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EXECUTIVE SUMMARY

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Freshwater eels (tuna) are very important in the lives of the Ngāti Hine people and anecdotal observations indicate a decline in the numbers of both the downstream migratory adults and juvenile populations since the 1970s. Ngāti Hine are concerned about how this decline will affect the ability of tangata whenua to sustainably harvest eels for their sustenance, commercial, and customary needs, particularly kaumātua and kuia that continue to rely on this resource as a staple dietary item.

The aim of this project (EEL2007-07) was to assess the distribution, species composition, age structure, growth rate, and sex composition of freshwater eels in the Kawakawa (Taumārere) River catchment (Northland, New Zealand) to provide a reference point for any future monitoring of the population and management of the customary fishery. The project was undertaken in close collaboration with Te Rūnanga o Ngāti Hine.

To assess the current status of eel stocks in Te Rohe Whenua o Ngāti Hine, 16 sites were surveyed in the Kawakawa and Waitangi River catchments with fyke nets, Gee minnow traps, and electric fishing. A total of 782 eels were captured during the survey of which overall 46% were longfin eels.

In comparison to other New Zealand catchments, the density of eels in the Kawakawa and Waitangi River catchments appeared low. Although most of the eels captured were of harvestable size (i.e., mostly between 400 and 600 mm), the large eels that are preferred for customary take (over 750 mm) were rare. The age of shortfin eels analysed (N = 69) ranged from 2 to 25 years and the rate of growth within the Kawakawa River catchment was similar to that in other regions. However, growth in nearby Lake Owhareiti, where shortfin was the only eel species caught, was markedly faster. The longfin eels aged (N = 61) ranged from 7 to 24 years, and no marked differences in growth rate between sites were apparent.

Means of maintaining a sustainable eel population in the catchment are proposed. These include: implementing nationwide harvest controls, measures to ensure that a sufficient number of eels reach maturity, ensuring that the present habitat is not further degraded, ensuring that eels maintain their access to terrestrial prey during floods, removing migration barriers, and stocking of Lake Owhareiti.

1. INTRODUCTION

Freshwater eels (tuna) are very important in the lives of Ngāti Hine and are intimately linked with their ability to practise manaakitanga (hospitality) and tākoha (gift, donation). In addition to providing a staple food source for tangata whenua (people of the land), eels play an intricate role in the tikanga (customs), whakataukī (proverb, saying), myths, and legends of Ngāti Hine. There are many events, place names, and stories within Te Rohe Whenua o Ngāti Hine (the land area of Ngāti Hine) pertaining to the eel, and hence the Ngāti Hine people have been called the "tuna people". Thus, well known as eel fishers, Ngāti Hine have considerable knowledge of eel habitat and behaviour, and have maintained their customary fisheries for several centuries.

Te Rohe Whenua o Ngāti Hine is identified as "*Haere mai Ōpua ki Pouerua: i Pouerua ki Tautoro, te maunga Tōtoro i roto Kereru; i reira, Hikurangi; Hikurangi ki Mangakāhia;i Mangakāhia ka huri mai ki Moengawahine; whakawhiti tonu ki runga i te tihi o Motatau, ko Unuwhao; haere mai ki runga i tena kāweka kia tau mai ki Hūkerenui; ka huri iho ki Akerama; nā ki Taumārere. He rohe nui, nā te mana o tēnei wahine a Hineamaru*" (Tā Himi Henare quoted in Shortland & Nuttall 2008). Within Te Rohe Whenua o Ngāti Hine there are many streams, rivers, lakes, and wetlands that form the catchment of Te Awa Tapu o Taumārere. The Taumārere or Kawakawa River flows out into the Waikare Inlet and the catchment covers about 820 square kilometres (NRC 2009). Nearby Lake Owhareiti (2596455E 6645475N) in the Waitangi River catchment belongs to Ngāti Hine and is vested in a trust (Shortland & Nuttall 2008). The lake, about 96 ha in area (Conning & Miller 2000, Wells & Champion 2010), has a maximum depth of 15–16 m (Rowe 1999, Wells & Champion 2010) and is the largest lake within Te Rohe Whenua o Ngāti Hine.

Ngāti Hine customary fishing relies on the ability of the freshwater fisheries resources to sustainably service the needs of at least 13 Ngā Marae o Ngāti Hine (Matawaia, Otiria, Tere Awatea, Te Aroha, Motatau, Eparaima Makapi, Mohimui, Kawiti, Te Rito, Horomanga, Maungārongo, Tau Henare and Mīria), and about 30 neighbouring marae. Eel harvest is required to provide manaakitanga at hui (meetings) and tākoha, as well as providing for the normal consumption of at least 400 whānau (families) (Shortland & Nuttall 2008). Some intermittent commercial fishing is known to occur within the catchment (Tohe Ashby, Trustee and Chairman of Te Rūnanga o Ngāti Hine, pers comm., 2008). The area falls within sub-area 1C – Bay of Islands (Beentjes 2008) which has an annual reported commercial eel catch ranging from 1.5 to 12.0 tonnes from the period 2003–2007 (Appendix 1).

New Zealand's freshwater eel populations are under pressure from activities such as overexploitation, habitat removal, and the construction of in-stream barriers (Beentjes et al. 2005, Jellyman 2007). Poor water quality and reduced access to suitable habitats have been identified by Ngāti Hine as issues that are affecting their eel populations (Shortland & Nuttall 2008). Anecdotal observations and interviews with kaumātua (elder) and kuia (female elder) from Ngāti Hine indicate a decline in the numbers of both the downstream migratory adults and juvenile populations since the 1970s (Tohe Ashby, pers comm., 2008). Ngāti Hine are concerned about how this decline will affect kaumātua and kuia that rely on this customary resource as a staple dietary item, and the ability of Ngāti Hine to meet their cultural, health, and social requirements.

Freshwater eels feature prominently in the Ngāti Hine Environmental Management Plan 2008 (Shortland & Nuttall 2008). The specific objectives outlined in this plan pertaining to eels include:

- to be able to harvest eels for their sustenance, commercial, and customary needs;
- to be able to manāki (to care for) their manuhiri (visitors) in the style that they are renowned for;
- to be eel self sufficient and confident that their freshwater resources are being sustainably managed;
- that Ngāti Hine are recognised as kaitiaki (guardians) and hence are the decision makers and managers of their eels and the associated freshwater resources.

In addition to satisfying the requirements of the MFish project, the information contained in this report will contribute to the environmental audit that Ngāti Hine is undertaking within their rohe. This audit will provide a baseline to assist Ngāti Hine in their role as kaitiaki and enable them to monitor the success of initiatives undertaken in the future, by themselves and other agencies, to improve the habitat and eel population within Te Rohe o Ngāti Hine.

1.1 Project objectives

In November 2007 the Ministry of Fisheries (MFish) contracted NIWA (project EEL2007-07) to assess the present status of eel stocks in the Kawakawa (Taumārere) River and tributaries. The specific objectives of this study were as follows.

1. To assess the distribution, species composition, age structure, growth rate, and sex composition of freshwater eels in the Kawakawa river catchment to provide a reference point for any future monitoring of the population and management of the customary fishery.

This project was undertaken in close collaboration with Te Rūnanga o Ngāti Hine who assisted in site selection, site access, fieldwork, and a review of this report.

2. METHODS

2.1 Survey area and design

In February 2008, Ngāti Hine and NIWA representatives met at Motatau School to discuss this project and identify sampling sites of high customary importance to the iwi (tribe). Sixteen sites were chosen and sampled during the present survey (Figure 1, Table 1, Appendix 2). Lake Owhareiti and the Puketōtara Stream in the neighbouring Waitangi River catchment were also included in this survey as this lake is an important customary fishery for Ngāti Hine. This survey was conducted in two stages. The study began on 7 April 2008 (new moon, 6 April), but was interrupted by heavy rain and flooding on 14 April 2008. Eels are most active during the summer months and, for this reason, surveying the remainder of the sites was delayed until 3 to 7 November 2008 (full moon, 13 November). All the field work was carried out using a combination of experienced Ngāti Hine members and NIWA staff.

The sites surveyed were referenced by GPS and the site characteristics recorded using the parameters described in the New Zealand Freshwater Fish Database standard form (see http://neptune.niwa.co.nz/fwdb/ for details) (Appendix 2). Photographs of most of the sampling sites were also taken.

A combination of sampling methods, primarily targeting freshwater eels, was used during the survey. This included:

- coarse meshed fyke nets (single leader 6 m length, diameter 750 mm), 15 mm mesh;
- fine meshed fyke nets (single leader 6 m length, diameter 600 mm), 6 mm mesh;
- electric fishing;
- Gee minnow traps, 3 mm mesh.

Fyke nets and Gee minnow traps were used wherever large bodies of water (i.e., over about 1 m water depth) were present and electric fishing was not effective. However, where both shallow (i.e., under about 0.75 m water depth) and deep waters were present, a combination of netting and electric fishing methods were used. The physical location of the areas where fyke netting and electric fishing were undertaken within a site was not the same (i.e., they did not overlap; the choice of technique and number of nets deployed at each site varied depending upon physical characteristics of the available habitat within each site, such as water depth).

Before each use, all nets and other equipment were sanitised by placing them in a solution of 4% sodium chloride (sea salt) and then air dried to minimise the risk of spreading unwanted organisms.

Apart from 130 eels retained for ageing purposes and 10 bullies that were preserved to confirm species identification, all other fish were returned live at the point of capture.

2.2 Netting

Coarse fyke nets of commercial size were used to target eels whose body depth was larger than the mesh size. These nets were baited with perforated cat food sachets (predominantly pilchard). Fine fyke nets were used to target eels of all smaller sizes, as well as smaller fish, and were also baited with cat food. Gee minnow traps were used to target small fish such as īnanga and bullies and were baited with trout food pellets.

Twelve sites were surveyed with fyke nets. Of these sites, 10 were mainstem river/stream sites (Kawakawa River, Waiomio Stream, Orauta Stream, Terewatoa Stream, Ramarama Stream, Horahora Stream, and Takapau Stream) and two were lakes (Owhareiti and Kaiwai). Based upon the area of fishable water present at the site, between 2 and 20 fine and coarse meshed fyke nets were set about 25 m apart (with the exception of the lakes) in similar habitats. In fast flowing water, the fyke nets were fixed to one bank, with the cod-end against the bank and leader pointing downstream. In slow moving and still water, the leader was placed against the bank and the net was fished at right angles to the bank. Each fyke net was secured at each end using wooden stakes and/or weights. One Gee minnow trap was set alongside each coarse mesh fyke net via a short rope that was tied to the wooden stake holding the end of the fyke net.

In addition to the above overnight sets, depletion fyke netting (serial depletion over three consecutive nights fishing) as outlined by Jellyman & Graynoth (2005) was used. For this, 8–10 fyke nets were set about every 25 m along a stretch of river/stream. Every day, for three days, the catch from each fyke net was counted and weighed (total weight), the species were identified and retained in fine mesh catch bags until the last day of sampling when the entire catch of eels was individually measured and weighed. Due to resource constraints, depletion fyke netting was carried out at only three sites during the current survey (Site 1 - Kawakawa River at SH1, Site 2 - Waiomio Stream at SH1, and attempted unsuccessfully at Site 10 - Horahora Stream). These results were then used to provide an indication of fyke netting efficiency per species as outlined by Jellyman & Graynoth (2005). The development, trial, and use of this technique in New Zealand rivers and streams is relatively recent (e.g., Jellyman & Graynoth 2005, Crow et al. 2009; Jellyman 2010) but is considered to provide more detailed information when compared to reporting only catch per unit effort.

Depletion netting was also attempted at Site 10, but flooding occurred on day three and prevented the nets from being reset. Due to the flood the assumption of a closed population was violated and therefore the population estimates obtained for Site 10 were invalid. Currently it is not possible to undertake accurate depletion netting in lakes as immigration from areas outside the sampling reach could occur (Jellyman & Graynoth 2005). Lakes Kaiwai (Site 7) and Owhareiti (Site 12) were therefore omitted from these analyses.

2.3 Electric fishing

All electric fishing was undertaken using a Kainga EFM300 battery-powered backpack and all fishing was carried out in an upstream direction to minimise disturbance to the habitat in advance of fishing that area. Unless no eels were caught in the first pass, at least one additional pass was undertaken to ensure that depletion methods could be used to estimate the population.

A combination of multiple pass (quantitative) and single pass (semi-quantitative) electric fishing sampling was also undertaken to provide additional information to that collected by fyke nets. The six sites sampled using electric fishing were: Waiomio Stream (2 passes, 25 m length), Terewatoa Stream (2 passes, 10 m length), Puketōtara Stream at Pakaraka (2 passes, 30 m length), Puketōtara Stream at the outlet of Lake Owhareiti (2 passes, 30 m length), Pokapū Stream below culvert (2 passes, 20 m length) and Pokapū Stream above culvert (single pass, 10 m length).

2.4 Catch processing

Catch composition

Catches from individual nets were processed separately. Eels captured were anaesthetised in Aqui-S (a registered clove oil based fish anaesthetic), identified by species, measured (to the nearest 1 mm) and weighed (to the nearest 1 g). Bycatch information (species and numbers captured) was also recorded.

Age structure

For ageing purposes, saggital otoliths from 130 eels were removed from across the range of the length distribution captured (140–840 mm). Most of the otoliths were obtained from the lower catchment (Sites 2, 3, and 4) as removing eels from these areas had the least impact on the population and future availability for the neighbouring families. A smaller number of otoliths were obtained from the upper Waiharakeke (Sites 9 and 10), Lake Kaiwai (Site 7), and above Otiria Falls (Site 6) as fewer eels were captured from these areas.

Eels sacrificed for otolith extraction were sedated in Aqui-S and euthanised by severing of the notochord at the base of the head followed by bleeding (all processed eels were retained for consumption by Ngāti Hine). Otoliths were prepared following the methods of Hu & Todd (1981). Essentially this method consists of breaking the otoliths in half transversely by placing them, convex side uppermost, between the folds of a piece of thin, clear plastic and pressing across the centre with a scalpel blade. The otolith halves were then burnt by placing them on a scalpel blade over a bunsen flame until they turned brown. Following the burning, the otoliths were embedded in clear Silastic 732 RTV with the broken edge placed flush with a glass slide. Mounted otoliths were viewed using a compound microscope and annual hyaline rings counted across the largest axis.

Age was expressed in terms of years in freshwater, ignoring the first ring that surrounds the core which represents marine larval growth. Ageing relies on dense annual bands on the otolith, caused by decreased growth rates in winter. In Northland, where winter temperatures are warmer, eels could potentially feed for much longer and could take advantage of winter floods to feed on land invertebrates. When this occurs, false growth checks may be deposited. Consequently, when reading the otoliths in the current study, faint bands appearing between darker bands were ignored. Even with this approach, about 80% of the otoliths were considered difficult to read, 10% very difficult to read, and only 10% were relatively easy to read.

Sex composition and gonad maturity

The sex composition of eels was determined using two methods. The first involved field observations of gonads from selected eels that were sacrificed for ageing. In this assessment the gonad descriptions of Beentjes & Chisnall (1998) and the field key developed by Jellyman et al. (2006) were used. The second criterion for assigning sex was based upon Jellyman & Todd's (1982) study of the length distributions of migratory eels which indicated that shortfin eels larger than 55 cm, and longfin eels larger than 75 cm, were mostly females. All eels were inspected for the presence of migratory features (i.e., enlarged eyes, darkened pectoral fin, flatter and slender head, silver colour (for shortfins) or bronze coloration (for longfins)).

2.5 Data analysis

Length-weight relationships

Regression analysis was used to examine the relationship between weight and length of eels and how that relationship changed between sites. Separate relationships were examined for longfin and shortfin eels (over 300 mm). Both the weights and lengths were log transformed. Differences between sites in this relationship were examined by fitting a full model allowing different slopes and intercepts for each site, and then fitting restricted models, the first fitting parallel lines and the second fitting a common line for all sites. The significance of the slope and intercept differences were calculated from these. The residual standard deviation and variance (%) explained were used to summarise the model fits.

Where actual weights were not measured in the field, length-weight relationships (using least squares linear regression, STATISTICA 7.1) for each species were used to derive estimates of individual weights for use in biomass estimates.

Catch per unit effort and population estimates

The catch per unit effort (CPUE) for fyke net catches was expressed as number/net/night and kg/net/night for each species, except for two sets of nets at the depletion sites where the species were not separated and only the length and total weight of eels captured was recorded. In all CPUE, population, and biomass analyses, the catch from the most downstream net was not included in the analyses as this net was expected to catch eels from outside the sampling area (Jellyman & Graynoth 2005).

Population estimates and associated standard errors were calculated using Carle & Strub's K-pass removal method in R (version 2.12.0) using the Fisheries Stock Assessment Methods (FSA version 0.2-1) add-on package (Carle & Strub 1978; Ogle 2008). Biomass estimates were obtained by multiplying the estimated population by the average weight of the eels captured at each site. For sites where some eels were measured but not weighed, the weights of these eels were estimated using the length-weight regressions.

It is recognised that netting efficiencies are dependent upon the method of deployment (e.g., bait type), habitat present, and eel population structure (e.g., ratio of longfins to shortfins). Ideally, depletion fyke netting would have been undertaken at every site surveyed, but due to time and resource constraints this was not feasible. Following Jellyman & Graynoth (2005) at Sites 2 and 3, where depletion netting was undertaken, the Carle & Strub (1978) maximum weighted likelihood method was used to estimate population numbers and biomass (no./m^2 and no./100 m length). The data derived at Sites 2 and 3 were used to provide an estimate of netting efficiency for the first day of netting for each species. These netting efficiencies were then used to provide a population estimate for the rest of the sites that were surveyed for only one night.

For sites that were electric fished, the Carle & Strub (1978) method was also used to obtain a population estimate from catches obtained in the two runs/passes that were made. The Carle & Strub method is commonly used in Europe to estimate fish population from two passes as it produces more reliable estimates, especially for eels (e.g., Lambert et al. 1994, Feunteun et al. 1998, Lafaille et al. 2005). As eels captured in the first electric fishing run tend to be the largest eels present (Graynoth & Taylor 2004), the total weight of eels obtained in the two electric fishing runs was used to estimate total biomass of the population.

Growth rate

Eel growth was calculated from length-at-age data obtained from the reading of otoliths that were extracted during the study. Linear regressions are considered to best describe the growth of eels longer than 250–300 mm. Growth rates for eels over 300 mm were compared by calculating the mean annual length increment (mm/yr) and associated 95% confidence limits for eels from each site. The average length of glass eels at arrival in freshwater was subtracted from the length of the eel upon capture (Beentjes & Chisnall 1998). For longfins, an arrival length of 63 mm was subtracted and for shortfins a length of 60 mm was subtracted (Jellyman 1977). Annual growth increments for individual eels were therefore calculated as follows:

- Shortfins: (total length – 60) / age
- Longfins: (total length – 63) / age

3. RESULTS

3.1 Species composition

A total of 782 eels were captured during the present survey, of which 46% were longfins. Longfins comprised more than 50% of the total catch from Sites 1 (Kawakawa River at mouth), 2 (Kawakawa River at SH1), 5 (Orauta Stream, below the Otiria Falls), and 6 (Orauta Stream, above the Otiria Falls) (Tables 2 & 3).

3.2 Length, weight and age characteristics

Of the eels captured, only 1% of longfins and 12% of shortfins were less than 300 mm in length (Figures 2 & 3). Although most of the eels captured during the survey were in the 400–600 mm range (about 330–600 g), on average larger longfins were captured at Site 10 (Horahora Stream), while shortfins from Lake Owhareiti (Site 12) were larger than shortfins from other sites (Tables 2 & 3, Appendices 3 & 4). The median length of all longfin eels captured from the catchment was 475 mm, and for shortfin eels 555 mm (Figures 2 & 3). The average weight for all shortfins captured and weighed on site was 455 ± 364 g, and for longfins 427 ± 750 g.

The length-weight relationships for longfin and shortfin eels (over 300 mm) from each site surveyed are presented in Appendices 5 and 6. For longfins, there were significant slope (P = 0.012) and intercept (P = 0.005) differences between the sites. However, the variance explained changed only marginally, from 96.1% for the single line to 96.4% for the model with different intercepts and slopes; the increase in residual standard deviation was only 4%. For shortfins the differences in slope between sites were not significant (P = 0.143), but intercept differences were (P = <0.001). Again the variance explained changed only marginally, from 96.6% for the single line to 97.0% for the model with different intercepts and slopes; the increase in residual standard deviation was only 6%. Therefore the differences observed in length-weight relationships for longfin and shortfin eels between the sites were small, and thus for practical purposes the data were combined to produce a single line for each species (Appendices 5 & 6). The missing weights of 70 shortfins and 5 longfins (10% of the total dataset by number, Appendix 7) were derived from these length-weight regressions to enable estimates of total biomass (g/m^2 and kg/100 m length) per site.

The length-weight relationships for longfin and shortfin eels (all eels, all sites combined) were (where weight is in grams and length is in millimetres):

- Shortfins: ln weight = 3.128*(ln length) – 13.887 (where N = 350, r^2 = 0.97, P < 0.001),
- Longfins: ln weight = 3.341*(ln length) – 14.996 (where N = 342, r^2 = 0.96, P < 0.001)

Length-at-age

The age of the 69 shortfin eels whose otoliths were examined ranged from 2 to 24 years (Figure 4). The 61 longfin eels examined ranged in age from 7 to 24 years (Figure 5). Upon visual examination of Figures 4 and 5, eels obtained from the sites surveyed appeared to have similar growth rates, with the exception of shortfins from Lake Owhareiti where growth was markedly faster (Appendices 8 & 9). Mean annual length increments and 95% confidence intervals were calculated (where N was more than 2 eels) to further examine differences in growth rates between the sites (Table 4, Figures 6 & 7). For longfin eels, the mean annual length increments ranged from 28.5 ± 5.9 (Site 6, Orauta Stream) and 41.1 ± 29.5 mm per year (Site 9, Ramarama Stream) (Table 4, Figure 7). Shortfin eels from the Kawakawa River catchment exhibited mean annual length increments ranging between 28.9 ± 3.1 (Site 4, Waiomio Stream) and 37.9 ± 2.3 mm per year (Site 2, Kawakawa River). In comparison a mean annual length increment of 99.3 ± 27.8 mm per year was observed for shortfins from Lake Owhareiti in the Waitangi catchment (Table 4, Figure 6). The data from this site were therefore examined separately from the rest of the records.

The following linear age-length relationships for eels longer than 300 mm were therefore derived (where length is in millimetres and age is in years):

- Shortfins (Kawakawa River catchment): length = 22.341*age + 244.65 (N = 60, r^2=0.49, P<0.001)
- Shortfins (Lake Owhareiti): length = 70.625*age + 194.02 (N = 7, r^2=0.79, P<0.01)
- Longfins (Kawakawa River catchment): length = 24.289*age + 200.42 (N = 61, r^2= 0.64, P<0.001)

Linear age-length regressions were used to estimate the age for all the eels longer than 300 mm captured during the study where the otoliths were not taken. Using the actual and estimated ages, shortfins (N = 370) captured were found to range from 2 to 25 years, with a mode of 16 years of age. Longfins (N = 352) ranged from 5 to 46 years of age, with a modal value of 9 years of age.

In addition, the age-length regressions were used to predict the average age of a 300 mm eel, and thus obtain an estimate of the average growth rates between freshwater entry and 300 mm. For shortfin eels in the Kawakawa River catchment (excluding Lake Owhareiti), the age-length regression predicts that 300 mm length would have been reached at an age of 2.5 years. Mean freshwater growth within those 2.5 years is thus estimated at about 97 mm per year. For Lake Owhareiti, the age-length regression of shortfins predicts that 300 mm length would be attained by 1.5 years of age. Freshwater growth within this period is therefore estimated to be about 160 mm per year. For longfins, the age-length regression predicts that in the Kawakawa River catchment, 300 mm in length would be attained by age 4. During this early period in freshwater, mean annual growth for longfins before reaching 300 mm is thus estimated at 58 mm per year.

3.3 Sex composition

All eels were inspected for the presence of migratory features. During the survey, two migrant shortfins were observed at Sites 4 (700 mm, 740 g) and 10 (810 mm, 965 g). These eels were measured and released back into the catchment.

Most of the eels euthanised for otolith extraction and gonad examination in the field were female (Table 5). The longfins that were visually examined and classified as females ranged from 430 to 840 mm (corresponding to 7–24 years of age) while female shortfins ranged from 440 to 970 mm (corresponding to 5–22 years of age). Shortfins that were visually examined in the field and classified as males ranged between 350 and 680 mm (corresponding to 2–24 years of age), but only one longfin (365 mm, 9 years of age) was classified as male (Figures 8 & 9).

Jellyman & Todd (1982) proposed a minimum length at migration of 550 mm for shortfin females and 750 mm for longfins. Beneath these length criterion eels could either be female, male, or immature. Based on the assumption that the same criteria are indeed applicable to Northland, and extrapolating this method to the entire dataset (while also recognising the actual sex composition of eels whose gonads were observed in the field), an estimated 52% of all the shortfins captured during the survey could be classified as female, but only between 4 and 7% of the longfin eels captured could be classified as such. However, caution must be exercised when interpreting the sex composition data using the method of Jellyman & Todd (1982), particularly for shortfins, as 3 males over 550 mm were observed during the current survey (see Figure 8).

3.4 Distribution and population estimates

Eels were caught in fyke nets at all the sites surveyed using this method except for Site 8 on the Terewatoa Stream at the outlet of Lake Kawai (but one shortfin was caught by electric fishing at this site). Both species of eels were usually captured in the fyke nets but no longfins were captured at Site 12 (Lake Owhareiti). For both species the highest catches were generally observed in the lower reaches of the catchment, i.e., below Otiria Falls (Table 6).

Longfin eels were poorly represented in the catches obtained by electric fishing and were not recorded from Sites 8 (Terewatoa Stream) and 14 (Puketōtara Stream) (Tables 1 & 7). Both species were absent from Site 16 (Pokapū Stream), which was situated upstream of a perched culvert; however this result must be interpreted with some caution as only a small 20 m^2 area immediately above the culvert was fished during the current survey. More extensive sampling at this site is required to ascertain whether this culvert is a barrier to fish passage and/or a remnant eel population exists further upstream. Using the Carle & Strub (1978) method, the highest density (no./m^2) of shortfins obtained by electric fishing was recorded at Site 14 followed by Site 4 (Waiomio Stream). However, as larger eels were caught at Site 4, biomass estimates at Sites 4 and 14 were comparable (Table 7).

At two of the three sites where fyke nets were repeatedly set, good depletion was obtained on subsequent lifts (Table 8). However, it was not possible to be confident of the depletion estimate for Site 10 (Horahora Stream), as immigration/emigration was likely to have occurred due to the heavy rains and flooding experienced on day two. Based on the catches from the two sites where depletion netting was effective, the average netting efficiency for the first night of fishing was estimated at 0.33 (SD = 0.13) for shortfins and 0.51 (SD = 0.01) for longfins (Table 9). Because these values were obtained from only two sites there is likely to be some uncertainty in the population estimates derived using these capture efficiencies for the other sites surveyed. For example, depletion netting was carried out at Sites 2 and 3, yielding total population estimates of 132 and 57 shortfin eels respectively (Table 9). In comparison, if we were to apply the average netting efficiency (0.33) to the first night's catch at these two sites, we would derive values of 170 (i.e., +38 eels, overestimate) and 42 (i.e., -15 eels, underestimate) shortfin eels. Population estimates for longfins using these two approaches produce values that are in closer agreement, where depletion netting at Sites 2 and 3 resulted in total population estimates of 123 and 34 longfin eels respectively (Table 9). In comparison, using the average netting efficiency (0.51) we observe values of 125 (i.e., +2 eels) and 33 (i.e., -1 eel) respectively. This comparison highlights the potential uncertainty associated with this approach and therefore caution must be exercised when interpreting the results.

Using these netting efficiencies to obtain a population estimate for all the locations that were netted, clear differences between sites became apparent with Sites 11, 9, and 2 having highest populations (no./100 m^2) of shortfins and Sites 5, 2, and 6 having the largest populations of longfins (Table 10) (note however that Site 1 which is tidal, and therefore excluded from this comparison, had the highest relative catch of longfins). Biomass estimates (g/m^2) based on fyke netting catches gave fairly similar trends, but electric fishing catches also indicated relatively high biomasses of shortfins at Sites 4, 13, and 14 (Table 11).

Bycatch species

A wide range of fish species was caught as bycatch during this survey, including common bully (*Gobiomorphus cotidianus*), īnanga (*Galaxias maculatus*), common smelt (*Retropinna retropinna*), giant bully (*Gobiomorphus gobioides*), torrentfish (*Cheimarrichthys. fosteri*), yelloweye mullet (*Aldrichetta forsteri*), triplefin species (Tripterygiidae family), parore (*Girella tricuspidata*), and the introduced species rainbow trout (*Oncorhynchus mykiss*) and gambusia (*Gambusia affinis*) (Table 12).

The most commonly encountered family were Eleotridae (bullies). Within this group giant bullies were recorded only in the estuarine region. Īnanga and kēwai (kōura or freshwater crayfish) were also captured at several sites. Īnanga is mostly a diadromous fish (i.e., needs to migrate to and from the sea to complete its life cycle) so its presence at Sites 9, 10, and 11 most likely indicates reasonably free upstream passage on the Waiharakeke and Taikirau Streams.

4. DISCUSSION

4.1 Limitation of the methods used

Fyke nets were the main sampling method used in this survey of the Kawakawa River catchment. These nets are recognised to be size selective, with eels smaller than 400 mm tending to be underrepresented in the catch (Jellyman & Graynoth 2005). Smaller eels can be captured by electric fishing and the data collected in the survey supports this contention, with the average length and weight of these eels being lower than that of those eels captured by netting. Unfortunately, electric fishing for eels is effective only in clear and open shallow reaches and at depths of less than 0.75 m, and is not suitable for large rivers and lakes, especially if water clarity is poor. It is therefore accepted that the survey methods used in this study cannot have equally sampled all sizes of eel across the entire catchment.

The survey was carried out in two stages which, although not ideal, was unavoidable due to severe weather conditions preventing further progress in April 2008. Fyke net catches of shortfins have been shown to be principally influenced by changes in water level, while activity of longfins appear to be mainly influenced by water temperature (Jellyman 1991). Before water levels had receded enough in autumn 2008 to allow the study to continue, winter had arrived and it was judged best to resume the study in November when water temperatures had warmed up.

According to Jellyman & Graynoth (2005), depletion netting can provide an estimation of a population within a reach fished and can also provide an estimate of the proportion of the population that is caught by setting nets on one night only. This proportion (i.e., capture efficiency) can then be used to estimate populations at sites where only one night of fishing is undertaken. The development, trial, and use of this technique is relatively recent (Jellyman & Graynoth 2005) and the results of this survey will contribute to the on-going assessment of this technique to derive robust population estimates for eels in New Zealand waterways.

In an ideal survey, netting efficiencies would have been calculated for individual sites or at least in a broader range of habitat characteristics/catchment areas. However, the depletion netting method is very labour intensive and during the current survey resource limitations meant that netting efficiencies were estimated based on results from only two sites (i.e., Kawakawa River mainstem and Waiomio Stream, a tributary in the lower catchment), as repeated sampling at a third site was interrupted by a flood. It is also accepted that it is not possible to undertake accurate depletion netting in lakes (and possibly in tidal reaches), as immigration from areas outside the sampling reach could occur. Furthermore, the population estimates calculated from the netting are only for the portion of the population that is retained by the size of the mesh used and nets are unlikely to capture all eels of nettable size (Jellyman & Graynoth 2005).

In order to reduce the number of large eels euthanised during sampling, the minimum proportion of female eels potentially supported by the catchment is sometimes estimated using the length criterion proposed by Jellyman & Todd (1982), where the minimum length at which female longfins can mature and emigrate is about 75 cm, and for shortfins is 55 cm. During the current study, shortfin males 55 cm or over were observed, and therefore the length criterion of Jellyman & Todd (1982) may not be applicable to this catchment. A similar conclusion was made during a recent survey of nearby Lake Omapere and the Utakura River (Williams et al. 2009). Further targeted research into the sex composition of the tuna heke (migrant eels) in the Northland region is required to confirm this observation.

4.2 Species composition

Both shortfin and longfin eels were captured at most sites, except in Lake Owhareiti where only shortfin eels were found. A large proportion of the eels captured in the tidal reaches of the Kawakawa River were longfins (82% at Site 1 and 55% at Site 2). Longfin eels are known to inhabit brackish estuaries (McDowall 1978) but it is principally the shortfin eel that is thought to dominate in estuarine habitats (Jellyman 2007). However, the predominance of longfin eels in the estuarine-influenced sites sampled during the current study is not unusual and has been reported elsewhere (e.g., estuaries of the Waimakariri and Rakaia rivers, see Eldon & Kelly (1985)). One possible explanation for this predominance of longfins in some parts of the Kawakawa catchment is the abundance of cover such as tree roots and other woody debris which Burnet (1952) established as favouring longfins. Another possibility is limited fishing pressure as Chisnall et al. (2003) reported that longfins are more vulnerable to overfishing than shortfin. Certainly, the size of the eels and the CPUE analyses both support the contention that, at least in comparison to rivers such as the Waikato, there appears to be limited fishing pressure in the lower Kawakawa River.

Based on records from: (1) the New Zealand Freshwater Fish Database; (2) the catch sampling programme of the commercial eel catch from the Northland region (Chisnall & Kemp 2000); and (3) CPUE analysis of the commercial eel catch (Beentjes & Bull 2002), it was anticipated that the proportion of longfins captured during the present study would be around 30%, not close to the 50% found. Consequently it appears that past survey efforts have concentrated on different habitats and that most of the commercial catch from Northland is derived from habitats such as lakes and wetlands that tend to be dominated by shortfins. Therefore the lower Kawakawa River is possibly an important reserve of longfin eels for the Kawakawa River catchment, if not for Northland.

Of the eels captured during sampling, only about 13% of longfins and 18% of shortfins were smaller than 400 mm. The low number of juvenile eels captured is likely to be a reflection of the sampling methods (i.e., largely fyke netting) employed and the habitats fished rather than an indication of poor recruitment. However, at sites that were electric fished (a technique generally accepted as being most likely to capture juvenile eels) although shortfin elvers were generally common, few if any longfins juveniles were caught. This low density of juvenile longfins has been noted in other catchments, with concerns having been raised for the long-term sustainability of longfins in New Zealand (e.g., Beentjes & Chisnall 1997). It has recently been recognised that even electric fishing surveys can greatly underestimate the abundance of small (40–90 mm) fish that engage in daytime concealment behaviour (Davey & Kelly, in press) and the lower proportion of juvenile longfins could simply be attributed to their ability to conceal themselves better. Thus, it is not clear whether the low proportion of juvenile longfins in comparison to juvenile shortfins in the current study is a survey artefact or otherwise.

Before this study, there were 28 historical fish records in the New Zealand Freshwater Fish Database (NZFFD) for the Kawakawa River catchment. As in the adjacent catchments, there was a variety of both indigenous (88% of records) and introduced species (12% of records) reported in the catchment. Shortfin eels were the most commonly encountered species recorded, being present at 50% of the 28 sites. Longfin eels have been recorded at 25% of these sites. Other species recorded include lamprey (*Geotria australis),* grey mullet (*Mugil cephalus*), giant bully, torrentfish, smelt, redfin bully (*Gobiomorphus huttoni*), īnanga, black mudfish (*Neochanna diversus*), Crans bully (*Gobiomorphus basalis*), banded kōkopu (*Galaxias fasciatus*), common bully, kēwai/kōura (*Paranephrops* spp.), catfish (*Ameiurus nebulosus*), and gambusia (*Gambusia affinis*). In addition to longfin and shortfin eels, of these previously reported species, only seven (giant bully, torrentfish, smelt, īnanga, common bully, kēwai, and gambusia) were also recorded in the present survey. In addition, rainbow trout, triplefins, parore, and yelloweye mullet were added. These differences reflect the type of habitat surveyed and methodology used rather than a change in diversity or abundance, but it is nevertheless pleasing that no catfish (an introduced pest fish) were found on this latest survey and that no other pest species appear to have invaded the Kawakawa River catchment.

4.3 Population and biomass estimates

In depletion netting, capture efficiency can be affected by various factors, such as immigration or emigration, net avoidance, mesh size selectivity, and changing weather conditions (Jellyman & Graynoth 2005). Successful depletion netting, therefore, relies upon controlling for these factors. In reality, this is not always possible and the heavy rains that fell overnight on 14 April no doubt contributed to increased mobility and hence increased catch of eels observed at Site 10 on that night. The fact that fyke net catches can be so markedly influenced by a change in weather poses some serious questions about the technique and the measurements it is making in such situations. Fish surveys are mostly undertaken during weather conditions that permit the work to be undertaken safely in terms of the equipment and personnel involved. The large catch of eels on a stormy night indicates that the conditions which are poor for researchers may actually be the conditions under which eels become more active, for feeding or other behavioural reasons, and therefore more easily caught in nets. Further research is required to ascertain the importance of access to habitat and land-based food supplies during periods of high flows for eel populations, particularly in areas that are prone to flooding such as the Kawakawa River catchment. Potentially this could mean that population estimates only provide an estimate of the number of eels that are active at the time of the survey. Any factor that affects the mobility of eels (e.g., moon phase, flooding) will invariably affect the estimate. Therefore future comparisons, using methods that have been standardised, will need to take these 'external' factors (season, moon phase, and weather patterns) into consideration also.

The depletion fyke netting technique does not appear to have been widely used to assess populations of shortfins, and the effectiveness of the method for this species is not known. Longfins are known to respond well to baited nets in comparison to shortfins (Jellyman & Graynoth 2005). This may be because they become piscivorous at a smaller size than shortfins (Jellyman 1989) which could mean that they are more sensitive to bait. The lower catch efficiency of shortfins (0.33 ± 0.13) during the depletion netting in comparison to longfins (0.51 ± 0.01) could indicate that longfins are more easily caught by baited fyke nets, but could also indicate an interaction between the two species. The observation of Jellyman & Graynoth (2005) that most large shortfins were captured after most catchable longfins had been removed certainly support the species interaction effect contention, and it is possible that the catch efficiency changes dependent upon the population composition and structure. This possibility needs to be tested in future studies.

So far, Jellyman & Graynoth's (2005) study of the Aparima and Kaiapoi Rivers is the only published attempt in New Zealand to provide a population estimate by fyke netting, with most other studies using the electric fishing technique which is limited to shallower water bodies. Jellyman & Graynoth (2005) gave the estimated density of longfins at between 1.3 and 2.9 eels/m in the Aparima River and 0.2 eels/m in the Kaiapoi River. For shortfins, they estimate the population of the Kaiapoi River as 0.1 eels/m. The equivalent population estimate for the Kawakawa River is at the middle to lower end of this range (i.e., longfins ranged between 0.0 and 0.7 eels/m, shortfins ranged between 0.0 and 0.5 eels/m). Low CPUE was also obtained from a single night of fyke netting in the two lakes surveyed, indicating lack of recruitment for Lake Owhareiti and possibly habitat issues and/or poor recruitment into Lake Kaiwai.

As for the fyke netting population estimates, the density of longfins obtained at sites that were electric fished were also relatively low. For example, in their recent study of what they considered to be relatively high eel density streams, Graynoth et al. (2008) reported densities ranging from 0.3 to 0.6 longfins/m^2 (30–58 g/m^2). In comparison, densities obtained in the Kawakawa catchment ranged from 0.00 to 0.03 longfins/m^2, indicating that longfin densities in the current study could be considered low to very low. For shortfin eels, Graynoth et al. (2008) reported densities between 0.5 and 0.9 shortfins/m^2. This density was exceeded at Sites 4 (1.0) and 14 (1.9), but was somewhat lower at the other sites electric fished (0.0–0.3).

Only two sites (both on the Orauta Stream) entered previously in the NZFFD recorded both the number of eels captured and the length of stream electric fished. The estimated average density of longfin eels for these two sites is 0.06 eels/m^2, which is higher than any of the estimates obtained during the present survey (see Table 7).

4.4 Length and weight

Of the close to 800 eels captured during the study only 19 were 800 mm or over and, for sites where there were comparatively large numbers of eels captured (Sites 1, 2, 3, 7, 9, and 11), no obvious differences in length distributions between areas were observed. Therefore, there appear to be very few large eels (i.e., females) within the catchment.

The two large shortfins (1160 mm, 3358 g and 1250 mm, 4080 g) captured in Lake Owhareiti are possibly records for this species as McDowall (1990) reported that their maximum size is about 1000 mm and 3.5 kg. The eels from this lake exhibited extremely fast growth rates which may explain the very large size reached. The lake has only an intermittent overland outlet and this is expected to reduce emigration (as well as recruitment) and may also facilitate the ongoing growth of these eels (Tesch (2003) reported that migrant eels are capable of reverting to being feeders).

The length-weight relationships that were derived for the catchment indicated that longfins were heavier for their length than shortfins. However, the median size of the shortfins captured was greater than that of longfins. A possible reason for this is that longfins, being more easily caught by fishers, tend to be removed from the population first. A second possibility is that longfins being of greater diameter are retained more easily than shortfins by the mandatory escape tubes on commercial fyke nets.

It is known that some intermittent commercial fishing takes place within the Kawakawa River catchment (Tohe Ashby, pers comm., 2008). To better understand the effect of harvest on the size and species composition of the eel population, robust information on harvest activities (commercial, recreational, and customary) is required. As commercial catch data are reported only by region (i.e., sub-area 1C – Bay of Islands) rather than by catchment, such data are not available at present.

4.5 Age, growth, and habitat

Eel growth is dependent upon eel density, interspecific interactions, food availability, and water temperature. Northland winters are warmer than those in other New Zealand regions and therefore growth rates may not be as limited here as in other cooler regions (Jellyman 1997). This may cause some problems when assessing eel age estimates for Northland eels as the normal annual winter check rings may not apply here and these eels may be a lot younger than thought. Narrow black hyaline rings which are considered to be winter rings may in fact be periods of slow growth, and many false checks may well have been present in the otoliths that were examined.

The mean annual length increments for longfin eels from the Kawakawa and Waitangi River catchments were higher than those reported from North Island hydro-electric lakes, forested streams, and most pastoral streams studied by Chisnall & Hicks (1993). For shortfin eels, the mean annual length increments obtained in the current survey were also higher than shortfins examined by Chisnall & Hayes (1991) from the Whangamarino wetland, a Hakarimata Range stream, Lake Waahi, and Lake Whangape. They were also higher than those recorded in the neighbouring Waitangi River catchment (27 mm per year in Waiaruhe River, and 20 mm per year in Manaia Stream) (NIWA, unpublished report). However, the average annual length increments obtained from Lake Waikare by Chisnall & Hayes (1991) were greater than those of all the sites in the Kawakawa River catchment except for Lake Owhareiti, which was almost double the average annual length increment of Lake Waikare.

The predicted growth of shortfin eels between freshwater entry and 300 mm length was also markedly higher for shortfins in Lake Owhareiti than those from the Kawakawa River catchment. The growth rate of larger shortfin eels in Lake Owhareiti was also much faster than for the rest of the catchment. These observations, combined with the length-age relationship for Lake Owhareiti, indicate that growth in the lake is amongst the highest recorded in New Zealand to date. Lake Owhareiti currently has low eel recruitment because upstream access for juveniles is possible only through underground passages (which may have become blocked in recent years) or by intermittent overland access (Tohe Ashby, pers. comm. 2008). The lake is known to have been artificially stocked with elvers (species composition unknown) in recent times (Warren Thornburn, retired commercial fisher, pers comm. 2008) and may have been seeded previously. Currently, the low number of eels in this lake and the huge food resource, as evidenced by the large bycatch of bullies obtained during this survey (80 common bullies/fyke net) and previous studies (e.g., 155 common bullies/fyke net; Rowe (1999)), indicates that this lake is extremely productive and could, with careful stocking that ensures overstocking does not occur, sustain a much greater population of fast growing eels.

The minimum commercial weight limit for freshwater eels is 220 g with a maximum landing weight of 4 kg. For shortfins, the minimum weight would be equivalent to 475 mm (about 4 years old in Lake Owhareiti to 10 years elsewhere) and 447 mm (10 years old) for longfins. Using these lengths and relating them to the length frequency data, it is estimated that 84% of the longfins captured in this study could legally be landed compared to 65% of the shortfins. Comparative figures for the Waikato River, where there is substantial commercial exploitation, are 32% for longfins and 21% for shortfins (NIWA, unpublished data). These figures not only provide an indication of the value of the stock that currently exists in the Kawakawa and Waitangi River catchments, but also further emphasis the sensitivity of the population to fishing pressure and particularly highlight the vulnerability of longfins.

Based on research in New Zealand on the length distribution of migrant eels (Jellyman & Todd 1982), the minimum length at which female longfins are estimated to mature and emigrate is about 75 cm. This is also the minimum preferred size for customary take (MFish 2008). Based on the length distribution of longfins sampled during the study, only about 4% of the longfin eels captured during this survey exceeded this size. Consequently it appears that there are very few eels left in the Kawakawa and Waitangi River catchments which are of a size preferred for customary take, and that there are very few female longfins being supported by the catchment that could potentially contribute to the spawning stock. The estimated age distribution of the eels captured during the study indicated that most shortfins were between 12 and 19 years of age while longfins were between 9 and 14 years. For longfins, the time needed for females to reach the minimum reproductive size in the Kawakawa River catchment is estimated to be about 22 years. This emphasises not only the vulnerability of the population to fishing pressure but also indicates that management measures taken nationwide could take decades to show results.

Because eels spawn well offshore and new recruits rely primarily on sea currents to reach our coasts, recruitment into New Zealand’s waterways needs to be managed on a national scale. Currently, apart from sites where there are recruitment barriers, such as Site 16 where there is an overhanging culvert, above Otiria falls, and Lake Owhareiti where access is limited, there are no clear indications of a recruitment problem in the Kawakawa and Waitangi River catchments.

5. RECOMMENDATIONS

5.1 Future surveys and the depletion fyke netting method

Sampling methodology and deployment techniques are important in any fish survey. To ensure that comparable data are collected in any future eel population surveys of the Kawakawa and Waitangi River catchments, the same sites (or a selection of sites) and standardised survey techniques (notably mesh size and deployment method) will need to be employed. Jellyman & Chisnall (1999) have shown that it was possible to use brush collectors to sample small eels in deep water bodies, and there may be value in further evaluating this technique as a means of catching small eels. However, use of this or of any other methods should be considered supplementary to those used in the present study.

Heavy rain events are conditions under which eels become more active, for feeding or other behavioural reasons, and are therefore more easily caught in large numbers. Further research is required to ascertain the importance of access to habitat and land based food supplies during periods of high flows for the maintenance of healthy eel populations, particularly in areas that are prone to flooding, such as the Kawakawa River catchment.

In terms of the depletion fyke netting methodology, further development of the technique is required to better understand how species interactions, population composition and structure influences fyke net catches and the resulting population and biomass estimates.

Jellyman & Todd (1982) proposed a minimum length at migration of 550 mm for shortfin females and 750 mm for longfins. However, caution must be exercised when interpreting the sex composition data of Northland eels using the method of Jellyman & Todd (1982), particularly for shortfins, as three males 550 mm or greater were observed during the survey. Further targeted research into the sex composition of the tuna heke (migrant eels) in the Northland region is required to confirm this observation.

5.2 Fishing pressure

In order to better understand the effect of harvest on the size and species composition of the eel population, robust information on harvest (commercial, recreational, and customary) is required. While relatively low eel densities were observed in areas like the upper Waiharakeke, in comparison to rivers such as the Waikato, there appears to be limited fishing pressure in the lower Kawakawa River.

In general, the average annual length increments for both longfin and shortfin eels from the Kawakawa catchment were higher than those reported elsewhere in New Zealand. In this study, about 84% of the longfins captured could legally be landed compared to 65% of the shortfin eels. These figures indicate the value of the stock that currently exists in the Kawakawa and Waitangi River catchments, but also, when compared to regularly commercially fished catchments, emphasises the sensitivity of freshwater eel populations to fishing pressure, and particularly highlights the vulnerability of longfins.

5.3 Preservation of spawning stocks

As very few large eels (i.e., females) were captured, coupled with the observation that it takes about 22 years for female longfins to reach the minimum reproductive size in the Kawakawa River catchment, it is recommended as a precautionary measure that fishing pressure (including customary and recreational take) on large female longfins be reduced to ensure that female longfins that could potentially contribute to the spawning stock are produced by the catchment.

While densities of longfin eels in the catchment were fairly low, the lower Kawakawa River is possibly an important reserve of longfin eels for the Kawakawa River catchment, if not for Northland. However, as eels spawn well offshore and new recruits rely primarily on sea currents to reach the coast of New Zealand, recruitment needs to be managed on a national scale. Limiting the harvest of eels residing in the lower reaches of the Kawakawa River could be considered as part of a national management strategy which, although of no immediate benefit to the local population, may contribute to the overall future longfin eel recruitment into New Zealand waters.

5.4 Lake Owhareiti and Lake Kaiwai

Limited recruitment was observed above Otiria Falls (and into Lake Kaiwai) and into Lake Owhareiti. Shortfin eels in Lake Owhareiti exhibited growth rates, and attained lengths, that are amongst the highest recorded in New Zealand. The results obtained in this study indicate that this lake is extremely productive and could, with careful stocking, sustain a much greater population of fast growing eels. It is estimated that shortfins in Lake Owhareiti would take only about four years to reach the minimum commercial weight limit of 220 g. As passage for elvers into this lake is limited due to blocked underground passages which historically facilitated access, a low cost elver transfer/stocking programme could be initiated.

There are two key factors for Ngāti Hine to take into consideration if revitalising the Lake Kaiwai (which has very limited public access) eel fishery is deemed a priority. While the eel stocks could be improved by facilitating elver passage over the Otiria Falls (e.g., trap and transfer, elver ramps, brush collectors, overhanging bundles of ropes, etc), the density and diversity of fish prey species within this lake are very low. Further fisheries and water quality studies of the catchment are required to ascertain whether Lake Kaiwai is able to support an increased eel population.

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Table 1: Location of sites sampled within the Kawakawa (Taumārere) and Waitangi River catchments.

Site number	Site location (access)	Date sampled (2008)	NZMS coordinates	Fishing methods[a]
1	Kawakawa River at mouth (Waikare Rd)	8 April	E2609443, N6647885	5 CFYN, 5 FFYN, 10 GMT
2	Kawakawa River mainstem (State Highway 1)	8–10 April	E2607418, N6647166	5 CFYN, 5 FFYN, 10 GMT
3	Waiomio Stream (State Highway 1)	8–10 April	E2608431, N6644388	5 CFYN, 5 FFYN, 10 GMT
4	Waiomio Stream (Waiomio Rd)	8 April	E2608331, N6643218	2 CFYN, 1 FFYN, EFM
5	Orauta Stream (below waterfall, Otiria Rd)	8 April	E2602033, N6644305	3 CFYN, 2 FFYN, 5 GMT
6	Orauta Stream (above waterfall, Otiria Rd)	8 April	E2601960, N6644310	4 CFYN, 1 FFYN, 5 GMT
7	Lake Kaiwai (Ngapipito Rd)	9 April	E2595175, N6641290	4 CFYN, 4 FFYN, 3 GMT
8	Terewatoa Stream (Ngapipito ad)	9 April	E2595518, N6641638	2 CFYN, 7 GMT, EFM
9	Ramarama Stream (Henare Rd)	11 April	E2604642, N6633977	4 CFYN, 4 FFYN, 8 GMT
10	Horahora Stream (Mihirata Rd)	13–14 April	E2606350, N6631860	4 CFYN, 4 FFYN, 8 GMT
11	Takapau Stream (Matawaia/Opahi Rd)	4 November	E2601329, N6635002	5 CFYN, 5 FFYN, 5 GMT
12	Lake Owhareiti (Ludbrook Rd)	13 April	E2596210, N6645900	10 CFYN, 10 FFYN, 20 GMT
13	Puketōtara Stream (State Highway 1)	3 November	E2598200, N6649050	EFM
14	Puketōtara Stream (Ludbrook Rd)	4 November	E2596872, N6646729	EFM
15	Pokapū Stream (below culvert, Kaka Rd)	5 November	E2596366, N6637453	EFM
16	Pokapū Stream (above culvert, Kaka Rd)	5 November	E2596150, N6637470	EFM

[a], Fishing methods: CFYN, Coarse meshed fyke net; FFYN, Fine meshed fyke net; GMT, Gee minnow trap; EFM, Electric fishing.

Table 2: Characteristics of the longfin eel catch sampled from the Kawakawa (Taumārere) and Waitangi River catchments.

			Length (mm)				Weight (g)				
Site number	Total eels caught	Total longfin (% of total catch)	Number measured	Average ± SD	Median	Range	N[a]	Average ± SD	Range	N[b]	Average ± SD
1	84	69 (82)	69	538 ± 175	490	320–1 310	68	627 ± 1 192	70–8 110	69	619 ± 1 192
2	262	145 (55)	141	466 ± 87	455	255–840	141	295 ± 243	40–1 865	141	295 ± 243
3	83	32 (39)	32	491 ± 60	488	385–680	32	319 ± 144	120–805	32	319 ± 144
4	45	2 (4)	2	495 ± 92	495	430–560	2	300 ± 184	170–430	2	300 ± 184
5	54	50 (93)	50	470 ± 71	464	265–650	50	289 ± 154	30–800	50	289 ± 154
6	18	15 (83)	15	547 ± 135	510	360–840	15	583 ± 524	110–1 790	15	583 ± 524
7	9	4 (44)	4	638 ± 143	575	550–850	4	850 ± 749	400–1 970	4	850 ± 749
8	1	0 (0)	-	-	-	-	-	-	-	-	-
9	42	6 (14)	6	528 ± 105	493	435–682	6	315 ± 152	170–560	6	315 ± 152
10	65	11 (17)	11	705 ± 283	655	430–1 270	11	1 680 ± 2 353	180–6 625	11	1 680 ± 2 353
11	72	23 (32)	22	478 ± 70	453	360–625	19	304 ± 146	160–770	22	306 ± 147
12	13	0 (0)	-	-	-	-	-	-	-	-	-
13	9	1 (11)	1	282	282	-	0	-	-	1	47
14	19	0 (0)	-	-	-	-	-	-	-	-	-
15	6	1 (17)	1	354	354	-	1	100	-	1	100
16	0	0 (0)	-	-	-	-	-	-	-	-	-

[a], Average weight is from the sub-sample of fish (indicated by N) caught and weighed at each site.
[b], Average weight is for the total number of eels caught using both actual weights and derived weights (where ln weight = 3.341*(ln length) – 14.996).

Table 3: Characteristics of the shortfin eel catch sampled from the Kawakawa (Taumārere) and Waitangi River catchments.

			Length (mm)				Weight (g)				
Site number	Total eels caught	Total shortfin (% of total catch)	Number measured	Average ± SD	Median	Range	N[a]	Average ± SD	Range	N[b]	Average ± SD (g)
1	84	15 (18)	14	643 ± 45	640	560–735	14	556 ± 119	360–800	14	556 ± 119
2	262	117 (45)	117	589 ± 104	580	300–820	116	483 ± 263	90–1 200	117	479 ± 265
3	83	51 (61)	51	572 ± 107	585	140–765	50	442 ± 199	100–975	51	434 ± 199
4	45	43 (96)	43	307 ± 214	249	62–745	7	556 ± 206	340–820	43	163 ± 248
5	54	4 (7)	4	535 ± 81	535	440–630	4	370 ± 202	200–660	4	370 ± 202
6	18	3 (17)	3	463 ± 58	465	405–520	3	250 ± 125	130–380	3	250 ± 125
7	9	5 (56)	5	579 ± 57	610	515–630	5	474 ± 141	310–580	5	474 ± 141
8	1	1 (100)	1	350	350	-	0	-	-	1	84
9	42	36 (86)	36	613 ± 80	623	420–760	36	472 ± 186	120–910	36	472 ± 186
10	65	54 (83)	54	528 ± 107	515	275–810	54	346 ± 215	35–980	54	363 ± 215
11	72	49 (68)	46	511 ± 98	523	250–670	40	332 ± 170	40–650	46	326 ± 165
12	13	13 (100)	13	670 ± 318	615	240–1 250	13	1 128 ± 1 365	35–4 080	13	1 128 ± 1 365
13	9	8 (89)	8	461 ± 213	450	110–800	0	-	-	8	324 ± 365
14	19	19 (100)	19	217 ± 140	138	93–490	7	120 ± 83	20–240	19	47 ± 75
15	6	5 (83)	5	138 ± 37	140	100–190	0	-	-	5	5 ± 4
16	0	0 (0)	-	-	-	-	-	-	-	-	-

[a], Average weight is from the sub-sample of fish (indicated by N) caught and weighed onsite.
[b], Average weight is for the total number of eels caught utilising actual weights and derived weights (where ln weight = 3.128*(ln length) – 13.887).

Table 4: Mean annual length increments (i.e., from river entry to time of capture) of longfin and shortfin eels aged from the Kawakawa (Taumārere) and Waitangi River catchments.

Species	Site number	Site location	N	Length range (mm)	Age range (years)	Mean annual length increment ± 95% CL[a] (mm/y)
Longfin	2	Kawakawa River	46	312–760	7–15	37.2 ± 1.6
	4	Waiomio Stream	2	430–560	9–16	35.9
	6	Orauta Stream	5	490–840	19–24	28.5 ± 5.9
	7	Lake Kaiwai	3	550–590	14–18	32.4 ± 7.0
	9	Ramarama Stream	3	455–682	11–14	41.1 ± 29.5
	10	Horahora Stream	2	430	7–8	56.3
Shortfin	2	Kawakawa River	30	365–820	9–22	37.9 ± 2.3
	3	Waiomio Stream	1	143	4	20.8
	4	Waiomio Stream	7	540–745	14–24	28.9 ± 3.1
	7	Lake Kaiwai	4	515–620	13–18	34.2 ± 9.6
	9	Ramarama Stream	10	440–760	11–20	36.3 ± 4.7
	10	Horahora Stream	9	275–680	8–21	32.5 ± 5.6
	12	Lake Owhareiti	8	240–970	2–11	99.3 ± 27.8

[a], CL = Confidence limit.

Table 5: Sex composition of longfin and shortfin eels from the Kawakawa (Taumārere) and Waitangi River catchments were gonads were visually examined in the field.

Species	N	Length range (mm)	Gonads visually examined in the field: % immature eels[a]	% male	% female
Longfin	20	312–840	20	5	75
Shortfin	58	140–970	21	12	67

[a], Gonads undifferentiated, therefore sex of the eel was not able to be determined.

Table 6: Catch per unit effort (CPUE, number per net per night and kilograms per net per night) on the first day of fishing with coarse mesh (CFYN) and fine mesh fyke nets (FFYN) at 12 sites in the Kawakawa (Taumārere) and Waitangi River catchments (Note: the catch from most downstream fyke nets, removed from analysis for river/stream sites. The full site names and total number of fyke nets deployed at each site are presented in Table 1).

Site	No. of nets[b]		CPUE (number per net per night) (*number of eels captured in brackets*[b])						CPUE (kg per net per night)					
			Longfin			Shortfin			Longfin		Shortfin		All eels	
number	CFYN	FFYN	CFYN	FFYN	ALL	CFYN	FFYN	ALL	CFYN	FFYN	CFYN	FFYN	CFYN	FFYN
1	4	5	7.0 (*28*)	6.2 (*31*)	6.6	2.0 (*8*)	0.4 (*2*)	1.1	3.7	4.5	1.1	0.2	4.8	4.7
2[a]	5	4	7.8 (*39*)	6.3 (*25*)	7.1	8.4 (*42*)	3.5 (*14*)	6.2	-	-	-	-	6.8	3.7
3[a]	5	4	1.8 (*9*)	2.0 (*8*)	1.9	1.8 (*9*)	1.25 (*5*)	1.6	-	-	-	-	1.2	1.5.
4	1	1	1.0 (*1*)	1.0 (*1*)	1.0	1.0 (*1*)	2.0 (*2*)	1.5	0.4	0.2	0.3	1.3	0.8	1.5
5	2	2	11.5 (*23*)	12.0 (*24*)	11.8	1.0 (*2*)	1.0 (*2*)	1.0	3.5	3.4	0.3	0.4	3.8	3.9
6	4	0	3.5 (*14*)	-	3.5	0.3 (*1*)	-	0.3	2.1	-	0.03	-	2.1	-
7	4	4	0.8 (*3*)	0.3 (*1*)	0.5	1.0 (*4*)	0.3 (*1*)	0.6	0.7	0.1	0.5	0.1	1.2	0.2
8	1	0	0.0	-	0.0	0.0	-	0.0	0.0	-	0.0	-	0.0	-
9	3	4	1.7 (*5*)	0.3 (*1*)	0.9	2.0 (*6*)	6.0 (*24*)	4.3	0.5	0.1	1.2	2.8	1.7	2.9
10	3	4	0.0	0.5 (*2*)	0.3	1.0 (*3*)	0.8 (*3*)	0.9	0.0	0.3	0.6	0.3	0.6	0.5
11	4	5	3.3 (*13*)	2.0 (*10*)	2.6	3.5 (*14*)	6.4 (*32*)	5.1	1.0	0.5	1.0	2.0	2.1	2.5
12	10	10	0.0	0.0	0.0	0.7 (*7*)	0.6 (*6*)	0.7	0.0	0.0	0.5	1.0	0.5	1.0

[a], Nets set on three consecutive days but weight by species not measured on day 1.
[b], Excluding net/catch from most downstream fyke net for river/stream sites.

Table 7: Numbers and total weight of eels captured by electric fishing tributaries of the Kawakawa (Taumārere) and Waitangi River catchments. Population estimate as a total no. and no./m^2 (derived by the Carle & Strub (1978) method) and biomass estimates as g/m^2 (derived from the weight of eels caught in Run 1 &2) are also shown. LF, longfin, SF, shortfin.

Site number	Site location	Number of passes	Area fished (m^2)	Number caught in Run 1		Number caught in Run 2		Weight caught (g) Run 1 & 2		Estimated total population by number in reach (standard error)		Population estimate (no./m^2)		Biomass estimate (g/m^2)	
				LF	SF	LF	SF	LF	SF	LF	SF	LF	SF	LF	SF
4	Waiomio Stream	2	75	0	20	0	19	0	4 240	0	77 (30.5)	0	1.0	0.0	56.5
8	Terewatoa Stream	2	5	0	1	0	0	0	84	0	1	0	0.2	0.0	16.8
13	Puketōtara Stream	2	69	1	8	0	0	47	2 590	1	8	0.01	0.1	0.7	37.5
14	Puketōtara Stream	2	15	0	10	0	9	0	880	0	29 (9.6)	0	1.9	0.0	58.7
15	Pokapū Stream	2	30	1	5	0	0	100	30	1	5	0.03	0.3	3.3	1
16[a]	Pokapū Stream	1	20	0	0	-	-	0	0	0	0	0	0	0.0	0.0

[a], This result must be interpreted with caution as only a small 20 m^2 area immediately above a perched culvert was fished during the current survey. More extensive sampling would be required to ascertain whether this culvert barrier to fish passage and/or a remnant eel population exists further upstream.

Table 8: Catch per unit effort (CPUE, number per net per night and kg per net per night) for eels sampled from the Kawakawa (Taumārere) River catchment using the depletion fyke netting method. CFYN, Coarse mesh; FFYN, Fine mesh. (Note: at each site the catch of the most downstream net was omitted from these CPUE analyses).

Site number	Lift number	No. of nets set per night		CPUE (number per net per night)				CPUE (kg per net per night)	
				Longfin		Shortfin		All eels	
		CFYN	FFYN	CFYN	FFYN	CFYN	FFYN	CFYN	FFYN
2	1	5	4	7.8	6.3	8.4	3.5	6.8	3.7
	2	5	4	5.2	1.7	5.2	2.7	3.1	1.3
	3	5	4	2.0	1.0	1.6	2.3	1.3	1.2
3	1	5	4	2.0	1.8	1.8	1.3	6.8	3.7
	2	5	4	1.2	0.0	3.0	1.5	1.7	0.4
	3	5	3[b]	1.0	0.0	0.4	1.3	0.7	0.4
10[a]	1	3	4	0.0	0.3	1.3	0.7	1.2	1.0
	2	3	4	0.5	1.7	4.0	2.7	4.5	4.3

[a], Immigration due to changing weather conditions, therefore assumptions of population estimation (see Table 9) violated.
[b], Note that on night 3, a fine fyke net broke and therefore only 3 nets were used during this set.

Table 9: Population estimates for depletion fyke netting using the Carle & Strub (1978) method (see Jellyman & Graynoth (2005)).

		No. eels captured[a]							
Species	Site number	Lift 1	Lift 2	Lift 3	Total catch (No.)	Estimated total population (N)	Standard error	P_1	P_2
Shortfin	2	56	37	17	110	132	10.8	0.42	0.83
	3	14	21	6	41	57	11.5	0.25	0.72
	10[b]	6	46	-	52	-	-	-	-
Longfin	2	64	33	14	111	123	6.2	0.52	0.90
	3	17	9	5	31	34	2.7	0.50	0.91
	10[b]	2	7	-	9	-	-	-	-

P_1, proportion of catch on night 1 relative to estimated total population; P_2, proportion of total catch relative to estimated total population.
[a], Catch from most downstream fyke net excluded.
[b], Flooding occurred on lift/night 2 at Site 10 therefore assumptions of a closed population violated and population estimates are invalid.

Table 10: Population and biomass estimates (no./100 m length, g/m^2 and kg/100 m length) for sites (excluding lakes) surveyed using fyke netting in the Kawakawa (Taumārere) River catchment.

Species	Site number	No. caught during one night of fyke netting[a]	Area of reach sampled (m^2)	Estimated total number in reach sampled (no.)[b]	Population estimate[b] no./100 m^2	Population estimate[b] no./100 m length	Biomass estimate g/m^2	Biomass estimate kg/100 m length
Shortfin	1[c]	10	2 500	30	1.2	12	6.7	6.7
	2[d]	56	1 625	132	8.1	53	38.8	23.7
	3[d]	14	750	57	7.6	23	33.5	9.9
	4	1	225	3	1.3	4	2.3	2.2
	5	4	250	12	4.8	10	17.9	3.6
	6	1	375	3	0.8	2	2.0	0.6
	8	0	25	0	0	0	0.0	0.0
	9	30	600	90	15.2	46	71.5	21.5
	10	6	600	18	3.0	9	14.2	4.3
	11	44	750	133	17.8	53	58.0	17.4
Longfin	1[c]	59	2 500	115	4.6	46	28.6	28.6
	2[d]	64	1 625	123	7.6	49	22.3	13.6
	3[d]	17	750	34	4.5	14	14.5	4.3
	4	4	225	7	3.5	11	10.5	3.1
	5	47	250	92	36.9	74	106.5	21.3
	6	14	375	27	7.3	22	42.7	12.8
	8	0	25	0	0	0	0.0	0.0
	9	6	600	11	2.0	6	6.2	1.85
	10	2	600	4	0.7	2	3.3	1.0
	11	15	750	29	3.9	12	12.0	3.6

[a], Most downstream fyke nets excluded.
[b], With the exception of Sites 2 and 3, estimates calculated from the catch on the first day of fishing divided by the average netting efficiency obtained for each species from depletion fishing sites (0.33 for shortfins; 0.51 for longfins).
[c], Indicates that the population estimate may have been affected by immigration/emigration as this site is subjected to strong tidal influence.
[d], Where actual population estimates were calculated from depletion fyke netting, these values are used.

Table 11: Population and biomass estimates (no./100 m length, g/m^2 and kg/100 m length) for sites (excluding lakes) surveyed using electric fishing in the Kawakawa (Taumārere) and Waitangi River catchments.

Species	Site number	Area sampled (m^2)	Population estimate no./100 m length	Biomass estimate g/m^2	Biomass estimate kg/100 m length
Shortfin	4	75	588	56.5	63.9
	8	5	10	16.8	0.1
	13	69	27	37.5	8.6
	14	15	133	58.7	6.2
	15	30	45	1.0	0.3
	16[a]	20	0	0.0	0.0
Longfin	4	75	0	0.0	0.0
	8	5	0	0.0	0.0
	13	69	3	0.7	0.1
	14	15	0	0.0	0.0
	15	30	5	3.3	0.5
	16[a]	20	0	0.0	0.0

[a], This result must be interpreted with caution as only a small 20 m^2 area immediately above the perched culvert was fished during the current survey. More extensive sampling would be required to ascertain whether this culvert barrier to fish passage and/or a remnant eel population exists further upstream.

Table 12: Bycatch of freshwater fish species (including kēwai or freshwater crayfish) captured in Kawakawa (Taumārere) and Waitangi River catchments; where ✓ = present.

Site number	Kēwai	Common bully	Īnanga	Smelt	Giant bully	Torrentfish	Rainbow Trout	Gambusia	Triplefin	Parore	Yelloweye mullet
1		✓	✓	✓	✓				✓	✓	✓
2	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
3	✓	✓	✓	✓							
4	✓	✓	✓	✓				✓			
5	✓	✓	✓	✓							
6	✓	✓									
7		✓									
8											
9		✓	✓					✓			
10		✓	✓								
11	✓	✓	✓					✓			
12		✓						✓			
13	✓	✓									
14											
15	✓	✓									
16		✓									

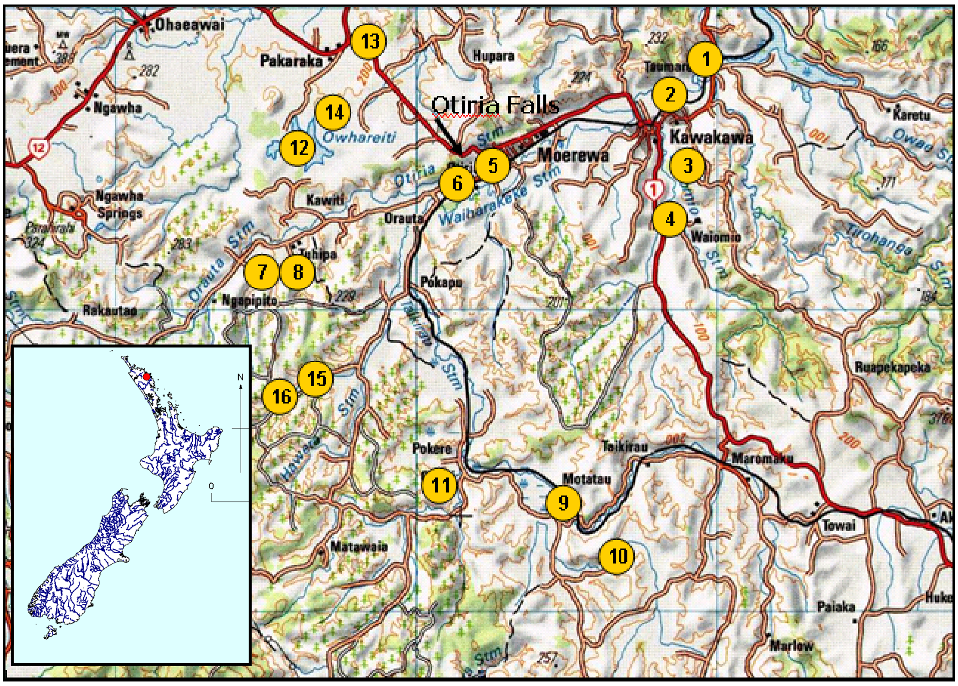


Figure 1: Approximate location of sites sampled for freshwater eels within the Kawakawa (Taumārere) and Waitangi River catchments in April and November 2008. Inset map shoes location of the catchments (red) surveyed in relation to the rest of New Zealand. NZMS262© sourced from Land Information New Zealand data, Crown Copyright Reserved.

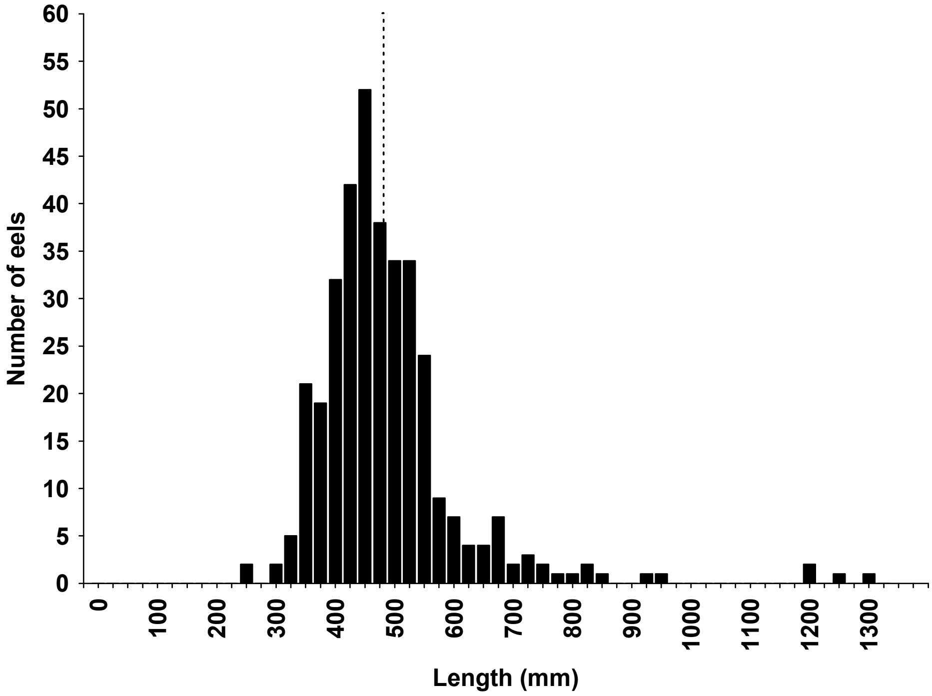


Figure 2: Length frequency of longfin eels captured from the Kawakawa (Taumārere) and Waitangi River catchments (N = 354). Dotted line indicates median length (475 mm).

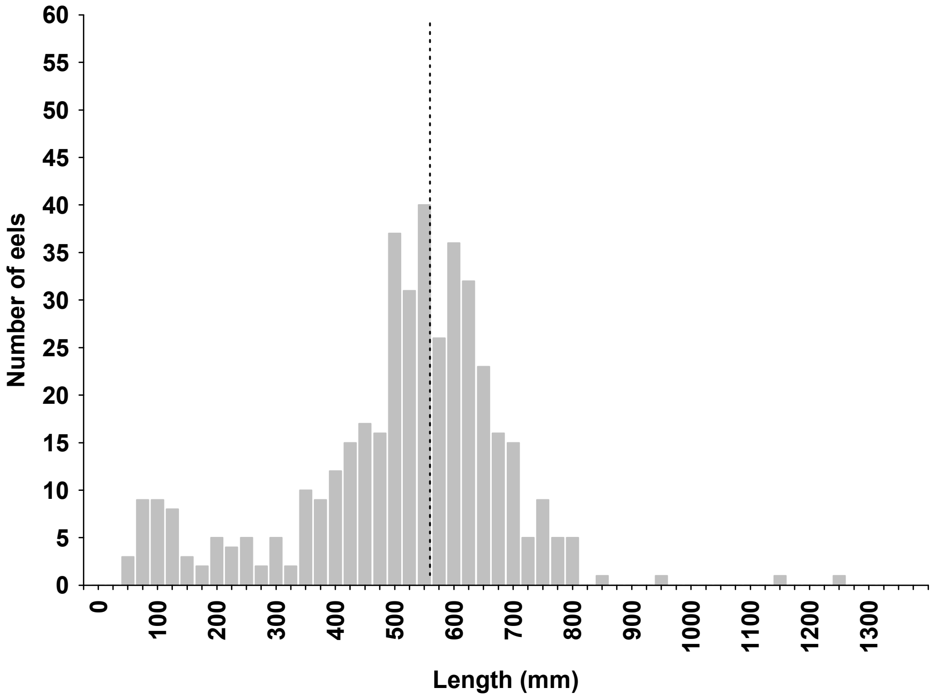


Figure 3: Length frequency of shortfin eels captured from the Kawakawa (Taumārere) and Waitangi River catchments (N = 420). Dotted line indicates median length (555 mm).

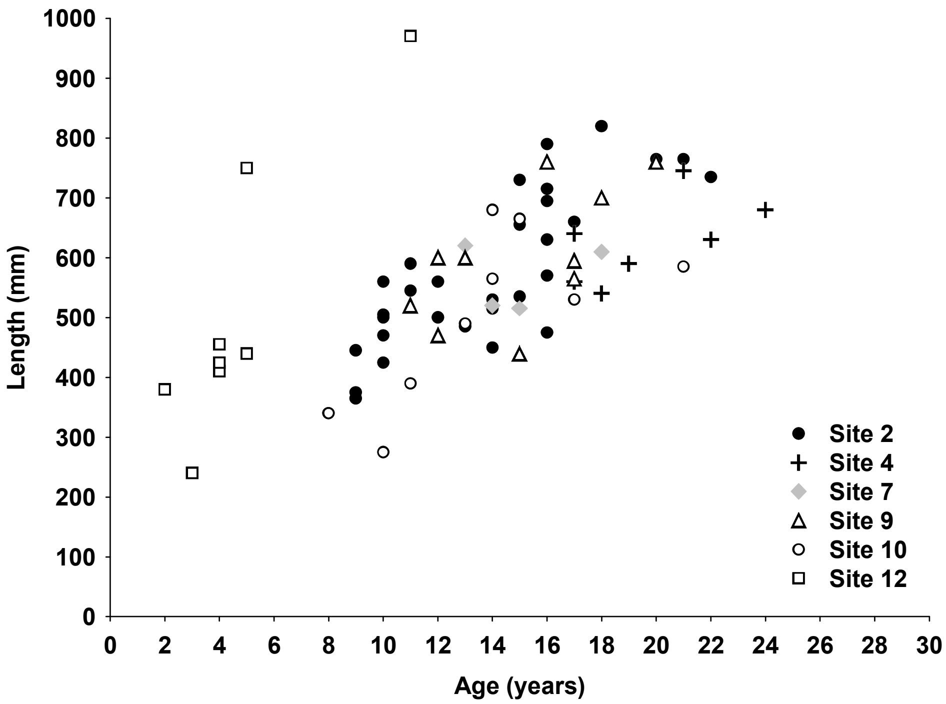


Figure 4: Length at age for shortfin eels (N = 69) from the Kawakawa (Taumārere) and Waitangi River catchments.

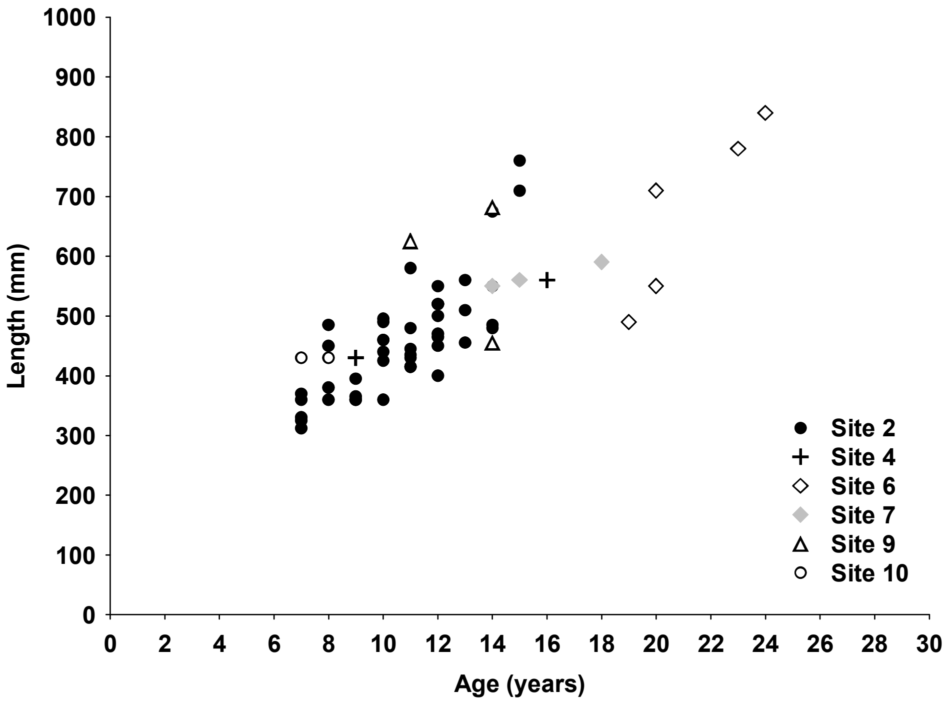


Figure 5: Length at age for longfin eels (N = 61) from the Kawakawa (Taumārere) and Waitangi River catchment.

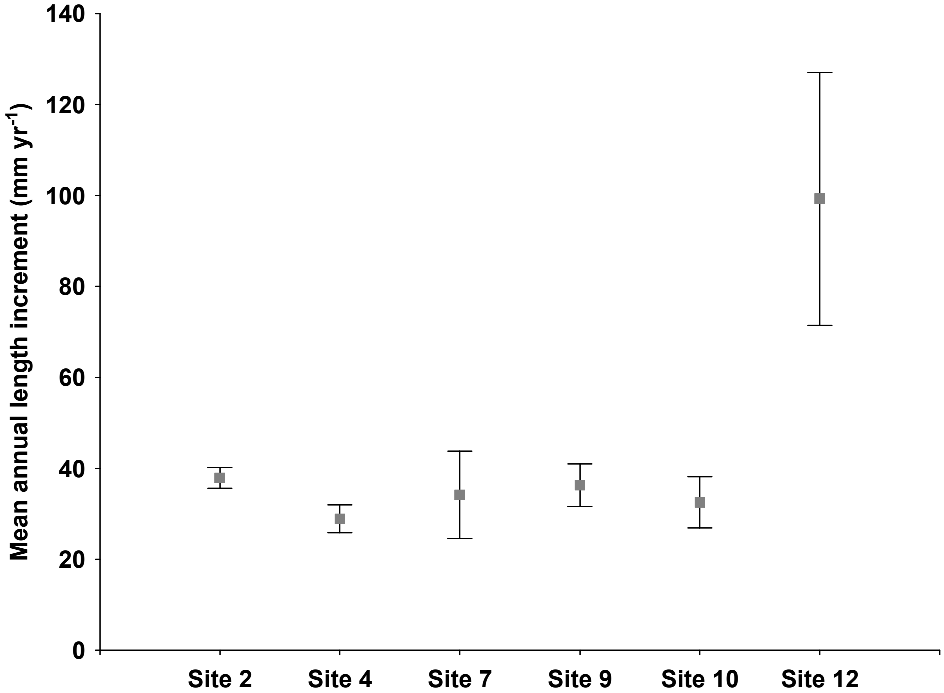


Figure 6: Mean annual length increment (mean and 95% confidence intervals) for shortfin eels from the Kawakawa (Taumārere) and Waitangi River catchments.

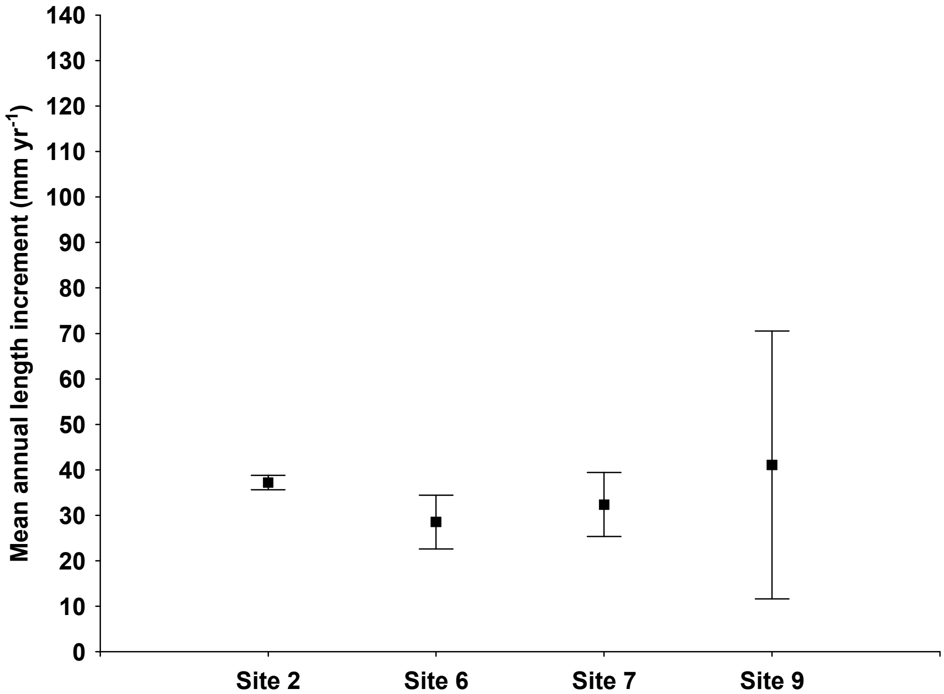


Figure 7: Mean annual length increment (mean and 95% confidence intervals) for longfin eels from the Kawakawa (Taumārere) River catchment.

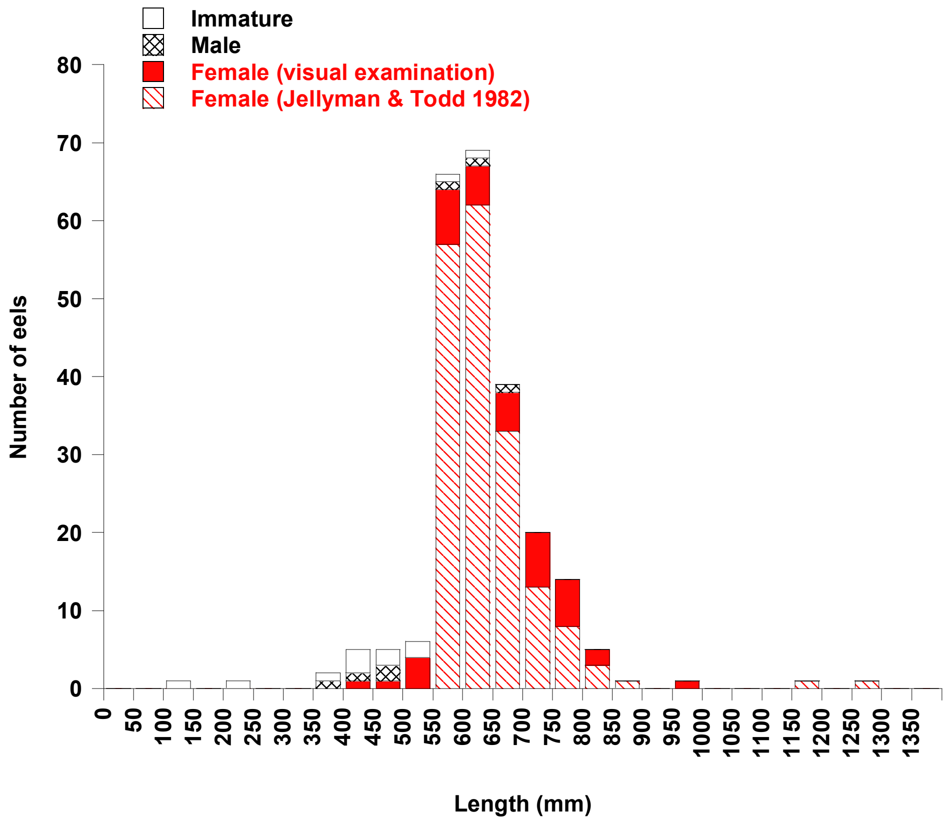


Figure 8: Sex composition of shortfin eels from the Kawakawa (Taumārere) and Waitangi River catchments using visual examination of gonads in the field (N = 58) and Jellyman & Todd's (1982) length-based estimate for female shortfin eels (i.e., ≥ 550 mm, N = 179).

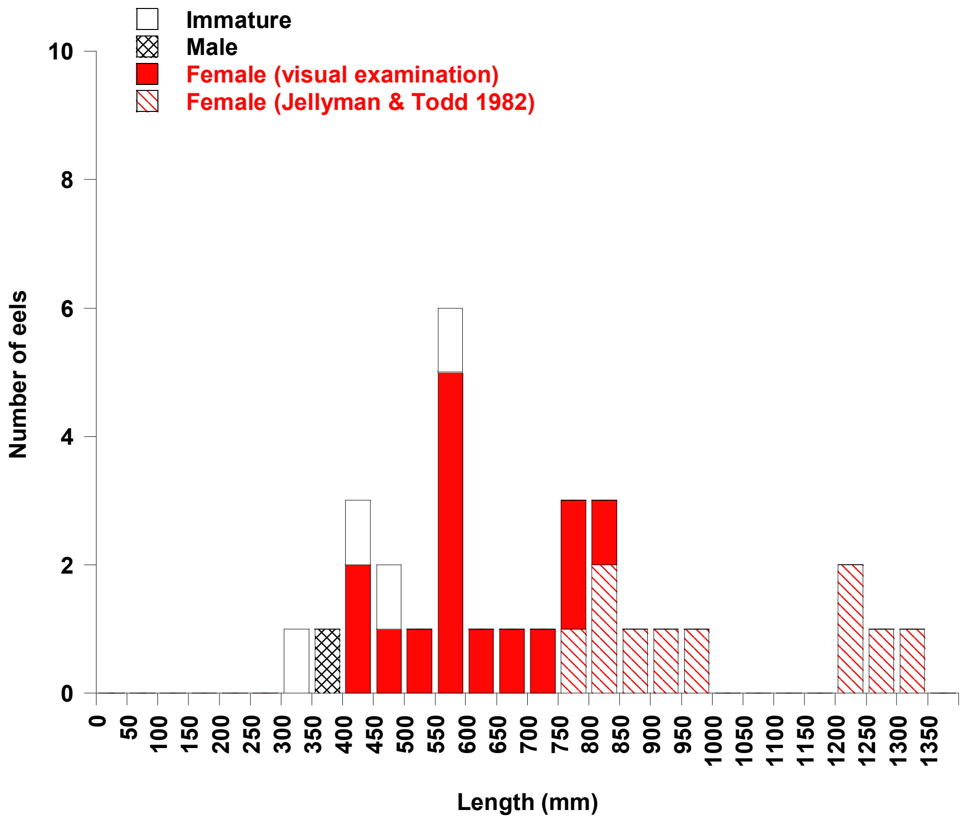
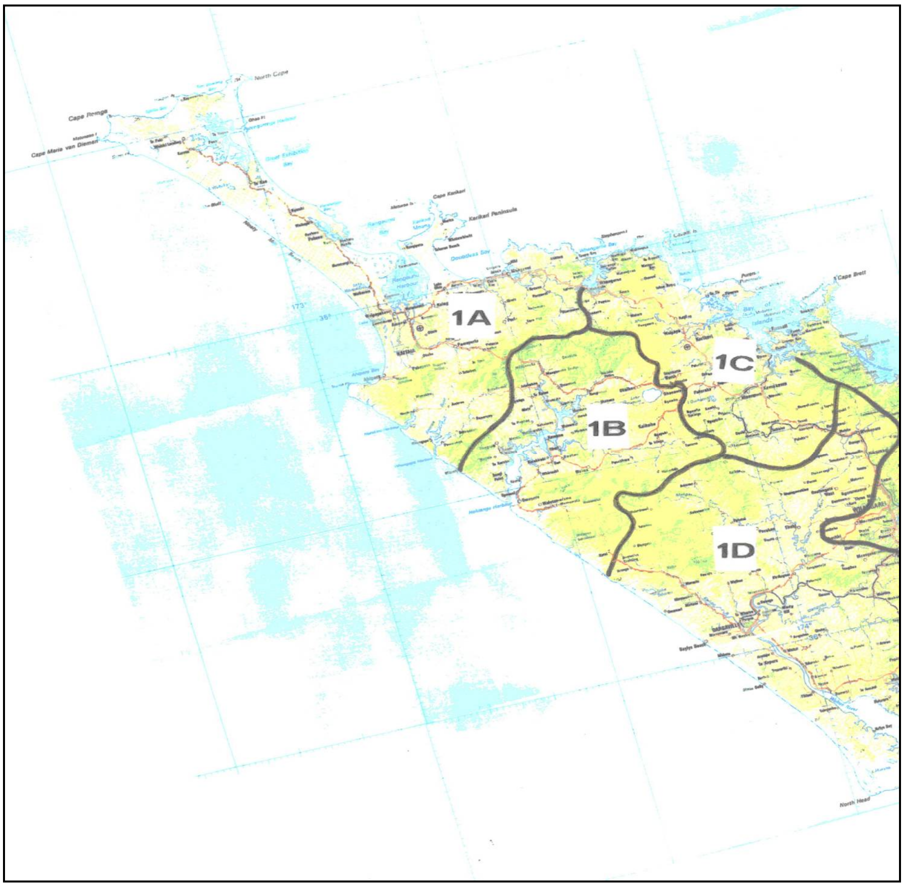


Figure 9: Sex composition of longfin eels from the Kawakawa (Taumārere) and Waitangi River catchments using visual examination of gonads in the field (N = 20) and Jellyman & Todd's (1982) length-based estimate for female longfin eels (i.e., ≥ 750 mm, N = 10).

Appendix 1: Reported freshwater eel commercial catch for sub-area 1C – Bay of Islands (from Beentjes 2008).



	Weight (kg)			Species composition (%)	
Year	Longfin	Shortfin	Total	Longfin	Shortfin
2003–04	4 309	7 725	12 034	35.8	64.2
2004–05	3 973	5 228	9 201	43.2	56.8
2005–06	710	864	1 574	45.1	54.9
2006–07	1 270	2 302	3 572	35.6	64.4

Appendix 2: Habitat descriptions of sites surveyed in the Kawakawa (Taumārere) and Waitangi River catchments.

Site 1: Kawakawa (Taumārere) River, at mouth.

Habitat type	100% run
Substrate	10% mud, 20% sand, 30% coarse gravel, 40% cobble
Riparian vegetation	70% grass/tussock, 20% scrub/willow, 10% flax/raupō
Instream cover	Macrophytes, instream debris, undercut banks, bank vegetation
Landuse	80% farming, 20% scrub
Average stream width	10 m
Average stream depth	1.5 m
Notes	No fencing

Site 2: Kawakawa (Taumārere) River, at SH1.

Habitat type	100% run
Substrate	40% sand, 30% mud, 20% coarse gravel, 10% cobble
Riparian vegetation	90% grass/tussock, 10% scrub/willow
Instream cover	Macrophytes, instream debris, undercut banks, bank vegetation
Landuse	100% farming
Average stream width	6-7 m
Average stream depth	1 m
Notes	No fencing

Site 3: Waiomio Stream, at SH1.

Habitat type	100% run
Substrate	80% mud, 10% mud, 10% fine gravel
Riparian vegetation	80% grass/tussock, 10% scrub/willow, 10% raupō/flax
Instream cover	Macrophytes, instream debris, undercut banks, bank vegetation
Landuse	100% farming
Average stream width	3 m
Average stream depth	1 m
Notes	Open pasture, no fencing of waterway, turbid water

Site 4: Waiomio Stream, Waiomio Rd.

Habitat type	100% run
Substrate	80% mud, 20% fine gravel
Riparian vegetation	20% farming, 80% scrub
Instream cover	Macrophytes, instream debris, undercut banks, bank vegetation
Landuse	20% farming, 80% scrub
Average stream width	3 m
Average stream depth	0.7 m
Notes	Little fencing of waterway

Site 5: Orauta Stream, below Otiria Falls.

Habitat type	20% pool, 80% run
Substrate	30% mud, 40% sand, 20% fine gravel, 10% coarse gravel
Riparian vegetation	20% grass/tussock, 30% scrub/willow, 50% raupō/flax
Instream cover	Instream debris, undercut banks, bank vegetation
Average stream width	2 m
Average stream depth	0.5 m
Landuse	100% scrub

Site 6: Orauta Stream, above Otiria Falls.

Habitat type	100% run
Substrate	30% mud, 30% sand, 20% fine gravel, 10% coarse gravel, 10% bedrock
Riparian vegetation	80% scrub/willow, 20% raupō/flax
Instream cover	Instream debris, undercut banks, bank vegetation
Landuse	100% scrub
Average stream width	0.5 m
Average stream depth	3.0 m

Appendix 2 (continued)

Site 7: Lake Kaiwai.

Habitat type	100% pool
Substrate	Unknown
Riparian vegetation	100% raupō/flax
Instream cover	Undercut banks, bank vegetation
Area	Details from NRC (2008) indicate that Lake Kaiwai and two other wetlands in the catchment of Otiria Stream cover less than 80 ha.
Maximum depth	No details available. No bathymetric surveys of this lake have been conducted to our knowledge.
Landuse	20% exotic, 10% farming, 40% scrub, 30% swampland

Site 8: Terewatoa Stream.

Habitat type	100% run
Substrate	90% mud, 10% sand
Riparian vegetation	100% raupō/flax
Instream cover	Macrophytes, undercut banks, bank vegetation
Landuse	100% swampland
Average stream width	0.5 m
Average stream depth	0.5 m
Notes	Outlet of Lake Kaiwai

Site 9: Ramarama Stream.

Habitat type	100% run
Substrate	75% mud, 10% sand, 10% fine gravel, 5% boulder
Riparian vegetation	100% grass/tussock
Instream cover	Macrophytes, undercut banks, instream debris, bank vegetation
Landuse	100% farming
Average stream width	3 m
Average stream depth	0.8 m

Site 10: Horahora Stream.

Habitat type	10% still, 10% backwater, 80% run
Substrate	65% mud, 10% sand, 10% fine gravel, 10% coarse gravel, 5% boulder
Riparian vegetation	10% grass/tussock, 90% scrub/willow
Instream cover	Macrophytes, instream debris, undercut banks, bank vegetation
Landuse	100% farming
Average stream width	3 m
Average stream depth	1 m
Notes	Started to rain heavily overnight on 14/04/08

Site 11: Takapau Stream.

Habitat type	80% pool, 20% run
Substrate	100% mud
Riparian vegetation	15% native, 15% willows/scrub, 70% grass/pasture
Instream cover	Macrophytes, instream debris, bank vegetation, undercut banks
Landuse	15% native, 85% farming/pasture
Average stream width	3 m
Average stream depth	1 m

Site 12: Lake Owhareiti. Waitangi River catchment.

Habitat type	100% pool
Substrate	70% mud, 15% sand, 5% fine gravel, 10% coarse gravel
Riparian vegetation	10% native, 10% exotic, 60% farming, 20% scrub
Instream cover	Macrophytes, bank vegetation
Landuse	10% native, 10% exotic, 60% farming, 20% scrub
Area	95.9 ha
Maximum depth	16 m
Notes	Parts of the lake are not fenced off

Appendix 2 (continued)

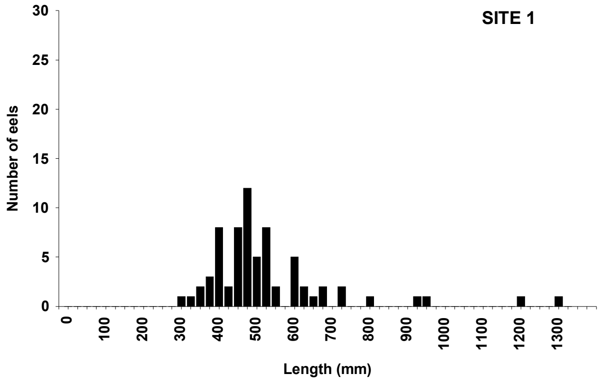
	Site 13: Puketōtara Stream, at SH1. Waitangi River catchment.
Habitat type	100% run
Substrate	5% mud, 20% sand, 20% fine gravel, 50% coarse gravel, 5% cobble
Riparian vegetation	100% grass/tussock
Landuse	100% pasture
Average stream width	2.3 m
Average stream depth	0.2 m
Notes	Fenced, two fishers have had their nets in this waterway, also spearing

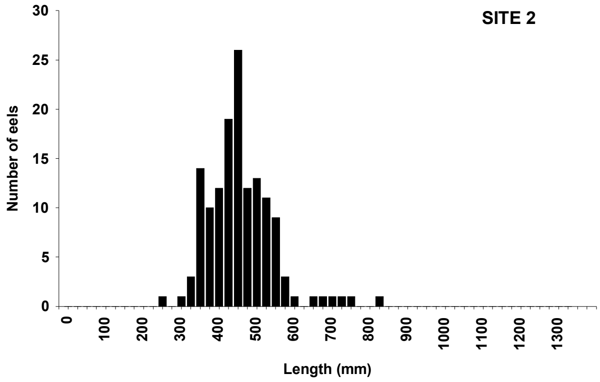
	Site 14: Puketōtara Stream, at Ludbrook Rd. Waitangi River catchment.
Habitat type	100% run
Substrate	90% mud, 5% sand, 5% fine gravel
Riparian vegetation	100% watercress & flax-like plant
Instream cover	Macrophytes, instream debris, bank vegetation
Landuse	100% pasture
Average stream width	0.5 m
Average stream depth	0.1 m
Notes	Water take and wetland/watercress patch upstream of this site Not fenced on one side (closest to lake)

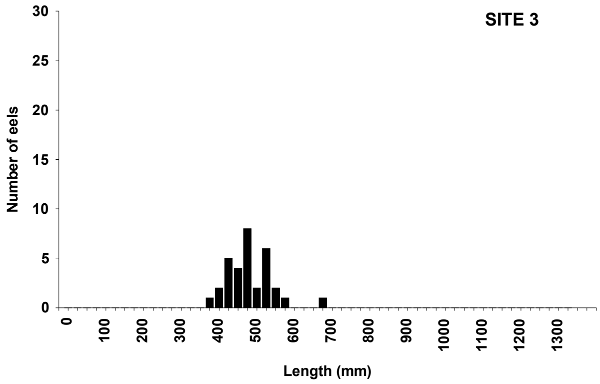
	Site 15: Pokapū Stream, below culvert.
Habitat type	20% pool, 80% run
Substrate	100% mud
Riparian vegetation	50% exotic forest, 50% grass/tussock
Instream cover	Instream debris, undercut banks, bank vegetation
Landuse	50% exotic forest, 50% grass/tussock
Average stream width	1.5 m
Average stream depth	0.4 m

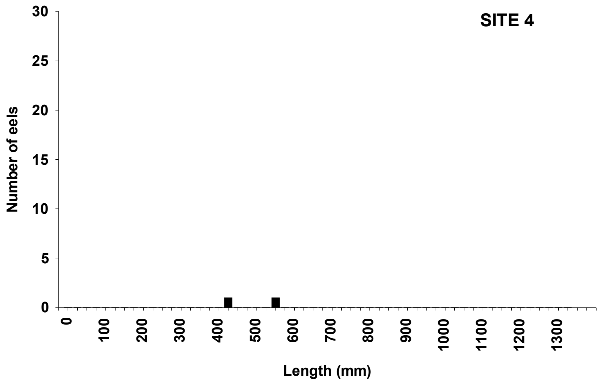
	Site 16: Pokapū Stream, above culvert.
Habitat type	100% run
Substrate	100% mud
Riparian vegetation	5% native, 5% exotic, 30% grass/tussock, 10% scrub/willow, 50% raupō/flax
Instream cover	Macrophytes, instream debris, undercut banks, bank vegetation
Landuse	5% native, 75% exotic forest, 20% scrub
Average stream width	2 m
Average stream depth	0.6 m
Notes	Above culvert

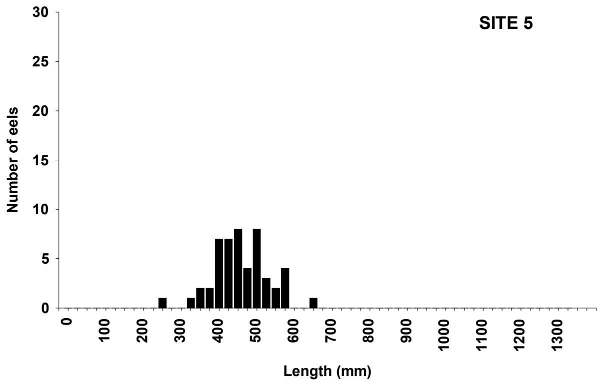
Appendix 3: Longfin eel length frequencies for each site surveyed in the Kawakawa (Taumārere) and Waitangi River catchments.

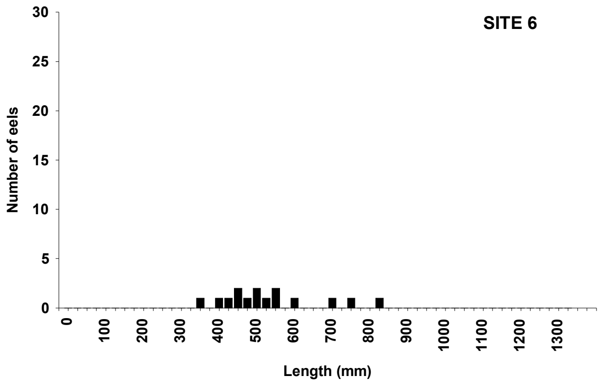


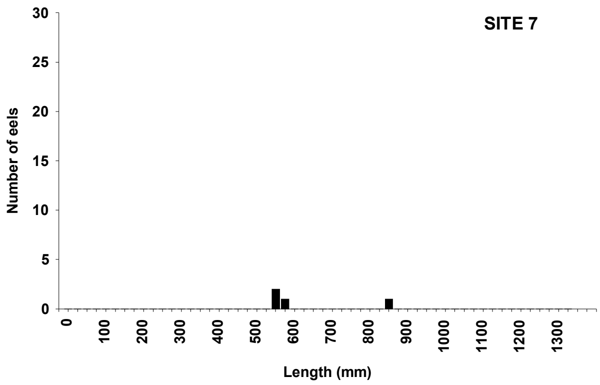


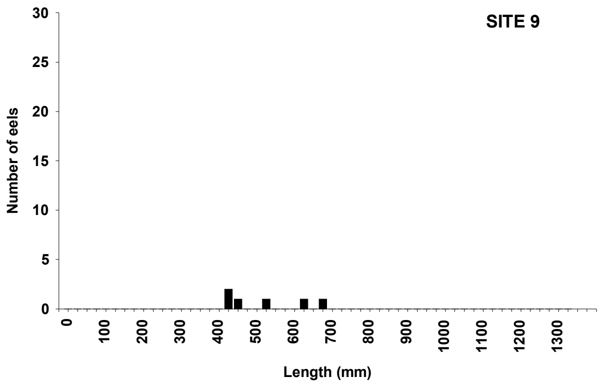












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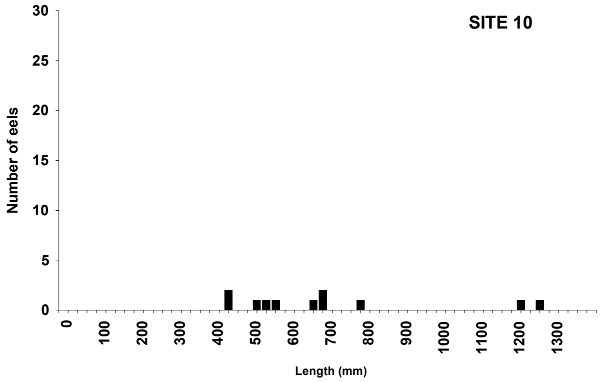
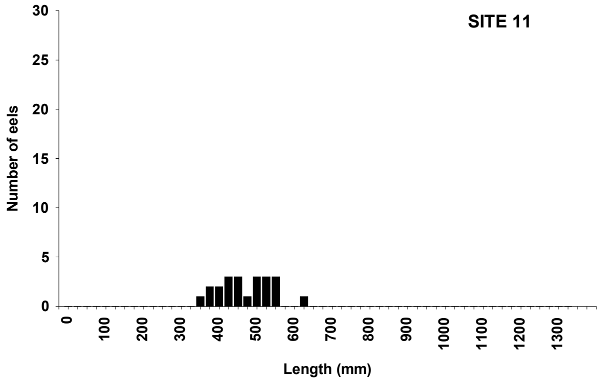
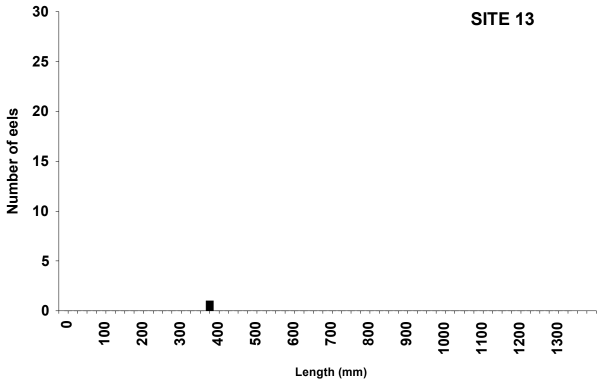
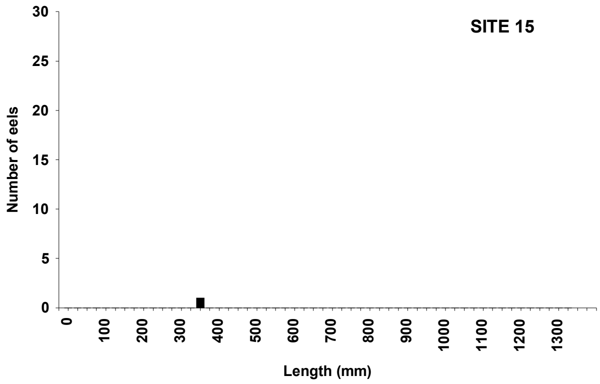
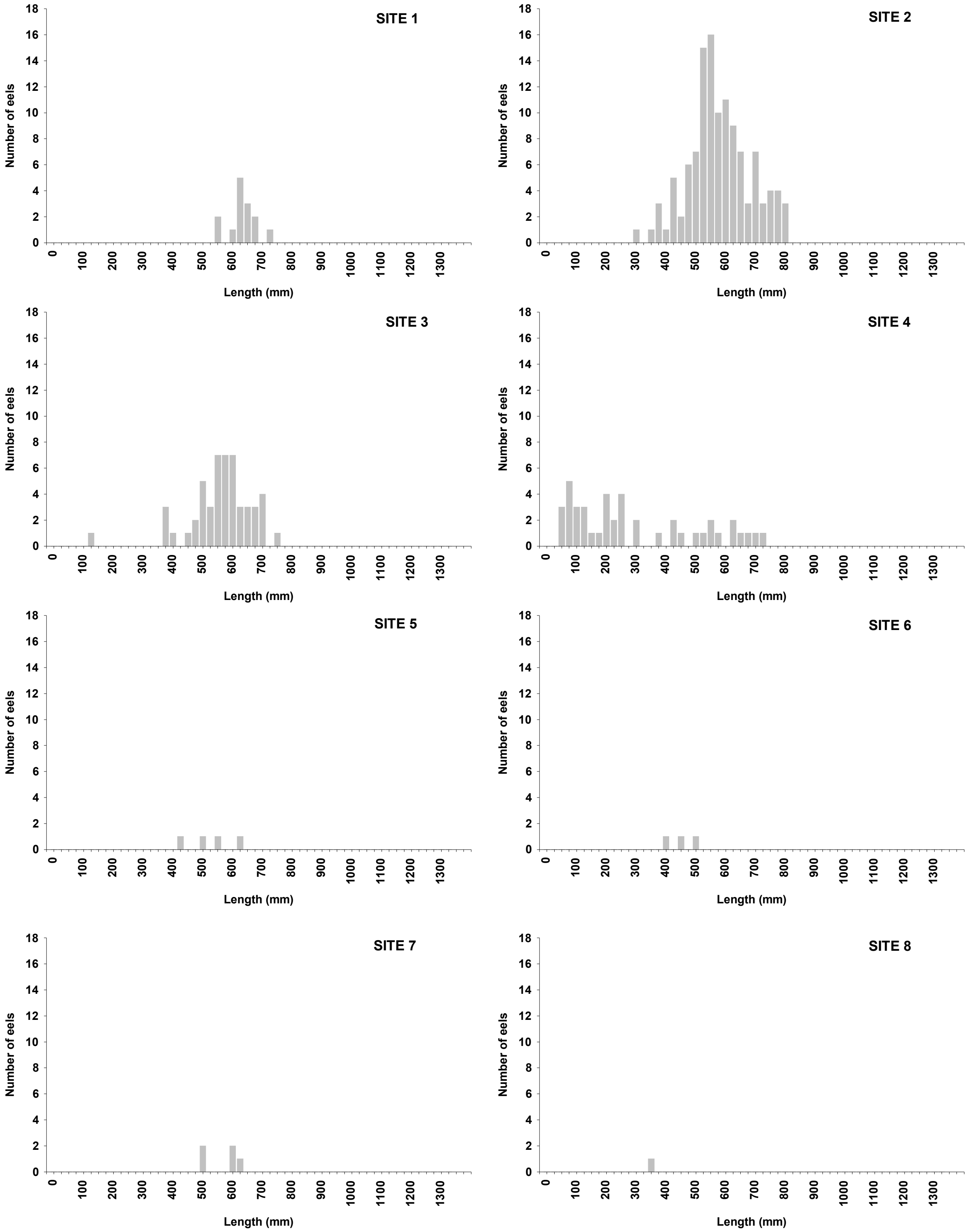








Appendix 4: Shortfin eel length frequencies for each site surveyed in the Kawakawa (Taumārere) and Waitangi River catchments.



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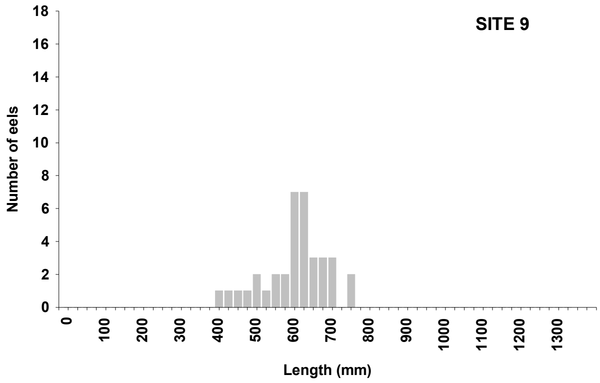
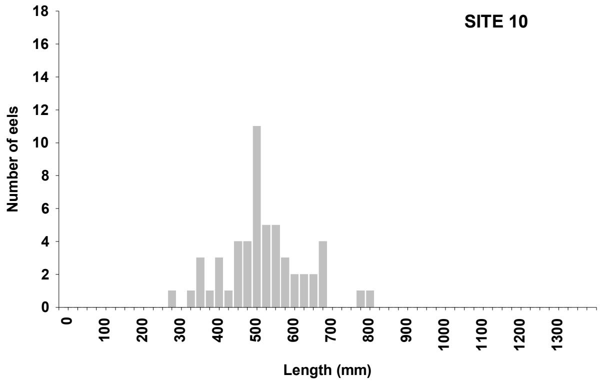
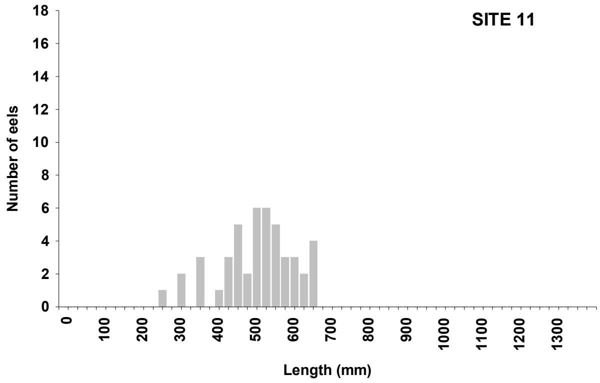
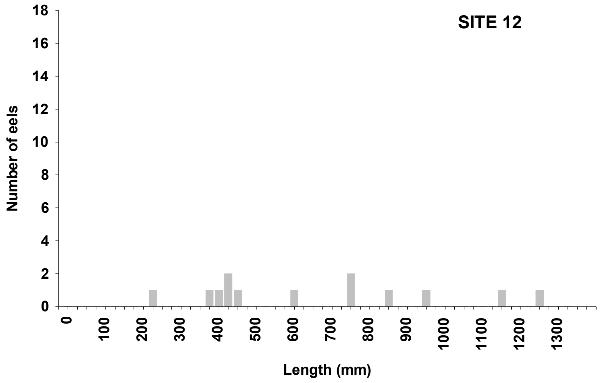
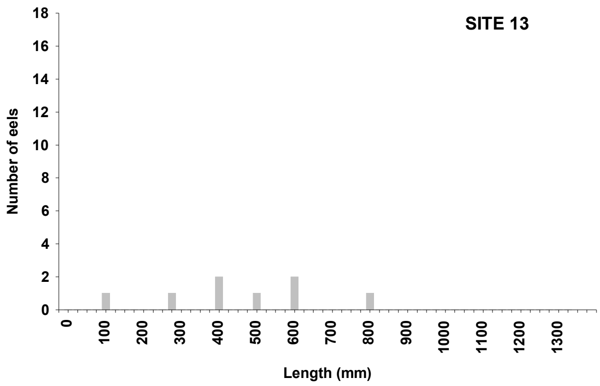
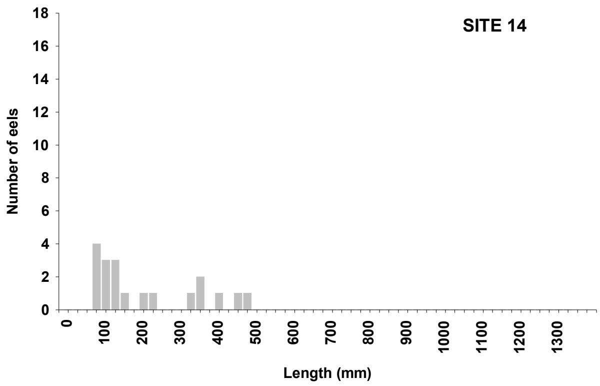


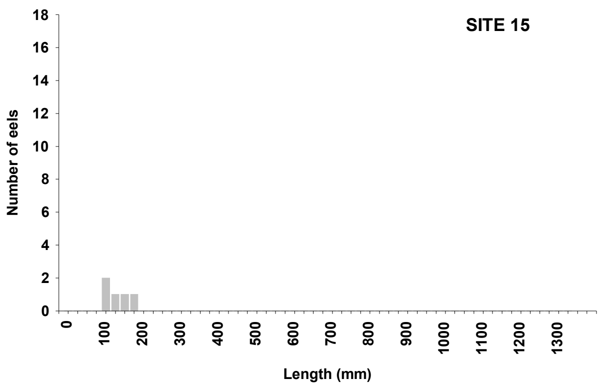




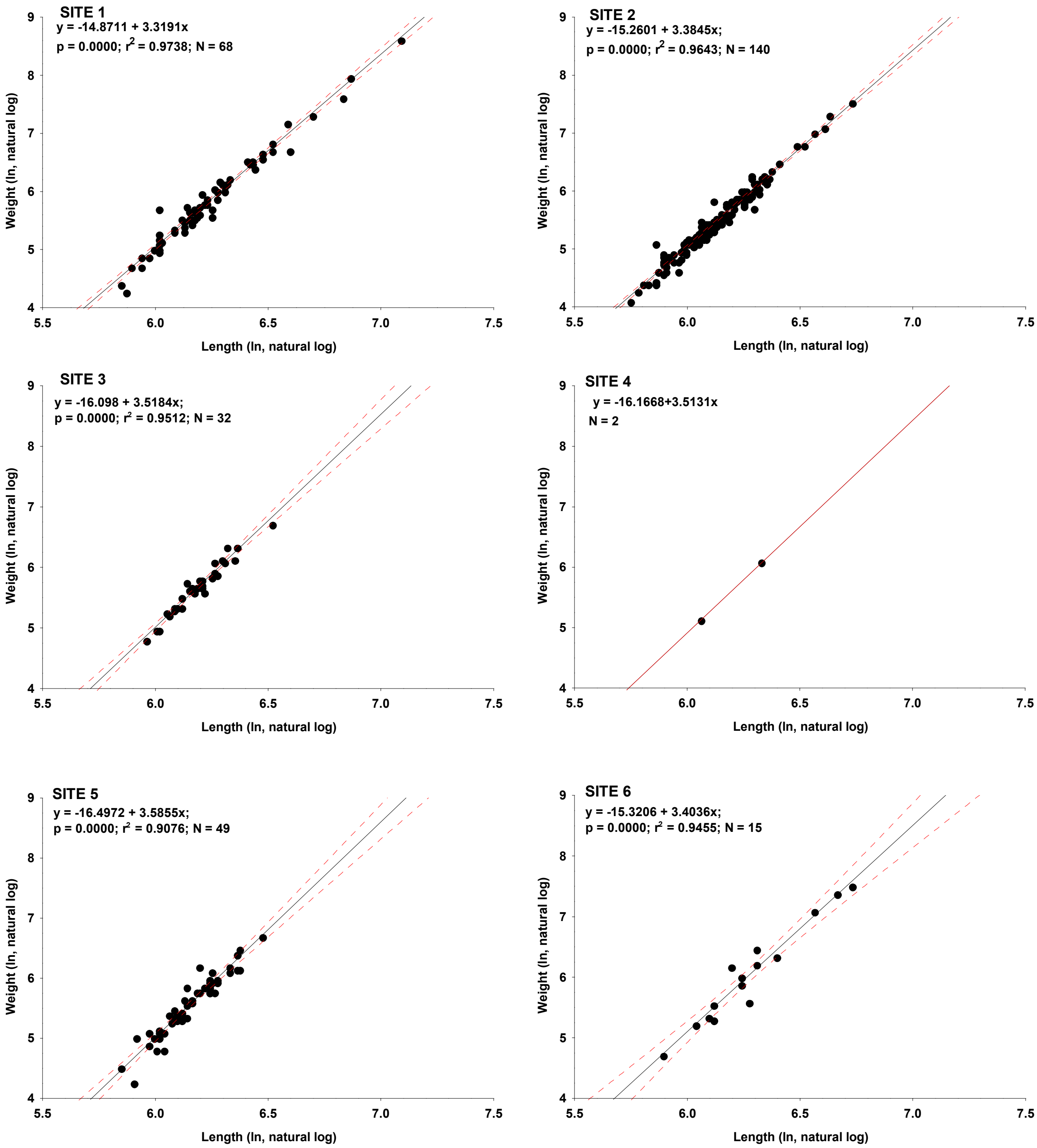








Appendix 5: Longfin eel (> 300 mm) length-weight relationships for each site surveyed in the Kawakawa (Taumārere) and Waitangi River catchments. Least squares regression analysis undertaken in STATISTICA 7.1 where dotted lines indicate 95% confidence intervals.



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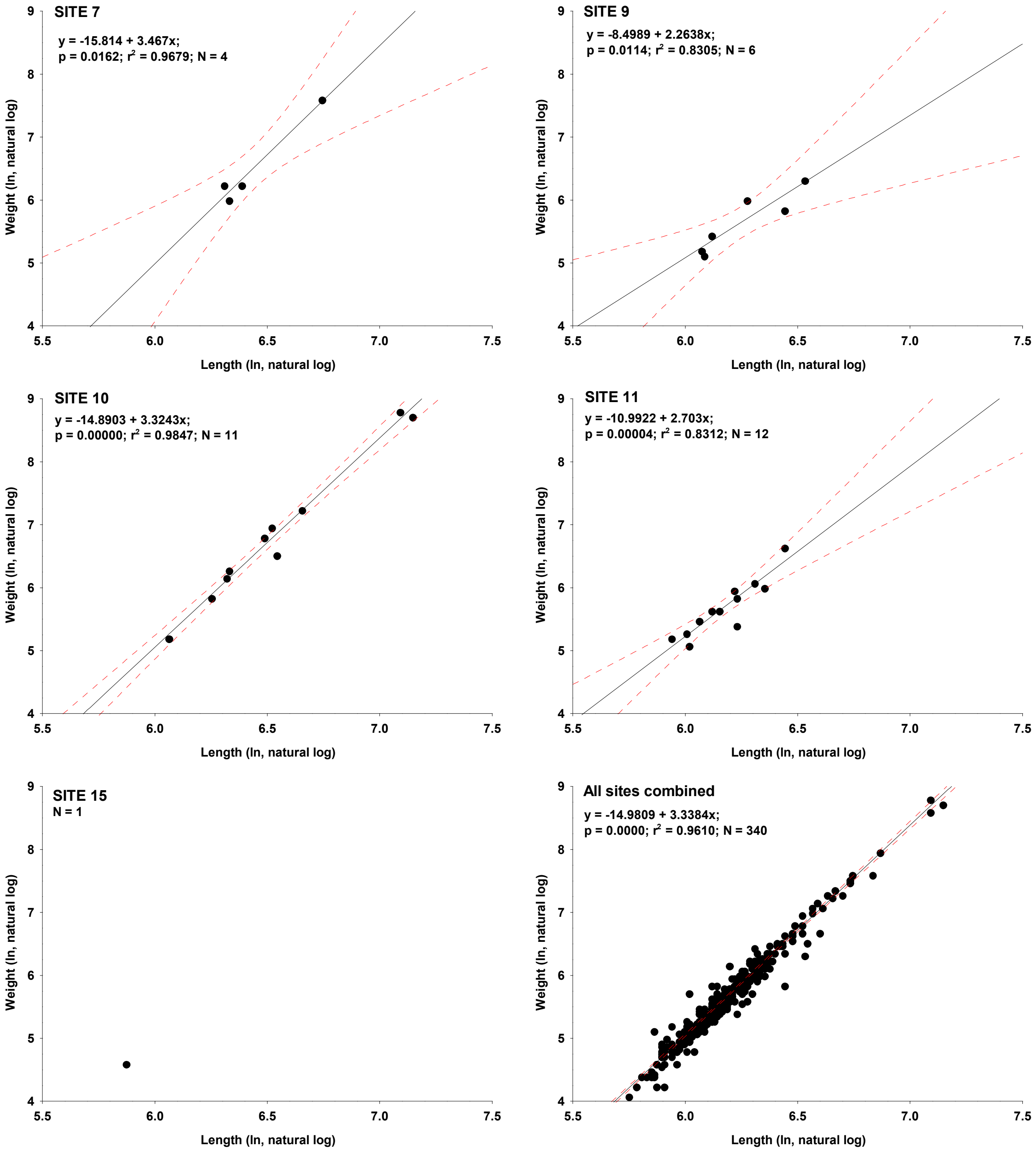

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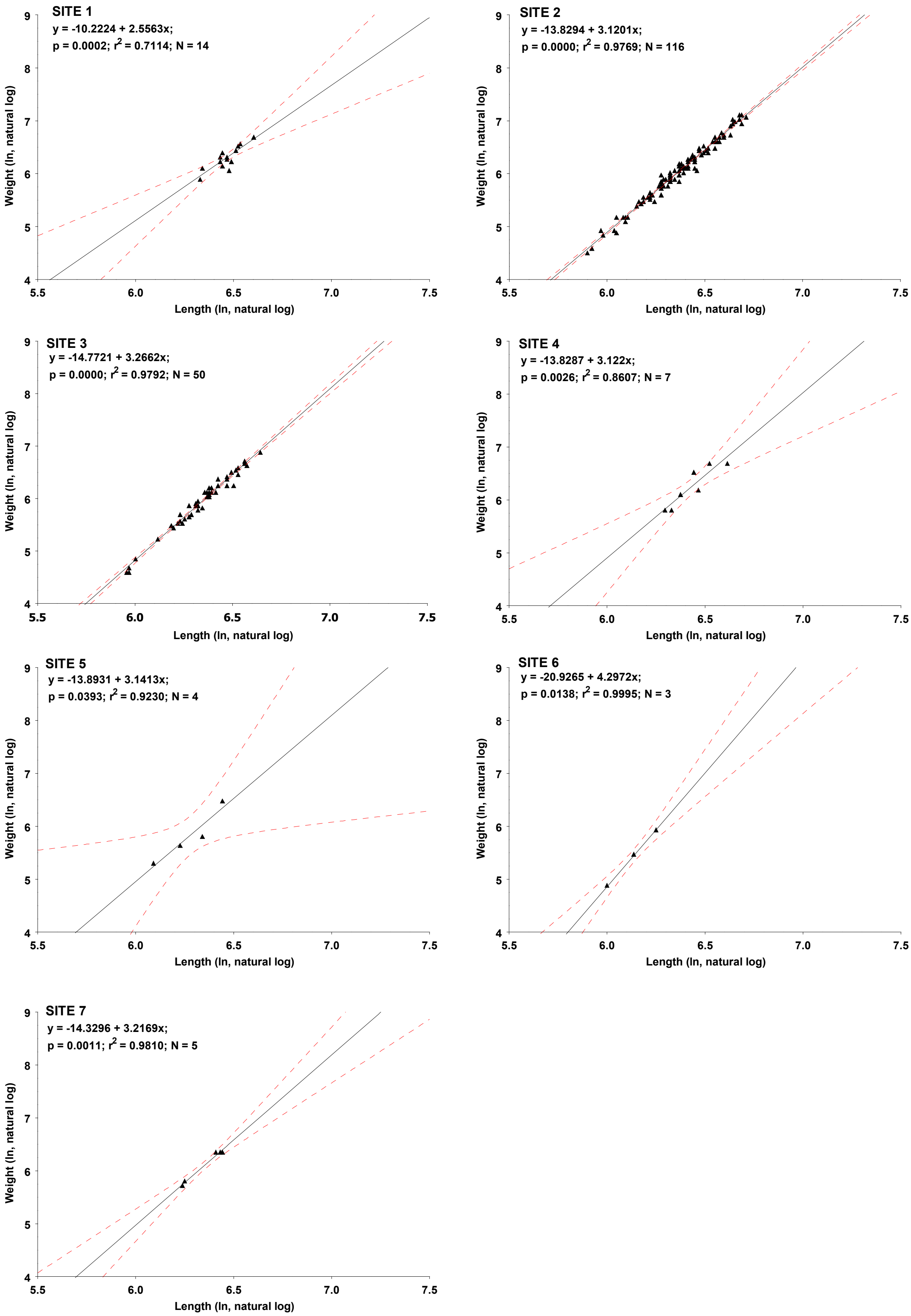

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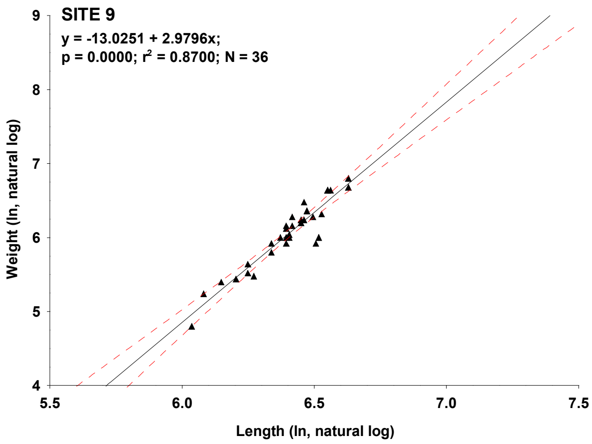
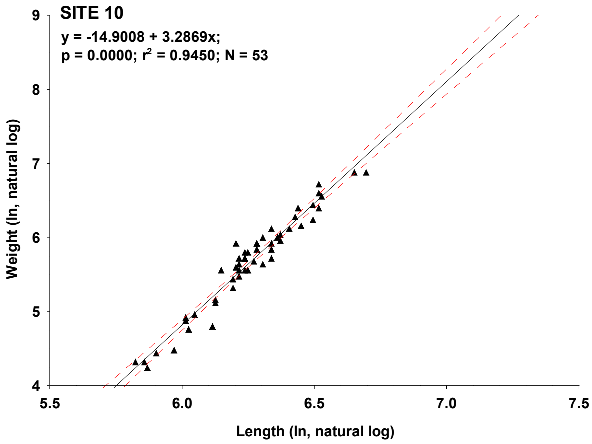
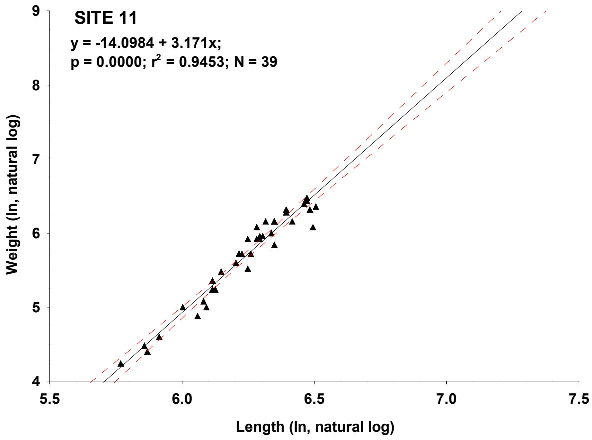
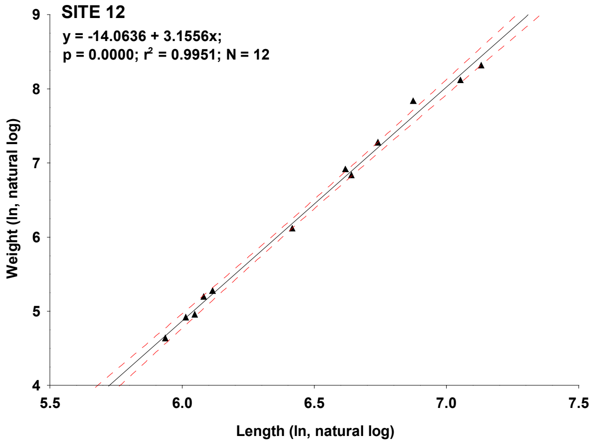
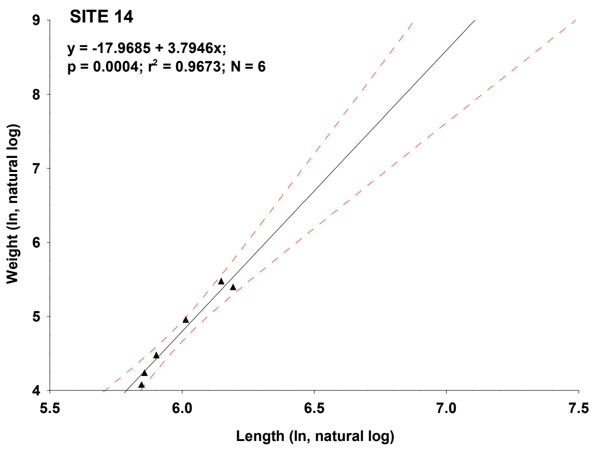
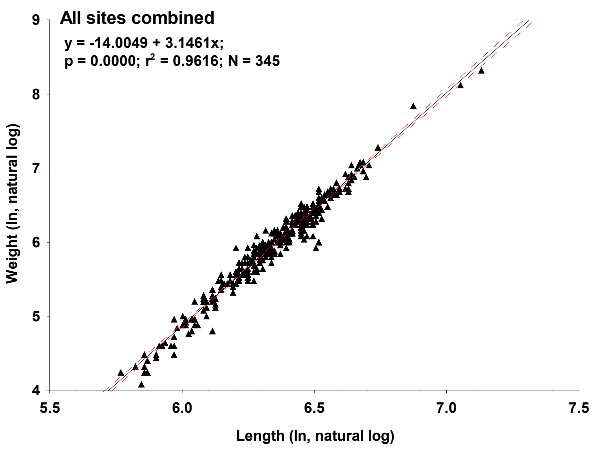




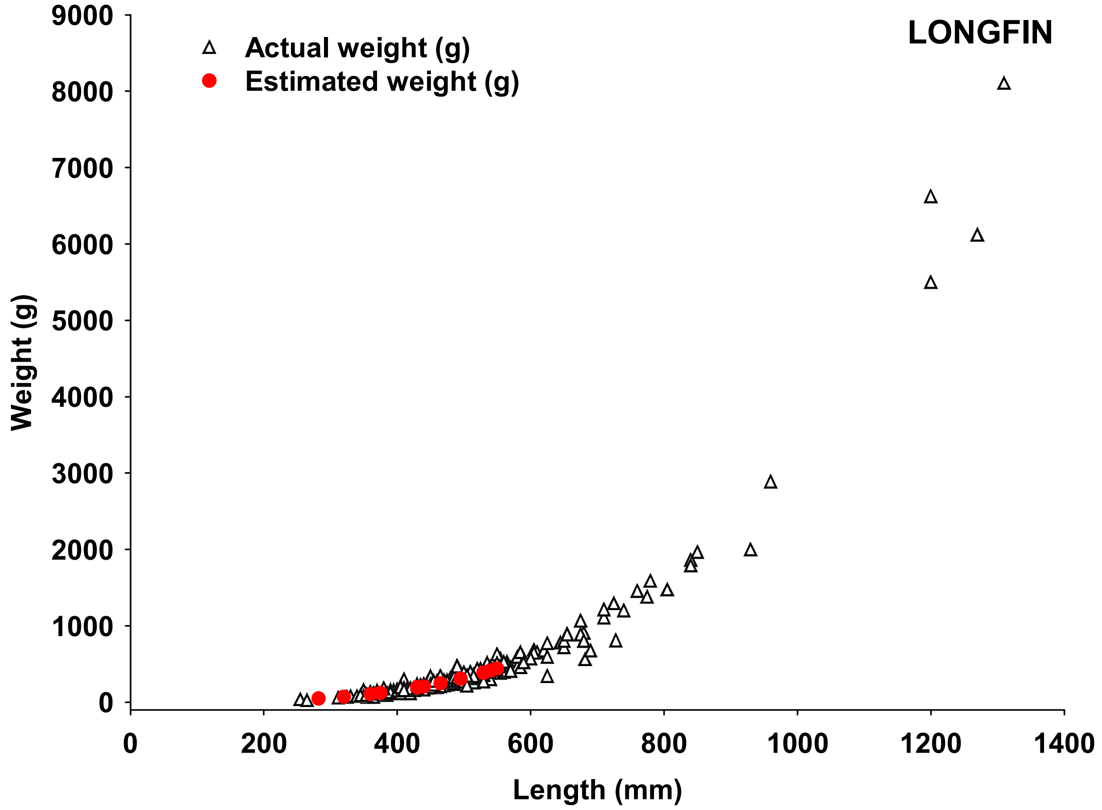


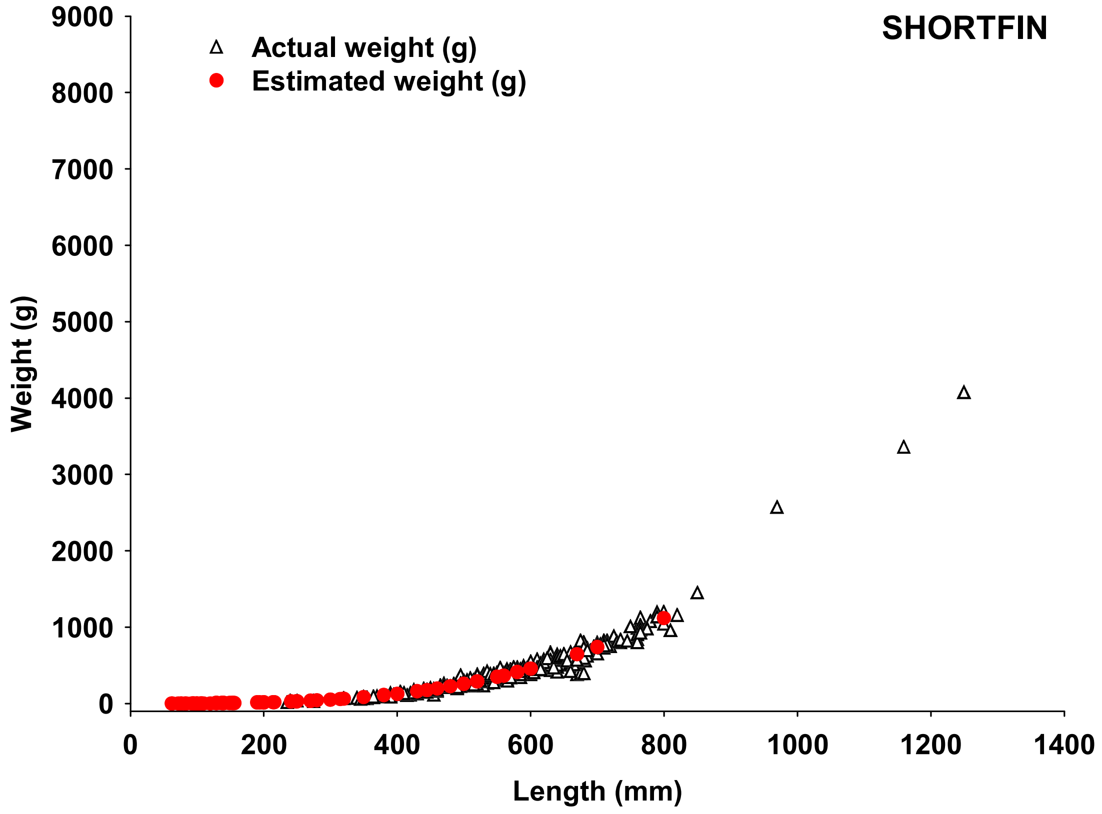




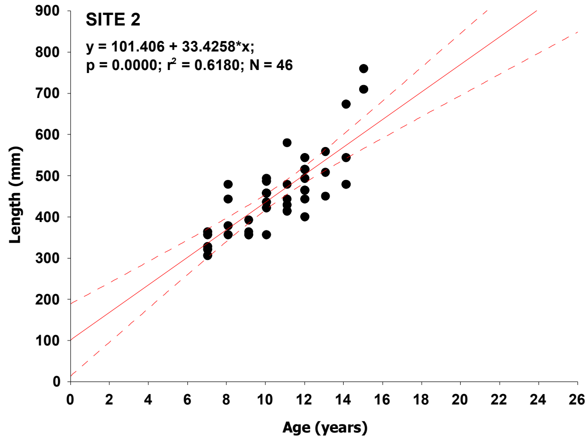


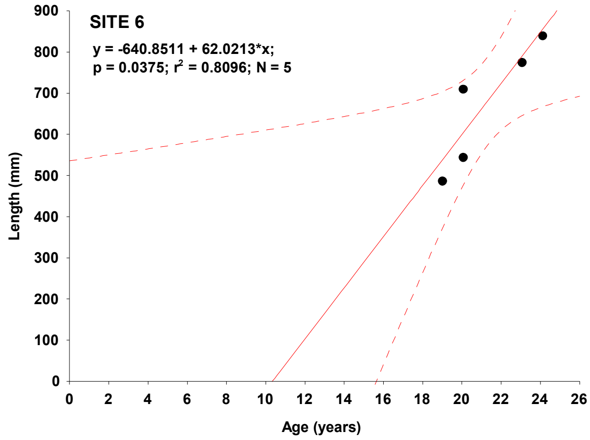
Appendix 7: Actual (i.e., measured in the field) *vs.* estimated weight (i.e., using length-weight regressions) for longfin (top) and shortfin (bottom) eels sampled from the Kawakawa (Taumārere) and Waitangi River catchments.

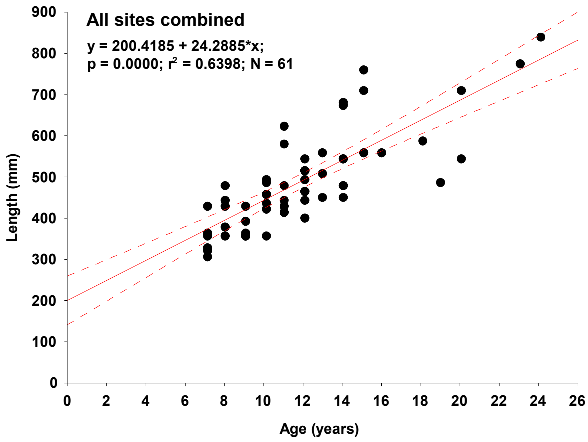




Appendix 8: Longfin eel length-at-age relationships for selected sites surveyed in the Kawakawa (Taumārere) and Waitangi River catchments. Least squares regression analysis undertaken in STATISTICA 7.1 where dotted lines indicate 95% confidence intervals.







Appendix 9: Shortfin eel length-at-age relationships for selected sites surveyed in the Kawakawa (Taumārere) and Waitangi River catchments. Least squares regression analysis undertaken in STATISTICA 7.1 where dotted lines indicate 95% confidence intervals.