lamprey	*Geotria australis*	1.5	3.4	2.30
Unidentified galaxias	*Galaxias* sp	1	3.4	3.45
Shortjaw kokopu	*Galaxias postvectis*	0	1.7	

3.4 Fish community patterns

The NMDS analysis of fish presence-absence data throughout the WMA had a stress score of 0.13, suggesting that there were some patterns in the data. Correlations of individual species against axes 1 and 2 showed that shortfin eels and mosquito fish were found in sites with low axis 1 scores. Correlations with environmental data showed that these sites were typified by warm summer temperatures, and high pasture land use (Figure 5). Samples with low axes 2 scores were characterised by the presence of common bullies and koura, while samples with high axis 2 scores were characterised by longfin eels and banded kokopu (Figure 5). No environmental parameters were correlated to this axes, suggesting it represented an unknown environmental gradient.

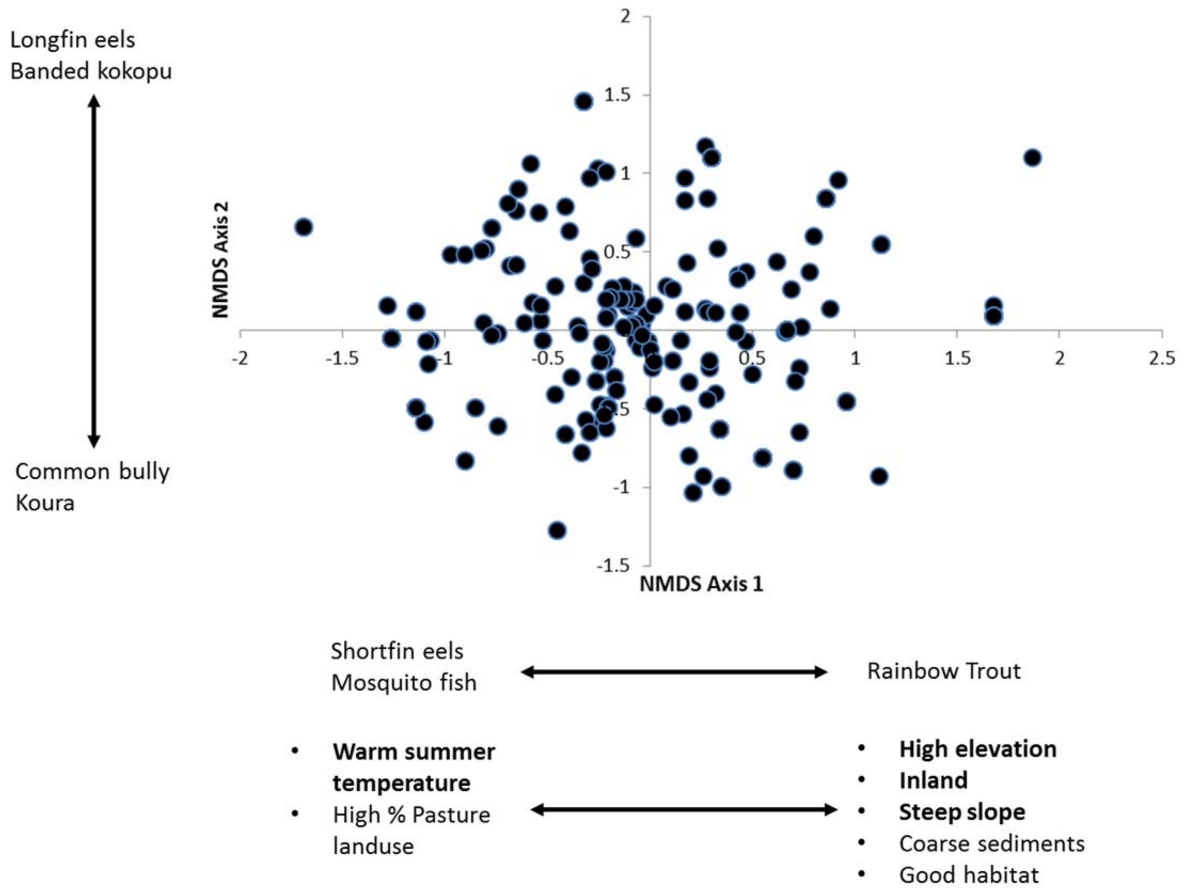

Figure 5 *Results of a NMDS ordination of fish species presence-absence collected from the combined data set of 251 sites of both the NZFFD and the 2016 survey. Graph shows which fish species, and environmental factors were correlated to each of the NMDS axis 1 and 2 scores. Variable names in bold were those identified in the BEST analysis as structuring invertebrate communities (see text).*

The RELATE analysis showed a significant similarity between the similarity matrices based on environmental or ecological data (Spearman rank correlation coefficient = 0.309, P <0.001). The BEST procedure identified five environmental variables that were shown to be responsible the observed patterns to the invertebrate data (Figure 5). Four of these were also identified in the regression analysis of environmental data against NMDS axis 1 scores.

The results of this analysis showed that there were strong environmental gradients in streams throughout the Kaituna-Maketu and Pongakawa-Waitahanui WMA, and that these gradients were in part responsible for structuring fish communities found in each site. Major drivers of community structure appeared to be a mixture of elevation and distance to sea. In particular, the effect of altitude and distance to sea on fish communities can clearly be seen by the strong reduction in the number of species with each of these variables (see, for example, Figure 6). Other large scale factors such as catchment topography, climatic variables such as average some temperature, and land cover were also implicated in structuring fish communities throughout the WMA. This has also been shown in other studies (e.g. Hicks and McCaughan 1997; Rowe et al 1999), where, for example, banded kokopu were found only in streams draining native bush or exotic forest, but were absent from streams draining pasture.

These studies also highlighted that fish densities and biomass were generally higher in pasture streams than forested streams, reflecting the generally higher algal biomass and subsequent invertebrate food in these streams. Finally, it is likely that even small-scale factors such as sediment size and habitat availability were also important in structuring fish communities, as these have also be shown to affect fish distributions within streams (e.g. Jowett and Richardson, 1995).

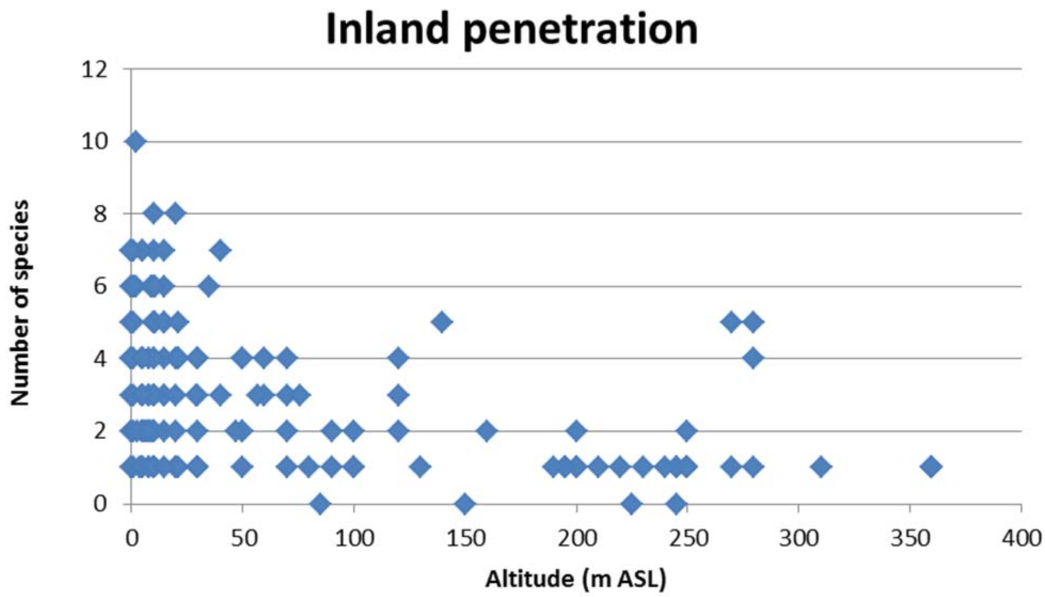

Figure 6 Relationships between the number of fish species found at each site and its altitude, showing a strong reduction in species richness with altitude.

3.5 Assessment of fish integrity

Of the 251 sites throughout the Kaituna WMA, approximately one third (88 sites) had Fish IBI scores characteristic of poor integrity classes (Figure 7). Approximately 23% of sites had scores characteristic of either moderate or excellent fish integrity, and 16% of sites had scores characteristic of sites of good fish integrity. Six sites had no fish.

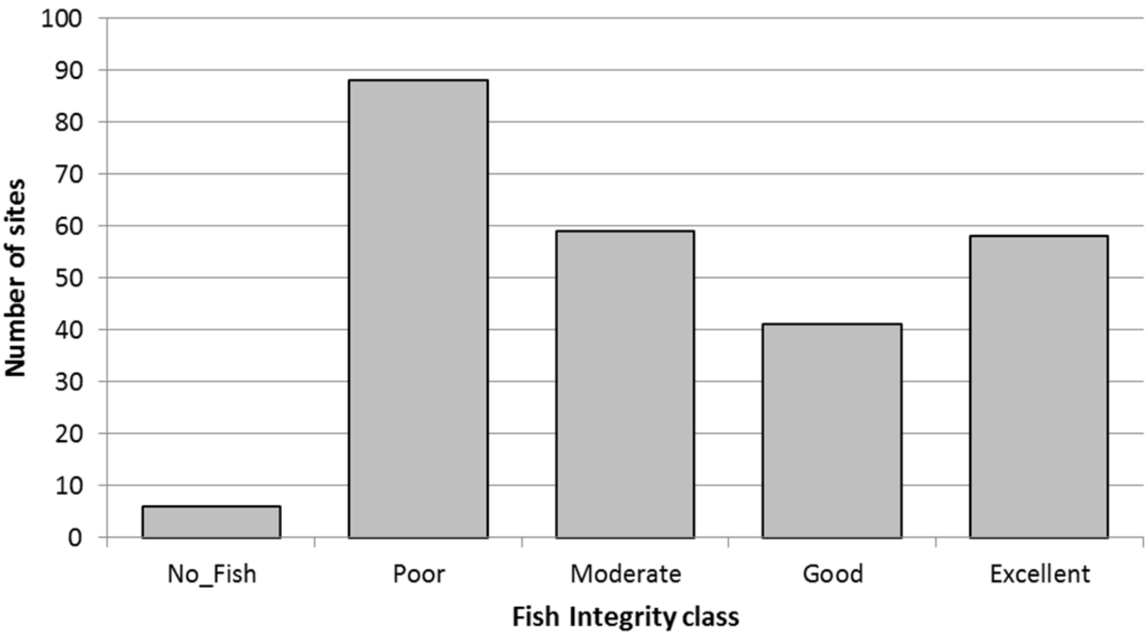

Figure 7 Number of sites throughout the Kaituna WMA allocated to one of five fish integrity classes based on the Fish IBI scores.

ANOVA showed no significant difference between Fish IBI score and dominant land cover within the catchment of each site (Figure 8). Streams draining catchments dominated by indigenous forest, exotic forest or pasture all had similar Fish IBI scores (approximately 33), although these were all highly variable. Streams draining urban catchments had the lowest scores. However, these were much more highly variable emphasising that some urban streams have high Fish IBI scores, whilst others had very low scores.

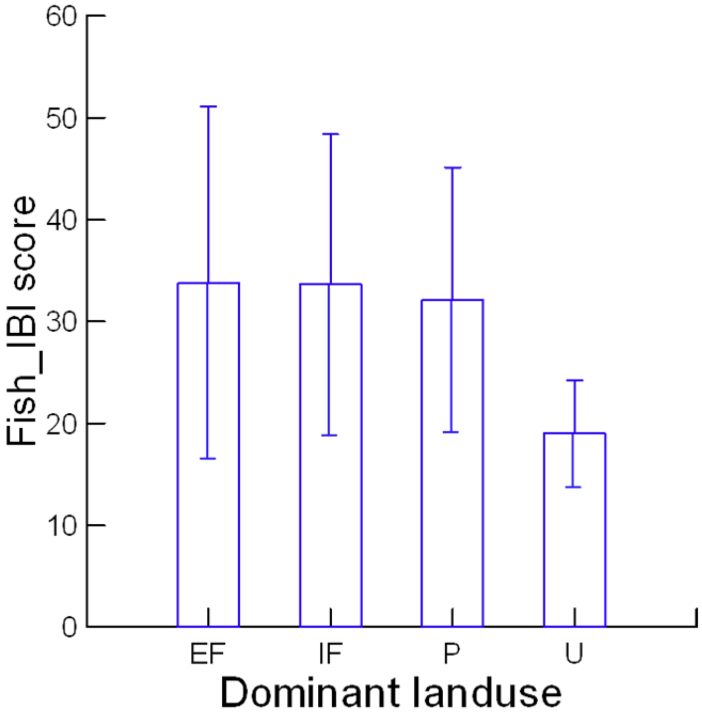

Figure 8 *Mean (+ 1 SE) of Fish IBI score of streams draining different dominant land cover within the Kaituna WMA. EF = exotic forest; IF = indigenous forest; P = pasture; U = urban.*

Significant regressions (P <0.001) were found between Fish IBI scores and both distance to sea and elevation, but the explanatory power of these regressions was very low (approximately 5%). This meant that although Fish IBI scores did vary according to distance to sea or elevation, the effect of this was generally very small. Fish IBI scores were therefore controlled by factors other than distance to sea or elevation. Regression analysis of Fish IBI scores against the percentage of land cover of indigenous forest, exotic forest, horticulture, pasture and urban areas showed, at best, significant but very weak relationships to percentage cover of exotic forest and horticulture (Table 8). These results suggest that factors other than land use appear important in determining the overall Fish IBI at a site.

Table 8 *Summary of regression analysis of Fish IBI against percentage cover of five land-use classes above each sampling site (n = 252). Table shows the significance value of the regression (model P value), as well is a statistical power (model r^2 value).*

Land-use	*Model P value*	*Narrative statement*	*Model r^2 value*	*Narrative statement*
Native vegetation	0.098	Not significant	0.007	No relationship
Exotic forests	0.016	Significant	0.023	Very weak relationship
Horticulture	0.022	Significant	0.021	Very weak relationship
Pasture	0.182	Not significant	0.007	No relationship
Urban	0.112	Not significant	0.010	No relationship

Examination of the spatial distribution of the five different Fish integrity classes showed little pattern within the WMA (Figure 9). For an example, sites assessed as having poor fish integrity were found both in lowland areas around Te Puke, as well as sites further inland at the upper reaches of the Kaituna River, Waitahanui, and Mangorewa rivers. Further analysis is required tease out better relationships between environmental factors controlling Fish IBI scores within a site.

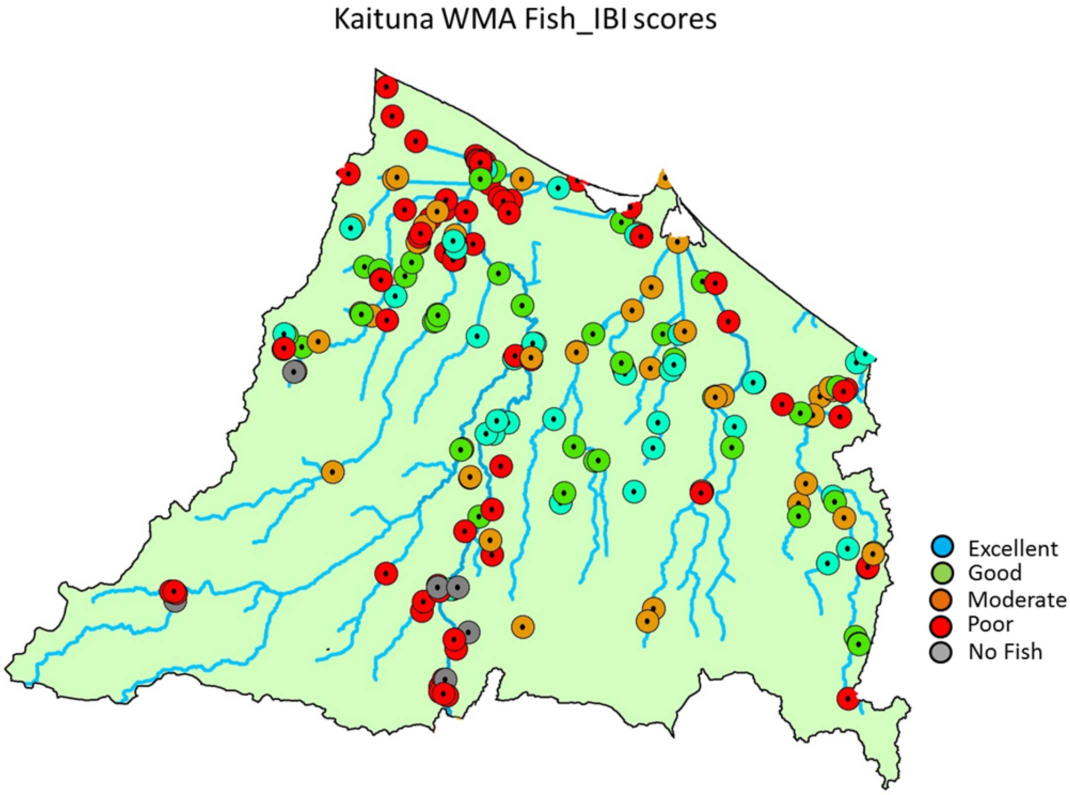

Figure 9 *Distribution of Fish IBI classes throughout the Kaituna WMA. Note the lack of apparent geographical pattern between fish integrity classes.*

3.6 Distribution of dominant taxa

3.6.1 Overview of native fish

In this section we describe observed distribution patterns of the dominant fish species found throughout the Kaituna-Maketu and Pongakawa-Waitahanui WMA. Although brief notes on the natural history features of each species is given, interested readers are encouraged to consult the wide range of textbooks written by the late Dr Robert McDowall (see McDowall 1990; McDowall 2000; McDowall 2011), as well as selected webpages such as those produced by both NIWA (see https://www.niwa.co.nz/freshwater-and-estuaries/nzffd/identification-guides-and-keys) and the Department of Conservation (see http://www.doc.govt.nz/nature/native-animals/freshwater-fish/) should they wish to obtain further information. Much of the information about the individual species below has been gleaned from these sources.

As a general note preceding the section, the reader is reminded that many of the 21 native fish occurring in the WMA exhibit a diadromous behaviour: i.e. they need to migrate between the sea and freshwater as a part of their life cycle. These migrating fish thus need the ability to freely move between rivers and streams that support good habitat, and the sea. Any instream barriers such as flood gates, pump stations, road culverts or dams can therefore prevent or restrict this natural upstream and downstream migration of fish. This means that even a small, badly designed road culvert can have huge implications to the upstream fish fauna, even though instream habitat conditions above this culvert could be ideal.

The annual migration of fish from the sea into freshwater is best known by the "whitebait runs" during the spring each year. Iwi have traditionally relied on these upstream migrations to collect mahinga kai, and whitebaiting continues to be a highly popular activity throughout the region. The annual autumnal downstream movement of large migrant eels is also well-known, and this was likely to have formed an important component of mahinga kai to iwi throughout the region.

3.6.2 **Eels**

Figure 10 Shortfin eel (source Auckland Council).

Figure 11 Longfin eel ©Tony Eldon.

There are two main species of eel in New Zealand: shortfin and longfin eels (Figure 10; Figure 11). Longfin eels typically penetrate further inland, and are more commonly found in stony bottomed, fast-flowing streams. Longfin eels can remain in rivers and streams for many years until they undergo physiological changes in readiness for their downstream migration out to sea. Some large females do this only after 60+ years. Shortfin eels, in contrast, are primarily found in lowland areas, particularly in slow flowing rivers, ponds and wetlands with generally soft bottomed substrates. Short fin eels usually migrate at a much earlier age than longfin eels, at around 20 + years. Although the conservation status of shortfin eels appears stable, considerable concern exists as to the conservation of longfin eels: indeed they are regarded by the Department of Conservation as “In decline, threatened” (Goodman et al. 2014).

As with many native fish, both eel species require access to the sea to complete their life cycle. In this instance, eels display a catadromous behaviour whereby mature adults swim downstream from rivers during autumn and into the ocean to breed. Although the exact location of spawning sites is yet to be determined, evidence suggests that eels spawn in deep ocean trenches somewhere to the west of Fiji. Once the fertilised eggs have hatched in these deep trenches, the larval eels undergo a series of complex metamorphic changes, and slowly drift back to New Zealand on the prevailing ocean currents. Once they return to coastal areas around the country, the small larval eels (which at this stage are called leptocephalus) transform themselves into juvenile glass eels. These gather in river estuaries prior to migrating back upstream - usually in spring. These glass eels soon develop pigmentation, and turn into elvers that swim upstream in search of suitable habitat. They then live here from anywhere between 20 to 80+ years (depending on the species), before migrating back to sea to spawn again before dying.

Within the Kaituna-Maketu and Pongakawa-Waitahanui WMA, differences in the distribution of short and longfin eels is clearly evident, with longfin eels being found further inland and at higher elevations than shortfin eels (Figure 12; Figure 14). Previous fishing surveys found shortfin eels present in mostly low elevation sites relatively close to the coast, such as streams around Te Puke, the Pongakawa and Waitahanui. Shortfin eels were also found relatively far inland up the Kaituna River (Figure 15). The recent survey undertaken found new records of shortfin eels in the upper parts of the Wharere, as well is the Ohineangaanga, and reaches of the Waikoura and Kirikiri Streams. (Figure 14).

Longfin eels penetrate much further inland than shortfin eels, and were found in sites at high altitude (250 – 300 m ASL; Figure 13). They were found in most sites sampled during the 2016 survey, which extended their inland range in many catchments previously surveyed. For example, three new records were found in the upper reaches of the Wharere stream, as well is the Pokopoko stream (Figure 12). The finding of a large longfin eel in the Onaia Stream on Kokako Track also represented one of the furthest inland records of this species in a newly surveyed sub catchment of the Mangorewa.

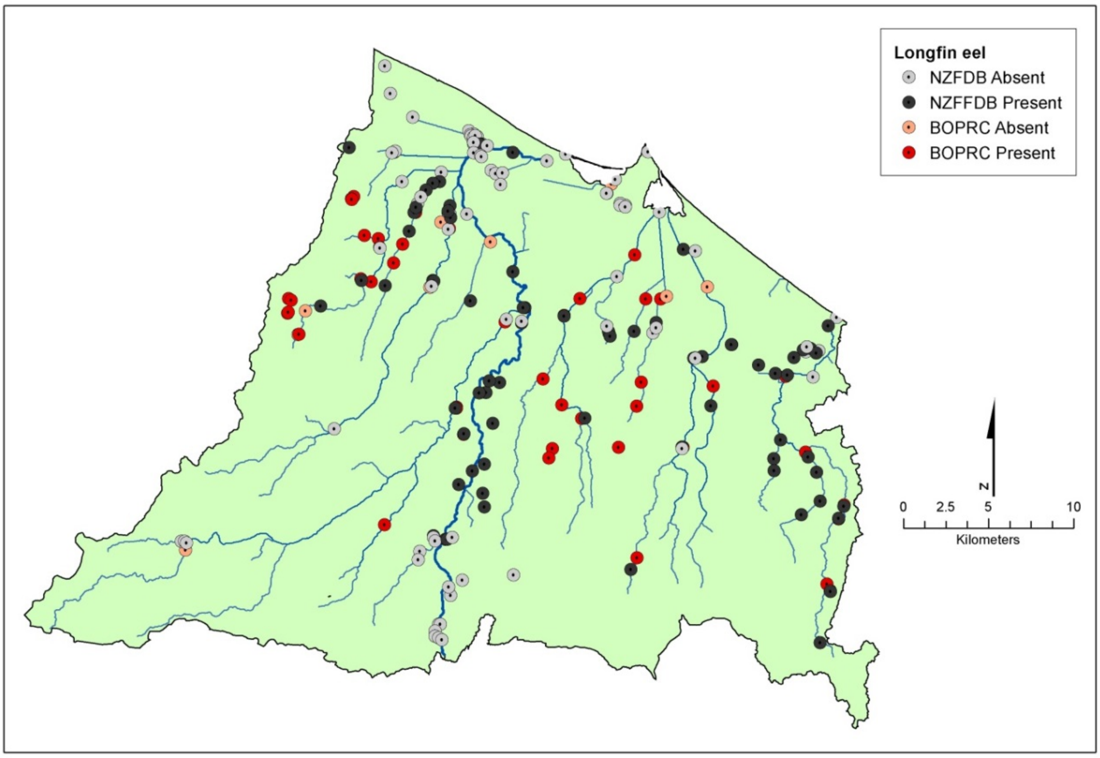

Figure 12 Distribution of longfin eel throughout the Kaituna-Maketu and Pongakawa-Waitahanui WMA. NZFFD sites represented by grey symbols (species absent) or black symbols (species present), while the 2016 surveys represented by pink symbols (species absent) or red symbols (species present).

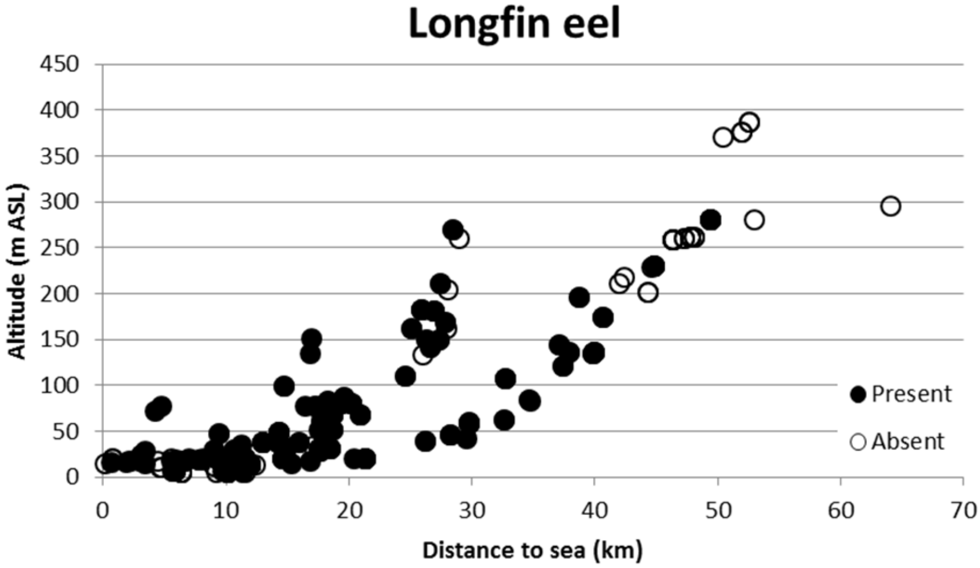

Figure 13 *Distribution of longfin eel showing its relationship to distance to sea and altitude.*

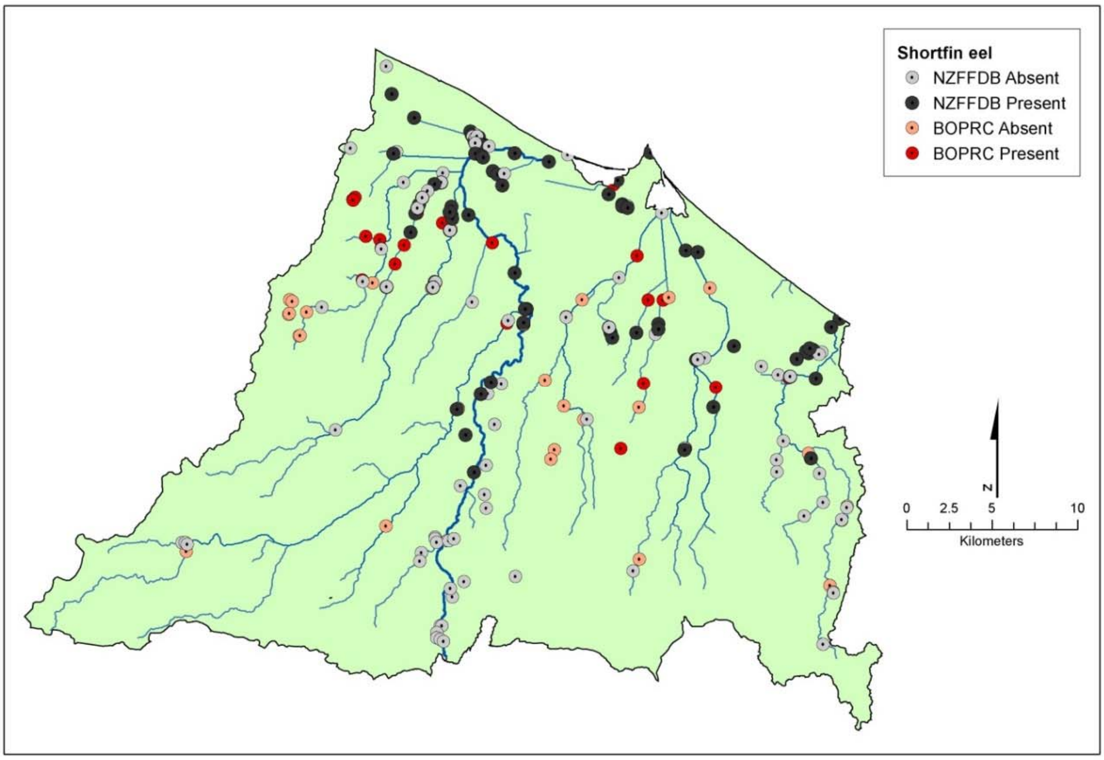

Figure 14 *Distribution of shortfin eel throughout the Kaituna-Maketu and Pongakawa-Waitahanui WMA. Conventions as per Figure 10. Note the fewer number of sites supporting shortfin eels further inland.*

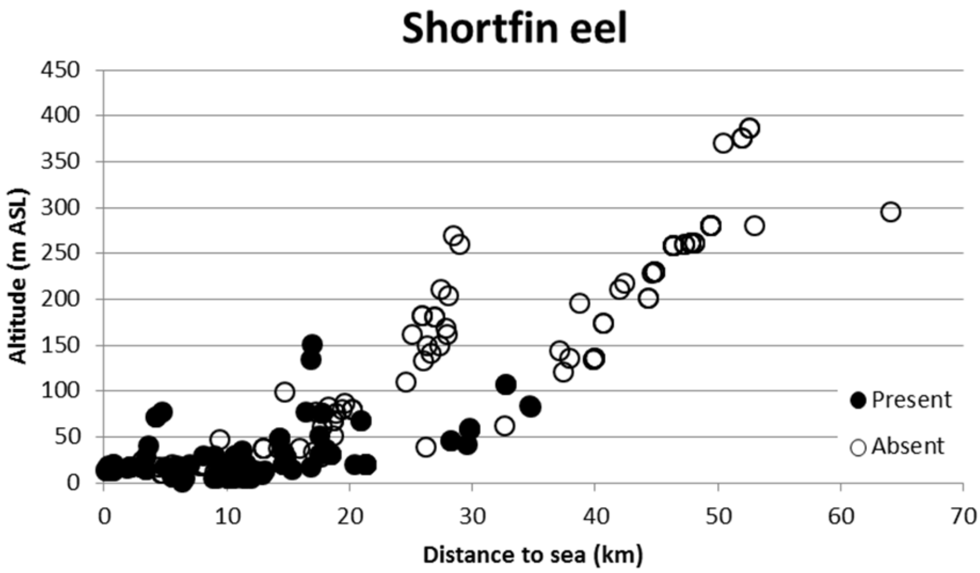

Figure 15 *Distribution of longfin eel showing its relationship to distance to sea and altitude.*

Examination of the size distribution data of both eel species collected during the 2016 survey revealed some concerning trends and patterns. Of the 511 longfin eels collected, the size classes showed a distinct lack of the smallest size class (<100 mm), whereas the next two size classes (100 – 200 mm and 200 – 300 mm supported far more individuals (Figure 16). A similar pattern was observed for the shortfin eels (Figure 16). This lack of small elvers in the population is of concern, as it suggests that there is insufficient recruitment of young eels throughout the catchment. The reasons for this are unknown, but for longfin eels, reflect a nation-wide pattern of apparent reduced recruitment that is manifested through lower elver numbers (Jellyman 2012; Wright 2013). It is recommended that further fisheries surveys are conducted throughout the WMA to see if this trend continues.

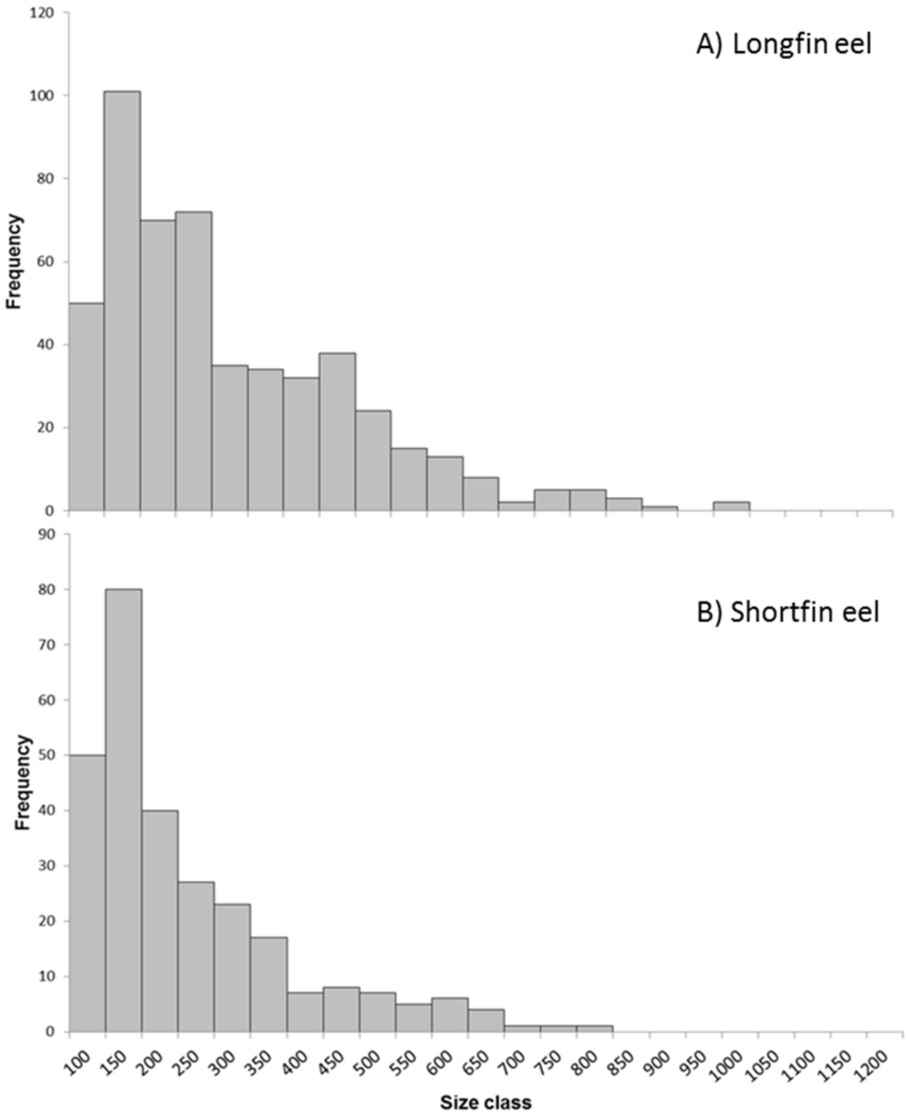

Figure 16 *Size – frequency distribution of A) 511 longfin eels and B) 278 shortfin eels collected from 52 sites throughout the Kaituna WMA that were electric-fished during autumn 2016.*

3.6.3 **Banded kokopu**

Figure 17 *Banded kokopu (source www.niwa.co.nz).*

Banded kokopu (Figure 17) are one of the five galaxiid species found in the Kaituna-Maketu and Pongakawa-Waitahanui WMA. As with most galaxiids, juveniles of banded kokopu are members of the generic "whitebait fishery" that enter our rivers each spring. They are generally the smallest of the five whitebait species and, like koaro, juvenile banded kokopu are very good climbers. This behaviour can distinguish them from other whitebait species such as inanga, as they can often be seen trying to “escape” from whitebait buckets by wriggling up their sides. Despite the juveniles being strong climbers, the species do not penetrate far inland, and are found mainly relatively close to the coast.

Adult banded kokopu are characterised by thin, pale, vertical bands running up the sides and over the back of the fish. They are often found in small, shaded streams that are well shaded by overhanging canopy vegetation. They are most commonly found in slow flowing areas such as pools where there is ample instream cover such as an undercut bank, large rocks or wood debris. Banded kokopu mostly consume terrestrial insects that fall into the water (Main and Lyon 1988). They can commonly grow over 200 mm (McDowall 1990).

Previous records of banded kokopu within the WMA showed them to be found in rivers to the East of the Kaituna River, such as the Waitahanui, Pongakawa, and Kaikokopu (Figure 18). The recent survey work produced new records of banded kokopu in the Waikoura Stream, and the upper reaches of small forested streams draining into the Whataroa. New records were also found for the Mangorewa, as well as sites further inland up the Wharere (Figure 18). Their distributions from all surveys showed that they were restricted to the sites within 40 km to the coast, and less than 250 m above sea level (Figure 19).

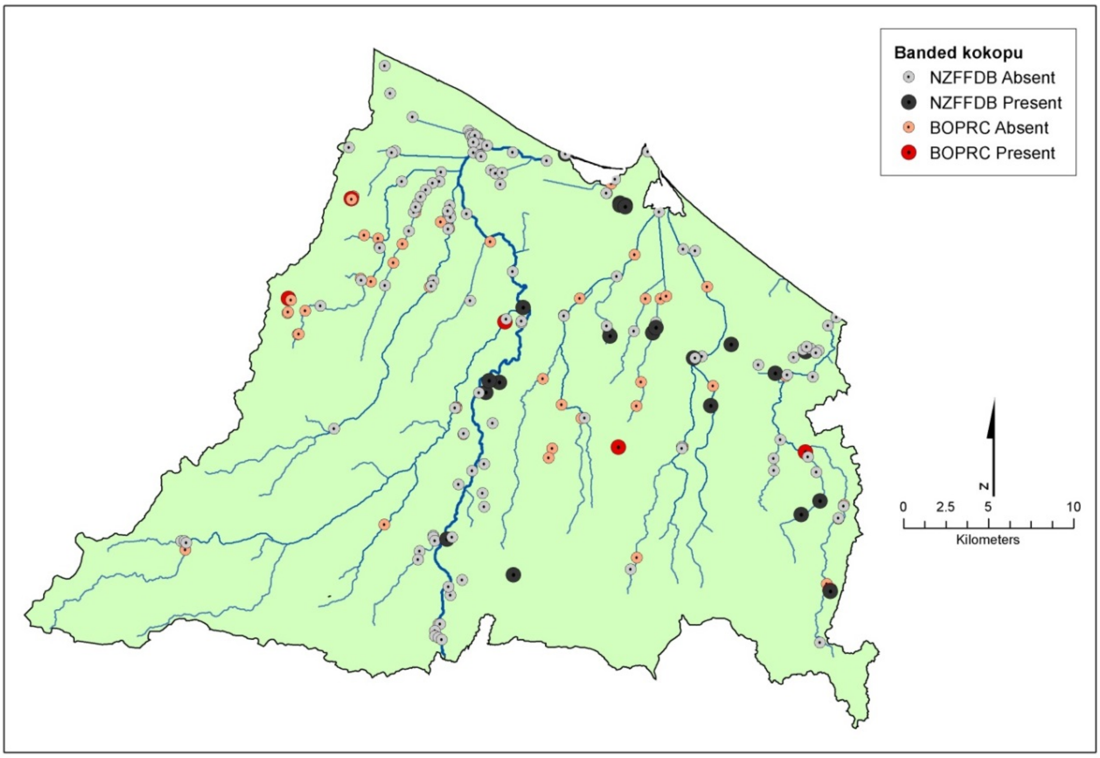

Figure 18 Distribution of banded kokopu throughout the Kaituna-Maketu and Pongakawa-Waitahanui WMA. Conventions as per Figure 10.

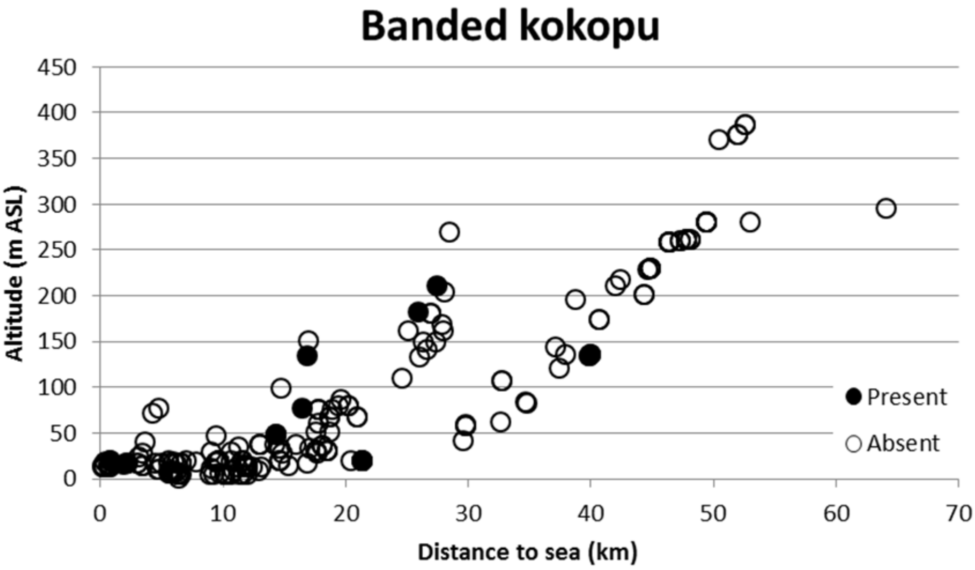

Figure 19 *Distribution of banded kokopu showing its relationship to distance to sea and altitude.*

3.6.4 **Koaro**

Figure 20 *Koaro, showing the irregular light and dark mottling pattern.*

Adult koaro are characterised by having their sides and back covered in a variable pattern of highly irregular light and dark patches, or bands, that seem to “glisten” in the light (Figure 20). The juveniles have great climbing abilities and can penetrate well inland. Like giant kokopu, their whitebait can be distinguished from other whitebait species by wriggling up the sides of buckets that they are placed into. Koaro seem to prefer fast flowing, highly turbulent streams with large substrates, and are mostly restricted to streams lined with native bush. As with many galaxiids, they lay their eggs in bankside vegetation, and rely on subsequent floods to re-wet these eggs where they can hatch and the larvae are washed downstream to the sea. This reliance on bankside vegetation may explain their distribution to catchments with only well-vegetated banks.

Large populations of koaro existed in the Rotorua lakes prior to European colonisation and the introduction of trout. Given their great climbing abilities, it is unlikely that even the Okere Falls would have prevented them from naturally colonising Lake Rotoiti, and Lake Rotorua. Koaro can however also form landlocked populations within lakes. Here, adults living in streams that flow into the lakes can lay their eggs amongst bankside vegetation. Upon hatching, these eggs are washed into the lakes, where larvae can live and grow before returning to the rivers and streams (McDowall 1990). The introduction of rainbow and brown trout has resulted in much lower densities of koaro in the Rotorua lakes: indeed most populations are now restricted to only small spring fed streams where trout are not found.

Most surveys in the Kaituna-Maketu and Pongakawa-Waitahanui WMA have failed to find koaro: indeed there were only three records of koaro from the NZFFD, all of which were in the Kaituna River (Figure 21). This would reflect firstly their preference for fast flowing turbulent water with large substrates, whereas many of the streams in this WMA are characterised by highly mobile pumice beds. Another potential reason for the lack of koaro throughout the WMA could reflect the requirement for well shaded streams in native bush. The recent surveys found populations of koaro in small streams draining into the Whataroa, as well as one stream in the upper Waitahanui (Figure 21). This latter stream was characterised by a well-established buffer of native vegetation around pine plantation forestry. Finding koaro in the Waitahanui is a new record within this catchment.

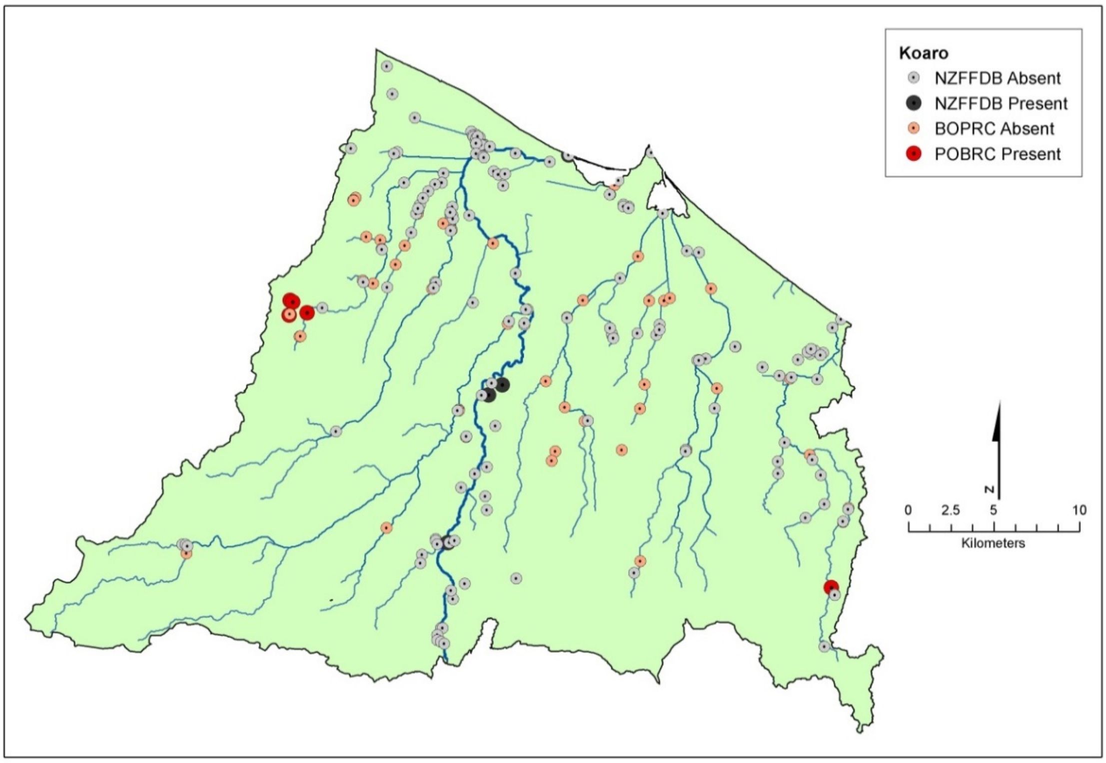

Figure 21 Distribution of koaro throughout the Kaituna-Maketu and Pongakawa-Waitahanui WMA. Conventions as per Figure 10.

3.6.5 **Inanga**

Figure 22 Adult inanga. Note the silver belly and slender body (source www.aucklandzoo.co.nz).

The term “whitebait” refers to the upstream juvenile migrating phase of five species of galaxiids. These small fish have spent the previous six or so months at sea, where they developed from larvae that had hatched the previous autumn and been carried downstream to the sea, where they turn into the larger juvenile “whitebait”. These fish generally display large spring migrations from the sea back up rivers and streams throughout the country, and this migration phase is responsible for a popular and widespread fishing activity. Inanga are one of the five galaxid species that make up the generic “whitebait” fishery in New Zealand. They also comprise the main species of whitebaiters’ catches, contributing upwards of 70 to 100% of the total catch.

Adult inanga are the smallest of all of the whitebait species, usually reaching 100 - 110 mm. They have a very distinctive silvery belly and a somewhat forked tail (Figure 22), and these features make them easy to distinguish from the other galaxiids. Inanga live in the same habitats as smelt, and can sometimes be confused with them. However, smelt have scales and an adipose fin, features that are easy to see on close examination. Furthermore, smelt have a peculiar “cucumber” odour to them.

Unlike other galaxiids, inanga cannot climb, and as such are considered to be a lowland species. They can overcome small barriers by burst swimming, but do not penetrate any great distance inland unless the river gradient is very gradual. Inanga inhabit open rivers, streams, lakes, and swamps near the coast and can often be seen shoaling in open water.

Inanga spawn amongst riparian vegetation near the upper limit of the saltwater wedge at high tides. Unfortunately, the amount of available habitat for spawning has decreased in many lowland streams due to extensive channel modifications, reinforcing banks with rock protection works, and grazing cattle to the water’s edge. Furthermore, many lowland areas in the Bay of Plenty, as in other parts of the country, have lost huge areas of swamp and wetland as land has been developed.

Results from the recent survey generally confirmed the distribution of inanga to sites generally close to the coast, although two sites in the upper Wharere Stream that supported inanga represented new records for this species in this catchment (Figure 23). Finding inanga in the mid-Pokopoko also represents a new inland record of the species in this catchment.

As expected, the distribution of inanga throughout the WMA was restricted to streams are generally less than 50 m above sea level. Although most records also found inanga relatively close to the coast, there were some records of inanga found at sites 30 km inland (Figure 24).

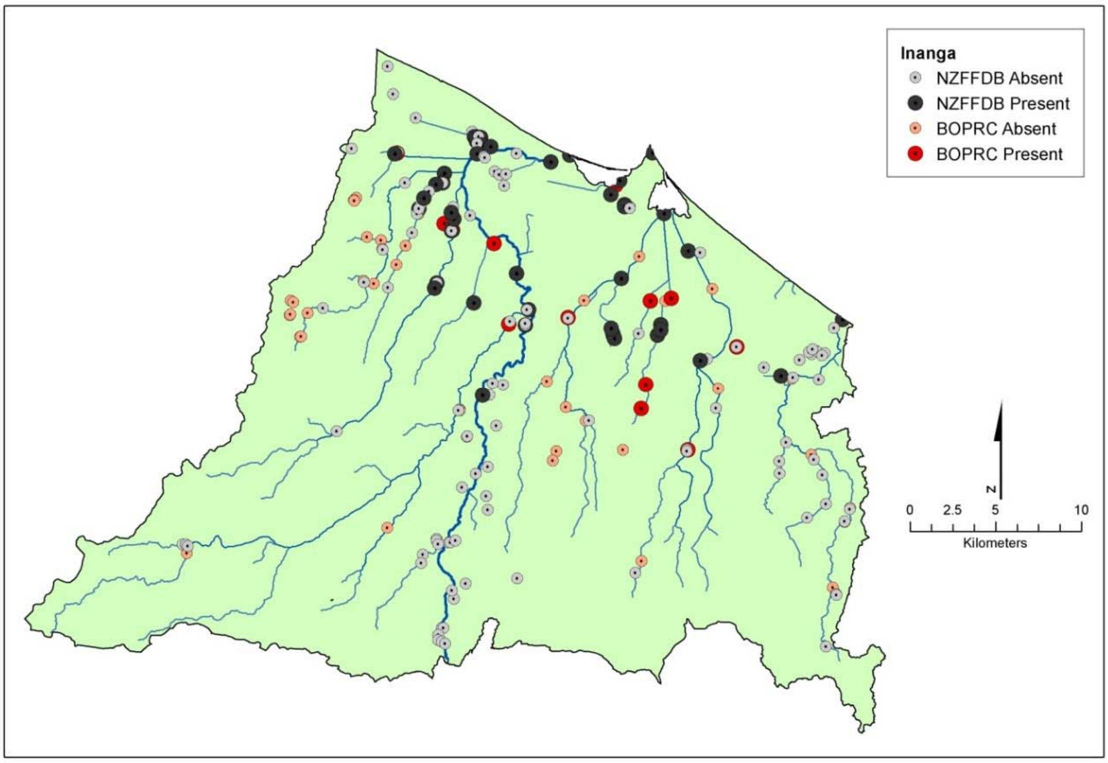

Figure 23 *Distribution of inanga throughout the Kaituna-Maketu and Pongakawa-Waitahanui WMA. Conventions as per Figure 10.*

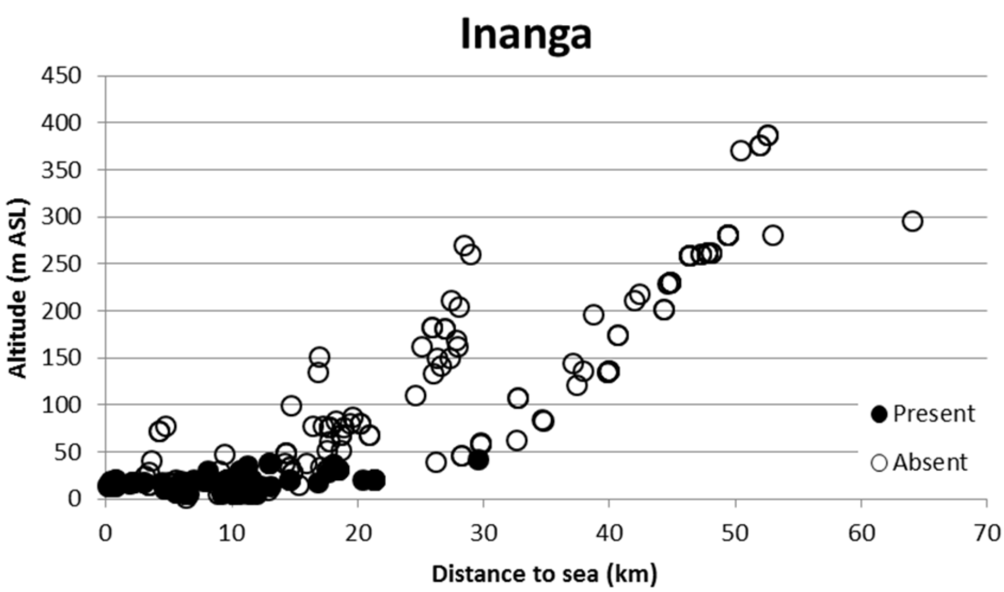

Figure 24 *Distribution of inanga showing its relationship to distance to sea and altitude. Note the absence of inanga from sites with an elevation greater than 50 m above sea level.*

3.6.6 **Common bully**

Figure 25 Common bully (source www.landcareresearch.co.nz).

As their name suggests, common bullies (Figure 25) are found everywhere in New Zealand. There are three other bully species that are easily confused with common bullies, and identification is often difficult without a microscope. Sometimes faint vertical lines along the cheek are a good characteristic, but this is not always reliable. They are generally only relatively small fish, growing only up to about 150 mm in length. They can live in marine, fresh water or brackish waters, where they spend their time living on the bottom of the streambed where they prey upon small invertebrates such as insect larvae and crustacea. They are normally found in still or slow-flowing water and are probably one of the most likely bullies to be seen.

As with many New Zealand fish, common bullies require access to the sea to complete their life cycle, although land-locked populations have become established in many lakes. Sea-going populations occur in river and streams near the coast, and where they are an important prey species for trout and eels.

They appear to be the second most common bully in the WMA, next to redfinned bullies. Previous surveys have found populations at sites along the Kaituna River, and in other streams such as the Waiari, Ohineangaanga, Raparapahoe and Waikoura that flow into the Kaituna (Figure 26). Their distribution up the entire Kaituna River most likely reflects a combination of both sea-run populations migrating upstream, as well as lake populations being swept through the Okere Falls from Lake Rotoiti downstream into the Kaituna River. This would explain their occurrence at sites 50 km or more inland, and-300 m (Figure 27). Common bullies were also observed in three streams flowing into the Waihi Estuary: the Pokopoko, the Pongakawa and the Kaikokopu. The recent surveys did not extend their distribution range in the WMA, with the records being found in the mid reaches of the Pongakawa and the Kaikokopu, both of which have previous records of species.

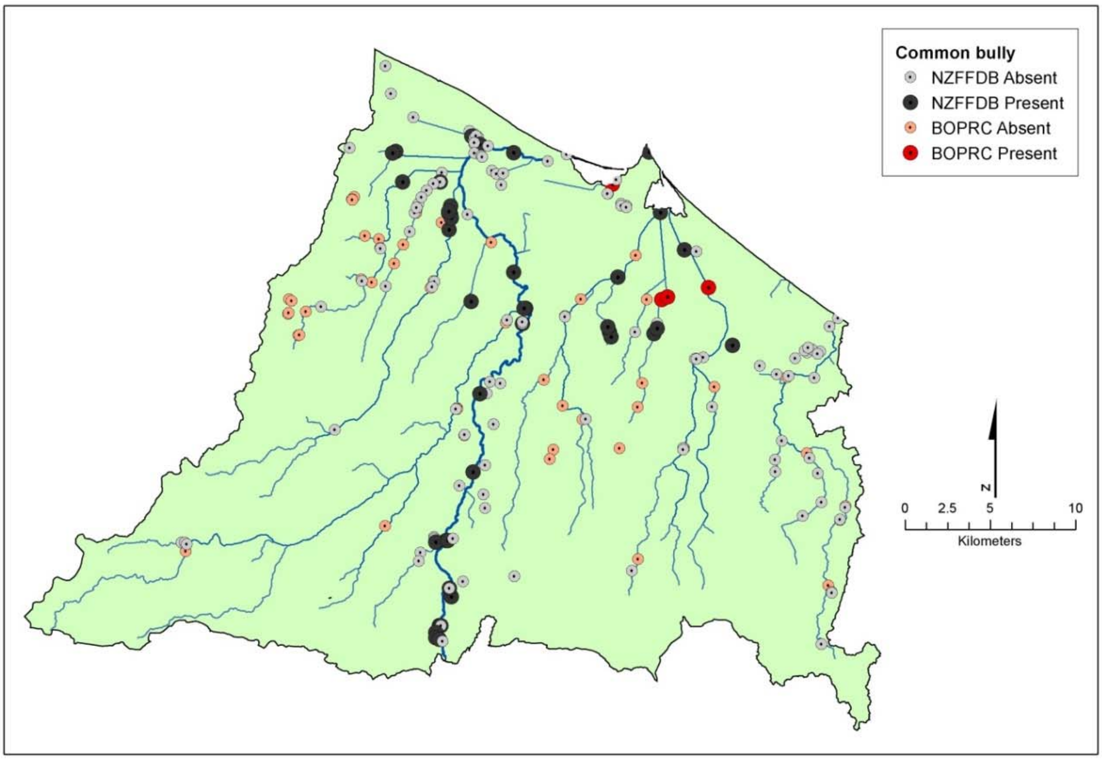

Figure 26 *Distribution of common bully throughout the Kaituna-Maketu and Pongakawa-Waitahanui WMA. Conventions as per Figure 10.*

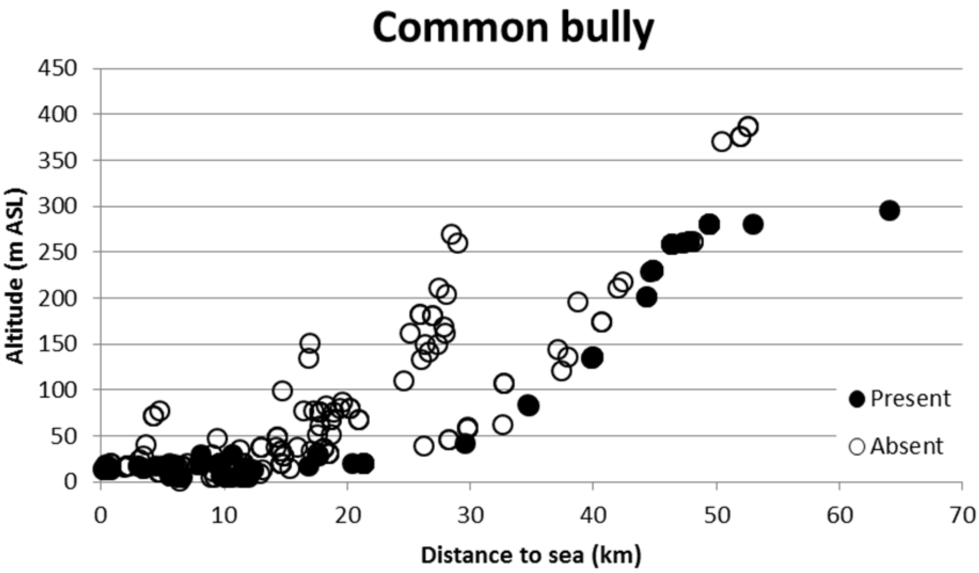

Figure 27 *Distribution of common bully showing its relationship to distance to sea and altitude.*

3.6.7 **Redfin bully**

Figure 28 Redfin bully (mature male, showing the characteristic red fins, and blue stripe along the top of the front dorsal fin (source www.qldaf.com).

Redfin bullies need free access to and from the sea to complete their life cycle, and do not establish land-locked populations like common bullies do (McDowall 1990). Thus, they tend to live near the coast even though they are very good climbers. Spawning takes place in fresh water and after hatching the larvae are swept out to sea. The juveniles enter fresh water in the spring and reach maturity about two years later. They are widespread throughout the country, and are one of the most common fish in the Bay of Plenty.

Male redfin bullies have bright red markings on their dorsal, anal, and tail fins, as well as the body and cheeks (Figure 28). They also have a blue-green stripe on the outer edge of the front dorsal fin. They are one of the most colourful freshwater fish, especially large individuals. Only the males have the distinctive red fins: females have the same patterns, but their fins are brown instead of red. Small individuals also lack the red colour to the fins, and in many cases look similar to common bully at first glance. However, a distinctive feature of redfin bullies is the presence of diagonal stripes along their cheeks, making for positive identification against the common bully.

These fish occur mainly in runs and pools of small, bouldery streams, and prefer habitats with a moderate flow of water with pools and riffles. Here, they feed on aquatic insects such as mayfly, caddis fly and chironomids. Because of their dependence on boulder habitats, they are more sensitive to the effects of siltation in streams than other fish species.

Redfin bully were found throughout many waterways in the Kaituna-Maketu and Pongakawa-Waitahanui WMA (Figure 29), but were restricted mainly to streams within 30 km of the coast (Figure 30). The recent surveys confirmed this relatively coastal distribution, although new inland records were found in two sites in the upper Pokopoko, and three sites in the upper Wharere Stream.

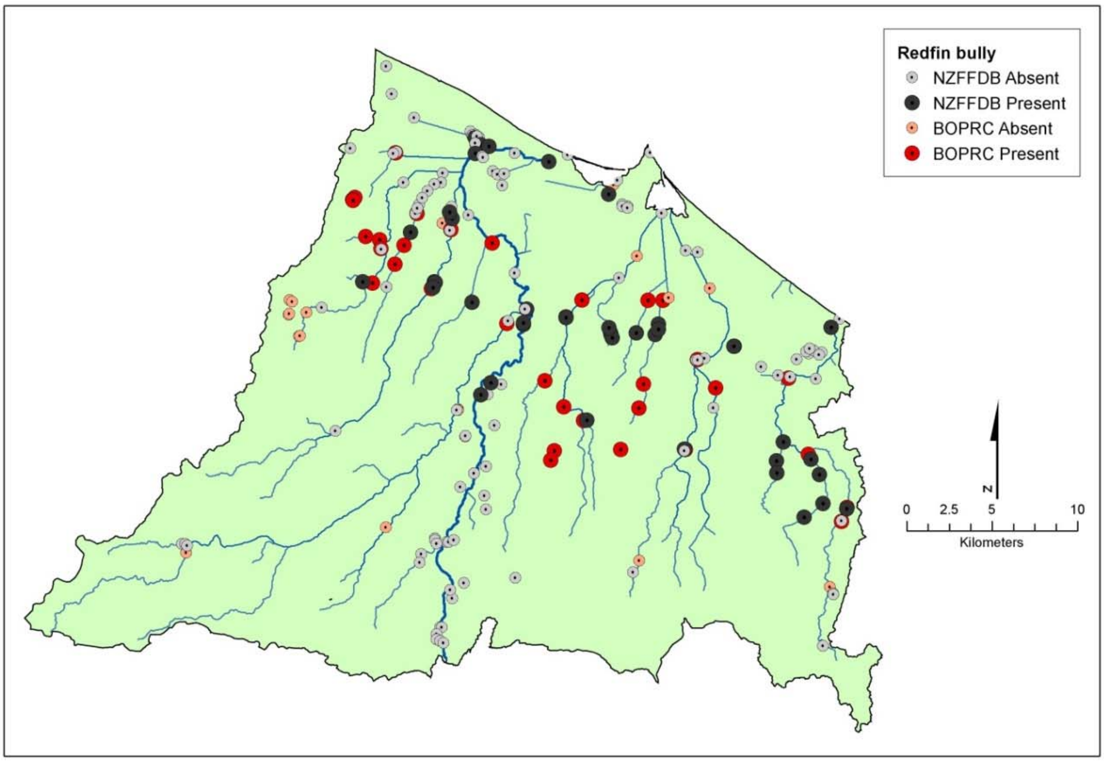

Figure 29 *Distribution of redfin bully throughout the Kaituna-Maketu and Pongakawa-Waitahanui WMA. Conventions as per Figure 10.*

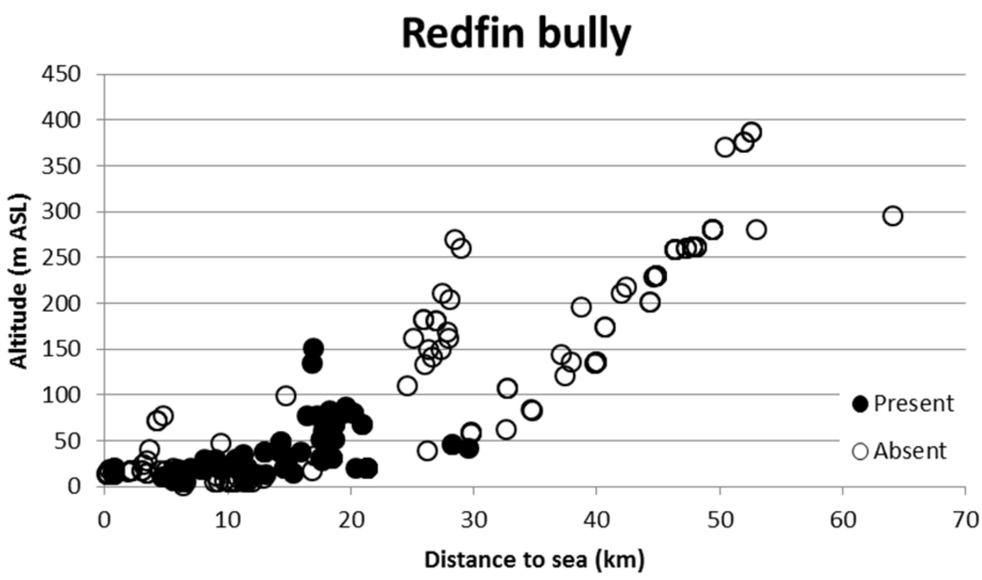

Figure 30 *Distribution of redfin bully showing its relationship to distance to sea and altitude.*

3.6.8 Rainbow trout

Figure 31 Rainbow trout, showing the characteristic red stripe along the side of the body in mature individuals (source http://underwater-fish.blogspot.co.nz/2011/11/rainbow-trout-oncorhynchus-mykiss.html)

Rainbow trout (Figure 31) are native to North America, where they are found in the westward draining rivers that flow into the Pacific Ocean. Trout were never naturally found in the southern hemisphere, but as with many countries, these fish were introduced into New Zealand in the early 1880s. Populations of rainbow trout, both self-sustaining and hatchery raised, are widespread throughout New Zealand. Rainbow trout are particularly valued in the Rotorua Lakes, and some of the large rivers in the Bay of Plenty. Although they form the backbone of this major recreational fishery, introduced trout have had a large negative effect on native fish by preying on them or out-competing them for food and habitat.

Like other salmonids, the colouration of rainbow trout is variable. Lake-dwelling fish are generally uniformly silver with small, darker spots along the back, mainly above the lateral line. The backs of river dwelling fish are often more olive-green, and the red band, or rainbow, along the lateral line more prominent. When rainbow trout move into rivers and streams for spawning, this band intensifies in colour, and red slashes may occur on the cheeks and in the folds beneath the lower jaw.

Most rainbow trout migrate to their spawning grounds, with both lake and river dwelling fish moving upstream to suitable locations, often in small tributaries. Here they can congregate in large schools just prior to spawning. In lakes without suitable spawning tributaries, spawning can occur along the lakeshore. The main spawning season for rainbow trout is June and July, but the season can be extended to October in some lakes, especially those in the colder regions of the North Island.

Rainbow trout are widespread throughout the Kaituna-Maketu and Pongakawa-Waitahanui WMA (Figure 32), where they have been found in major catchments such as the Raparapahoe, the Waiari, the Mangorewa and Kaituna rivers, the Pongakawa and the Waitahanui. The recent 2016 survey also extended this distribution into the Wharere stream (Figure 32). Rainbow trout were found throughout the longitudinal and altitudinal gradients in the WMA (Figure 33), most likely reflecting their powerful swimming ability.

However, their distribution would most likely be controlled by the dominant substrate type in streams, as these fish generally prefer streambeds with course cobbles and gravels, as opposed to fine highly mobile pumice streambed.

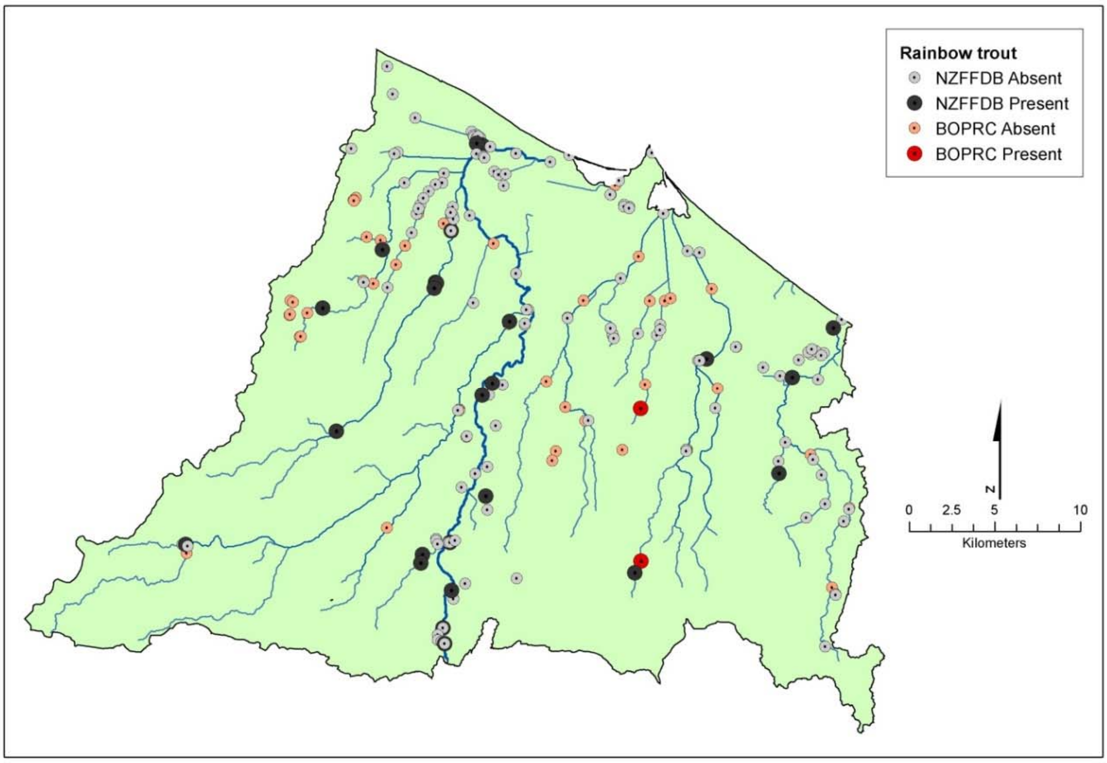

Figure 32 *Distribution of rainbow trout throughout the Kaituna-Maketu and Pongakawa-Waitahanui WMA. Conventions as per Figure 10.7*

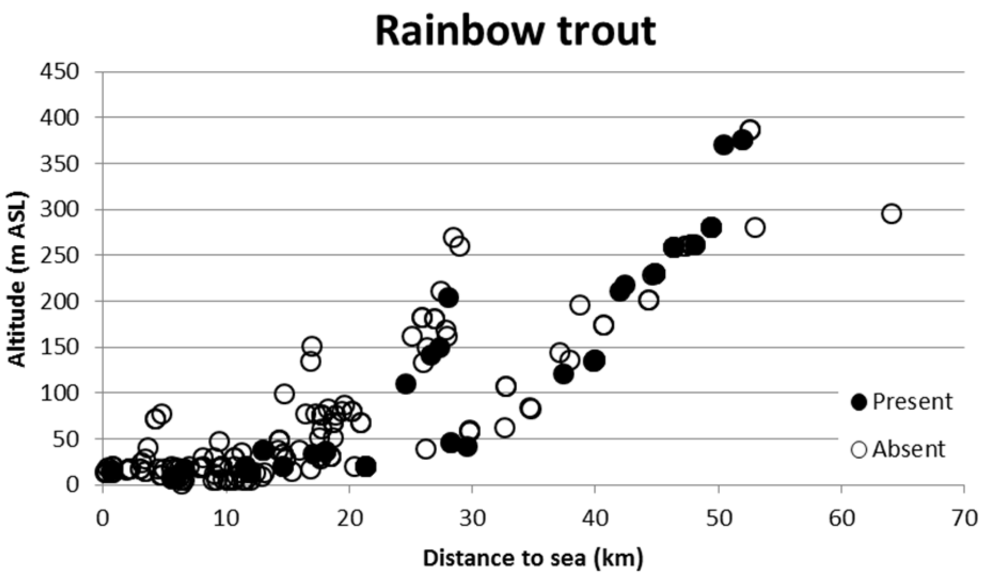

Figure 33 *Distribution of rainbow trout showing its relationship to distance to sea and altitude.*

3.6.9 **Smelt**

Figure 34 Adult smelt, showing the distinctive forked tail, as well is the small adipose fin between the dorsal fin and tail. Note also that this species has distinctive scales, whereas galaxiids such as inanga do not (source: www.thestyx.org.nz).

Smelt (Figure 34) are relatively small schooling fish that live in lowland streams near the sea. Unlike other New Zealand native fish, they have a small fin (the adipose fin) located between the large dorsal fin and the tail. Smelt also have scales and a distinctly forked tail. They also have a very distinct smell, like a cucumber. There are two species of smelt in New Zealand, but these are very difficult to tell apart.

Smelt are widespread throughout New Zealand, and throughout the WMA (Figure 35). They live in rivers and streams, as well as lakes. Most smelt in sea-draining rivers require access to the sea (i.e., they are diadromous), where they spend most of their lives. Some individuals return to freshwater as juveniles in the spring, but most return as adults in summer when they are about 10 cm long. Populations living in the Rotorua Lakes are non-diadromous, and so con complete their life cycle without access to the sea. Smelt may have been introduced to the Rotorua Lakes following the depletion of koaro there as a result of predation by introduced trout. Smelt do not climb well, but are good swimmers and will penetrate well inland in river systems that are not too steep such as the Kaituna River. They can also be sensitive to pollutants like ammonia and stressors such as high water temperature. For example, Richardson et al (1994) examined temperature tolerances of eight common native fish, and found that while shortfin eels were most tolerant of high temperatures (25^{o}C+), other fish like smelt and inanga were less tolerant. The presence of smelt in waterways thus indicates that the water quality is likely to be suitable for other fish.

They are found throughout the WMA, and although the recent survey did not find any new populations in catchments, they were found at some sites further inland than previously recorded Figure 35.

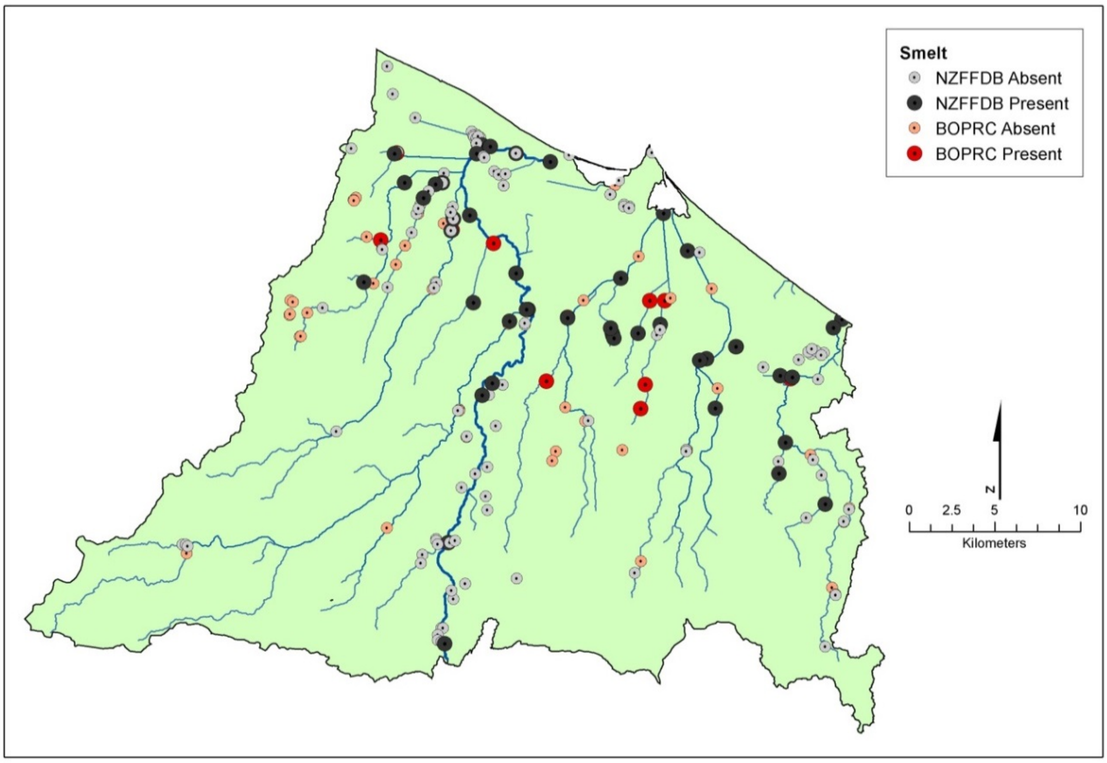

Figure 35 *Distribution of smelt throughout the Kaituna-Maketu and Pongakawa-Waitahanui WMA. Conventions as per Figure 10.*

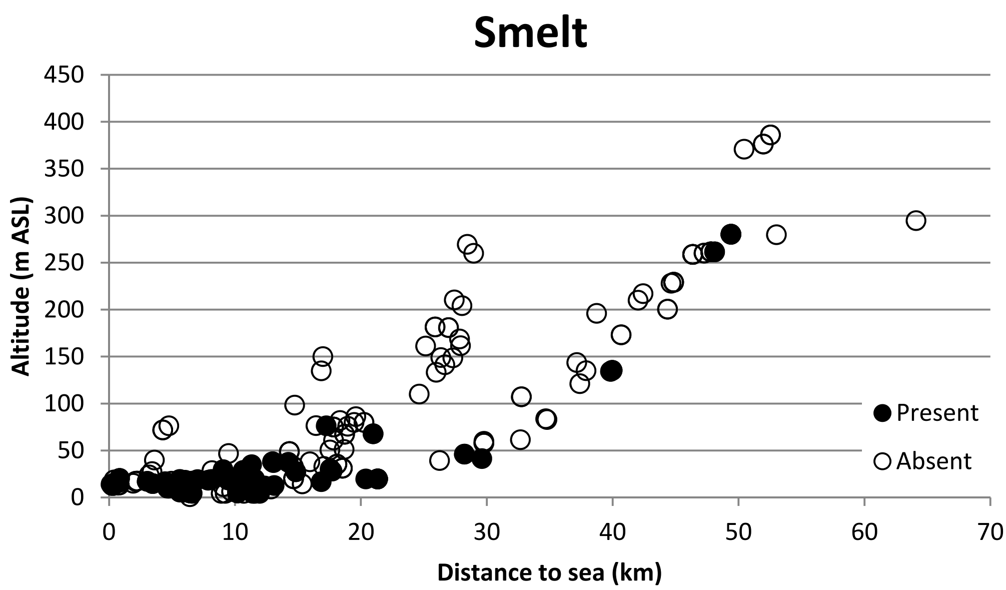

Figure 36 *Distribution of smelt showing its relationship to distance to sea and altitude.*

3.6.10 **Koura**

Figure 37 Freshwater crayfish (or koura), commonly collected throughout the WMA (source www.doc.govt.nz).

Freshwater crayfish, or koura (Figure 37), and not fish, but belong to one of the large invertebrate groups: the Crustacea. These animals are part of the Decapod group: animals with 10 legs, similar to lobsters, and crabs. The two species of koura are found only in New Zealand. The larger *Paranephropus zelandicus* is found mainly in the east and south of the South Island, and on Stewart Island. The smaller species, *Paranephrops planifrons*, is found throughout the North Island and in Marlborough, Nelson and the West Coast. Koura live in mostly slow flowing water such as lakes ponds, and wetlands, but are also found amongst the streambed in small streams, where they shelter amongst gravels and cobbles.

Kōura are valued by iwi as a major mahinga kai species. In particular, the Te Arawa and Taupō lakes supported extremely productive kōura fisheries. Like their marine cousins, koura are scavengers that feed on leftovers, and they do not actively hunt for food. They consume a variety of food, including organic matter such as leaves, as well as freshwater insects.

Unlike many of the native fish, koura complete all their life cycle in freshwaters. Females produce eggs between April and December, but mostly in May and June. These eggs, between 20 to 200, are carried under side flaps along the underside of the abdomen. The eggs hatch about three to four months later, with newly hatched koura looking just like miniature adults. They cling to their mothers until they are nearly
4 mm long, around December of their first year, after which time they become independent. Like other invertebrates, koura do not grow continually. Instead, they have a tough exoskeleton that covers their entire body. When they outgrow this exoskeleton, they need to moult and shed their old skin. Their new skeleton is soft for a few hours, so they expand their body tissues until this hardens. They then continue to grow into this new skeleton until the process is repeated when they outgrow this new skeleton.

These animals are found in streams flowing through a variety of land cover, including native bush, exotic forest, and pastoral waterways. However, they are rarely found in urban streams because of chemical pollution, increased flood flows from stormwater inputs, and loss of habitat. Instream habitat such as woody debris, undercut banks, cobbles, and boulders is very important for these animals as it provides shelter from predation and cannibalism. Kōura also prefer pools and areas of slow or no flow.

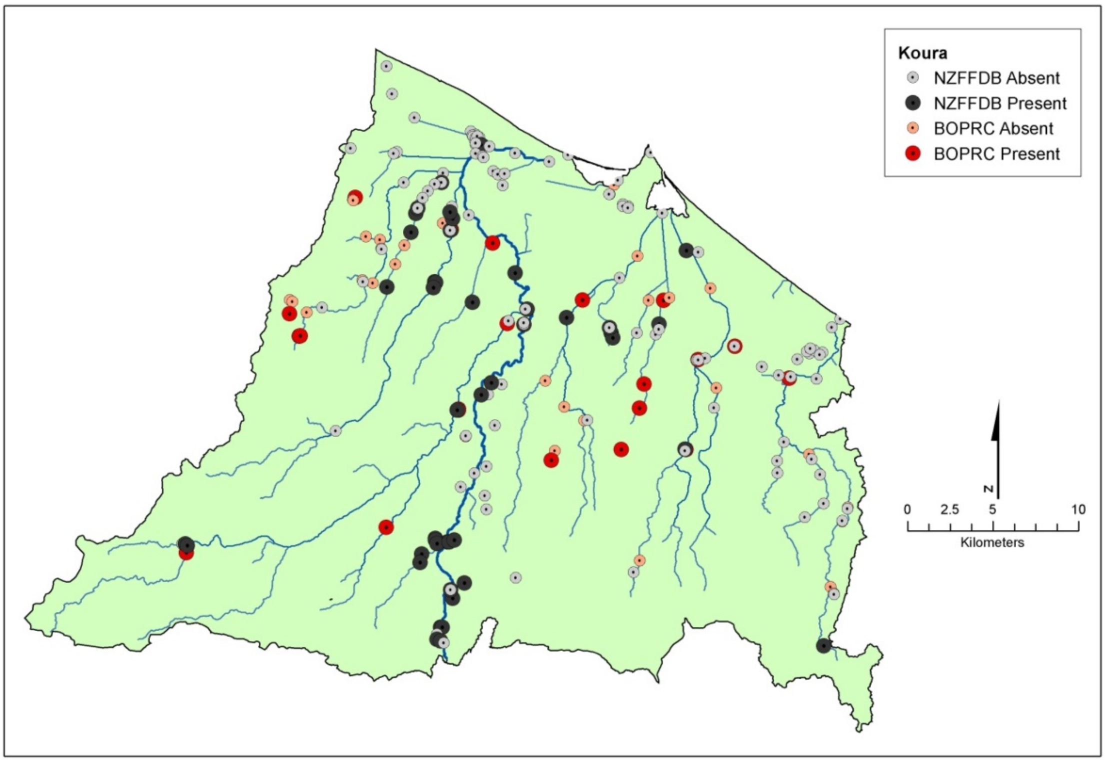

Figure 38 Distribution of koura throughout the Kaituna-Maketu and Pongakawa-Waitahanui WMA. Conventions as per Figure 10.

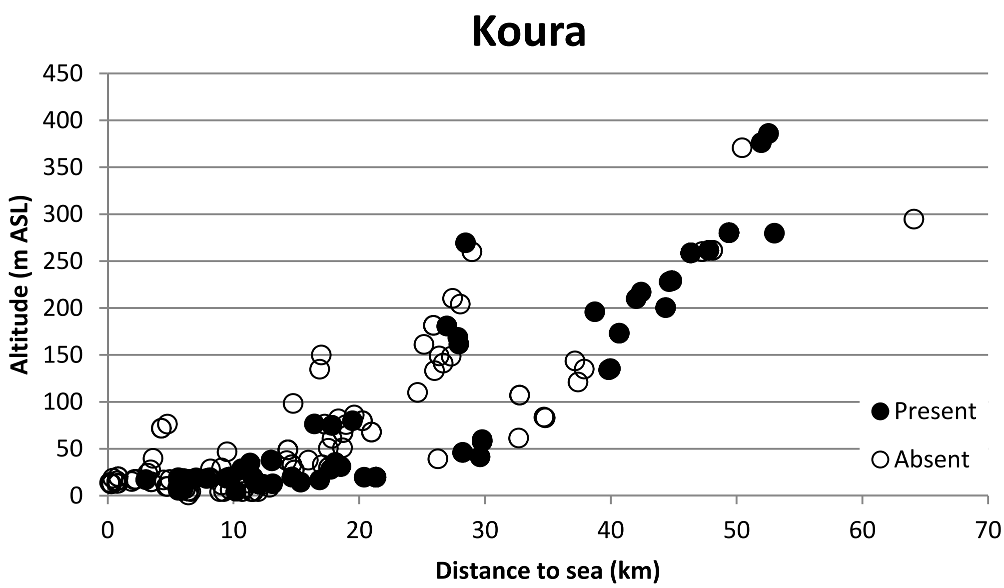

Figure 39 Distribution of koura showing its relationship to distance to sea and altitude.

3.6.11 **Mosquito fish**

Figure 40 Mosquito fish, showing the larger female (top), and smaller male (bottom) (source: www.fishlaboratory.com).

Mosquito fish (or Gambusia) are quite small fish with a green-silver sheen. Females may reach 60 mm, but males are usually less than 40 mm (Figure 40). They mature at six weeks old and are short lived, but breed rapidly and repeatedly enabling populations to build up to large numbers very quickly. Females give birth to live young, and a single female produces several broods a year. Each brood has about 50 offspring, and these can reach sexual maturity in as little as three to four weeks. Given such prolific reproductive behaviour, gambusia can quickly expand to out-number native species and take over a waterway once they are introduced. They live in shallow areas of slow flowing ponds, wetlands and streams, particularly around aquatic plants. They are extremely tolerant of poor water quality, high salinity levels and even low oxygen levels, by “air gulping” at the water’s surface. Indeed, large populations of these fish have been observed in many of the drains in both the Kaituna and Rangitaiki plains, even when the levels of dissolved oxygen in these drains are extremely low (<10% saturation).

Mosquito fish are native to south-eastern America, and in waters around the Gulf of Mexico. Their name reflects their ability to consume large numbers of mosquito larvae. Unfortunately, this ability led to their misguided introduction into countries where mosquitoes were thought to be a problem, often with unintended consequences on the native invertebrates and fish. In many cases, mosquito fish also consume other invertebrates, and can often “fin-nip” many of the more docile native fish, causing infection and mortality (not to mention hunger from the lack of suitable invertebrates). Mosquito fish were introduced into New Zealand sometime in the 1930s, and they have slowly dispersed throughout the North Island. Fortunately, they are still absent in the South Island, and although there was an incursion in Nelson around 2000, extensive eradication efforts have restricted their further spread there.

As expected for such a small, weakly swimming fish, mosquito fish were found mostly in small slow flowing drains around the Kaituna plains. Most of the previous records from the NZFFD were found in streams and drains around Te Puke, including the Waiari, Ohineangaanga, and Raparapahoe, as well as in small wetlands that drain into that the Kaituna River (Figure 41). There were also found in small drains flowing into both the Kaituna-Maketu Estuary, and the Waihi Estuary. The 2016 survey found new records of mosquito fish in the mid-reaches of the Pongakawa just above state highway two, as well as the mid-reaches of the Wharere stream (Figure 41).

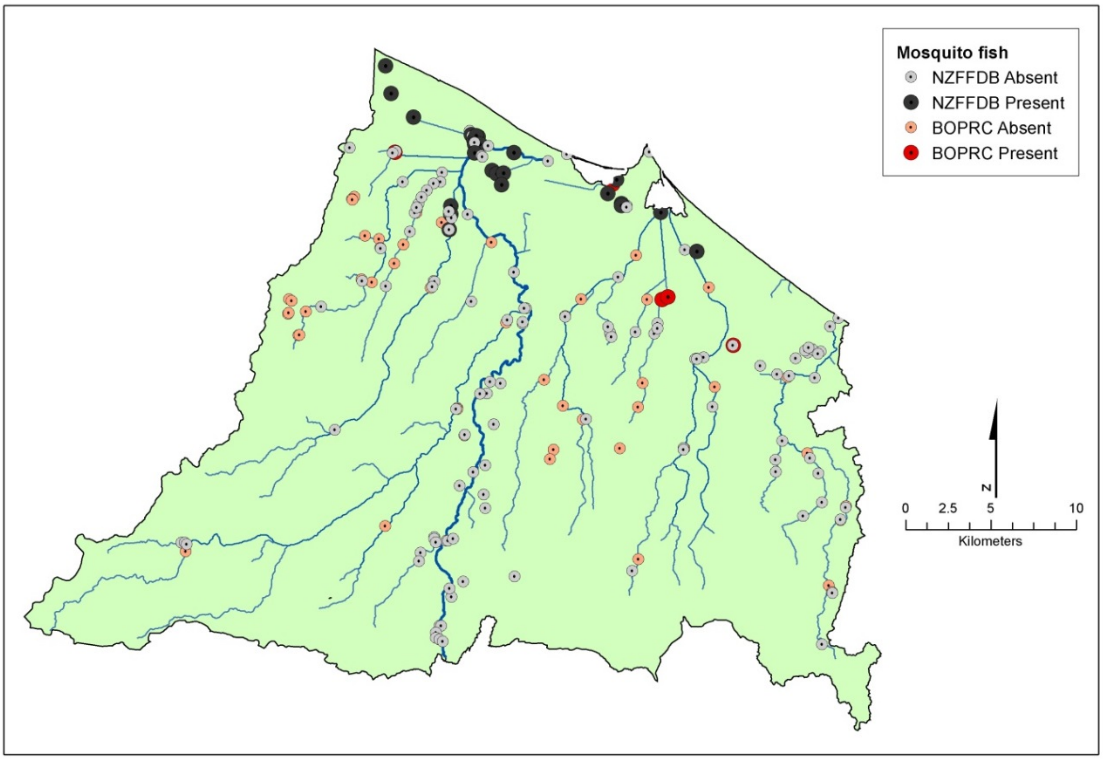

Figure 41 Distribution of Mosquito fish throughout the Kaituna-Maketu and Pongakawa-Waitahanui WMA. Conventions as per Figure 10.

Part 4: Discussion

The contemporary fishery survey work was done to fill in data gaps where previous fish surveys had been conducted over 16 years ago, or was targeting sites that appeared under-represented in the NZFFD. Such sites included smaller streams flowing through catchments dominated by native bush within the Kaituna-Maketu and Pongakawa-Waitahanui WMA. Despite surveying these new areas, the fish fauna found was similar to that previously recorded, although there were a few exceptions. The most notable finding was the record of shortjawed kokopu from a site in the Ohineangaanga Stream. This site was dominated by riffles, and had large substrates (30% boulder and 50% cobble). The riparian vegetation was dominated by native bush. These conditions are typical of those where shortjawed kokopu are found in (McDowall 1999).

However, because this fish is migratory, the young shortjawed kokopu must have swum up the Raparapahoe from its confluence of the Kaituna, and into the Ohineangaanga. From here it would have swum upstream through township of Te Puke to where it was found near the property at 162 No.2 Road. Both the Raparapahoe and Ohineanganaga are highly modified watercourses below State Highway 2. Here, they flow through farmland dominated by a mix of dairy farming and maize cropping, where they have been straightened. They are generally unshaded with little, if any, overhanging vegetation. Above State Highway 2, the Ohineangaanga has cut itself into a relatively deep and wide gorge which is surrounded by a mix of exotic and native vegetation. This shade is likely to be hugely beneficial to fish such as shortjawed kokopu, which would not be found this is shade was not present.

Given the heavily modified nature of both the lower Ohineangaanga and Raparapahoe streams, it was somewhat surprising to find shortjawed kokopu at this site. Their presence does not therefore imply that habitat conditions in the lower reaches are ideal to the survival and upstream movement of migrating fish. It is not an unreasonable assumption to suggest that there would be more likelihood of enhanced survival and successful upstream migration of fish through these lower reaches if riparian vegetation in these streams provided more cover, and if habitat conditions were more diverse than the current situation. Improving in stream habitat and enhancing riparian shade along these lower reaches is likely to have far reaching beneficial effects on fish communities - especially in the upper reaches of these waterways. It seems somewhat ironic that the upper reaches of many of the streams flowing seaward from the hills to the west and southwest of Te Puke and into the Kaituna River have habitat conditions and riparian vegetation which are well suited to native fish, yet migrating native fish need to "run the gauntlet" through these highly modified lower reaches to reach these other sites. It is highly likely that riparian enhancements to these lower reaches would have large biodiversity gains to the upper reaches in terms of improving access by migrating galaxiid species.

Other notable findings in the recent survey were new populations of koaro in small streams draining the Whataroa, and in a stream in the upper Waitahanui, and new records of banded kokopu in the Waikoura Stream, the upper reaches of the Whataroa, the Mangorewa and sites further inland up the Wharere. These sites were also well vegetated and shaded. It is likely that both Koaro and banded kokopu would be found in other waterways throughout the WMA which flow through undisturbed native forest, but which were not sampled due to access problems. The recent survey work also extended the ranges of some fish species to new sites inland, such as record of a large longfin eel in the Onaia Stream and of inanga in the mid-Pokopoko. These results highlight the importance of maintaining good fish access throughout waterways within the WMA to ensure that many of the migratory native fish can complete their life cycle. This means that it is also important to maintain both habitat and water quality conditions along waterways, especially in the often heavily modified lower reaches where they flow through productive farmland. Many native fish are highly secretive, and need overhanging bank vegetation, or aquatic plants to hide amongst.

These features are often conflicting with the current management of many of these waterways, as bank vegetation is often mown, debris removed, and macrophytes weeded to maximise hydraulic efficiency. There is thus an obvious need for better synergies between engineering and ecological requirements with an aim to fulfil objectives for both values.

Throughout the WMA, fish are under a wide range of pressures ranging from loss of habitat as a result of land-use change and engineering works to maximise hydraulic efficiency, constrain river channels and stabilise banks from erosion using a hard structures such as riprap. These activities, particularly when conducted in the lower reaches of rivers can have large detrimental effects to fish communities. For example, inanga require access to riparian vegetation which is inundated during the autumnal high tides to lay their eggs amongst. These eggs spend the following month slowly developing, before the larvae hatch from the eggs when they are next inundated the following month. To prevent the eggs from drying out, inanga require particular vegetation to spawn amongst, where the eggs can remain moist. Banks which have been protected from erosion by riprap consequently provide no ability for these fish to spawn. Furthermore, grazing river margins along stop banks during the autumnal spawning season will remove potential spawning vegetation for these fish. Although there is no doubt that eroding riverbanks need to be stabilised, it may be possible to utilise riprap in a more ecologically friendly manner, and use slightly lower gradient batters, or create flat ledges within the bank structure which are designed to become inundated at high tide. This riprap could be planted with desirable low-growing vegetation such as carex sedges, and reeds. It must also be remembered that riprap may also provide an element of stable habitat for other fish species which could find shelter amongst the spaces between the rocks, so the effects of riprap may only be species specific. Further studies are needed to investigate this hypothesis.

Other engineering structures such as the "borrow pits" in the lower Kaituna River have been shown to provide hugely important rearing habitat for young inanga which had migrated into freshwaters (Ellery and Hicks 2009). Similar ponds could conceivably be built into other waterways in their lower reaches to provide important rearing habitat for these fish.

In-stream habitat loss arising from land use change is arguably a far greater stressor for native fish than the loss of spawning sites, especially when considering that native fish do not return to their natal streams. Such habitat loss will include loss of both riparian vegetation which provides both shade and cover, and loss of coarse stream bed habitat as sedimentation causes in-filling of spaces between cobbles and boulders (Jowett and Boustead 2001). There is also a reduction in hydraulic variability within streams due to removal of debris and channel strengthening. Changes to stream bed material, and instream flow conditions can have major implications to fish, especially given their often strong habitat preferences for specific flows and substrate sizes (Jowett and Richardson 1995; Booker 2015). Finally, additional stressors such as increased water temperatures in pasture streams compared to forested streams is also likely to reduce habitat suitability for fish such as longfin eels and banded kokopu (Hicks and McCaughan 1997; Rowe et al 1999).

Other stressors throughout the Kaituna-Maketu and Pongakawa-Waitahanui WMA could also arise as a result of water abstraction, for either irrigation or frost fighting of horticultural crops during the winter. Under the current Water and Land Plan, a default allocation limit of 10% of the Q57-day flow flow (i.e., the lowest average seven day low flow which occurs over a 5 year period) has been established. This means that a minimum flow of 90% the Q5 seven day flow is left in the stream, which is deemed “acceptable” to maintain ecological values. In a review of water allocation throughout the Bay of Plenty, Donald (2013) showed that there were some streams within the WMA were over allocated - and some extremely so. For example, the Raparapahoe stream has an allocable flow of 57 L/s, but has 63.5 L/s allocated, or is 110% allocated. This is a relatively small amount of over allocation in contrast to the Wharere Stream. This stream has an allocable flow of only 28 L/s, but has been allocated 108 L/s, or 384% allocated.

Because of their large size and hydraulic habitat flow preferences, fish may be affected by periods of low flow in rivers. If over allocation results in unsuitable depths and velocities in a stream, fish may move out of stream patches where their flow requirements are not met. As an extreme example, fish were observed to actively swim away from drying reaches in the Selwyn River, South Canterbury, and migrate to upstream perennial reaches (Davey and Kelly 2007). Less extreme examples of fish movement into areas of suitable hydraulic habitat were found by (Jowett, Richardson et al. 2005) in the Waipara River, North Canterbury. Here, fish such as Canterbury galaxias and torrentfish became relatively more common in riffles than runs as flows reduced. Given their large size and need to seek areas that closely meet their hydrological requirements, it could be argued that fish may be the first ecological component to respond to long-term changes in a stream's flow regime. Thus, if long-term water abstraction reduces the availability of suitable hydraulic habitat, fish with preferences for fast and/or deep water may become less common as these habitats diminish. If this were a repeated phenomenon, then certain fish may become absent from reaches subject to reduced flows during summer as a result of over-allocation. This hypothesis would need to be tested through the implementation of a long-term quantitative monitoring programme in select catchments with good flow data.

A final pressure faced by most of the native fish in the WMA concerns maintenance of free access to and from the sea to allow them to complete their life cycles. There are numerous flood/tide gates or pumping stations throughout many of the smaller drains and streams in the lowland plains, and these may be preventing fish passage. In addition, there are likely to be many poorly constructed culverts and other road crossings that act as barriers to migration. A programme is currently underway to identify such barriers throughout the area, and these will then be prioritised for removal depending on factors such as upstream area and conditions, and ease of retrofitting or removing these barriers.

4.1 Recommendations for further work

This fish survey was initiated as a result of the gap analysis report to provide information on fish communities in sites where this information was lacking, or where the data was greater than 20 years old (Suren et al 2015). The results of this survey have yielded some useful information, including new records of threatened fish such as a shortjawed kokopu in the WMA, and have extended the distributional range of other fish species such as Koaro. Strong environmental gradients were also identified in streams throughout the WMA, which were in part responsible for structuring fish communities found in each site. As expected for a fauna dominated by migratory species, major drivers of community structure were elevation and distance to sea. Other large scale factors including catchment topography, climate and land cover were also implicated in structuring fish communities throughout the WMA, as were small-scale factors such as sediment size and habitat availability. While some of these factors are unaffected by human activities, other factors such as riparian vegetation, and in stream habitat have often been altered as a result of land-use activities.

Given the large range of pressures that fish are exposed to throughout the WMA, and the fact that they are often highly valued by communities, a number of extra studies and monitoring programs are suggested.

These can be broken into information gaps, physical habitat improvement works, and applied research, as follows:

Information gaps

1 Identification of barriers to fish passage, and prioritising the order to which these are remedied. This work has already started in parts of the Kaituna, and needs to be continued throughout the WMA. GIS analysis can be used to help identify priority waterways to undertake remedial work for fish passage. Prioritisation of fish barrier removal would be based on a mixture of:

- catchment area above the barrier,
- what potential species of conservation interest that are predicted to occur above these barriers,
- what the land use is above the barrier.

2 A better understanding of areas where inanga spawn is needed. Although some work has been done in waterways such as the Kaituna to identify the salt wedge, spawning areas in the lower reaches of many of the straightened canals are currently unknown.

Physical habitat improvement works

1 Creation of new inanga spawning and rearing areas. This may include investigating the use of pea-straw hay bales placed within the high tide mark of potential spawning zones for inanga to lay their eggs. Similar work has successfully been conducted in streams flowing through Christchurch with collaborative work by EOS Ecology, Ngi Tahu, and the University of Canterbury (See http://ngaitahu.iwi.nz/our_stories/whaka-inakacausing-whitebait-in-otautahi-rivers/ and http://www.eosecology.co.nz/Our-News/Whaka-Inaka-Causing-Whitebait.asp).

2 Creation of new fish habitat such as the current “borrow pits” in the lower Kaituna River along other waterways in the lower parts of the WMA, especially where these waterways have lost their connection to the surrounding floodplain through engineering modifications. Such work could be linked to any proposed work identifying sources of nutrients and sediments which are adversely affecting the Waihi estuary, and which may require modifications to the drainage network flowing into the estuary. Such modifications could include construction of wetlands to intercept nutrients and sediments. These wetlands could represent major habitat for fish as well.

Applied research

1 Initiate studies to determine the relative habitat values of riprap to different fish communities, and to develop and monitor the effectiveness of different bank profiles, and planting regimes to maximise potential spawning habitat along reinforced riprap banks.

2 Assessing the effectiveness of constructing new fish habitat throughout the area by carefully designed before-after and control impact studies.

3 Further analysing small scale habitat features such as bank undercutting, substrate size, flow type and shade to see how these help explain variability to fish communities.

It is only by obtaining further information from studies such as these can we help minimise further stressors from activities such as land use development on fish communities throughout the Kaituna-Maketu and Pongakawa-Waitahanui WMA, and, hopefully, increase the distribution and abundance of desired fish species throughout the area.

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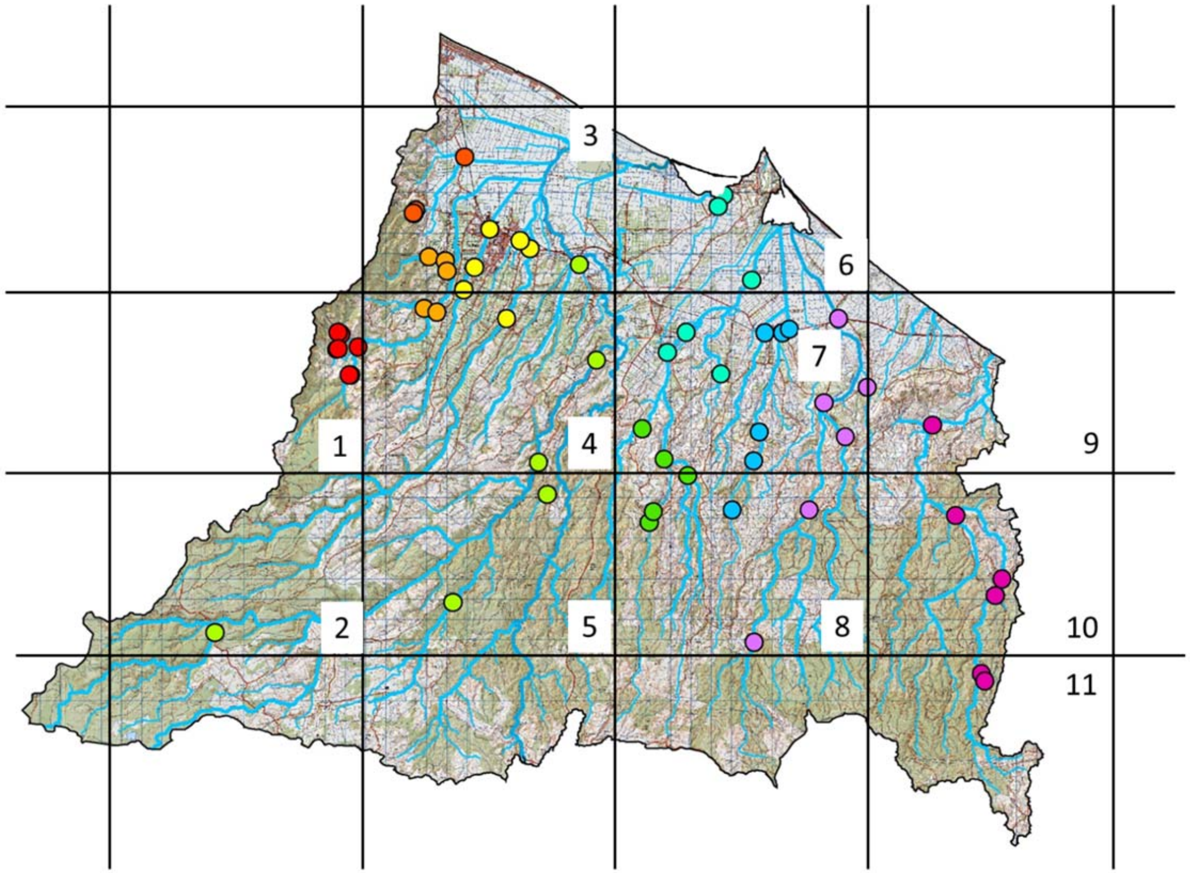
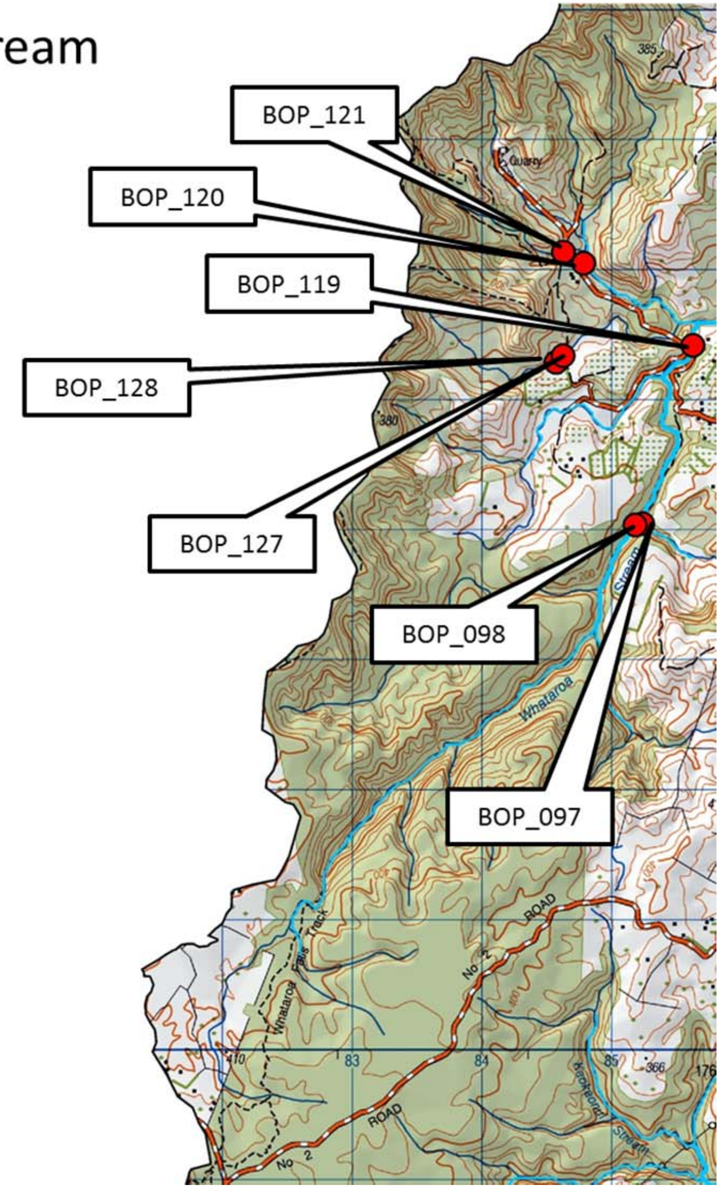
Appendices

Appendix 1 – Kaituna

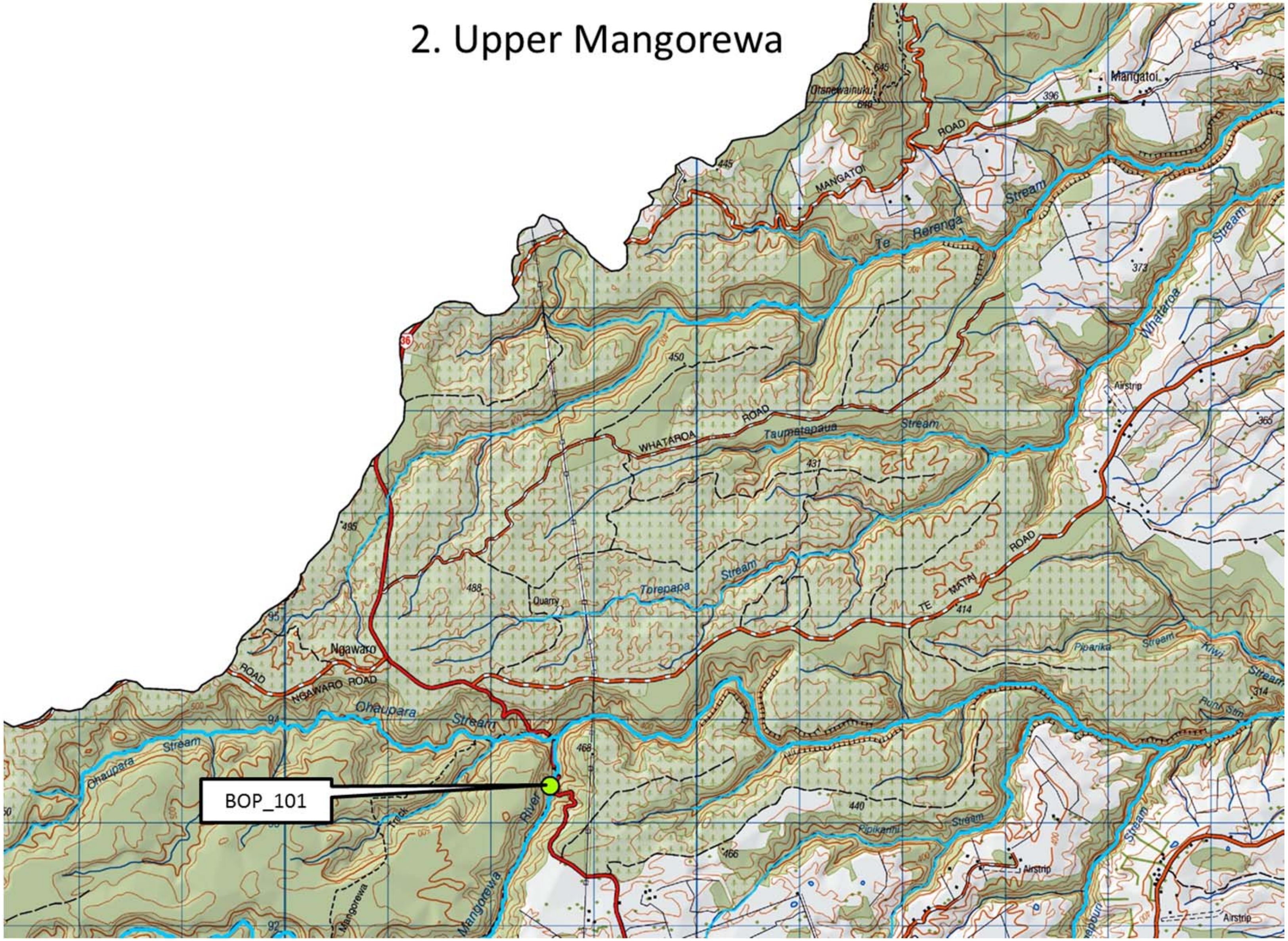
Maps showing the location of the sites where fish communities were examined during the 2016 survey. Information contained in the following tables shows the name and location of each site (eastings and northings in NZTM), distance inland and elevation. Also shown are the different types of fish (and crayfish) collected at each site and their abundance, as well as the calculated Fish Index of Biotic Integrity (IBI) class.

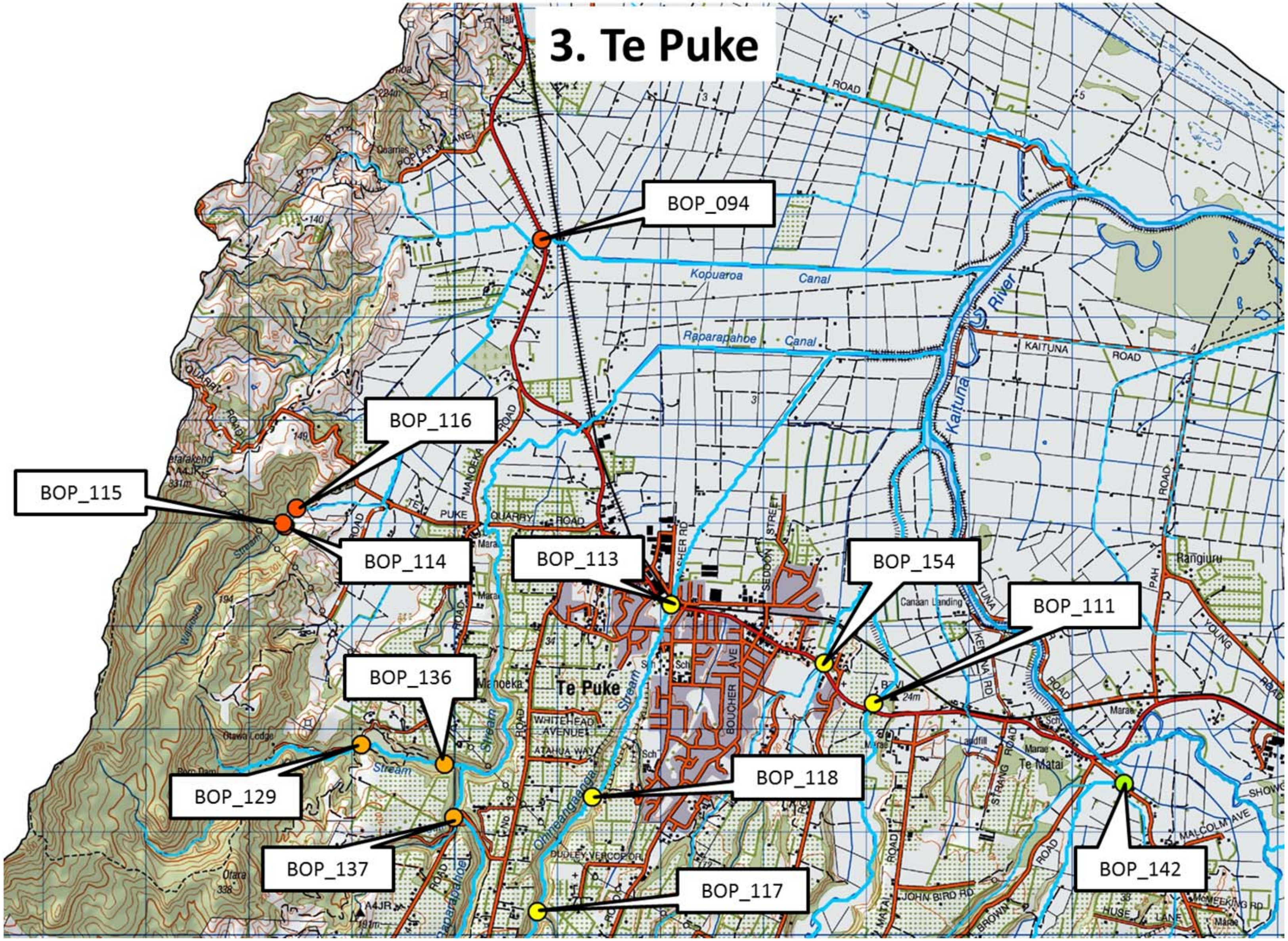


1. Whataroa Stream



2. Upper Mangorewa




3. Te Puke
BOP_094
BOP_116
BOP_115
BOP_114
BOP_113
BOP_154
BOP_111
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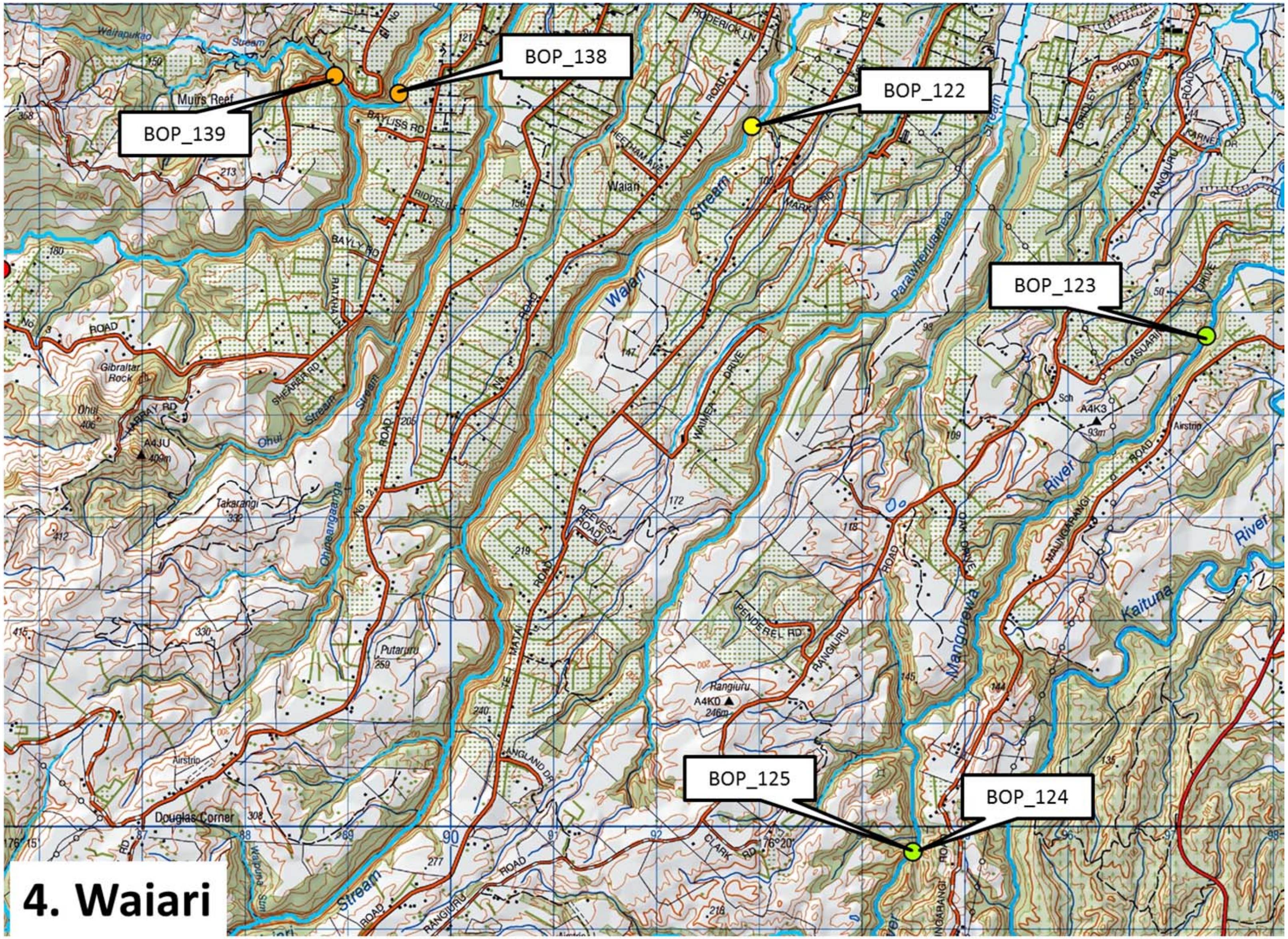
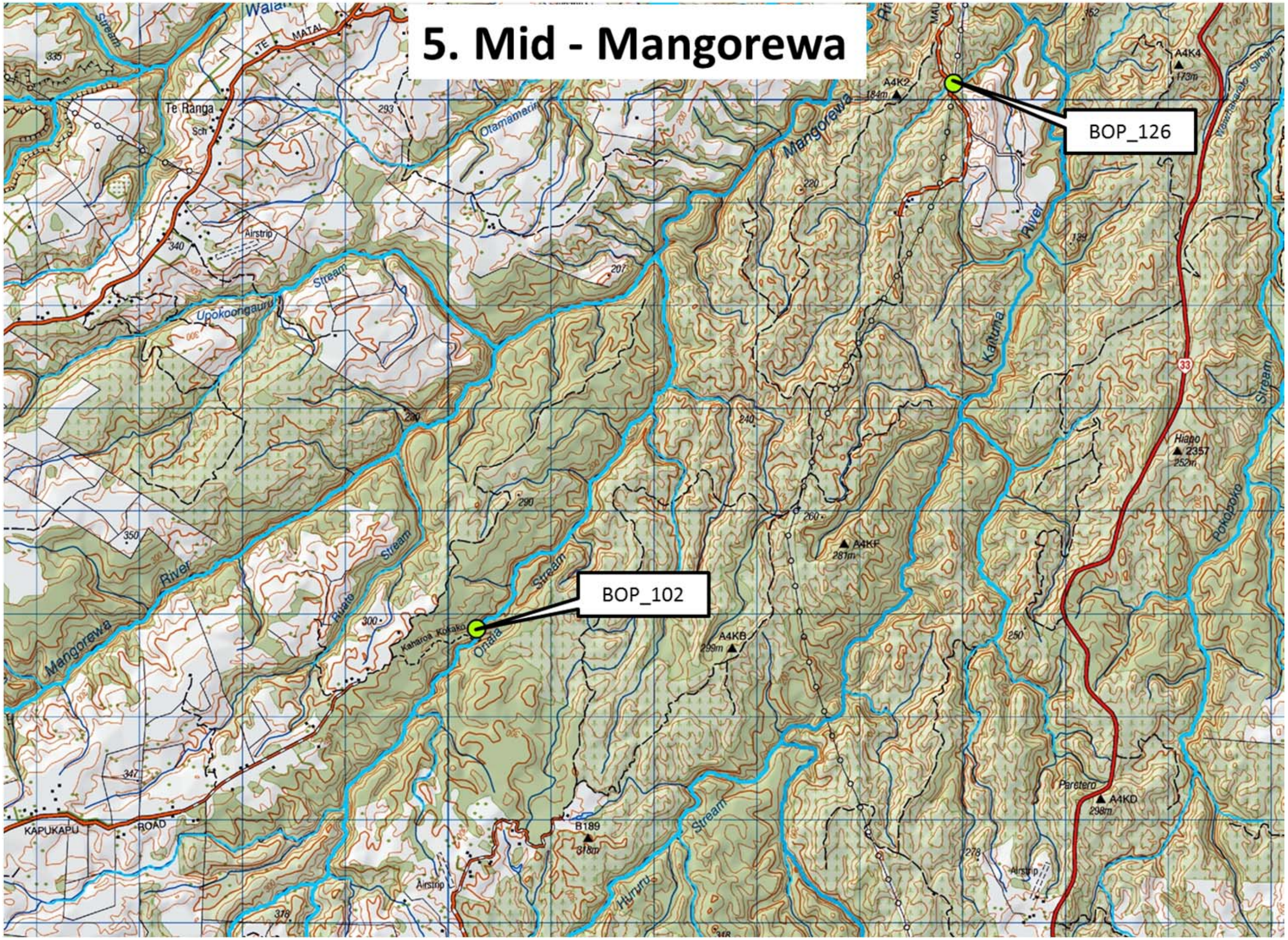
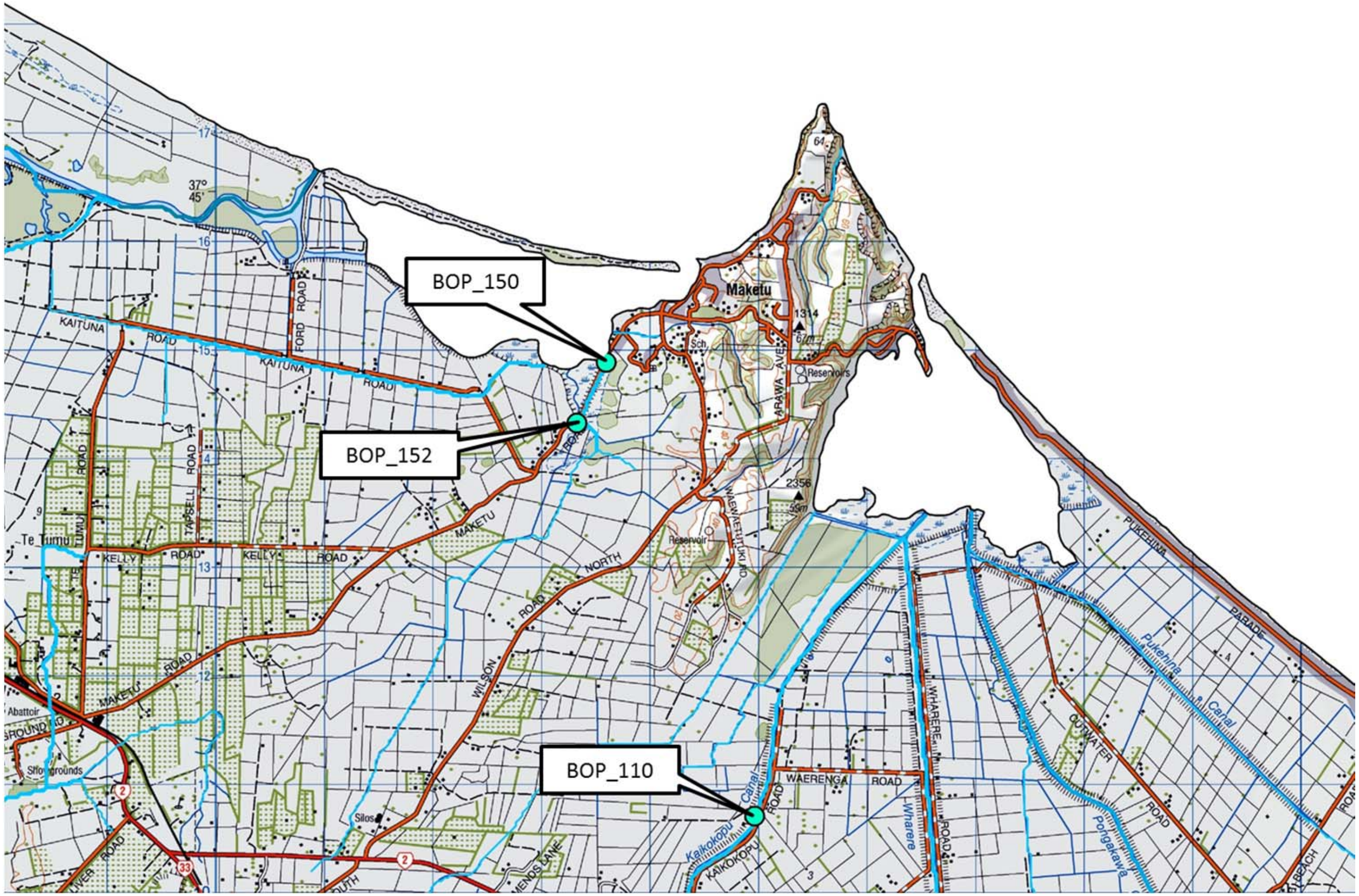
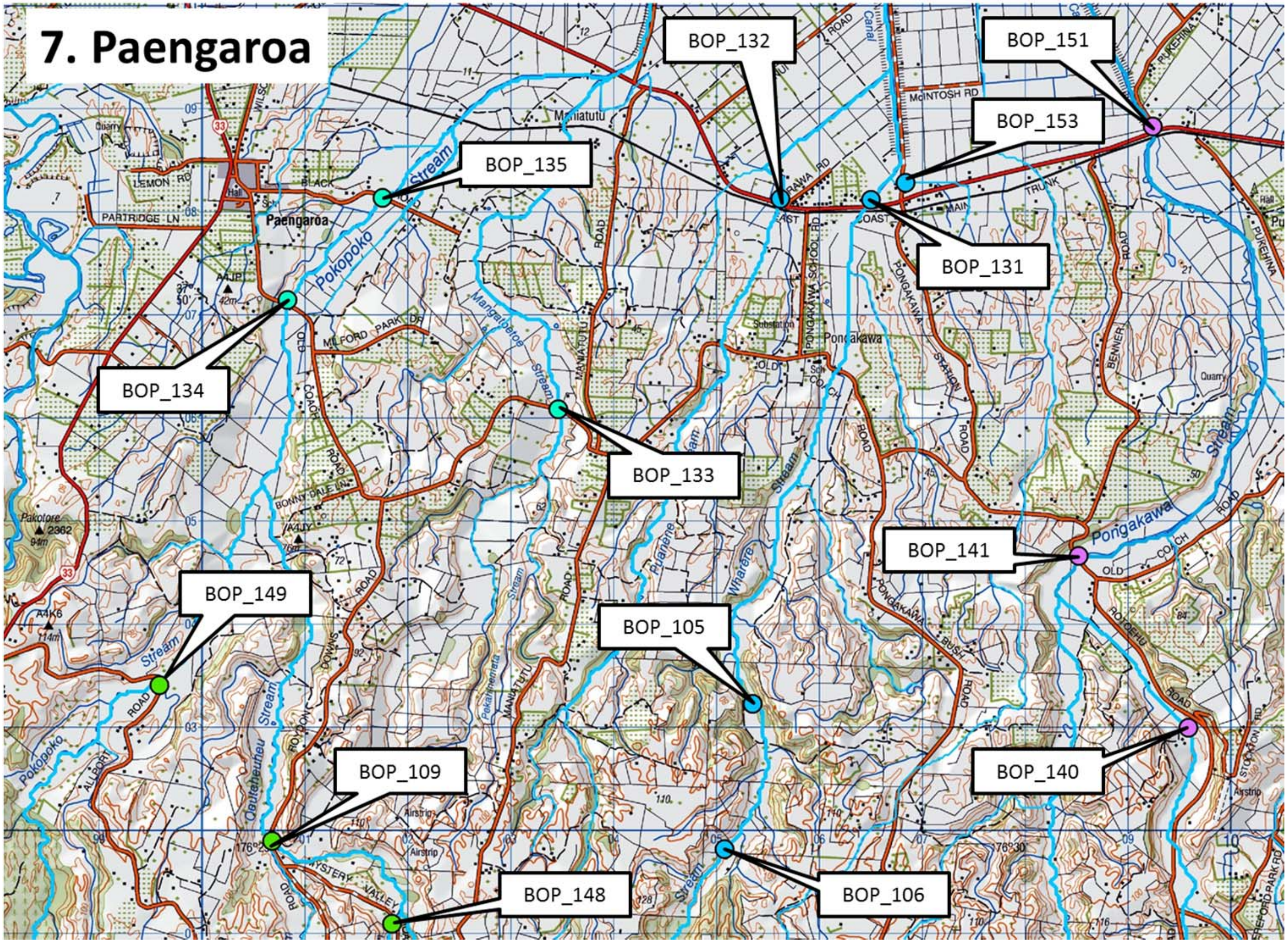
BOP_129
BOP_118
BOP_137
BOP_117
BOP_142

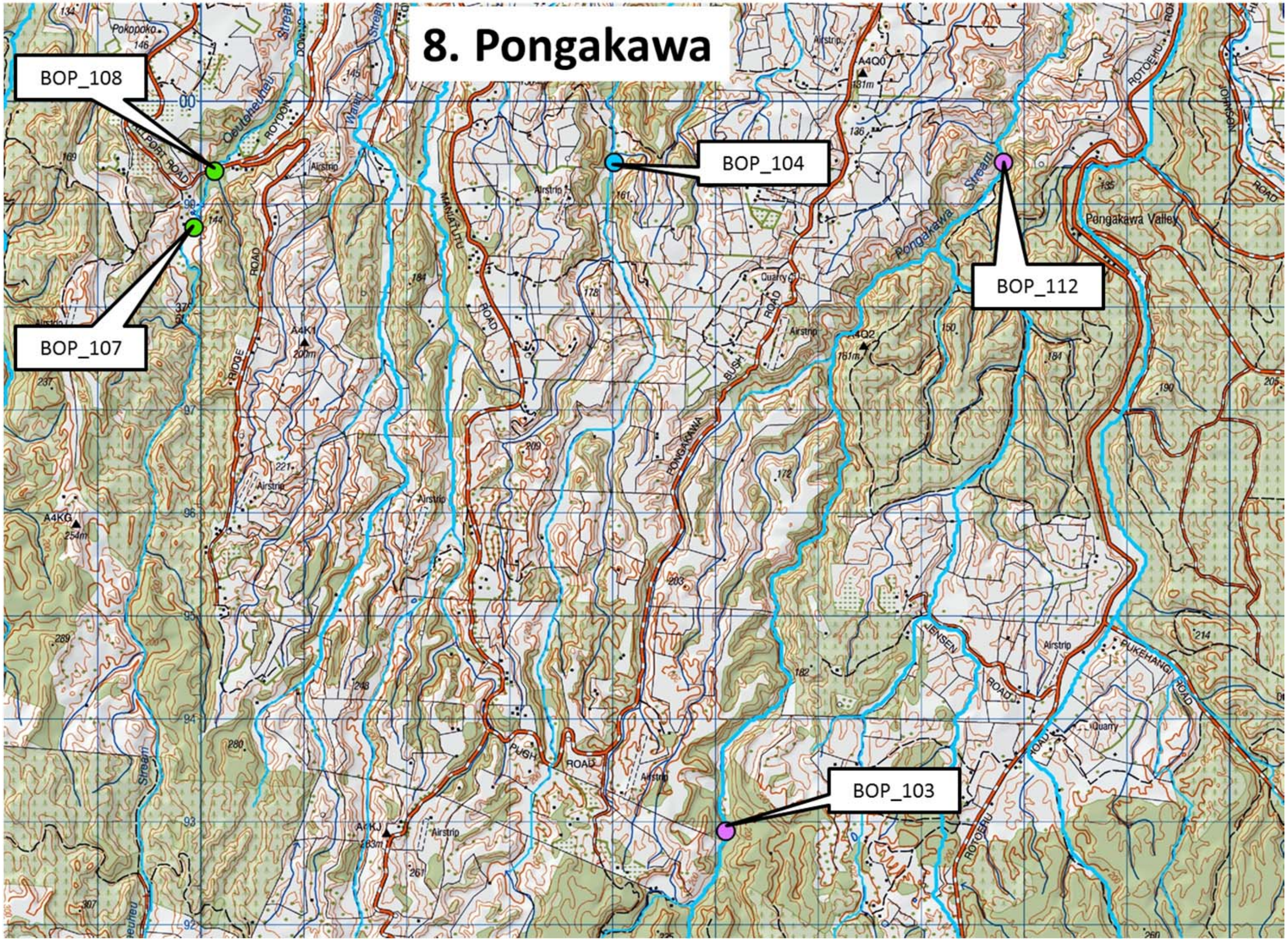

BOP_138
BOP_139
BOP_122
BOP_123
BOP_125
BOP_124
4. Waiari
Muirs Reef
Waiari
Gibraltar Rock
Takarangi
Putaruru
Rangiuru
Douglas Corner
Kaituna
Mangorewa
River
Stream


5. Mid - Mangorewa
BOP_126
BOP_102
Te Ranga
Airstrip
Upokoongaura Stream
Mangorewa River
Mangorewa
Kaituna River
Onaia Stream
Pokopoko Stream
Hururu Stream
Paretero
A4K2
A4K4
A4KF
A4KB
A4KD
B189
Hiapo
KAPUKAPU ROAD
33

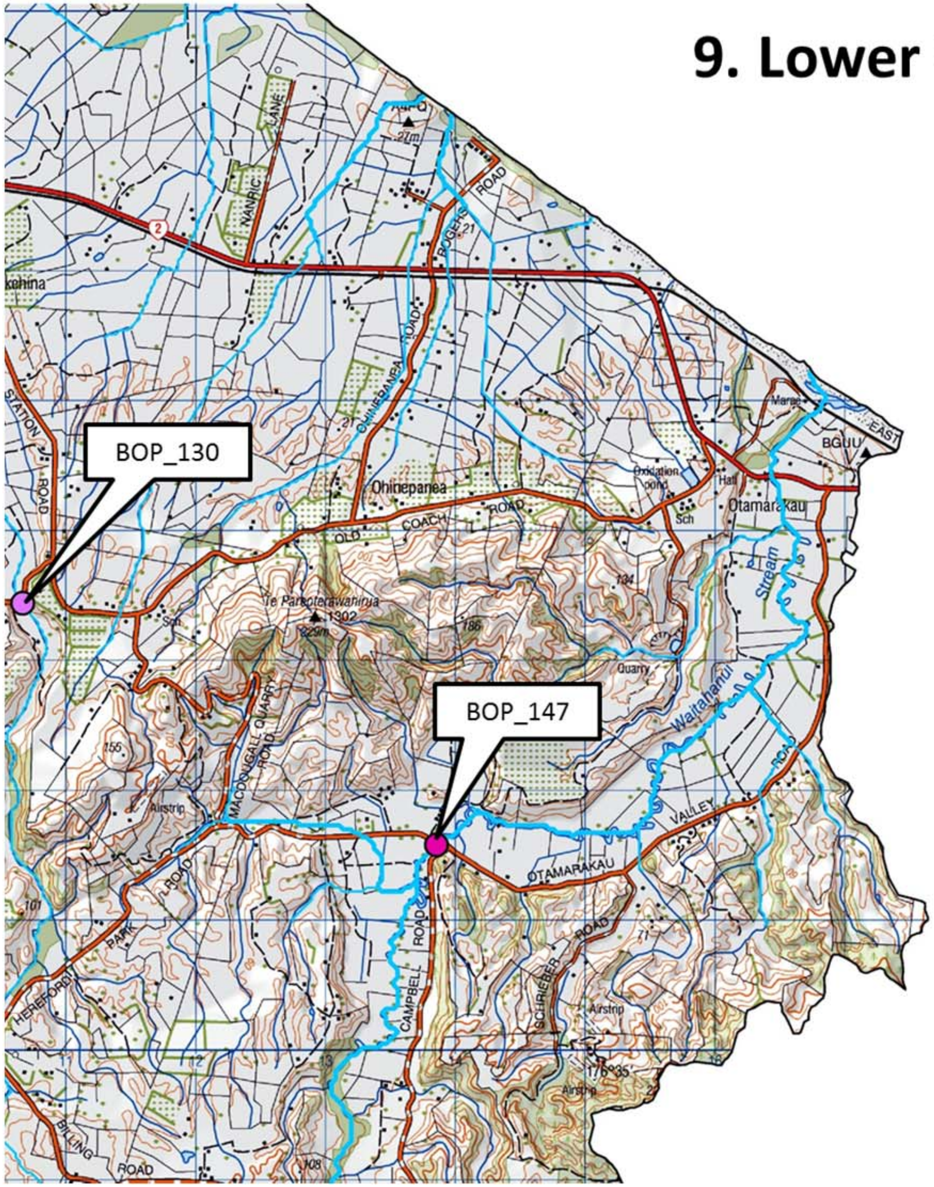
6. Maketu


BOP_150
BOP_152
BOP_110
Maketu
KAITUNA ROAD
FORD ROAD
MAKETU ROAD
NORTH ROAD
WILSON ROAD
KELLY ROAD
TAPSELL ROAD
WAERENGA ROAD
WHARERE ROAD
PUKEHINA PARADE
Te Tumu
Kaikokopu Canal
Pukehina Canal
Pongakawa
Wharere
Reservoirs
Reservoir
Abattoir
Silos

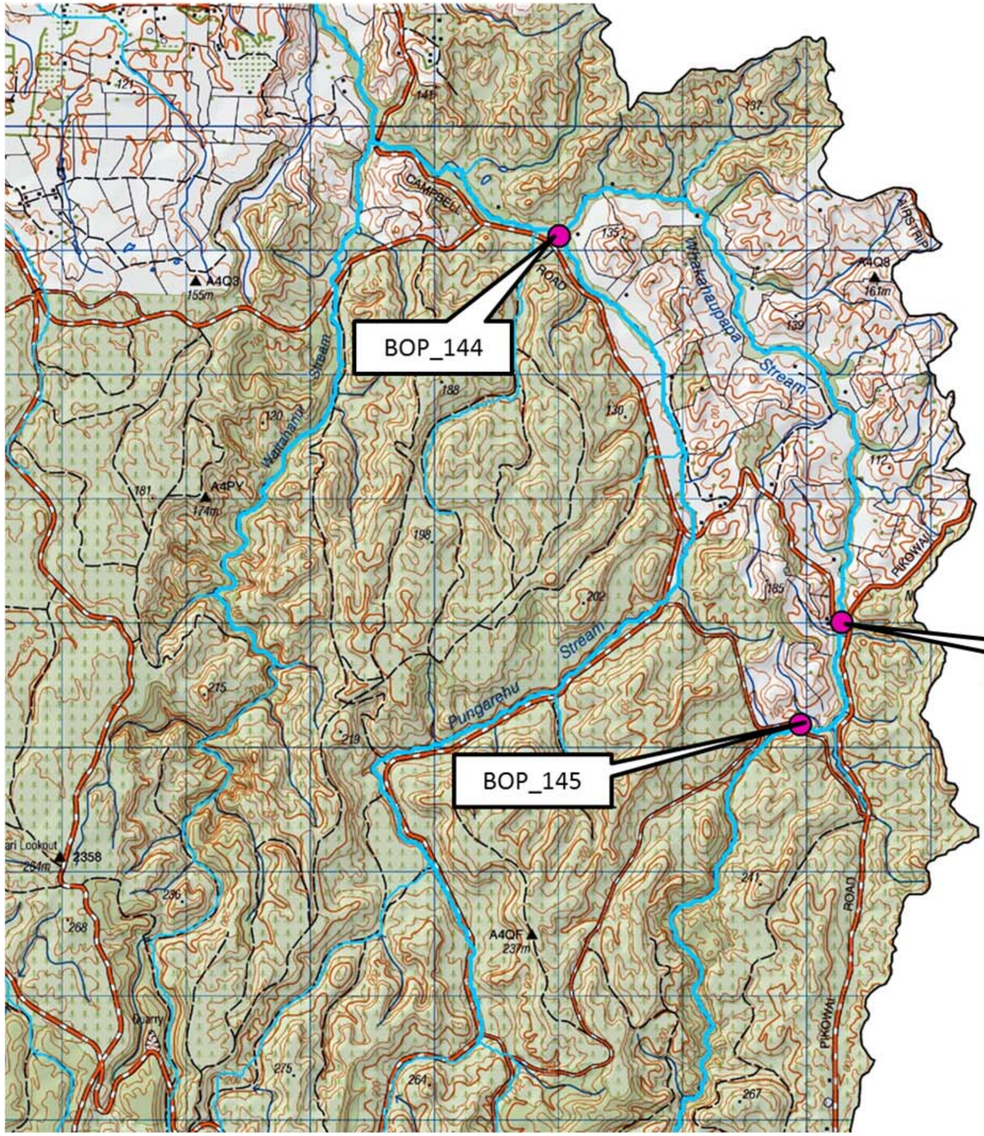

7. Paengaroa
BOP_132
BOP_151
BOP_153
BOP_135
BOP_131
BOP_134
BOP_133
BOP_141
BOP_149
BOP_105
BOP_140
BOP_109
BOP_148
BOP_106
Paengaroa
Pongakawa
Pokopoko Stream
Pongakawa
Mangatoetoe Stream
Waharere Stream

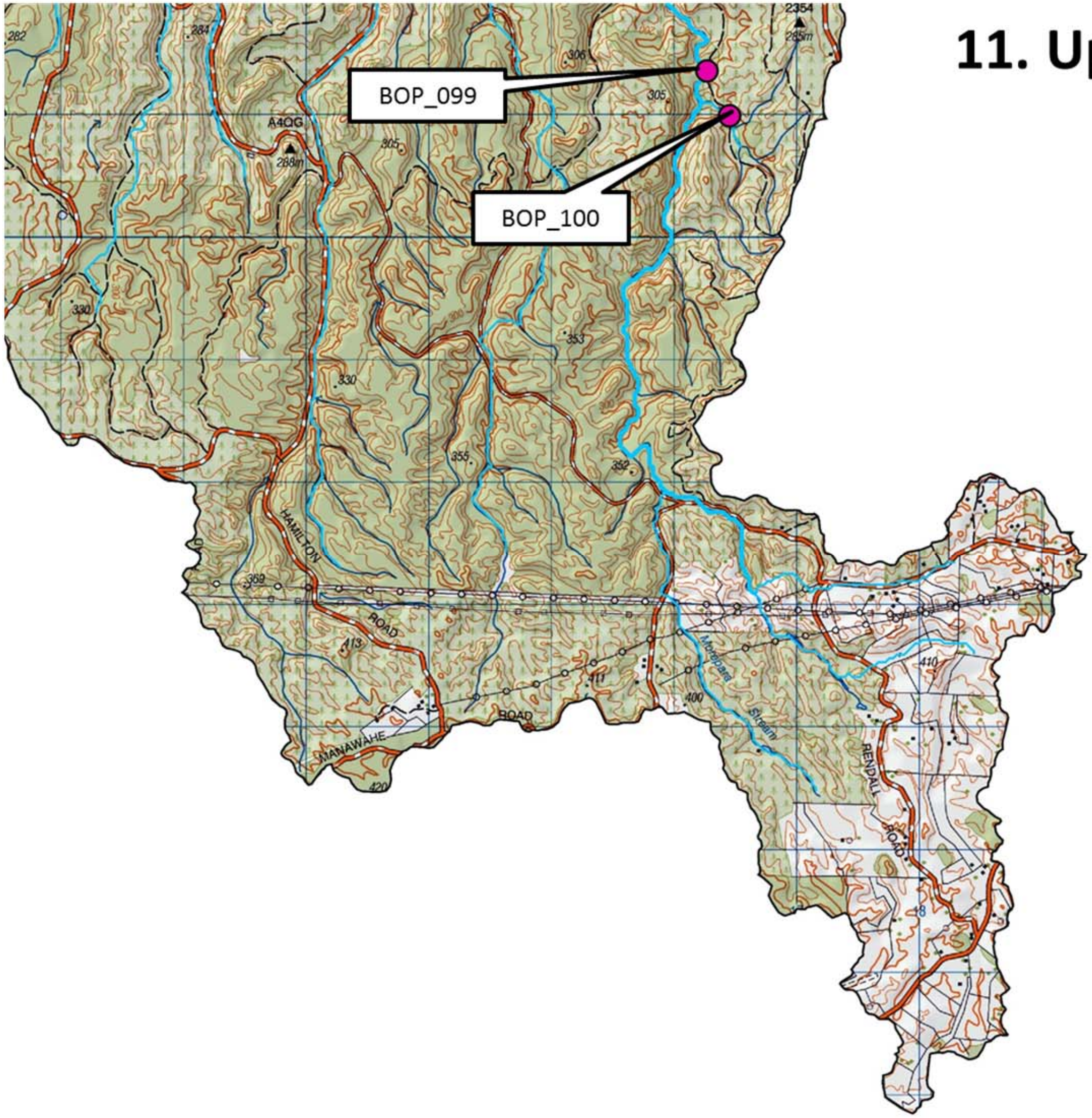

8. Pongakawa
BOP_108
BOP_107
BOP_104
BOP_112
BOP_103
Pongakawa Stream
Pongakawa Valley
ROTOEHU ROAD
JENSEN ROAD
PUKEHANGI ROAD
PUSH ROAD
ROTOEHU
BUSH ROAD
Airstrip
Quarry

9. Lower Waitahanui



10. Mid Waitahanui





11. Upper Waitahanui

Map Number	Site_Name	Site_ID	Easting	Northing	Elevation (m ASL)	Distance to Sea (km)	Richness	Fish_IBI	Species Found	Number
3	Kopureo Drain	BOP_0094	1890841	5816757	5	11	7	Excellent	Shortfin eel	88
									Longfin eel	4
									Unidentified eel	184
									Inanga	21
									Mosquito fish	14
									Redfin bully	9
									Smelt	38
1	Tributary into Whataroa at Road Bridge	BOP_0097	1885234	5806050	169	28	3	Moderate	Longfin eel	9
									Unidentified eel	2
									Koura	2
1	Whataroa Stream below Dam	BOP_0098	1885177	5806038	162	28	1	No Fish	Koura	2
11	Pungarehu Stream at Pa Road	BOP_0099	1916267	5791358	161	25	2	Good	Longfin eel	11
									Koaro	1
11	Tributary into Whakahaupapa in Rotoehu Forest	BOP_0100	1916449	5790991	182	26	2	Excellent	Longfin eel	25
									Banded kokopu	4
2	Mangorewa Stream at State Highway 2 picnic area	BOP_0101	1878571	5793362	386	53	1	No Fish	Koura	2
5	Onaia Stream on Kokako Track	BOP_0102	1890273	5794857	196	39	2	Poor	Longfin eel	1
									Koura	38

Map Number	Site_Name	Site_ID	Easting	Northing	Elevation (m ASL)	Distance to Sea (km)	Richness	Fish_IBI	Species Found	Number
8	Upper Pongakawa	BOP_0103	1905098	5792912	142	27	2	Moderate	Longfin eel	17
									Rainbow trout	2
8	Wharere upper	BOP_0104	1904011	5799408	77	16	6	Excellent	Shortfin eel	1
									Longfin eel	37
									Unidentified eel	34
									Banded kokopu	3
									Redfin bully	3
									Koura	5
7	Wharere Lower	BOP_0105	1905349	5803229	35	11	8	Excellent	Shortfin eel	1
									Longfin eel	4
									Unidentified eel	8
									Giant kokopu	2
									Inanga	2
									Redfin bully	41
									Koura	1
									Smelt	30
7	Wharere middle	BOP_0106	1905074	5801819	37	13	7	Excellent	Longfin eel	10
									Unidentified eel	8
									Inanga	1
									Redfin bully	58
									Koura	9
									Rainbow trout	1

Map Number	Site_Name	Site_ID	Easting	Northing	Elevation (m ASL)	Distance to Sea (km)	Richness	Fish_IBI	Species Found	Number
									Smelt	13
8	Oueteheuheu at Redwood Farm	BOP_0107	1899929	5798778	80	19	5	Excellent	Longfin eel	28
									Unidentified eel	2
									Redfin bully	12
									Koura	10
									Brown trout	1
8	Oueteheuheu at NERM 053	BOP_0108	1900130	5799324	76	19	2	Good	Longfin eel	13
									Redfin bully	5
8	Oueteheuheu at Redwood Farm	BOP_0107	1899929	5798778	80	19	5	Excellent	Longfin eel	28
									Unidentified eel	2
									Redfin bully	12
									Koura	10
									Brown trout	1
7	Waiari on Roydon Downs Road (NERM010)	BOP_0109	1900676	5801901	38	16	3	Good	Longfin eel	7
									Unidentified eel	2
									Redfin bully	6
6	Kaikokopu Canal	BOP_0110	1904963	5810711	15	2	3	Moderate	Shortfin eel	5
									Longfin eel	5
									Giant Bully	4

Map Number	Site_Name	Site_ID	Easting	Northing	Elevation (m ASL)	Distance to Sea (km)	Richness	Fish_IBI	Species Found	Number
3	Waiari Stream at State Highway 2	BOP_0111	1894066	5812250	14	12	6	Excellent	Longfin eel	12
									Unidentified eel	8
									Inanga	8
									Redfin bully	11
									Koura	12
									Smelt	1
8	Pongakawa at water quality site	BOP_0112	1907798	5799410	31	19	6	Excellent	Shortfin eel	20
									Longfin eel	15
									Unidentified eel	16
									Inanga	2
									Redfin bully	11
									Koura	1
3	Ohineangaanga Stream, under bridge Te Puke Highway	BOP_0113	1892097	5813211	13	12	4	Good	Shortfin eel	24
									Longfin eel	5
									Unidentified eel	3
									Redfin bully	58
3	Waikoura Stream, Te Puke Quarry Road_Lower Site	BOP_0114	1888345	5813974	150	17	3	Good	Shortfin eel	1
									Longfin eel	3
									Redfin bully	5
3	Waikoura Stream, Tributary	BOP_0115	1888324	5814000	135	17	4	Excellent	Shortfin eel	1
									Longfin eel	20
									Banded kokopu	3

Map Number	Site_Name	Site_ID	Easting	Northing	Elevation (m ASL)	Distance to Sea (km)	Richness	Fish_IBI	Species Found	Number
									Redfin bully	15
3	Waikoura Stream, Te Puke Quarry Road_Upper Site	BOP_0116	1888459	5814147	15	15	4	Moderate	Shortfin eel	10
									Longfin eel	35
									Redfin bully	72
									Koura	4
3	Ohineangaanga Stream, 162 No.2 Road	BOP_0117	1890798	5810230	33	15	5	Excellent	Shortfin eel	4
									Longfin eel	28
									Shortjawed kokopu	2
									Galaxias sp	1
									Redfin bully	61
3	Ohineangaanga Stream, orchard 4WD track	BOP_0118	1891333	5811342	33	15	3	Good	Shortfin eel	5
									Longfin eel	16
									Redfin bully	23
1	Raparapahoe	BOP_0119	1885620	5807421	133	26	3	Excellent	Unidentified eel	1
									Koaro	1
									Brown trout	1
1	Tributary of Whatarua Stream	BOP_0120	1884780	5808053	149	26	2	Good	Longfin eel	1
									Koaro	1
1	Smaller tributary of Whatarua Stream	BOP_0121	1884623	5808139	210	27	3	Excellent	Longfin eel	9
									Koaro	5
									Banded kokopu	2

Map Number	Site_Name	Site_ID	Easting	Northing	Elevation (m ASL)	Distance to Sea (km)	Richness	Fish_IBI	Species Found	Number
4	Waiari - upper	BOP_0122	1892923	5808815	36	18	3	Good	Unidentified eel	5
									Lamprey	2
									Redfin bully	23
4	Mangorewa Stream above Kaituna	BOP_0123	1897344	5806771	20	21	8	Excellent	Shortfin eel	3
									Longfin eel	4
									Unidentified eel	10
									Banded kokopu	1
									Inanga	5
									Lamprey	8
									Redfin bully	18
									Koura	3
4	Tributary at Mangorewa - Saunders Farm	BOP_0124	1894503	5801705	60	30	2	Moderate	Longfin eel	1
									Koura	2
4	Mangorewa at Saunders gauging site	BOP_0125	1894488	5801755	58	30	3	Moderate	Longfin eel	7
									Unidentified eel	3
									Koura	4
5	Mangorewa - NERMN 119	BOP_0126	1894908	5800164	107	33	2	Moderate	Longfin eel	10
									Unidentified eel	1
1	Tributary of Whatarua Stream, Demeter Road, lower site	BOP_0127	1884566	5807289	181	27	2	Good	Longfin eel	6
									Koaro	1

Map Number	Site_Name	Site_ID	Easting	Northing	Elevation (m ASL)	Distance to Sea (km)	Richness	Fish_IBI	Species Found	Number
1	Tributary of Whatarua Stream, Demeter Road, upper site	BOP_0128	1884619	5807341	181	27	2	Poor	Longfin eel	2
									Koura	1
3	Kirikiri Stream	BOP_0129	1889088	5811850	30	18	4	Good	Shortfin eel	14
									Longfin eel	17
									Unidentified eel	9
									Redfin bully	62
9	Pongakawa Stream Tributary - Old Coach Road	BOP_0130	1910664	5805442	29	11	9	Excellent	Shortfin eel	47
									Longfin eel	6
									Inanga	4
									Galaxias sp	1
									Mosquito fish	1
									Giant Bully	1
									Redfin bully	18
									Koura	2
									Smelt	5
7	Wharere Stream	BOP_0131	1906497	5808120	18	6	9	Excellent	Shortfin eel	23
									Longfin eel	10
									Torrentfish	2
									Mosquito fish	2
									Common bully	4
									Giant Bully	8
									Redfin bully	50

Map Number	Site_Name	Site_ID	Easting	Northing	Elevation (m ASL)	Distance to Sea (km)	Richness	Fish_IBI	Species Found	Number
									Koura	2
									Smelt	5
7	Puanene Stream	BOP_0132	1905616	5808130	18	6	6	Excellent	Shortfin eel	19
									Longfin eel	14
									Unidentified eel	1
									Inanga	24
									Redfin bully	60
									Smelt	25
7	Mangatoetoe Stream - Old Coach Road	BOP_0133	1903460	5806088	20	10	7	Excellent	Shortfin eel	45
									Longfin eel	6
									Unidentified eel	1
									Inanga	5
									Giant Bully	1
									Redfin bully	42
									Smelt	31
7	Kaikokopu Tributary - Old Coach Road	BOP_0134	1900825	5807149	19	9	5	Excellent	Longfin eel	1
									Inanga	3
									Giant Bully	2
									Redfin bully	8
									Smelt	6
7	Kaikokopu Stream - Black Road Bridge	BOP_0135	1901751	5808138	19	8	4	Good	Longfin eel	6
									Giant Bully	1

Map Number	Site_Name	Site_ID	Easting	Northing	Elevation (m ASL)	Distance to Sea (km)	Richness	Fish_IBI	Species Found	Number
									Redfin bully	1
									Koura	1
3	Kirikiri Stream - 351 Manoeka Road	BOP_0136	1889896	5811662	30	18	4	Good	Shortfin eel	7
									Longfin eel	11
									Redfin bully	3
									Smelt	1
3	Raparapahoe Stream - No.4 Road	BOP_0137	1889985	5811143	51	18	3	Good	Shortfin eel	1
									Longfin eel	3
									Redfin bully	7
4	Raparapahoe downstream waterfall	BOP_0138	1889491	5809132	51	19	2	Moderate	Longfin eel	28
									Redfin bully	28
4	Pongakawa Tributary - Rotoehu Road	BOP_0139	1909584	5802997	28	15	4	Moderate	Shortfin eel	40
									Longfin eel	8
									Giant kokopu	1
									Redfin bully	31
7	Pongakawa Stream – State Highway 2	BOP_0141	1908517	5804666	20	12	4	Good	Longfin eel	2
									Giant Bully	4
									Redfin bully	1
									Koura	2
3	Parawhenuamea Stream	BOP_0142	1896501	5811475	13	13	6	Good	Shortfin eel	6
									Giant kokopu	1
									Inanga	3

Map Number	Site_Name	Site_ID	Easting	Northing	Elevation (m ASL)	Distance to Sea (km)	Richness	Fish_IBI	Species Found	Number
									Redfin bully	8
									Koura	4
									Smelt	1
10	Whakahaupapa	BOP_0143	1917277	5796010	68	19	4	Excellent	Longfin eel	9
									Unidentified eel	3
									Torrentfish	1
									Redfin bully	1
10	Pungarehu Stream at Campbell Road	BOP_0144	1915003	5799121	49	14	4	Excellent	Longfin eel	10
									Unidentified eel	6
									Banded kokopu	4
									Redfin bully	5
10	Marepara on Pa Road	BOP_145	1916946	5795189	80	20	4	Excellent	Longfin eel	4
									Unidentified eel	3
									Torrentfish	1
									Redfin bully	2
9	Waitahanui Stream @ Campbell Road	BOP_0147	1913850	5803582	17	7	8	Excellent	Shortfin eel	3
									Longfin eel	1
									Unidentified eel	1
									Giant kokopu	3
									Giant Bully	1
									Redfin bully	4
									Koura	2

Map Number	Site_Name	Site_ID	Easting	Northing	Elevation (m ASL)	Distance to Sea (km)	Richness	Fish_IBI	Species Found	Number
									Smelt	2
7	Waiari Stream at Mystery Valley Road	BOP_0148	1901842	5801098	61	18	3	Good	Longfin eel	21
									Unidentified eel	2
									Redfin bully	4
7	Pokopoko at Allports Road	BOP_0149	1899581	5803411	38	14	5	Excellent	Longfin eel	5
									Unidentified eel	13
									Giant kokopu	1
									Redfin bully	7
									Smelt	3
6	Maketū, Whakapoukorero Wetland north drain	BOP_0150	1903592	5814889	13	0	4	Moderate	Shortfin eel	8
									Inanga	1
									Mosquito fish	4
									Common bully	3
7	Pongakawa Canal	BOP_0151	1909236	5808829	19	6	1	Poor	Common bully	12
6	Waitepuia Stream	BOP_0152	1903324	5814332	13	1	1	Poor	Shortfin eel	5
7	Wharere Canal Trap 1	BOP_0153	1906833	5808284	18	6		Moderate	Unidentified eel	6
									Inanga	4
									Mosquito fish	1
									Common bully	7
3	Lawrence Oliver Park Stream	BOP_0154	1893587	5812642	14	11	2	Moderate	Shortfin eel	2
									Inanga	1