NIWA
Taihoro Nukurangi

Tuna population survey of Lake Omapere and the Utakura River

NIWA Client Report: WLG2009-39
April 2009

NIWA Project: NFL08301

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NIWA Client Report: WLG2009-39
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Executive Summary

This Te Wai Māori-funded research will assist the Lake Omapere Project Management Group to achieve it's overarching vision and successful outcome of Waiora, by providing the Lake Omapere Trust and Ngapuhi Fisheries Limited with the baseline information required to monitor and adaptively manage the long term well-being of the Lake Omapere tuna fishery. To our knowledge this is the first formal study of the tuna and freshwater fish populations undertaken in this catchment. This survey was undertaken by the Lake Omapere Trust, Ngapuhi Fisheries Limited and NIWA.

A total of 929 (271 kg) tuna were captured during the present survey, the majority (73%) from Lake Omapere. Although both shortfin and longfin tuna were captured at 83% of the sites sampled during this survey, overall the numbers of longfin tuna were low. While shortfins dominated the catch from Lake Omapere, longfins were more common in tributaries of the Utakura River.

Length-weight relationships for Lake Omapere and the Utakura River catchment indicated that longfins were heavier for their length than shortfins. However, the median length of the shortfins (525 mm) captured was greater than that of longfins (445 mm). In general much smaller eels were captured in the Utakura River and the tributaries of the lake, being largely a reflection of the greater efficiency of electric fishing at capturing small eels.

The age distribution of both shortfin and longfin eels in Lake Omapere and the Utakura River was similar the majority ranging between 4 and 14 years of age. The median age (8 years) was the same for both species. For both tuna species, the lowest average annual length increments were generally recorded below the falls in the Utakura River catchment. Observations indicate that shortfin tuna growth in Lake Omapere is amongst the highest recorded in New Zealand to date.

In Lake Omapere the occurrence of prey items in the diet of both shortfin and longfin tuna was dominated by chironomids and goldfish eggs. Longfins from the Lake Omapere and Utakura River catchment ate a larger variety of food items than shortfins of equivalent size, which is likely to reflect the variety of habitats the longfins were taken from. Future studies are required to quantify the relative importance of prey items to the overall growth and well-being of tuna in Lake Omapere. This should be designed to identify seasonal changes in food as well as changes in the main prey species that are associated with eel size.

The commercial fishery for shortfin eels is typically based on the harvest of immature females, as males are generally known to mature and emigrate below the commercial size. In Lake Omapere this situation may not be as clear cut as observations of the gonads in the field identified a number of shortfin males between 520–705 mm (260–610 g). Shortfin males longer than 598 mm have not been observed in previous research and although it is possible that inaccurate assessments were made in the

field, the characteristics and sex ratio of mature migrant tuna heke (katua) exiting Lake Omapere requires further investigation.

The time needed for longfin females to reach the minimum reproductive size in the Lake Omapere and Utakura River catchment is estimated to take about 13 years. It appears that there are very few eels left (both longfin and shortfin) in the Lake Omapere and Utakura River catchment which are of the large size preferred for customary take. But perhaps of more concern is that these records also indicate that very few large females are supported by the catchment and (contribute to the spawning stock. These results emphasise not only the vulnerability of the population to fishing pressure but also indicates that management measures taken nationwide could take decades to show results.

In order to better understand the effect of harvest on the size and species composition of the eel population over time, robust information on harvest (commercial, recreational and customary) activities within the Lake Omapere and Utakura River catchment is required. As a precautionary measure, to ensure future recruitment, it is recommended that fishing pressure (including customary and recreational take) on large female tuna be reduced, an action that may benefit future eel recruitment into New Zealand waters.

To optimise the survival and success of tuna during both their upstream and downstream migration a better understanding of the potential passage routes, including the possibility of a second lake outlet, during floods or otherwise is required. Further investigation is also required into the survival of migrant eels (katua) exiting the catchment. It is clear that some elvers surmount the waterfalls to reach Lake Omapere, and there is some history of facilitating elver passage in the past at the largest of these falls. We recommend re-implementation of a low cost overhanging elver rope(s) or trawl net-like structure to help facilitate as much elver passage into the lake while a more permanent solution is being investigated.

The information collected in this survey will form a valuable baseline of information upon which to monitor long term trends in tuna abundance. To ensure that comparable data are collected in any future tuna population surveys of Lake Omapere and the Utakura River catchment, the same sites (or a selection of) should be used and standardised survey techniques (notably mesh size and deployment method) maintained. Any additional sites and methods implemented should be considered supplementary to those used in the present study.

While this research has greatly increased our understanding of the tuna population in the Lake Omapere and Utakura River catchment, very little tuna population studies have been undertaken in the greater Ngāpuhi rohe. In November 2007 workshop attendees identified a number of other Taitokerau catchments that were significant to them, and where they would like more tuna population baseline information. After Lake Omapere, the Mangakahia and Taheke Rivers were identified by the group as the next priorities.

1. Background

1.1 Te Wai Māori Trust

In July 2007 Ngāpuhi Fisheries Ltd (NFL) was successful in securing funds from Te Wai Māori Trust (http://waimaori.maori.nz/) to investigate the species, age structure, growth rate and sex composition of tuna (freshwater eel) populations in Te Tai Tokerau to provide a reference point for any future monitoring and research of the tuna population of this area. The outcomes of this research will assist Ngāpuhi to better manage, protect and enhance their commercial and customary tuna fisheries. The National Institute of Water & Atmospheric Research (NIWA) was subcontracted by NFL to assist with the delivery of these research outcomes.

1.1.1 Contracted objectives

Overall objective:

1. The aim of this research is to build a framework to understand the status of tuna stocks in Te Tai Tokerau rohe. The research aims to enable Ngāpuhi to manage, protect and enhance their eel fishery. The information gained will assist Ngāpuhi to develop their commercial and customary management strategies for eels.

Specific objectives:

1. Design: Consult with Ngāpuhi to prioritise sampling sites of importance to Ngāpuhi and refine a workplan. The workplan which will detail the methodology and outcomes of the hui held with Ngāpuhi will be provided to Wai Māori by 31 July 2007.

2. Training course: Training course conducted by NIWA scientists for Ngāpuhi members in tuna biology and recruitment, sexing, appropriate sampling methods and otolith preparation for aging. A report on the outcomes of the training course is to be provided to Wai Māori no later than 30 September 2007.

3. Field work: Field work will include tuna sampling to be conducted during March 2008. Sampling will include fyke netting of mainstream river sites and electric fishing of selected tributaries. Modelling estimates will be used for other Tai Tokerau catchments based on the field work. A report to be provided to Wai

Māori that demonstrates that the field work was completed and methodology used no later than 31 March 2008. (Deadline amended to 31 March 2009).

4. Final report: The final report must include in-depth data analysis and monitoring framework development. Furthermore, the final report must be presented to Ngāpuhi and provide an overview of how this project will contribute to the planning for future research in Tai Tokerau. This report will be provided no later than 30 April 2008. (Deadline amended to 30 April 2009).

1.1.2 Tuna training course

This project commenced with a two-day "Tuna training workshop" held at Te Rūnanga a Iwi o Ngāpuhi office in Kaikohe on the 29-30 November 2007. This workshop was attended by approximately 25 participants over the two days (majority of participants listed in **Appendix 1**). The workshop was an opportunity for tangata whenua to hear about where 'western' science is placed in terms of tuna research, including an overview of general tuna biology (e.g. species identification, distribution, characteristics of life stages, aging, sex identification, recruitment, migration, and threats to the fishery), principles of research study design, data analysis and interpretation.

The workshop also encompassed a field trip to the Waipapa Stream (Kerikeri) in order to demonstrate the practical aspects of sampling tuna populations (e.g. deployment of fyke nets, g-minnow traps, electric fishing, catch data recording and otolith removal techniques). The survey results and a short discussion of this field demonstration are presented in **Appendix 2**.

Each attendee was supplied with a "tuna training manual" (Williams *et al.* 2007), and copies of the presentations given during the workshop were made available through the rūnanga office (Boubée *et al.* 2007). A CD with a copy of each of these resources and photos taken during the field surveys is supplied with this report.

1.1.3 Site selection and discussion

On the second day of the tuna training workshop the floor was opened for general discussion for tangata whenua to discuss related issues and identify key catchments/waterways within Te Tai Tokerau of high customary importance to the iwi for undertaking the field component of this research. The workshop and the associated discussions were reported to Te Wai Māori in September 2007 (**Appendix 3**). The study locations identified during this discussion included Hikurangi Swamp, Wairoa

River, Puhipuhi (headwaters), Waima River, Taheke River, Lake Manuwai, Lake Omapere and the Utakura River. It was concluded by the group and project leader that the fieldwork location of first choice would be the Lake Omapere and Utakura River catchment. The Mangakahia and Taheke Rivers were identified as the second priority. Permission was then sought from the Lake Omapere Trustees to progress this work, the results of which form the basis of the majority of this report.

2. Introduction

Ngāpuhi oral history speaks of Lake Ōmāpere as originally being swampland, which was covered in kauri forest. However, it is believed that in the early 1300s a fire destroyed the forest, clearing some 1,200 hectares of all cover and resulting in the formation of Lake Ōmāpere as we now know it. Pakiwaitara from Ngāpuhi also speak of Tākauere, a Tohunga who once resided in the forest. Tākauere transformed himself into a Taniwha when fire engulfed the area and now stands as the kaitiaki of Lake Ōmāpere and the underground systems which link it to the surrounding areas, including Ngāwhā, Waimate and Hokianga. Lake Ōmāpere sits mid-way between the Hokianga harbour and Pewhairangi (Bay of Islands), in the heart of the Ngāpuhi rohe.

Ron Wihongi a kāumatua from the hapū Te Uri O Hua relays the kōrero tawhito regarding the name of Lake Omapere and the importance behind it, in the 2007 documentary 'Restoring the Mauri of Lake Omapere'. In his kōrero Mr Wihongi spoke of 'pere' as the puku or belly of the taniwha, Tākauere and 'O' meaning kai or food; thus Omapere meaning food for the belly of the taniwha, Tākauere (Browne *et al.* 2007). This kōrero tawhito illustrates the way in which tangata whenua have always regarded Lake Omapere as a significant source of food which should be respected. The lake continues to be acknowledged as a highly significant taonga and mahinga kai site for the hapū and iwi which surround it, "The primary hapu with manawhenua around Lake Ōmāpere are Te Uri-o-Hua, Ngāti Korohue, Te Popoto, Te Ihutai, Honehone, and Ngāti Kuri" (Lake Ōmāpere Project Management Group 2006). Nevertheless, with the main outflow of the lake being the Utakura River which flows out to the Hokianga harbour, the lake catchment also supports many hapū communities who reside along the river and within the harbour.

2.1 Physical and biological characteristics of Lake Omapere

Lake Omapere is the largest lake in the Ngāpuhi rohe and, like Lake Owhareiti to the south, the lake basin appears to have been originally formed by lava flows (from Te Ahuahu volcano) damming the valley (Viner 1987). Dating of sediment cores has indicated that the 'modern' Lake Omapere is c.1000 years old and, in the form that we basically know it now, possibly originated through siltation of drainage in response to erosion induced by deforestation (McGlone 1983). It is almost circular in shape, occupying an area of 11.6 km² (c. 1,200 hectares), it has a small catchment of 32.7 km² which is predominantly vegetated by pasture (Livingston *et al*. 1986). It is shallow with a maximum depth of ~2.6 m and an annual lake height fluctuation of approximately 1 m (Champion & Burns 2001, Newnham et al. 2004). Several small streams flow into the southern half of the lake, the largest being the Pararataio Stream. The lake is located 238 m above sea level and the outflow (24 km inland) from the south west of Lake Omapere forms the Utakura River, which flows in a westerly direction to the Hokianga Harbour.

Wells & Champion (2008) present a summary of the ecological status of 80 Northland lakes, including Lake Omapere (NRC Lake No. 173), which they report as being extremely nutrient enriched. In 2001 the submerged vegetation of Lake Omapere collapsed and the lake remained in a de-vegetated state dominated by cyanobacterial (blue-green algae) blooms. Wells & Champion (2008) rank the status of this lake as "low" a ranking attributed to lakes that were either de-vegetated with poor water quality, or severely impacted by exotic pest species. The genetically distinct *Isoetes kirkii* var. *flabellata* (quillwort) was last collected from this lake in 1998 and may be extinct outside of cultivated plants held by NIWA. This plant has been classified as 'nationally critical' due to it only being found at this location (Hitchmough *et al.* 2007).

Champion & Burns (2001) report that the western shore of Lake Omapere supports dense bands (>75% cover) of the emergent plants *Baumea articulate* (jointed twigrush), *Schoenoplectus tabernaemontani (*kāpūngāwhā, lake clubrush*)* and *Typha orientalis (*raupō, bullrush*)* to a water depth of 1.2 to 1.3 m. The rush *Juncus gregiflorus* (wīwī, leafless rush) is common near the waters edge around the remainder of the shoreline. The exotic pest weed *Egeria densa* (commonly known as egeria or common waterweed) completely covered Lake Omapere during 1984. These surface-reaching stands of *E. densa* then collapsed in 1985 and the lake remained de-vegetated until 1994. Over the next 6 years *E. densa* re-colonised the lake until 2000 when it reached maximum biomass, with surface-reaching beds covering the lake. These beds disappeared in 2001 following the introduction of the weed eating grass carp and the lake has remained de-vegetated since then. The invasive aquatic plant *Utricularia gibba* (bladderwort) was noted in the eastern basin of the lake during 2000, but has not been seen since. Champion & Burns (2001) concluded that *Egeria densa* could re-establish and the cycle of vegetation collapse was likely to continue if unmanaged. It is probable that *Egeria* has now been eradicated from this lake by the grass carp, however, several more years monitoring are required to confirm this.

Black swan (*Cygnus atratus*) numbers appear to fluctuate with submerged plant biomass. Past surveys by the Ornithological Society of New Zealand (OSNZ) reported the presence of the nationally rare bittern (*Botaurus poiciloptilus*) and regionally significant fernbird (*Bowdleria punctata vealeae*) from this lake. Champion & Burns (2001) mention that Torewai or freshwater mussels/pipi (*Hyridella menziesi*), kēwai/kōura (*Paranephrops planifrons*), *Potamopyrgus antipodarum* (water snail, pointed end), *Austropeplea tomentosa* (snail species), *Hygraula nitens* (pond moth), dragonfly larvae, planarians (flatworms), freshwater sponges, bryozoans and chironomids (bloodworms, midges) have been recorded in Lake Omapere.

Torewai were once 'plentiful in thousands, in any part of the lake' (Hemi Wi Hongi, Native Land Court, 1929; *in* White 1998) but the population has since reduced markedly. Since January 2001 the Northland Regional Council (NRC) and the Lake Omapere Trustees have been undertaking regular dive surveys to monitor the population and results indicate that there is still a relatively high mussel density at the northern end of the lake. The overall mussel density in the lake in October 2007 was 22 mussel/m², and although the population now appears to be reasonably stable their distribution remains patchy (*see* http://www.nrc.govt.nz/Your-Council/Council-Projects/Lake-Omapere-Restoration-Project/Freshwater-mussel-research/).

An overview of the freshwater fish species found in Lake Omapere is presented in Sections 2.2 and 2.4.

2.2 Anthropogenic activities and the well-being of Lake Omapere

Legal and illegal activities to lower the water level of Lake Omapere have occurred over the last 100 years. Around the turn of the century the water level of Lake Omapere would rise and the adjacent farm land would be flooded during the winter months. The farmer that owned the land ('Omapere estate') abutting the south shore of the lake exerted pressure on the Crown to permanently lower the lake's water level (White 1998). A long and drawn out legislative process with the Māori owners of the lake ensued, over which time Crown representatives undertook activities to lower the water level of the lake at various points in time (Table 1).

The main land uses in the Lake Omapere catchment include a mix of dairy and dry stock farming and lifestyle blocks. In 1986, Livingston *et al*. (1986) estimated the dominant cover in the catchment area to comprise 60% pasture. Currently there is no formal public access to the lake, but in the past it has been used for boating and rafting races (Lake Omapere Project Management Group 2006).

Over the last quarter of the 20th century, the water quality of Lake Omapere deteriorated. The lake which is now classified as hypertrophic, is nutrient rich and has shifted from a lake dominated by aquatic plants to one which is dominated by planktonic algae. In the summer months, the lake can experience severe toxic algal blooms making it unsafe for human and stock use (Table 1). Trends in Lake Omapere water quality indicators are summarised and discussed in detail in reports such as Champion & Burns (2001), Gray (2006), Hamill (2006). Ongoing monitoring results are available on the NRC website (*see* http://www.nrc.govt.nz/Your-Council/Council-Projects/Lake-Omapere-Restoration-Project/Water-quality/).

Around 1988–89 large numbers of juvenile silver carp (*Hypophthalmichthys molitrix*) were released into the lake in an attempt to alleviate phytoplankton blooms (D Rowe, NIWA, pers. comm.). These fish were too small to withstand predation by shags and such like, and most will have died. Another alien species was introduced to the lake in August and December 2000 when the Lake Omapere Trust and the Northland Regional Council released 40,643 White Amur (also known as Chinese grass carp, *Ctenopharyngodon idella*) into the lake in an attempt to eradicate *Egeria* and so prevent the lake flipping between completely vegetated and wholly planktonic states (*see* Champion & Burns 2001). In 2002 a further 20,000 carp were released into the lake (Pullan 2002). Grass carp have been used in a number of waterways for the control of excessive macrophyte growth (e.g., Mitchell 1980, Wells 1999, Wells *et al.* 2003).

Some of these grass carp were removed at a later date as Baker & Smith (2006) report "The fish supplied by Gray Jamieson was released into the natural environment at an unknown age and had spent the last two years in Lake Omapere in Northland before being returned to the holding ponds at Warkworth…" The Northland Regional Coucil reports "it is known that 401 grass carp were removed between October 2004 and May 2005, and grass carp removal will continue." (*see* http://www.nrc.govt.nz/Your-Council/Council-Projects/Lake-Omapere-Restoration-Project/Fish-weed-management/). The Ministry of Fisheries also report that between 2004–06 a total of 2,078 grass carp, 3,830 goldfish and 5 silver carp were removed from the lake (S. Pullan, MFish, pers. comm.).

Table 1. Timeline of selected activities and events undertaken in the Lake Omapere catchment (references include White 1998, Champion & Burns 2001, Lake Omapere Project Management Group 2006, Browne *et al.* 2007, Wells & Champion 2008).

Period	Activities/events
~1300	Fire destroys kauri forest – Formation of Lake Omapere.
1895-1934	Mercury mining in Ngāwhā.
1903	Native Minister, James Carroll, visited Kaikohe and met with local "Mr Carroll said that the lake belonged to the Natives, and that they should lodge an application for investigation of title".
Oct 1903	Bay of Islands County Council passed a resolution that Crown lands abutting Lake Omapere be made a county endowment, and that the council had no objections to Austrians being allowed to dig for gum on the Crown lands on the northwestern shore of the lake. The council considered that 'if draining were carried out upon a satisfactory system the surrounding land now inundated by water would be improved.
1905	An owner of land adjoining the lake assumed the right to lower the level of the lake by interfering with the outlet at the western end of the lake which lay on Māori-owned land.
1910	Michie wrote to the Member for the Bay of Islands informing him that persons were again endeavouring to lower the lake, this time using dynamite to deepen the outlet. Michie asked that the Government intervene and halt the work. Appears that this petition resulted in the Under-Secretary of Justice ordering the Auckland Inspector of Police to investigate the matter.
1913	Māori first applied to the Native Land Court to get the title to Lake Omapere determined. However, it was not until 1929 – 16 years later – that the matter finally came before the court. To a large extent it appears that this delay was effected by various agents of the Crown conspiring to prevent the application being heard.
1913-1916	The owner of the Omapere estate, George Pitcaithly, around this time began to incessantly petition Parliament, seeking the Government's assistance in lowering Lake Omapere in order to bring more of his land into production.
1914	Trout and carp introduced to the lake prior to 1914, an inspector of forests reported local Māori having told him that numbers of crayfish in and around Lake Omapere had been greatly reduced through being eaten by introduced species of fish.
1914	The area's reserve status was revoked on account of all the gum that was easily retrieved having been recovered.
~1916	Construction of the Okaihau branch of railway, running between Okaihau and Kaikohe, and which traversed the western margin of the lake, crossing the Utakura stream immediately below the outlet.
1916	Thompson, Chief Drainage Engineer, informed the Under-Secretary of Lands that in the past, the outlet had been widened and deepened by the owners of the Omapere estate, and that also a certain amount of straightening and blasting had been undertaken. It was held that all these works had been unauthorised. In the report, the opinion was expressed that the outlet could be further widened and deepened in order to cope with the winter rains.
~1916-1919	Government agree to purchase the parts of the Omapere estate that were prone to flooding and used these lands to settle returned First World War servicemen upon.
1920	North Auckland Commissioner of Crown Lands wrote to the Under-Secretary of Lands and noted that since the ballot allocating the land, those now affected by the flooding 'have several times spoken to me about it and are now agitating the matter through the Returned Soldiers Association.' The commissioner expressed the view that he thought 'it necessary that something be done in the matter'.
1920	Campbell (succeeded Thompson as Chief Drainage Engineer) reported to the Under-Secretary of Lands on the feasibility of lowering Lake Omapere. Campbell recommended that the lake just be lowered rather than completely drained. Subsequent to the Under-Secretary of Lands receiving this report, he ordered that the work to lower the lake be undertaken.
1922	Crown lowers Lake Omapere. Coates, the Native Minister, ordered that the Survey Department prepare a plan to enable the Native Land Court to investigate title to Lake Omapere.

Table 1. **Timeline of selected activities and events undertaken in the Lake Omapere catchment (continued).**

Period	Activities/events
1929	At Kaikohe (March) & Auckland (June) hearings witnesses present evidence before the Native Land Court in the investigation of title articulating the nature and extent of the rights of the various hapū who had interests in the lake. In August Judge Acheson's decision issued, ruling that Māori use and occupation of the lake had been continuous and uninterrupted since 1840, and that the lake was incontrovertibly Māori customary land. In Sept 1929 the Crown appealed the Native Land Court's decision as to the title of Lake Omapere. However, just as the Crown had obstructed the initial inquiry, it deliberately delayed proceedings subsequent to the lodging of the appeal. It would be a further 24 years before the Crown's appeal was disposed of, i.e., it was never prosecuted.
Aug 1935	An application by the Public Works Department for approval to clear out the outlets of Lake Omapere was heard by the Native Land Court. The court agreed 'on the spot to the outlets being clear[ed] but not deepened or widened.'
Jul 1940	An application that the lake be made a tribal reserve is before the Māori Land Court.
1944	Proposed hydro-electric scheme for Lake Omapere.
Oct 1953	Crown announced that it had abandoned it's appeal for practical reasons – specifically that it was by then 'not considered that the ownership of the soil under Lake Omapere has any value to the Crown.'
1953	The Māori Affairs Act was passed. The lake was made a tribal reserve. The court appointed two panels of trustees – one being patrons, the other executives. The trustees were instructed by the court to complete the title to the lake by having a survey undertaken.
1956	Reference was made to the fact that an order of the Māori Land Court had vested in the trustees' both the lake's bed and its waters.
1964	Deep bores drilled in Lake Omapere for geothermal exploration.
1970	Speed boat races on Lake Omapere.
~1973	Kaikohe Borough Council applied to the Northland Catchment Commission for a permit to enable it to extract water for domestic supply from Lake Omapere.
1982	Commercial eeling activities commences.
1984	The exotic invasive *Egeria densa* completely covered the lake.
1984-85	Surface-reaching stands of *E. densa* collapse and the lake remains de-vegetated until 1994. Thick algal bloom (chlorophyll *a* measurements, indicative of algal numbers, 179 mg m^{-3}) reported on the lake reducing water clarity from > 2m (recorded in 1992) to 0.25 m. Rapid decline in black swan numbers from c.8000 to c.1000 birds.
Dec 1985	Northland Area Health Board prohibited taking of water from Lake Omapere on the grounds that it was polluted and a health danger. Also recommended against bodily contact with the polluted water as far as Horeke, Hokianga Harbour. Marae in the Utakura Valley were unable to conduct functions.
1988-1989	Attempt to introduce silver carp in lake to control algal blooms.
1992	Resuspension events in the lake impact on water quality.
1998	Single resuspension event impacts water quality.

Table 1. Timeline of selected activities and events undertaken in the Lake Omapere catchment (continued).

Period	Activities/events
2000	*E. densa* re-colonised the lake until 2000 when it reached maximum biomass, with surface-reaching beds covering the lake. 40,643 grass carp released (August and December) into Lake Omapere
1999–2001	Approximately 60 tonnes of eels removed from Lake Omapere to reduce predator numbers in preparation for stocking with grass carp.
2001	From 2001 onwards weed beds again collapsed and the lake has remained de-vegetated from 2002 until present (2008). Torewai populations decline.
Apr 2001	Adult brown bullhead catfish captured in fyke nets (possibly indicating an illegal liberation).
2002	20,000 grass carp released (January and February).
2004-2006	Removal of grass carp (2,078 grass carp, 3,830 goldfish and 5 silver carp removed).
Sept 2006	Lake Omapere Trust and Northland Regional Council's Chairman formally signed the 'Restoration and Management Strategy for Lake Omapere' Mark Farnsworth (NRC Chairman) & Mike Kelleher (Chairman of the Trust).
2008	Two planting day's organised for volunteers to plant native trees along the shore of Lake Omapere (28 June & 3 August 2008).
Nov 2008	Te Wai Māori funded tuna population survey of Lake Omapere undertaken by Ngāpuhi fisheries limited, Lake Omapere Trust and NIWA.

2.3 The Restoration and Management Strategy for Lake Omapere

Tiakina a Ranginui raua ko Papatuanuku kia a ora te mauri o nga taonga tuku iho
If you look after the lake, it will look after you

On 29 September 2006 the Chairman of the Lake Omapere Trust and the Chairman of the Northland Regional Council formally signed the 'Restoration and Management Strategy for Lake Omapere. Lake Omapere Project Management Group prepared a management strategy for Lake Omapere and its wider catchment. This voluntary strategy aims to improve the health of Lake Omapere by strengthening the trustees to exercise kaitiakitanga (Lake Omapere Project Management Group 2006).

The strategy outlines a number of actions and associated outcomes that are grouped under four elements - Ki uta ki tai, Mātauranga, Rangatiratanga, and Kotahitanga - to achieve the overarching vision and successful outcome of Waiora. In the achievement of this vision the following outcomes will be realised:

- **A healthy lake that sustains people** (including ability to use the water from the lake for drinking and recreational activities; ability to harvest shellfish and other food sources from the lake; ability to harvest food sources from the wider catchment and Hokianga Harbour; use of the lake for economic gain by the Lake Omapere Trust; reduced impacts of land use on the lake).

- **A return of native species of plants and animals to Lake Omapere** (including the return of raupō, harakeke, torewai and tuna to the lake and it's margins; restoration of plants surrounding the lake; control of pest species).

- **The protection of the Mauri of Tākauere and Lake Omapere.**

- **Increased knowledge and understanding of the Mauri of Lake Omapere and everything within** (including access and sharing of information on the lake; increased knowledge of the effects of the wider catchment on Lake Omapere and vice versa).

- **Everybody working together to protect and enhance Lake Omapere.**

- **Sustained long-term management for Lake Omapere and the wider catchment** (including an informed decision on the long-term lake water level).

There have been several successful planting days in the lake catchment over the last thee years, with over 15,000 plants being planted. As of 30 June 2007, 85% of the margins of Lake Omapere are fenced with more planned in the near future (NRC 2007). The Trustees and Council are continuing to work together with landowners, the community and other stakeholders to restore Lake Omapere and work towards the targets outlined in the strategy.

2.4 Tuna in the Lake Omapere catchment

Past

Lake Omapere was described by the trader Joel Polack (1838) as "celebrated for large conger [sic] eels, which are a food of much repute among the natives…Large eel abound in this lake, which are honoured by the natives with the appellation of atuas (gods)." The Utakura River at the outlet of Lake Omapere was traditionally such a prominent site for pā tuna that it was eventually divided into three separate channels.

Each channel was allocated to different hapū in order to settle disputes which occurred during the tuna heke (downstream migration). The three channels were a way of sharing the tuna heke between the different hapū, as the lake had the capacity to provide more than enough kai for everyone. White (1998) recounts a letter of protest written by W E Bedggood in regards to the lowering of the lake, "At certain times of the year the eels leave the lake by the thousands on their way to the deep sea to breed. The Maoris became acquainted with this fact, and by spreading a funnel-shaped net across the outlet, with an eel pot at the end, were enabled to catch them by the hundred. One man stood in the water and when the pot was full handed it to his mate on the bank, who handed him another to be fastened to the net, the full one being emptied into a pit with upright sides dug for the purpose".

The water level of Lake Omapere was lowered numerous times between 1903 and 1929 with many of the tangata whenua attesting to the adverse affects this had on the lakes katua (migrating/elder eel) fishery. As well as the lowering of the lake, the "introduction of trout and carp also appear to have affected the lake's ecology. In 1914, an inspector of forests reported local Maori having told him that numbers of crayfish in and around Lake Omapere had been greatly reduced through being eaten by introduced species of fish" (White 1998).

Evidence given by Hemi and Ripi Wihongi before the Native Land Court in 1929 stated that "Katua – eels that went out to sea each year in order to breed – were caught in weirs at various outlets of the lake over a three month period each year. Hemi Wi Hongi stated that Waitanumia and Te Kuaha were the principal outlets at which katua were caught. At each of these weirs two to three thousand eels would be caught each season. Ripi Wi Hongi corroborated his father's evidence and added that Ngaruawahia, Te Ahipara and Te Harakeke were other drains at each similar quantities of eels were caught" (White 1998).

In addition to the migrating adult tuna, a variety of eel known as tautoke were caught over the whole lake. White (1998) states "Ripi Wi Hongi stated before the Land Court that he estimated 'more than 10,000 tautoke eels per season were caught by spearing or with lines or baskets'. Traditionally Māori had used baskets or hīnaki to procure the tautoke eel from Lake Omapere. However, by the 1920's it appears that a method had been developed whereby they were caught from canoes using spears and torches." Evidence given by one witness before the Native Land Court attested that more eels were able to be caught when using the torch and spear method.

Evidence of a migrant tuna trap, constructed of rock and cement, immediately above one of the waterfalls (most downstream located waterfall of the three between the lake outlet and Imms Road, Photo 1) on the Utakura River is still visible (location map series NZMS260 E2579025, N6648294) (Photo 2).

In additional to the tuna, torewai, raupō, kuta and harakeke were also harvested from the lake (Lake Omapere Project Management Group 2006).

Photo 1. Waterfall on the Utakura River (coordinates NZMS260 E2579025, N6648294) (Photo: Erica Williams).

Present

A review of the ecological condition of Lake Omapere undertaken by Champion & Burns (2001) for the Ministry of the Environment states that no formal surveys on the fish populations had been undertaken in Lake Omapere at the time of their report.

Only 23 records have been submitted to date to the New Zealand Freshwater Fish Database (NZFFD) for the Utakura River and Lake Omapere catchment. These records date between 1965 (undertaken by NIWA) and 2007 (undertaken by the Department of Conservation). The majority (52%) of these records are surveys of wetlands and tributaries immediately surrounding the southern and western side of Lake Omapere. There are three records at locations on the northern side of the lake, in the upper waters of the Waiharakeke Stream (joins the Utakura River below the three waterfalls that are present downstream of the outlet of Lake Omapere). There are a further five records within the lake itself and three located along the Utakura River itself.

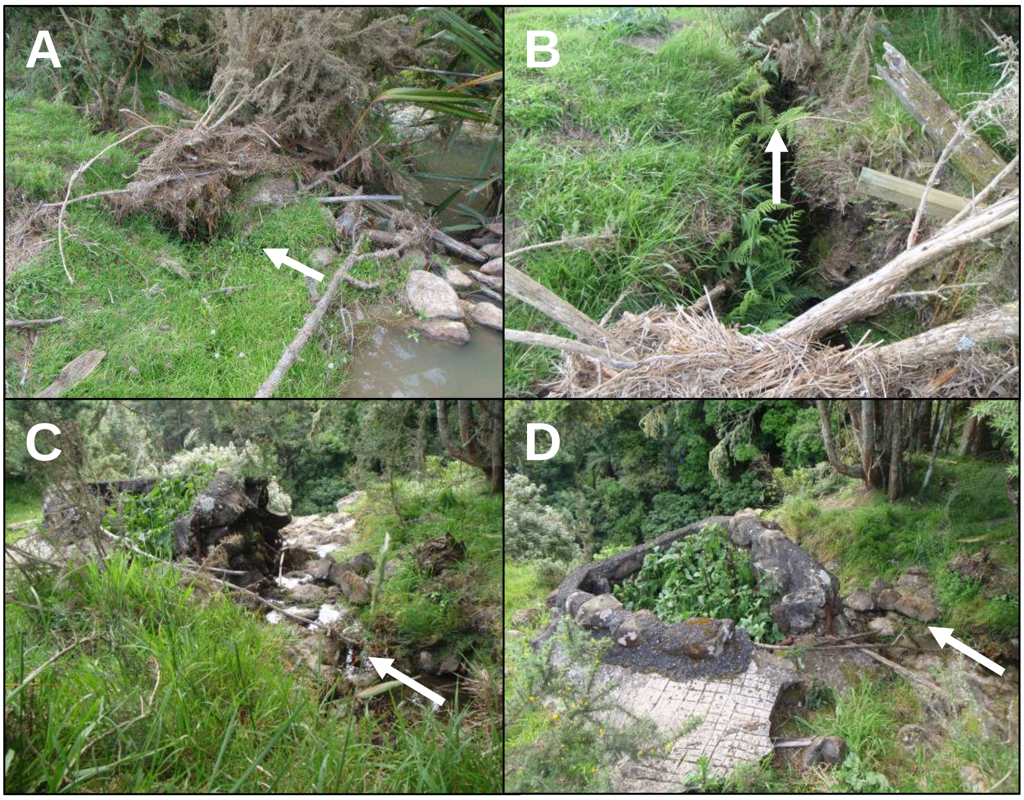

Photo 2. Rock and cement migrant tuna trap on the Utakura River. (A) Small side channel that diverts water from the Utakura River during floods towards the trap; (B) Side channel; (C) Upstream view of approach to migrant tuna trap; (D) Migrant tuna trap. Arrows indicate flow pathway and direction. (Photos: Erica Williams).

Overall, the majority of this sampling appears to have been focussed on wetland habitats to ascertain the distribution and abundance of the Burgundy mudfish (*Neochanna heleios*) (summarised in O'Brien & Dunn 2007). In addition shortfin (*Anguilla australis*) and longfin eels (*A. dieffenbachii*), banded kōkopu (*Galaxias fasciatus*), common smelt (*Retropinna retropinna*), kōura/kēwai (*Paranephrops spp*.) and the introduced species goldfish (*Carassius auratus*), mosquitofish (*Gambusia affinis*) and silver carp (*Hypophthalmichthys molitrix*) have been observed in the Utakura River and Lake Omapere catchment.

Wells & Champion (2008) extracted fish records for the Northland Region (comprising 295 records since 1980) from the NIWA Freshwater Biodata Information System (*see* FBIS, fbis.niwa.co.nz.). In addition to the species recorded in the NZFFD, the FBIS has records of common bully (*Gobiomorphus cotidianus*) and brown bullhead catfish (*Amieurus nebulosus*). In 2001, 15 large catfish were caught in the lake with fyke nets, but they have not been seen since (Ian Mitchell, pers. comm.). As mentioned previously, two introduced carp species (grass and silver) have been deliberately released into Lake Omapere for algal and weed control, but these species are unable to breed in lakes and most New Zealand rivers.

It is estimated that 60 tonnes of tuna were removed from the lake after a period of intensive fishing between 1999–2001, prior to stocking with grass carp (G Jamieson, pers. comm. *in* Champion & Burns 2001). Commercial eel fishing is known to have occurred in Lake Omapere in recent times and this data is summarised in Section 2.6.

2.5 Commercial eel fishing

History

In export terms, the commercial eel fishery in New Zealand began in earnest in the 1960s and expanded rapidly until the early 1970s, peaking at slightly over 2000 t in 1972 (MFish 2008). The commercial catch fluctuated over the following years and it was not until the 1980s that management constraints were introduced. A minimum size of 150 g was introduced in 1981 (this was increased in 220 g in 1992), with part-time fishers being excluded from the industry in 1984 and a moratorium on the issue of new fishing permits in 1988. In the following years, on a voluntary basis, the eel fishing industry agreed not to increase commercial fishing effort beyond the level of the late 1980s in a further attempt to reduce pressure on stocks. Regional management plans were created for the regions of the South Island in the 1990s. In October 2000, South Island eel stocks were introduced into the quota management system (QMS).

Under the QMS, commercial fishers are limited to a total allowable commercial catch (TACC) for each eel stock management area and their catch in an area is monitored against these limits. The overall total allowable catch (TAC) (which includes the catch of both commercial and non-commercial interests) is set to ensure that the current use of the eel fishery is more conservative than the catch previously taken from the fishery. This approach aims to protect eel stocks by permitting some fishing activity but reducing fishing pressure overall.

In October 2003 the Chatham Islands shortfin and longfin eels stocks entered the QMS, with the North Island also entering the quota management system in October 2004. For the North Island, quota decisions for the two eel species were made separately, with a longfin quota set at 18% below recent commercial catches in recognition of the fact that longfin were being harvested at a rate considered unsustainable by many fisheries managers.

Current management

Currently, the North Island commercial eel fishery is divided into four quota management areas (QMA) for eels, with both shortfin and longfin stocks in each QMA sharing common boundaries with the other management areas. The QMAs for shortfin eel also include the Australian longfin eel (*Anguilla reinhardtii*) despite comparatively few individuals of this species being landed each year, and despite this species not being found in the South Island. For the Chatham Islands, both eel species are considered under one QMA. In the South Island, there are six QMAs for freshwater eels (Figure 1).

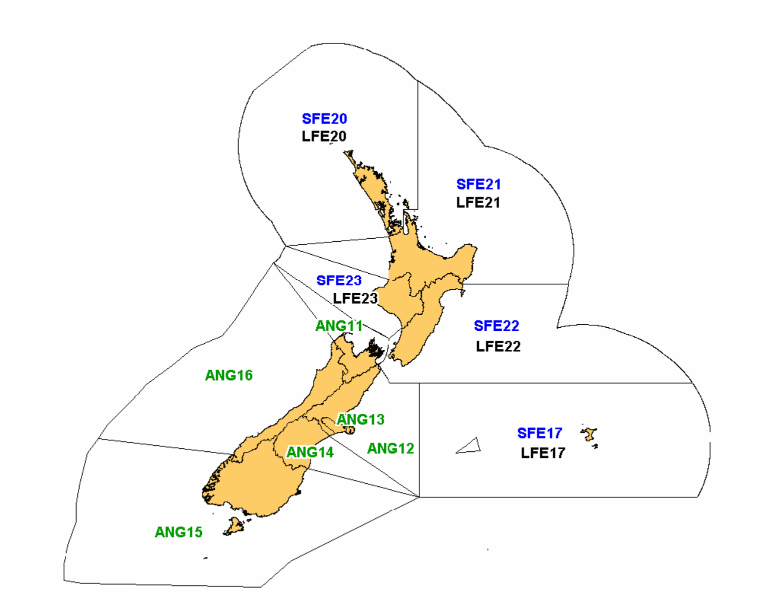

Figure 1. Map of stock quota management areas (QMAs) for commercially fished freshwater eels. LFE denotes longfin eels, SFE denotes both shortfin eels and Australian longfin eels. ANG is a combined code for longfin and shortfin eels (MFish 2008).

In 2007–2008, the TACC for longfin eels in all areas of the North Island and Chatham Island was 82 t under the QMS. For the same area, the TACC shortfin eel was 347 t. For freshwater eels in the South Island, the TACC was set at 420.1 t. All TACCs were reduced significantly from those set in 2007, with those for shortfin eels reducing from 10 to 30% depending upon the management area and those for longfin eels reducing by 35 to 48%. Since 2004–05, the actual catch recorded in New Zealand and Chatham Island as a whole has not reached the TACC. This may be due to reductions in fishing effort through the QMS and the effects of insufficient market demand. In 2007, a 4 kg maximum limit for freshwater eels that protects the large female longfins was introduced to all commercial fisheries in New Zealand. The sustainability of the fishery under current levels of harvest is unknown (MFish 2008).

Structure of the commercial catch

Commercial catch data between 1984 and the present indicates that the North Island provides 65% of the total New Zealand commercial eel catch; 66% of which are shortfin eels (Beentjes 2008a). Data from North Island processing factories in 2005–06 and 2006–07 (which cover 88 to 99% of all landings in each fishing season respectively) indicated that around 23% of the catch were longfin, with the remainder being shortfin eels. Data from the South Island processing factories in 2006–07 (which cover all landings in the fishing season) indicated that 78.5% of landings were longfin eels (Beentjes 2008a). This contrasts with data collected in the 1970s and early 1980s which indicated that around 90% of the eels processed in the South Island were longfin (Beentjes 2008b). Data from the North Island displays a similar picture, with an estimated decrease of 10–20% in current catches of longfin eels when compared with historical catches (Beentjes 2008b). This observed decrease in the proportion of longfin landed has been further supported by other analyses (Beentjes & Dunn 2003a, 2003b). In summary, it appears that on the basis of these recent figures, that a greater proportion of the freshwater eel catch processed in the North Island are shortfin, with longfin eels being processed in greater numbers in the South Island. However, proportionally, less longfin eels are being caught at present than historically.

Data collected from processing factories between the 1970s and 1990s, in both the North and South Islands, indicated that there has been a general decrease in the size of eels being landed (Beentjes & Chisnall 1997, Beentjes 2005). The current population structure of longfin eels caught in the main stems of South Island rivers indicates that the mean length is now c. 540 mm (and mostly males), compared to lengths of c. 600–900 mm in the 1930s and 1940s (Beentjes et al. 2006). This may indicate that adult female longfins have been overfished. For the North Island, records from both processing companies (New Zealand Eel Processing Co. Limited (New Zealand Eel, Te Kauwhata) and Aotearoa Fisheries Limited (Whenuapai)) indicate an increase in the size of longfins captured between 2003 and 2006. The records from both North Island processing factories also show that in 2003–04 and 2004–05 over one third of the longfin eels captured were female (Beentjes 2008b). These data demonstrates how vulnerable large female longfin eels are to being captured and removed from the fishery. This may have implications for future recruitment.

Market

The fishery has both a domestic and export market. In New Zealand, processed as well as live eels are available from markets and suppliers, with eel presented in restaurants all around the country. The New Zealand eel fishery has an estimated value of $6.1 m for export (MFish 2009), which equates to around 830,000 kg. In Belgium, Germany, Hong Kong (Special Administrative District), Italy, Republic of Korea, Netherlands, Taiwan, United States of America and the United Kingdom there is demand for New Zealand eels, which may be processed into various forms, frozen or sold as live eels. In Japan, freshwater eels are considered a delicacy and importing eels has become increasingly important in light of declines in Japan's domestic eel catch (Statistics New Zealand 2005).

2.6 Commercial eel fishing in the Northland Region

The quota management areas for the Northland commercial eel fishery is LFE 20 and SFE 20 (Figure 1). These areas range from approximately Pukekohe northwards (excluding the Coromandel). To provide more detail about how much (including species and size ranges) is being landed from different region within each reporting area the QMAs are broken down into Eel Statistical Areas (ESA) and finer scale Eel Statistical Area sub-areas (broadly equivalent to catchments). The ESA relevant to Tai Tokerau is coded AA Northland, and ranges in area from approximately Wellsford northwards. The Northland ESA has then been divided into five subareas, coded 1A–1E. The ESA sub-area which encompasses Lake Omapere and the Utakura River catchment is coded 1B Hokianga Harbour. In addition, sub-area 1B also contains the Mangamuka, Orira, Waihou, Waipapa, Whakanekeneke, Waimamaku and Waipoua Rivers. Lake Omapere is the largest lake within the Northland ESA.

The total weights landed and species composition from ESA sub-area 1B Hokianga Harbour, ESA AA Northland and the contribution of this region to New Zealand's overall commercial eel landings between 2003–04 and 2006–07 are shown in Table 2 (taken from Beentjes 2008a).

Commercial catches from the Hokianga Harbour subarea peaked in 2004–05 when it contributed more than 30% of the overall commercial catch from Northland for both shortfin and longfin eels. A significant decline in the contribution of longfin tuna to the commercial eel catch landed from the Hokianga Harbour sub-area has been observed between 2003 and 2007. This decline is not evident in the composition of the overall catch from Northland.

Over the four years examined by Beentjes (2008a) the Northland Region contributed between 13.5–21.2% and 17.6–26.0% of the commercial longfin and shortfin eel catch landed respectively.

Lake Omapere

Commercial eel fishing is undertaken in Lake Omapere and we are very grateful to Mr Ian Mitchell for providing his records for inclusion in this report (Ian Mitchell, pers comm.) (Table 3).

Table 3. Total weights (kg) of freshwater eels landed from Lake Omapere between 2000 and 2008 (I. Mitchell, pers comm.).

Year	Total weight (kg)
2000	52,272
2001	19,916
2002	Data missing
2003	No data, estimate of 13,000
2004	7,270
2005	8,646
2006	19,162
2007	16,479
2008	8,666

Mr Mitchell typically deploys about 60 fyke nets at a time, and in 2000 he fished for almost the whole year with the exception of the winter months. Since this time, he has fished the lake for about one month per year.

Mr Mitchell articulates that in the first year of fishing the lake he caught “quite a few” large longfin eels in the inlet drain. However, almost 99% of the catch now consists of shortfins. In 2000 the catch consisted of mostly large eels, but they were not in good condition and were ‘skinny’. In his opinion the quality of the eels in the lake has improved since 2000.

Table 2. Total weights (kg) of freshwater eels landed and species composition from ESA sub-area 1B Hokianga Harbour, ESA AA Northland and the contribution of this region to New Zealand's overall commercial eel landings between 2003–04 and 2006–07 (taken from Beentjes 2008a).

	Eel statistical sub-area Hokianga Harbour (1B)			Eel statistical area[a] Northland (AA)[c]			Aotearoa-wide[b] All sub-areas (AA–AY)		
Year	**Longfin**	**Shortfin**	**% longfin**	**Longfin**	**Shortfin**	**% longfin**	**Longfin**	**Shortfin**	**% longfin**
2003–04	3,912	7,871	33.2	22,353	77,868	22.3	105,281	299,386	26.0
				(17.5%)	(10.1%)		(21.2%)	(26.0%)	
2004–05	6,677	18,338	26.7	19,166	54,326	26.1	120,240	265,883	31.1
				(34.8%)	(33.8%)		(15.9%)	(20.4%)	
2005–06	634	13,921	4.4	13,847	58,362	19.2	102,651	334,578	23.5
				(4.6%)	(23.9%)		(13.5%)	(17.4%)	
2006–07	171	18,555	0.9	17,560	72,143	24.3	99,788	338,770	22.8
				(1.0%)	(25.7%)		(17.6%)	(21.3%)	
TOTAL	*11,394*	*58,685*	*19.4*	*72,929*	*262,699*	*21.7*	*427,960*	*1,238,617*	*25.7*
(2003–07)				*(15.6%)*	*(22.3%)*		*(17.0%)*	*(21.2%)*	

[a], Values in brackets represent contribution of ESA subarea 1B Hokianga Harbour to totals obtained for the Northland ESA (i.e., 1A–1E).

[b], Values in brackets represent contribution of Northland ESA (i.e., AA) to totals obtained for Aotearoa (i.e., AA–AY).

[c], Northland ESA is broken up into the following subareas: 1A = Kaitaia; 1B = Hokianga Harbour; 1C = Bay of Islands; 1D = Dargaville; 1E = Bream Bay.

3. Methods

All of the field work conducted in this survey was undertaken by NIWA staff and members of the Lake Omapere Trust. While Lake Omapere was the core focus of this survey, the opportunity was also taken to sample selected sites downstream in the Utakura River catchment. Field sampling was undertaken between the 10–14 November 2008 (Full Moon, 13 November). Locations of the 19 sites sampled are shown in Figure 2 with details provided in Table 4.

Table 4 Location of sites sampled within the Lake Omapere and Utakura River catchment.

Site No.	Location[1] (access)	Date sampled (2008)	NZMS coordinates	Fishing methods[2]
1	Lake Omapere (State Highway 1)	10 Nov	E2584877, N6650915	5 CFYN, 5 FYN, 5 GMT
2	Lake Omapere	10, 11 & 12 Nov	E2584071, N6651444	5 CFYN, 5 FFYN, 5 GMT
3	Lake Omapere	10 Nov	E2585431, N6650110	5 CFYN, 5 FFYN, 5 GMT
4	Lake Omapere	10 Nov	E2584245, N6650352	4 CFYN, 4 FFYN,
5	Lake Omapere	10 & 11 Nov	E2584840, N6650748	30 m Gill net
6	Lake Omapere	11 & 12 Nov	E2581945, N6651617	5 CFYN, 5 FFYN
7	Lake Omapere	11 Nov	E2582452, N6648265	5 CFYN, 5 FFYN
8	Lake Omapere	12 Nov	E2581054, N6649069	5 CFYN, 5 GMT
9	Lake Omapere	12 Nov	E2583021, N6650916	5 CFYN, 5 FFYN
10	Waikirikiri Stream (Waikerikeri Road)	10 Nov	E2571590, N6648971	EFM (48.6 m^2)
11	Waikirikiri Stream (Waikerikeri Road)	10 Nov	E2571561, N6648957	EFM (56 m^2)
12	Waikirikiri Stream (Mangataraire Road)	10 Nov	E2572217, N6649532	EFM (30 m^2)
13	Waihoanga Stream (Imms Road)	12 Nov	E2578362, N6648641	EFM (30 m^2)
14	Utakura River (Imms Road)	12 Nov	E2578358, N6648658	EFM (36 m^2)
15	Utakura River (Horeke Road)	11 Nov	E2574359, N6650484	EFM (60 m^2)
16	Unnamed tributary (Te Pua Road)	13 Nov	E2584550, N6648240	EFM (16 m^2)
17	Unnamed tributary (farm drain) (Te Pua Road)	13 Nov	E2584780, N6648656	EFM (16 m^2)
18	Unnamed tributary (farm drain) (Te Pua Road)	13 Nov	E2585328, N6648980	EFM (9 m^2)
19	Pararataio Stream (Te Pua Road)	13 Nov	E2585678, N6649355	EFM (75 m^2)

[1], Names of locations as known locally may be different from that on NZMS 260 series topomaps.

[2], Fishing methods: CFYN = Coarse mesh fyke net; FFYN = Fine mesh fyke net; GMT = Gee-minnow trap; EFM = Electric fishing.

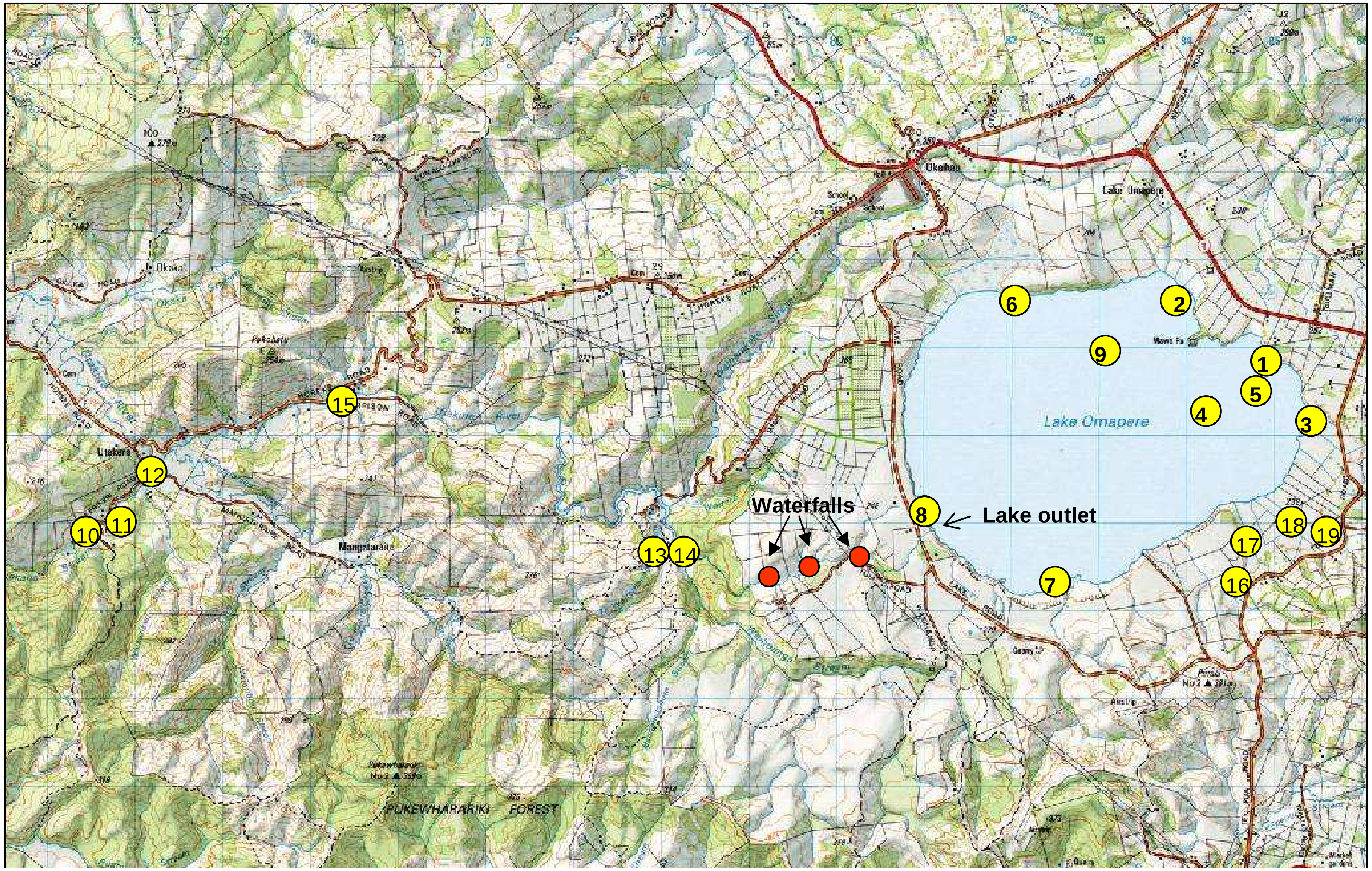

Figure 2. Approximate locations of sites sampled within the Lake Omapere and Utakura River catchment, November 2008.

3.1 Sampling methods

A combination of sampling methods, primarily targeting tuna, were utilised during the present survey including (Photo 3):

- Coarse mesh fyke nets (single leader, 15 mm mesh, baited);
- Fine mesh fyke nets (single leader, 6 mm mesh, baited);
- Electric fishing (EFM300, battery powered backpack);
- Gee-minnow traps (3 mm mesh, baited);
- Gill net (with three 10 m panels of 25, 45 and 65 mm mesh respectively).

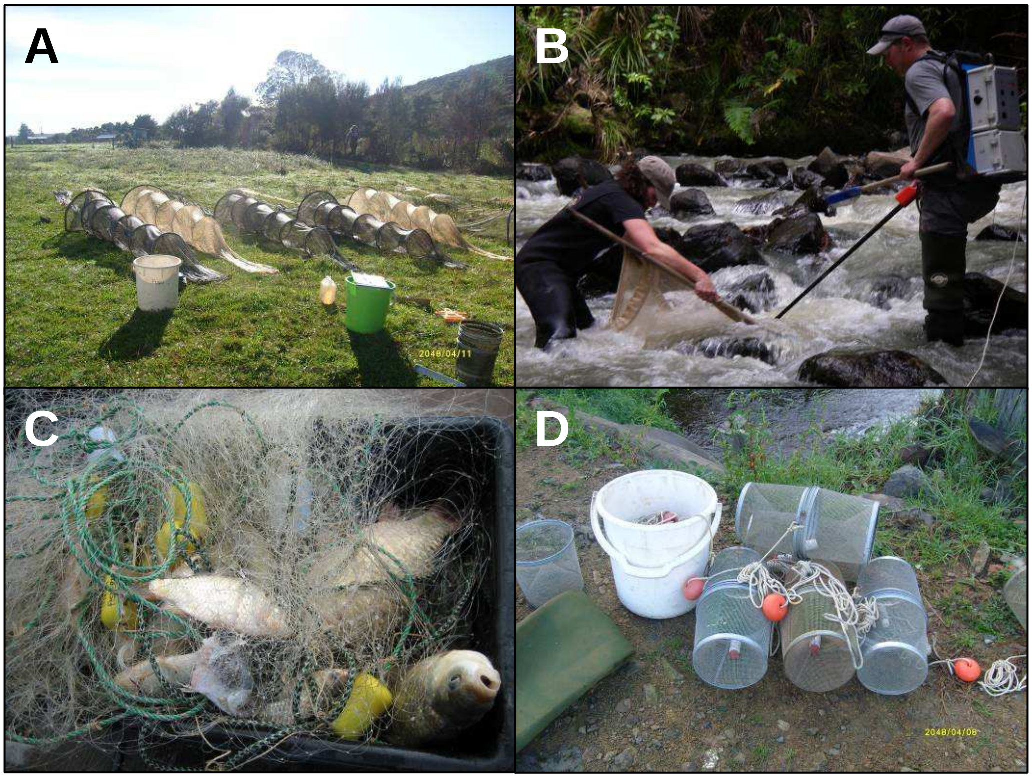

Photo 3. Sampling methods utilised during the survey of Lake Omapere and the Utakura River catchment. (A) Coarse mesh (black) and fine mesh fyke nets; (B) Electric fishing; (C) Gill net; (D) Gee-minnow traps. (Photos - A & D: Norma Cooper; B & C: Wakaiti Dalton).

Fleets comprised of 8–10 fine and coarse meshed fyke nets per site. Eight locations were fished within Lake Omapere representing a range of representative habitats (e.g., close to shore alongside different land uses, mid-water). At Sites 4 and 9 an even mixture of coarse and fine-meshed fykes were tied together in a ‘train’ and set in mid water. At other locations, every fyke net was secured at each end near the shore line using wooden stakes and weights. Gee-minnow traps were set alongside coarse meshed fykes on the first night of fishing and only at Sites 1, 2 and 3 (i.e., 10 November 2008). The single 30 m gill net was set for two nights perpendicular to the shore at Site 5.

The fyke nets were all baited with catfood held in punctured pouches (primarily pilchard flavoured) and set overnight. The Gee-minnow traps were baited with fish food pellets held in punctured plastic bottles.

According to Jellyman & Graynoth (2005), depletion netting (nets set over consecutive nights in the same location) can provide an estimate of a population within the area fished and an estimate of the proportion of the population caught on one night only. The application of this technique in static waters such as lakes has not been determined previously. Therefore in this study, nets at Site 2 were reset for three consecutive nights, and nets at Site 6 were reset for two consecutive nights.

A combination of multiple pass (exhaustive, quantitative) and single pass (semi-quantitative) electric fishing sampling was also undertaken in the Utakura River and selected tributaries. The 10 sites sampled using electric fishing were: Waikirikiri Stream (N = 3 sites), Utakura River and Waihoanga Stream (N = 3 sites), tributaries on the south eastern flank of Lake Omapere (N = 3 sites) and Pararataio Stream (N = 1 site).

All nets and other equipment used had been previously sanitised and dried to minimise the risk of spreading unwanted species. All of the goldfish (*C. auratus*) and grass carp (*C. idella*) captured during the survey were removed from the site at the request of the Lake Omapere Trust members (Photo 4). Apart from the tuna retained for ageing purposes and kōkopu species that were preserved to confirm identification, the remaining fish caught were returned live at the point of capture.

The sites sampled were referenced by GPS, and at each site we recorded date, catchment name, time, observer, length of waterway fished, tidal influence, presence of downstream barriers, average stream width, average stream depth, habitat type (e.g., % pool, run, riffle), substrate type (e.g., % mud, sand, gravel, boulder), riparian vegetation (e.g., % native, exotic, shrub, willow), surrounding land use type (e.g., native, farming, urban) on standard New Zealand freshwater fish database forms (which can be downloaded from http://neptune.niwa.cri.nz/fwdb/NZ%20FRESHWATER%20FISH%20DATABASE%20FORM.doc) (*see* **Appendix 4** for summary of habitat characteristics).

3.2 Catch processing

All of the eels caught were anaesthetised (using a clove oil based mixture), identified by species, measured (to the nearest 1 mm), and weighed (to the nearest 1 g). Where possible, the sex and stomach (diet) contents were identified for each tuna that was sacrificed for ageing purposes. The swim bladder was also examined for the presence of any parasites. By-catch information (species, numbers captured and fork length) was also recorded.

Photo 4. Goldfish (top) and grass carp (middle and bottom) removed from Lake Omapere, November 2008 (Photo: Tracey Dalton).

3.2.1 Otolith removal and processing

For ageing purposes, saggital otoliths were removed from a selection of the eels captured. These eels were sedated in clove oil and euthanased by severing of the notochord at the base of the head followed by bleeding (all processed eels were retained for consumption by the Lake Omapere Trust). Otoliths were removed (Photo 5) and prepared following the methods of Hu & Todd (1981). Essentially this method consists of breaking the otolith 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 uppermost. Mounted otoliths were viewed using a compound microscope and annual hyaline rings counted across the largest axis.

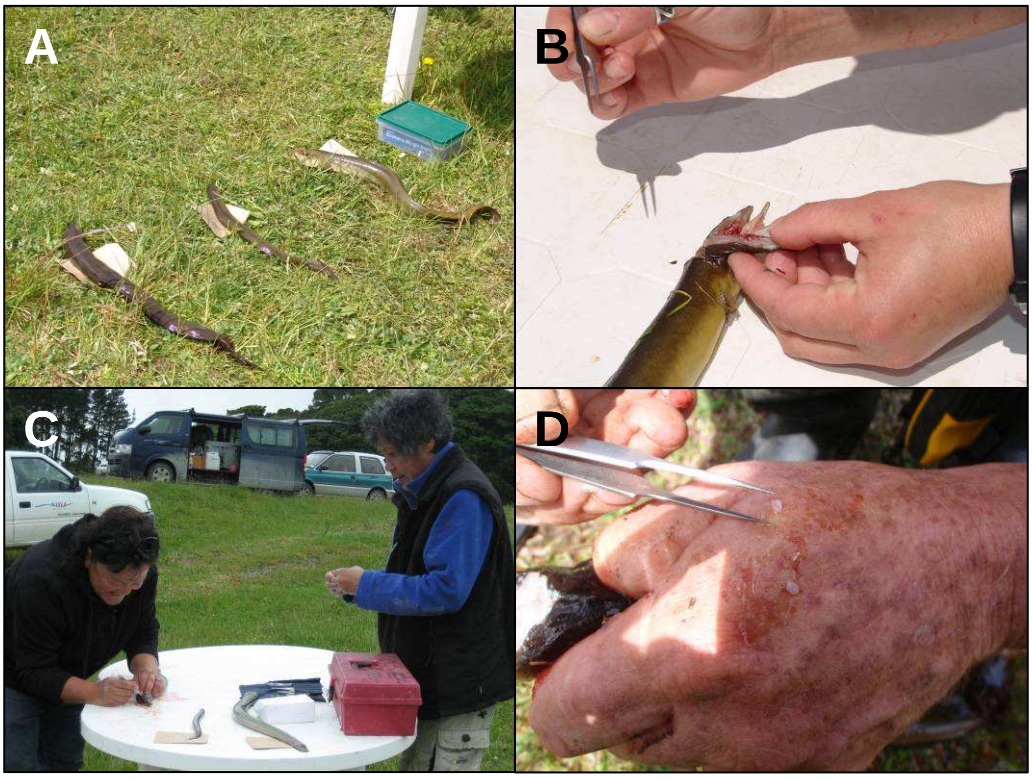

Photo 5. Some of the steps in the otolith removal process. (A) Tuna after they have been identified by species, measured & weighed ready with labelled paper envelopes for otolith removal; (B) Cutting through tuna skull to reveal otolith cavities; (C) Removing two otoliths from each side of the tuna's head; (D) Otoliths placed on the back of the hand to help remove the transparent membrane sac material surrounding each otolith, before placing into paper envelopes. (Photos - A & B: Tracey Dalton; C: Wakaiti Dalton; D: Bruce Davison).

Age was expressed in terms of years in freshwater, ignoring the first ring that surrounds the core because this represents marine larval growth. Some of the otoliths processed from Lake Omapere were found to be difficult to read with large numbers of multiple rings (possibly false rings – several rings are produced within one year) present. For the purpose of this study a conservative approach was taken and most multiple rings were ignored. For quality assurance purposes a subset of the otoliths were examined by three fisheries biologists experienced in reading eel otoliths.

3.2.2 Sex composition

The sex composition was determined using a combination of two methods. The first involved field observations of gonads from eels that were sacrificed for ageing (Photos 6 & 7). In this assessment the gonad descriptions of Beentjes & Chisnall (1998) and the field key developed by Jellyman *et al.* (2006) were used. The second criteria 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 eel features (i.e., enlarged eyes, darkened pectoral fin, flatter and slender head, silver (for shortfins) or bronze (for longfins) colour).

Photo 6. Example of a shortfin female eel from Lake Omapere, November 2008 (Photo: Tracey Dalton).

3.2.3 Diet

A qualitative visual assessment of the stomach contents of eels sacrificed for ageing was undertaken in the field, to identify the main prey species forming the food base for eels in this catchment. After making an incision along the length of the underside of the tuna with a sharp knife, the stomach was located and cut open lengthways. The contents were removed with tweezers onto a clean surface, visually examined and the items assigned into categories (e.g., aquatic *vs.* terrestrial items) where identifiable (Photo 8). If no contents were found, the stomach was recorded as empty.

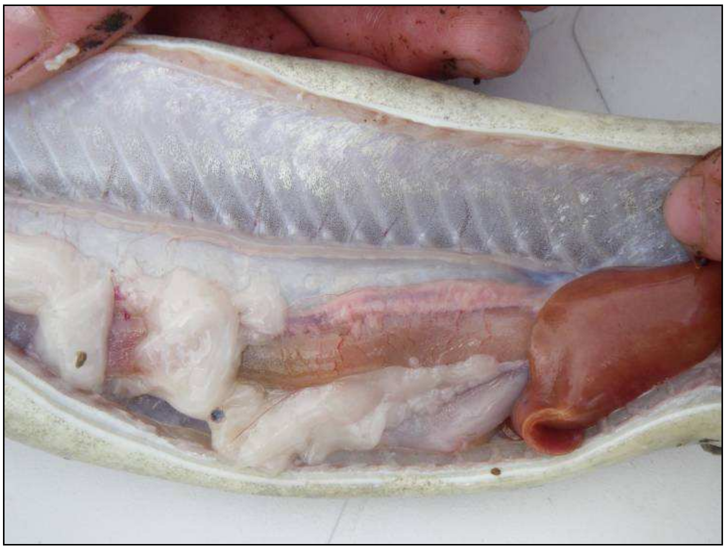

Photo 7. Example of a shortfin male eel from Lake Omapere, November 2008 (Photo: Jacques Boubée).

3.3 Data analysis

The catch per unit effort (CPUE) for fyke net catches is expressed as number/net/night and kg/net/night for each species (where information available).

The length and weight data were examined for normality using histograms and the Shapiro-Wilks W test in STATISTICA 7.1 (Statsoft, Inc., 2005). Data that did not satisfy the conditions of normality were transformed. At sites where some eels were not weighed on-site, derived weights were calculated using length-weight regression equations. These estimated weights as well as actual weight (where available) were then used to obtain estimates of total biomass (kg/net and g/m^2) for each site. A two-sample Student's *t*-Test (two-tailed) assuming unequal variances was used to observe any differences in the overall CPUE values by net type (i.e., coarse mesh *vs.* fine mesh fyke nets).

Growth rates of eels were 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, but it is recognised that growth immediately following river entry can be more rapid (Jellyman 1997). Growth rates at 15 and 20 years were calculated from length-at-age linear regressions for tuna from the Lake Omapere catchment. This indication of the estimated linear growth between 15 and 20 years (or as close as possible to these ages) was then compared to published figures as summarised in Jellyman (1997).

Photo 8. Example of a shortfin tuna's stomach contents being examined on the shores of Lake Omapere, November 2008 (Photo: Tracey Dalton).

For comparison of growth rates between the sites within the Lake Omapere catchment, a length of 60 mm was subtracted from the total length of shortfins, being the average length of glass eels on entry to river mouths; the equivalent length for longfins was 63 mm. The resulting length was then divided by the age of the eel to provide an average annual length increment (mm/y). To obtain an historical index of recruitment from age frequency distributions, the ages of eels greater than 300 mm were estimated using the derived age-length regressions.

4. Results

4.1 Species composition

A total of 929 tuna (271 kg) were captured during the survey with 73% of this catch obtained from Lake Omapere. Overall 11% of the catch were longfin eels. The highest proportion of longfins (67%) occurring in the Waihoanga Stream, a tributary of the Utakura River. The next highest proportion of longfin (35%) in the catch was obtained in the Waikirikiri Stream. In comparison, longfins made up only 5% of the total catch from the mainstem of the Utakura River (2 sites sampled). Overall longfin tuna comprised 9% of the total catch from Lake Omapere and it's south-western tributaries, and 17% of tuna from the Utakura River and associated tributaries (Table 5).

Table 5. Species composition of tuna sampled from the Lake Omapere and Utakura catchment.

Location	Site No.	Site	Total number	Total weight (kg)	% longfin
Lake Omapere	1	Lake Omapere	42	13.0	29
	2	Lake Omapere (reset, 3 nights)	40	18.2	15
	3	Lake Omapere	51	20.3	10
	4	Lake Omapere (train, deep set)	52	26.9	0
	5	Lake Omapere (reset, 2 nights)	–	–	–
	6	Lake Omapere (reset, 2 nights)	121	57.0	8
	7	Lake Omapere	40	13.7	18
	8	Lake Omapere	317	105.9	5
	9	Lake Omapere (train, deep set)	12	0.9	8
	16	Unnamed tributary	2	1.0	0
	17	Unnamed tributary	10	0.8	0
	18	Unnamed tributary	8	3.7	38
	19	Pararataio Stream	3	1.2	33
		OVERALL	*698*	*263*	*9*
Utakura River	10	Waikirikiri Stream	16	0.9	63
	11	Waikirikiri Stream	14	1.3	64
	12	Waikirikiri Stream	35	2.4	11
	13	Waihoanga Stream	12	2.0	67
	14	Utakura River	17	1.4	12
	15	Utakura River	137	0.6	4
		OVERALL	*231*	*9*	*17*
		TOTAL	**929**	**271.2**	**11**

4.2 Catch per unit effort (CPUE)

Catch per unit effort data (by number and biomass of tuna) are summarised in Tables 6 (electric fishing) and Table 7 (fyke nets). In terms of both numbers and biomass captured over a single night of fyke netting, the highest number of both shortfins and longfins were caught at Site 8 (close to shore set near the lake outlet) (Figure 3). No longfins were captured at Site 4 (set in ‘open’ mid-water), and low numbers observed at Site 9 (also a mid-water set). The lowest numbers of shortfin tuna were observed at Sites 2 (close to shore set, Mawe Pa) and 9 (set in mid-water) (Table 7, Figure 3). No significant difference in the catches (CPUE by number) of either longfin or shortfin tuna between the fine mesh and coarse mesh fyke nets was observed in this survey (Student’s two-tail *t*-Test, $P > 0.05$, $N = 11$).

Table 6. Relative density (no./m^2) and biomass (kg/m^2) of tuna from sites in the Lake Omapere and Utakura river catchment surveyed by electric fishing.

Location	Site No.	No. passes	Area fished (m^2)	Relative density (no./m^2)		Relative biomass (kg/m^2)	
				Longfin	Shortfin	Longfin	Shortfin
Utakura River	10	2	49	0.21	0.12	0.017	0.000[a]
	11	2	56	0.16	0.09	0.026	0.000[a]
	12	2	30	0.13	1.03	0.026	0.054
	13	2	30	0.27	0.13	0.066	0.000[a]
	14	3	36	0.06	0.42	0.039	0.001
	15	2	60	0.10	2.18	0.004	0.006
Lake Omapere tributaries	16	1	16	0.00	0.13	0.000	0.017
	17	1	16	0.00	0.63	0.000	0.013
	18	1	9	0.33	0.56	0.201	0.209
	19	1	75	0.01	0.03	0.003	0.014

[a], Shortfin elvers present.

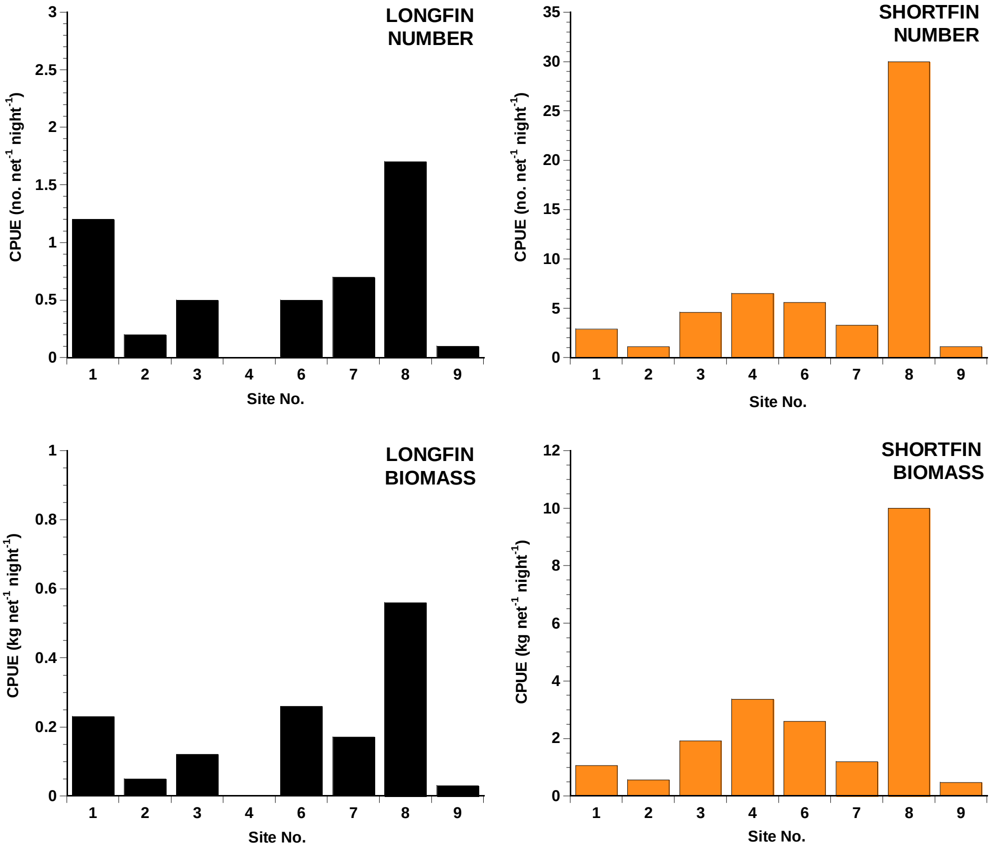

Figure 3. Catch per unit effort (CPUE) by number and biomass for longfin (left) and shortfin (right) tuna captured in fyke nets set Lake Omapere. Note different scales on graphs.

Table 7. Catch per unit effort (CPUE, no./net /night and kg/net/night) for tuna captured from Lake Omapere using fyke nets (CFYN = Coarse mesh; FFYN = Fine mesh; ALL = fyke net types combined).

		CPUE (no. net^{-1} $night^{-1}$)						CPUE (kg net^{-1} $night^{-1}$)					
		Longfin			Shortfin			Longfin			Shortfin		
Site No.	**Lift**	**FFYN**	**CFYN**	**ALL**	**FFYN**	**CFYN**	**ALL**	**FFYN**	**CFYN**	**ALL**	**FFYN**	**CFYN**	**ALL**
1		1.0	1.4	1.2	2.4	3.4	2.9	0.12	0.34	0.23	0.89	1.23	1.06
2	1	0.0	0.2	0.1	0.8	1.2	1.0	0.00	0.03	0.02	0.45	0.74	0.60
	2	0.0	0.0	0.0	1.6	1.0	1.3	0.00	0.00	0.00	0.92	0.50	0.62
	3	0.6	0.4	0.5	1.2	1.0	1.1	0.15	0.09	0.12	0.72	0.38	0.48
	ALL	0.2	0.2	0.2	1.2	1.1	1.1	0.05	0.04	0.05	0.59	0.54	0.56
3		0.2	0.8	0.5	4.8	4.4	4.6	0.05	0.19	0.12	2.13	1.68	1.91
4		0.0	0.0	0.0	4.8	8.3	6.5	0.00	0.00	0.00	2.44	4.29	3.36
6	1	0.4	0.4	0.4	5.0	10.0	7.5	0.12	0.22	0.17	2.20	4.86	3.53
	2	0.4	0.8	0.6	2.4	4.8	3.6	0.28	0.40	0.34	0.89	2.43	1.66
	ALL	0.4	0.6	0.5	3.7	7.4	5.6	0.20	0.31	0.26	1.55	3.64	2.59
7		0.4	1.0	0.7	2.8	3.8	3.3	0.11	0.23	0.17	0.96	1.44	1.20
8		0.0	3.4	1.7	30.6	29.4	30.0	0.00	1.13	0.56	9.52	10.53	10.03
9		0.2	0.0	0.1	1.4	0.8	1.1	0.07	0.00	0.03	0.40	0.54	0.47

Both longfin and shortfin eels were captured at sites surveyed by electric fishing in the Utakura River and associated tributaries (i.e., Sites 10–15). The highest number and biomass (per m^2) of longfin eels were observed at Site 13 (Waihoanga Stream). The highest number of shortfin eels (per m^2) was observed at Site 15 (Utakura River), and the highest biomass was observed at Site 12 (Waikirikiri Stream) (Table 6, Figure 4).

Although longfin eels were not recorded from either Sites 16 and 17, the highest numbers and biomass of longfin were observed at Site 18 (total area of 9 m^2 fished). While the highest numbers of shortfin eels were observed at Sites 17 and 18, the highest biomass was obtained at Site 18 (Table 6, Figure 4).

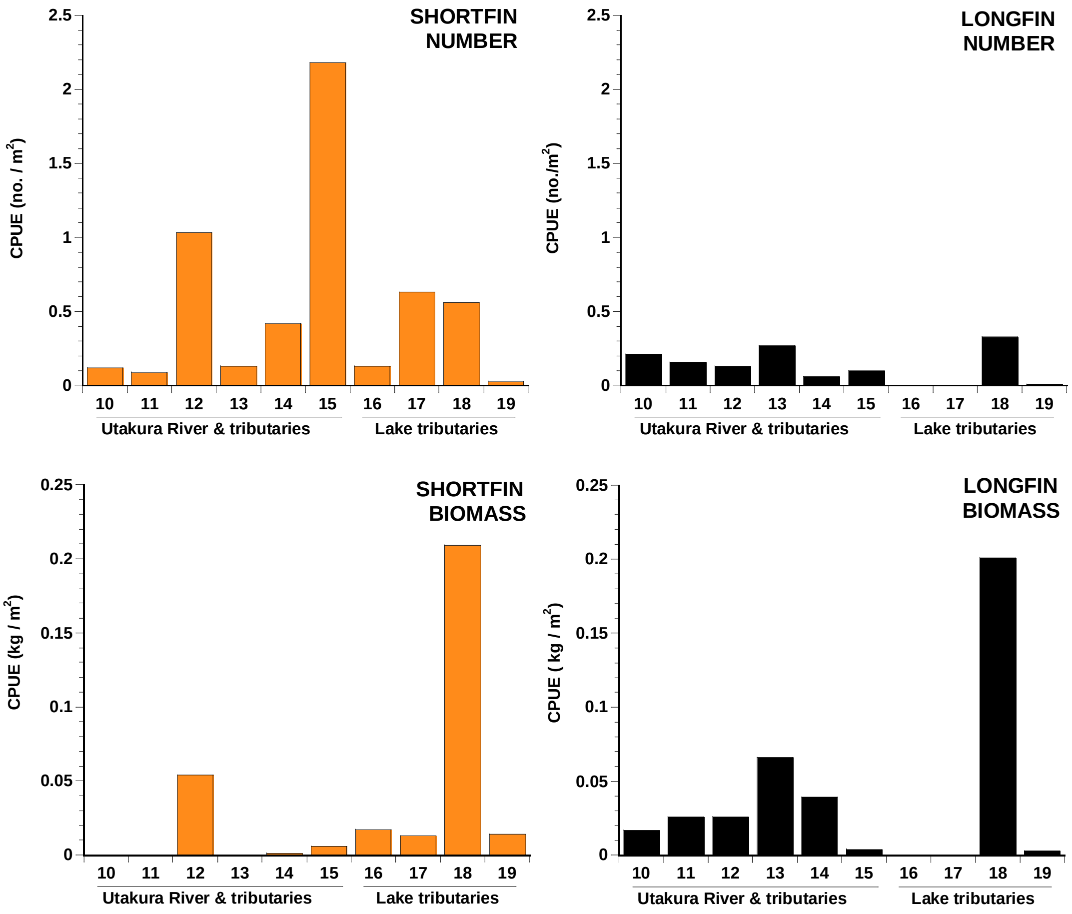

Figure 4. Catch per unit effort (CPUE) by number (no. / m^2) and biomass (kg / m^2) for longfin (left) and shortfin (right) tuna captured by electric fishing.

Fyke nets at sites 2 and 6 were reset in the same locations over 2-3 consecutive nights. No significant reduction in the numbers of eels captured over the consecutive nights fished was observed at either site, for either species. Although all of the records are not shown in the present report, the analysis did not indicate any significant differences (*P*>0.05) in the species composition or the length of eels being caught over consecutive nights (Figure 5).

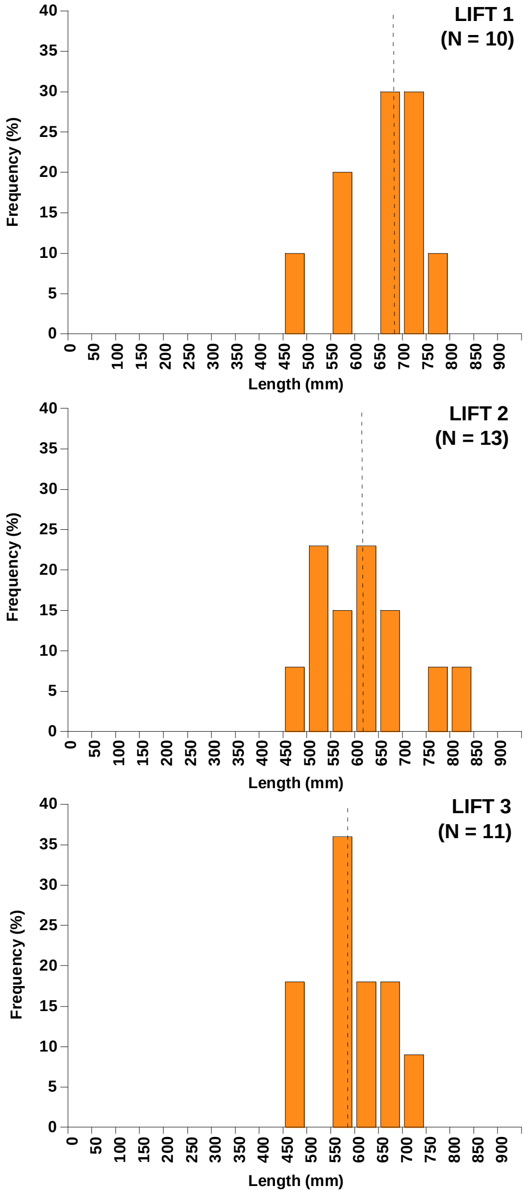

Figure 5. Length frequency (%) of shortfin eels captured over three consecutive nights fishing of Site 2, Lake Omapere. Dotted line indicates approximate median length.

4.3 Length and weight characteristics

The overall average length (± SD) of shortfin eels measured during this survey was 457 ± 218 mm (range 62–850 mm, median 525 mm) and 420 ± 137 mm (range 82–775 mm, median 445 mm) for longfin eels (Figure 6). The overall average weight (± SD) of longfin and shortfin eels measured during this survey was 286 ± 203 g (range 30–1,220 g) and 396 ± 214 g (40–1,290 g) respectively. A summary of the length and weight characteristics of tuna measured during this survey are presented in Table 8.

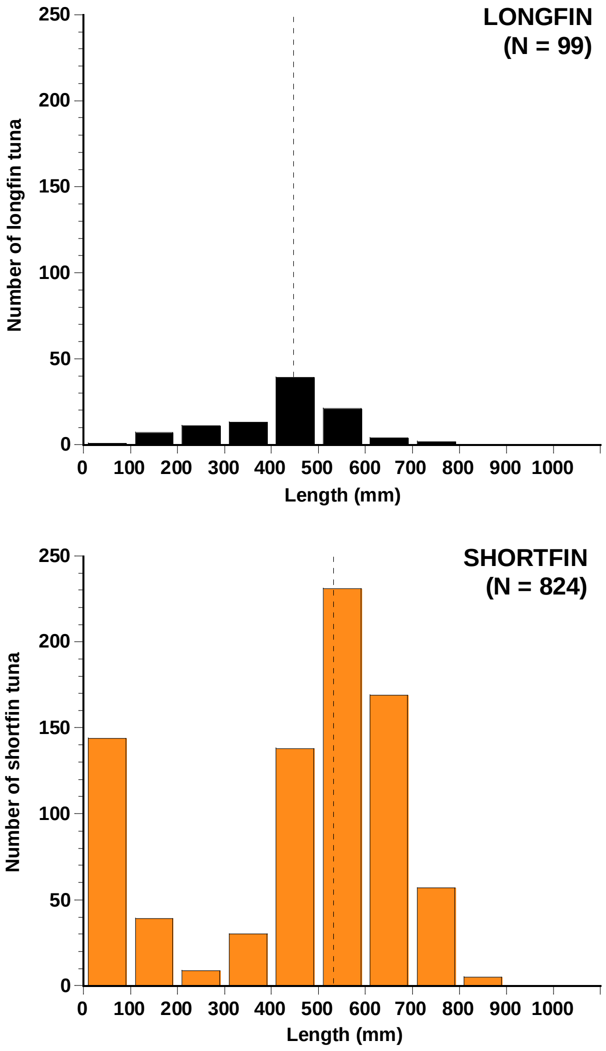

Figure 6. Length distribution (no.) of all tuna captured from the Lake Omapere and Utakura River catchment. Dotted line represents the median length of all tuna measured during this survey.

Table 8. Length and weight characteristics of tuna measured from the Lake Omapere and Utakura River catchment.

Site location[1]	Length (mm)						Weight (g)					
	Longfin			Shortfin			Longfin			Shortfin		
	N	Average ± SD	Range	N	Average ± SD	Range	N	Average ± SD	Range	N	Average ± SD	Range
Lake Omapere	57	472 ± 74	277–623	617	566 ± 101	268–843	57	307 ± 164	40–780	601	398 ± 213	40–1,290
Lake Omapere tributaries	4	530 ± 165	430–775	15	497 ± 170	155–700	–			–		
Utakura River	8	304 ± 215	82–745	146	94 ± 34	62–302	2	710 ± 721	200–1,220	–		
Waikirikiri Stream	22	313 ± 146	100–555	42	142 ± 136	69–850	16	178 ± 139	30–480	3	107 ± 61	40–160
Waihoanga Stream	8	405 ± 124	270–635	4	85 ± 4	80–90	8	246 ± 266	40–840	–		
Overall	*99*	*420 ± 137*	*82–775*	*824*	*457 ± 218*	*62–850*	*83*	*286 ± 203*	*30–1,220*	*604*	*396 ± 213*	*40–1,290*

[1], Sites were grouped as follows: Sites 1–9 = ‘Lake Omapere’, Sites16–19 = ‘Lake Omapere tributaries’, Sites 14–15 = ‘Utakura River’, Sites 10–12 = ‘Waikirikiri River’, Site 13 = ‘Waihoanga Stream’.

The length frequency of shortfin tuna was similar at the eight sites surveyed within Lake Omapere (Figure 7). In comparison, much smaller eels were captured in tributaries of the lake, being largely a reflection of the greater efficiency of electric fishing at capturing small eels. As expected, the length frequency of shortfins from the Utakura River catchment showed a predominance of small eels with approximately 75% of the total catch being elvers between 50–100 mm (Figure 8).

The length frequency of longfin tuna from Lake Omapere was also similar across the sites, with the majority of tuna being between 400–550 mm (Figure 9). Similar sized longfins were observed in the tributaries surrounding the lake. The largest longfin tuna captured during this survey was observed at Site 18. There were more smaller eels captured in the Utakura River compared to the lake and it's tributaries (Figure 10).

The relationships between length and weight for longfin and shortfin eels caught from Lake Omapere and the Utakura River was:

- Longfin: ln weight = 3.1052*(ln length) – 13.488 (where $N = 83$, $r = 0.98$, $P < 0.001$).

- Shortfin: ln weight = 2.9567*(ln length) – 12.861 (where $N = 604$, $r = 0.98$, $P < 0.001$).

The length distribution of tuna captured in this survey using the various sampling methods is presented (Figure 11, Table 9) to help illustrate some of the differences in the results observed above. For example, a lake versus a stream, will influence the range of species and size classes present, as well as the ability to deploy the various sampling methods. Only one shortfin eel was captured in the Gee-minnow traps set on the first night in Lake Omapere (360 mm total length). Coarse and fine mesh fyke nets generally captured tuna > 250 mm, while electric fishing was successful at sampling the smaller tuna size classes (60–200 mm) that were not evident using nets and traps (Figure 11, Table 9).

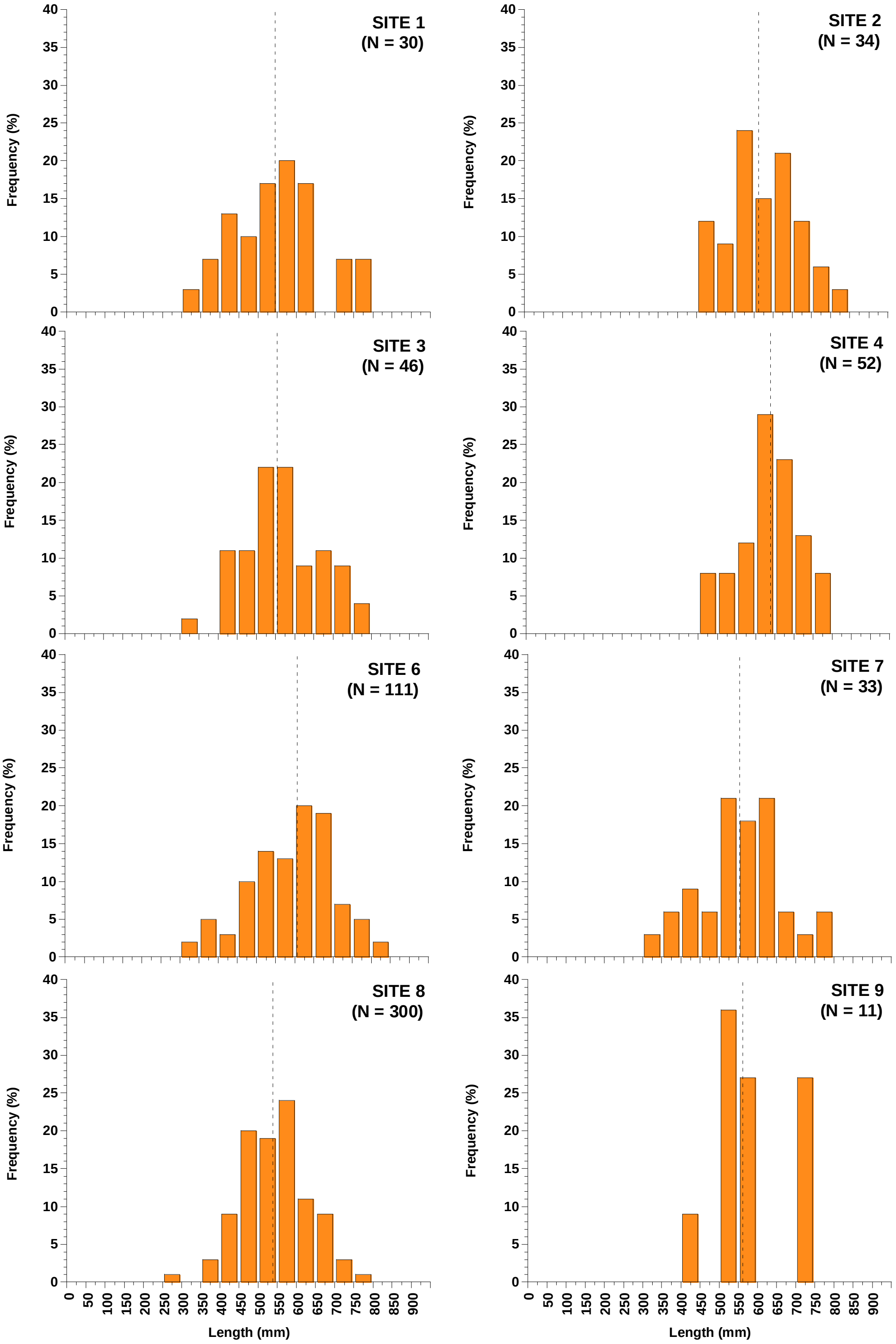

Figure 7. Length frequency (%) of shortfin tuna sampled from the eight sites surveyed within Lake Omapere. Dotted line indicates approximate median length.

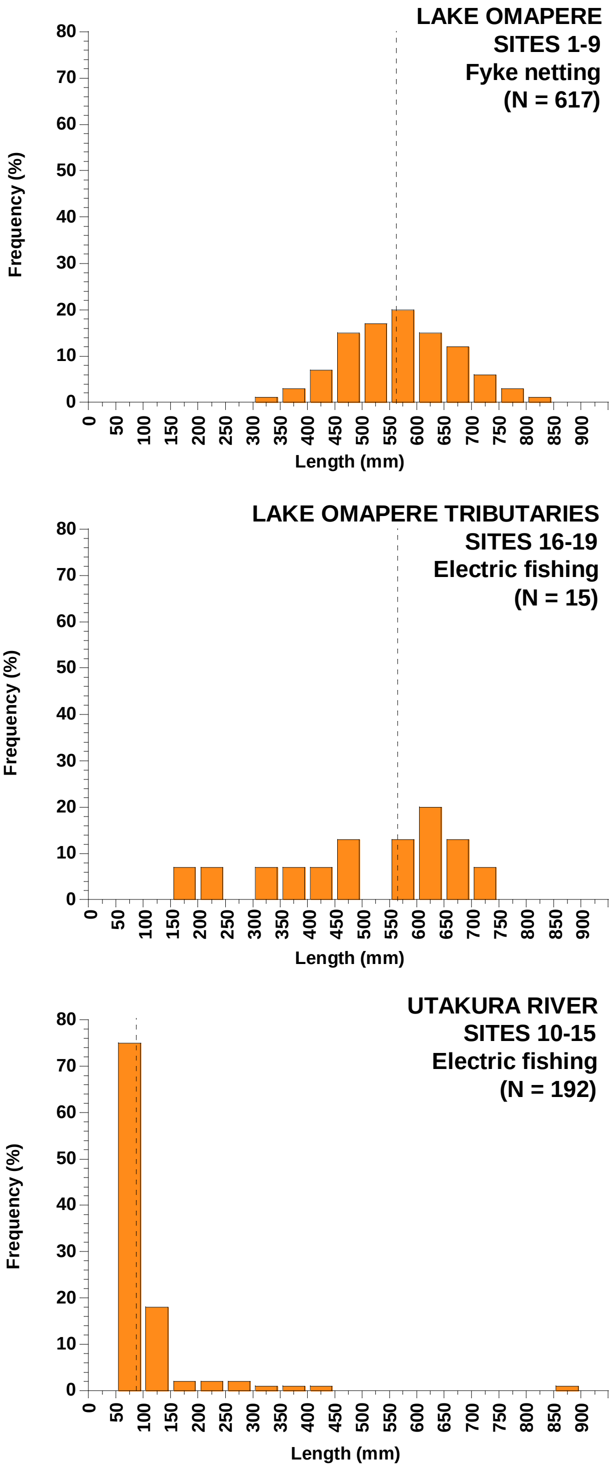

Figure 8. Length frequency (%) of shortfin tuna sampled from Lake Omapere, the tributaries of Lake Omapere, and the Utakura River. Dotted line indicates approximate median length.

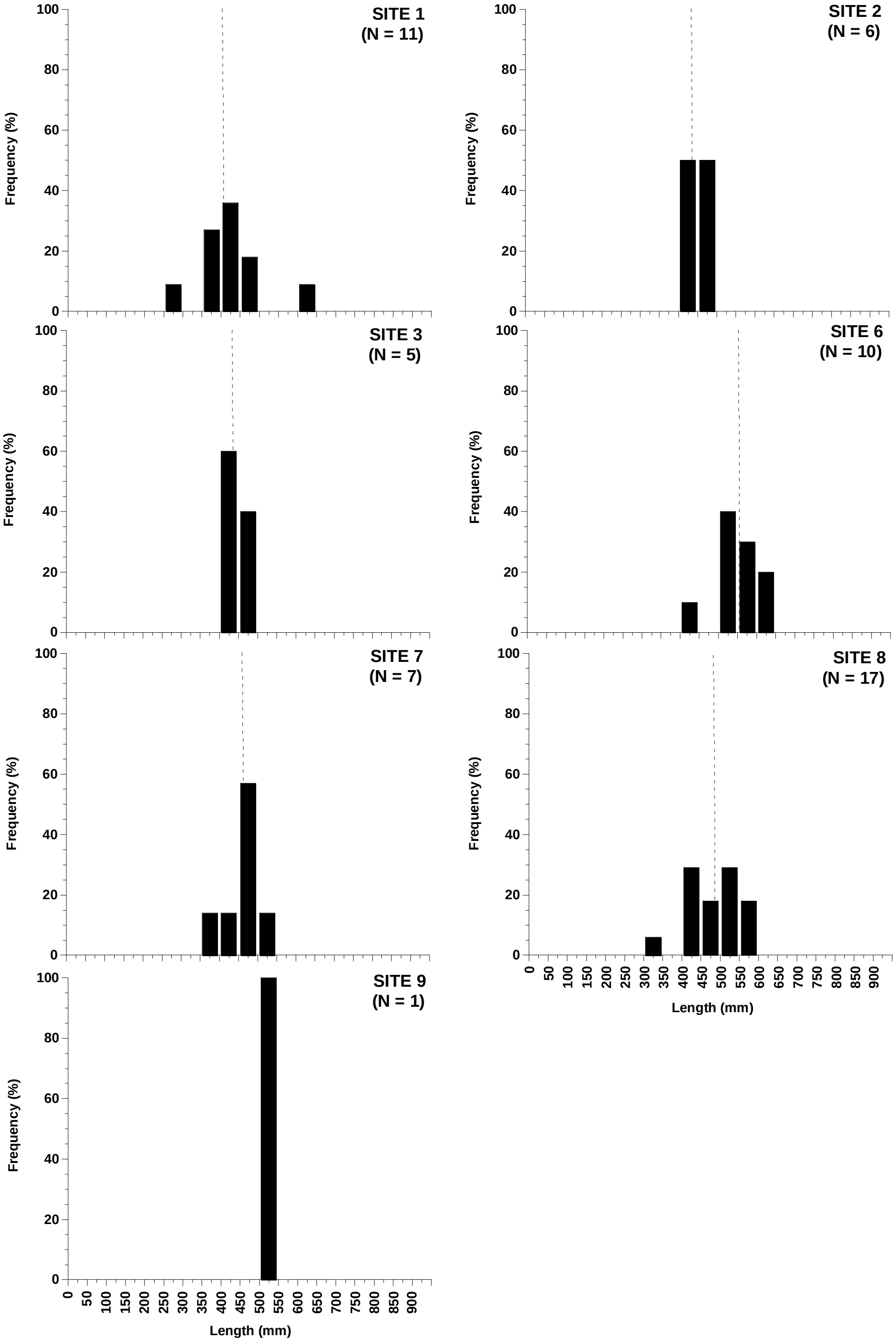

Figure 9. Length frequency (%) of longfin tuna sampled from eight sites within Lake Omapere. Dotted line indicates approximate median length. Note: no longfins were captured at Site 4.

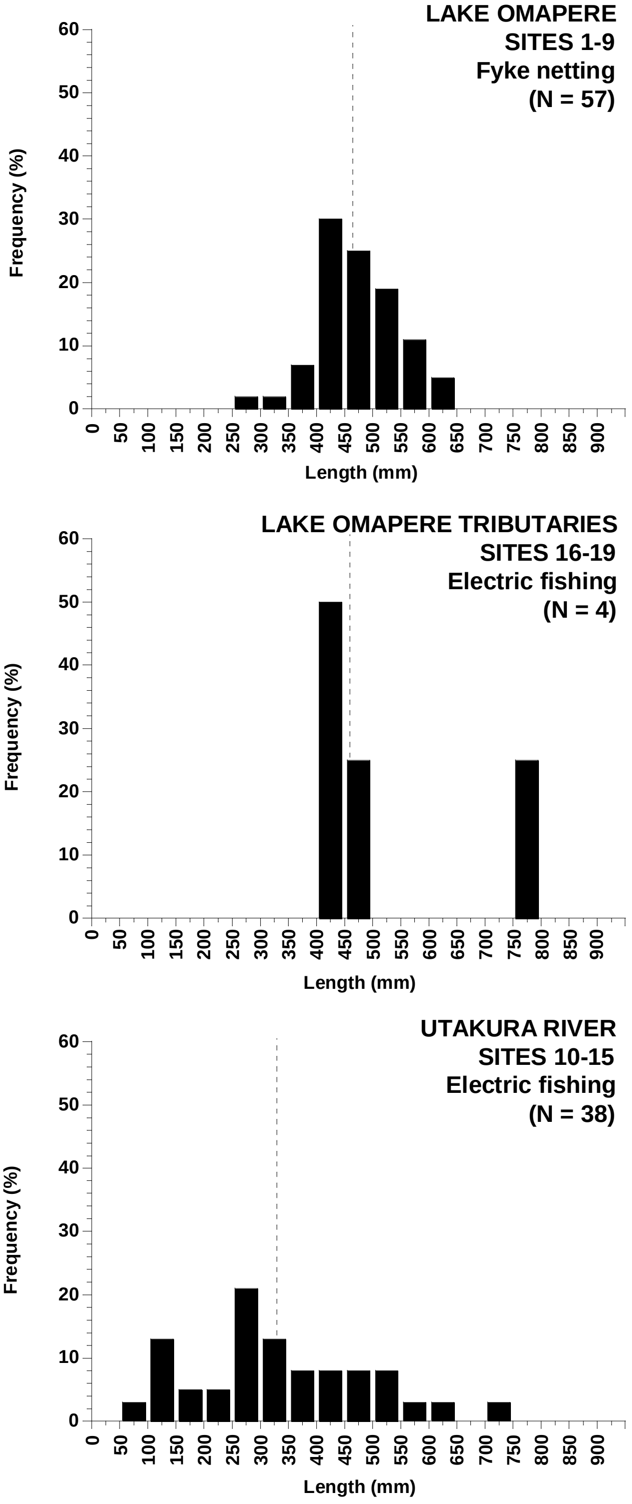

Figure 10. Length frequency (%) of longfin tuna sampled from Lake Omapere, the tributaries of Lake Omapere, and the Utakura River. Dotted line indicates approximate median length.

Table 9. Length characteristics (mm) of tuna captured by the various sampling methods deployed during survey of the Lake Omapere and Utakura River catchment, November 2008.

	Longfin			Shortfin		
Method	**N**	**Average ± SD**	**Range**	**N**	**Average ± SD**	**Range**
Gee-minnow trap	–	–	–	1	360	–
Coarse mesh fyke net	42	477 ± 70	303–623	331	576 ± 101	268–843
Fine mesh fyke net	15	457 ± 86	277–606	285	556 ± 98	300–795
Electric fishing	42	349 ± 168	82–775	207	133 ± 131	62–850

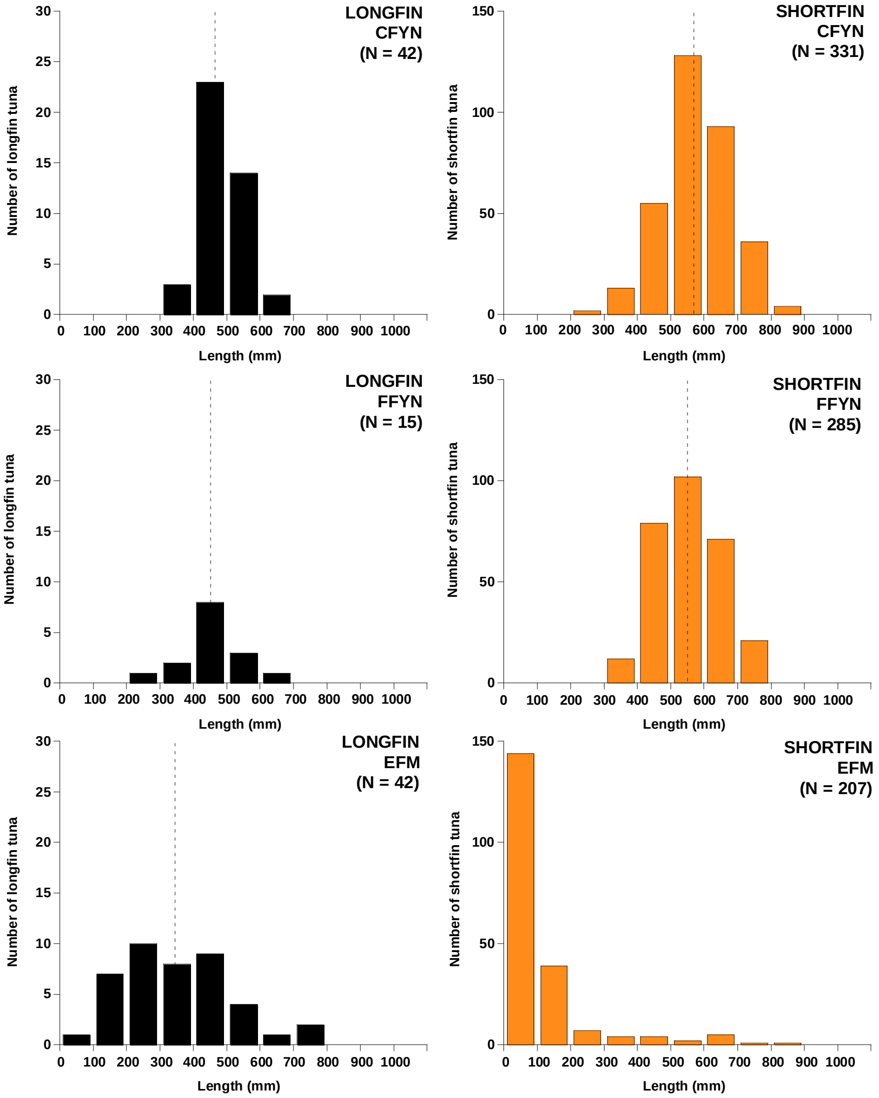

Figure 10. Length distributions (no.) of tuna captured by coarse mesh fyke nets, fine mesh fyke nets and electric fishing of the Lake Omapere and Utakura River catchment. Dotted line indicates approximate median length.

4.4 How old is that tuna?

Length at age

The age of the 64 shortfin eels (7% of total shortfins captured) whose otoliths were examined ranged from 3–13 years. In general, the shortfins obtained from the Utakura River (all from Site 12, Waikirikiri Stream) appear to be slower growing than those sampled from Lake Omapere (Table 10, Figure 12). However, the number of eels examined from the Waikirikiri is very small so may not truly reflect growth within this habitat.

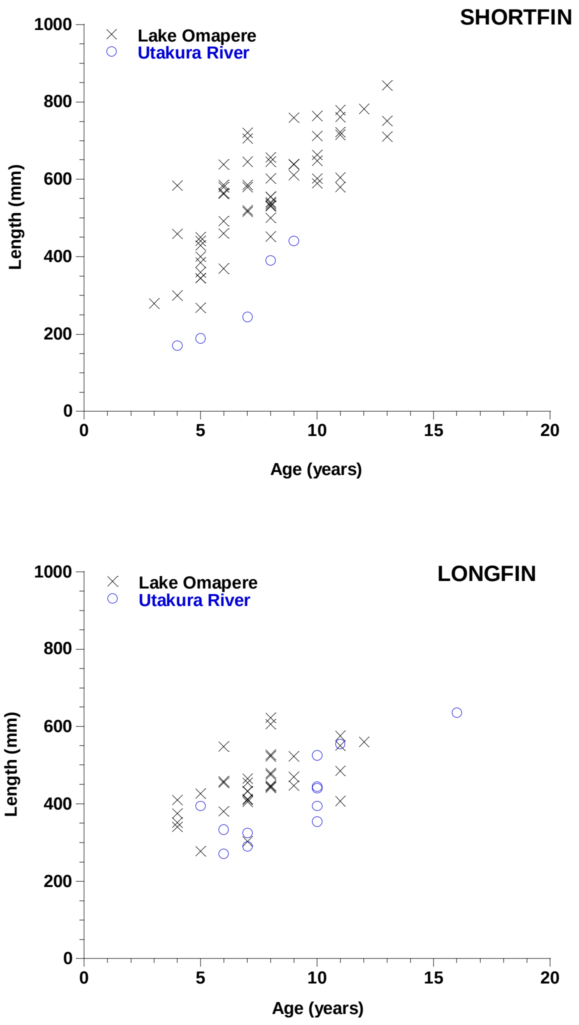

Figure 12. Age *vs.* length for tuna from the Lake Omapere and Utakura River catchment.

Table 10. Age and mean annual length increments (i.e., from river entry to time of capture) of longfin and shortfin eels aged from Lake Omapere and the Utakura River catchment, November 2008.

Species	Location	N	Length (mm)		Age (years)		Average annual length increment ± 95% CL[1] (mm)
			Average ± SD[1]	Range	Average ± SD[1]	Range	
Shortfin	Site 1	29	546 ± 115	344–764	7.5 ± 2.0	5–11	66.1 ± 4.5
	Site 3	1	344		5		56.8
	Site 4	15	611 ± 85	458–751	8.3 ± 2.8	4–13	71.5 ± 10.5
	Site 7	2	682 ± 109	605–759	10.0 ± 1.4	9–11	63.6 ± 27.6
	Site 8	12	568 ± 211	268–843	7.5 ± 3.3	3–13	68.6 ± 8.0
	Lake Omapere	***59***	***568 ± 137***	***268–843***	***7.7 ± 2.5***	***3–13***	***67.8 ± 3.9***
	Site 12	5	287 ± 122	170–440	6.6 ± 2.1	4–9	32.6 ± 3.8
	Utakura River	***5***	***287 ± 122***	***170–440***	***6.6 ± 2.1***	***4–9***	***32.6 ± 3.8***
Longfin	Site 1	11	417 ± 87	277–623	6.0 ± 1.6	4–8	60.8 ± 8.3
	Site 2	1	407		11		31.3
	Site 3	5	405 ± 21	432–475	7.8 ± 0.8	7–9	49.9 ± 3.0
	Site 6	4	527 ± 74	427–606	6.8 ± 1.5	5–8	69.8 ± 9.3
	Site 7	5	432 ± 51	351–480	6.4 ± 1.5	4–8	59.2 ± 8.3
	Site 8	9	490 ± 84	303–575	9.6 ± 1.7	7–12	44.9 ± 4.5
	Lake Omapere	***35***	***455 ± 79***	***277–623***	***7.5 ± 2.1***	***4–12***	***55.1 ± 4.4***
	Site 12	3	425 ± 118	325–555	7.7 ± 3.1	5–11	49.5 ± 17.1
	Site 13	8	406 ± 124	270–635	9.4 ± 3.3	6–16	36.8 ± 4.2
	Site 14	1	440		10		37.7
	Utakura River	***9***	***373 ± 87***	***270–555***	***8.0 ± 2.2***	***5–11***	***40.1 ± 7.3***

[1], SD = standard deviation, CL = confidence limit.

The 47 longfin eels examined (47% of total longfins captured) ranged in age from 4–16 years. No marked differences in age *vs* length between tuna in Lake Omapere and the Utakura River were apparent (Table 10, Figure 12). The oldest longfin eel (16 years) caught during this survey was from Site 13 (Waihoanga Stream). No otoliths were obtained from tuna captured in the tributaries around Lake Omapere.

Average annual length increment

For longfin eels, the average annual length (growth) increment ranged from 31 mm/y (N = 1, Site 2, Lake Omapere) and 70 mm/y^{-}(N = 4, Site 6, Lake Omapere). For shortfin eels, the smallest average annual length increment of 33 mm/y was recorded in the Waikirikiri Stream (Site 12, N = 5) a tributary of the Utakura River, with the greatest average annual length increment (72 mm/y) recorded at Site 4 in Lake Omapere (N = 15) (Table 10, Figure 13).

For both species, the average annual length increment was significantly higher in Lake Omapere compared to that observed in the Utakura River catchment (Student's two-tail *t*-Test, $P < 0.001$). In Lake Omapere, shortfins are growing significantly faster than longfins ($P < 0.001$), but no significant difference between the species was observed in the Utakura River catchment ($P = 0.07$).

Tuna age frequency distributions

As the average annual growth increment figures presented above include the faster growth rate that is known to occur from river entry up to about 300 mm in length, the following linear age-length relationships for eels longer than 300 mm were derived:

- Shortfin age = 0.0139*length – 0.0609 (N = 59, $r^2 = 0.56$, $P<0.001$)
- Longfin age = 0.0175*length – 0.0112 (N = 44, $r^2 = 0.33$, $P<0.001$)

From these age-length relationships, the approximate age distributions of all the longfin and shortfin eels greater than 300 mm were derived (Figure 14). The median age (8 years) was the same for both species. Due to the low numbers of tuna aged from the Utakura River catchment, all of the data were grouped together for this comparison. As expected, the derived age distribution plots (not shown) were very similar to the length distribution plots with no evidence of intermittent recruitment.

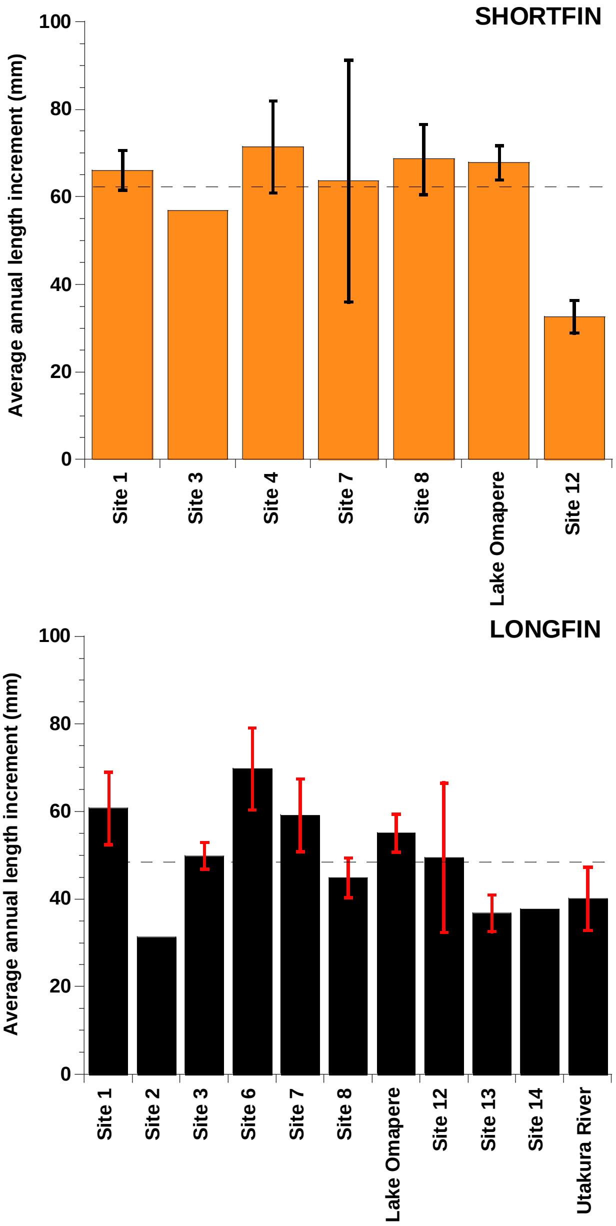

Figure 13. Average annual length increments (mm/y) for tuna from Lake Omapere and the Utakura River catchment. Error bars represent the 95% confidence limits. Dotted line indicates the median. 'Lake Omapere' summarises data from Sites 1–8 and 'Utakura River' summarises data from Sites 12–14.

The linear age-length regressions were also 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 Lake Omapere catchment, the age-length regression predicts that a 300 mm length would be reached at an age of 4.1 years. Mean freshwater growth within those 4.1 years is thus estimated at around 73 mm per year. For longfins, the age-length regression predicts that a length of 300 mm would be attained by age 5.2. During this early period in freshwater, mean annual growth for longfins is thus estimated at 57.3 mm.

Using these age to length relationships, it is possible to compare the growth of eels obtained in the present study to those of other regions (Figures 15 & 16). This comparison indicates that the growth rate for shortfin eels in Lake Omapere is amongst the highest recorded in New Zealand, while that of longfin eels is comparable to figures from Lakes Karapiro, Matahina and Pounui.

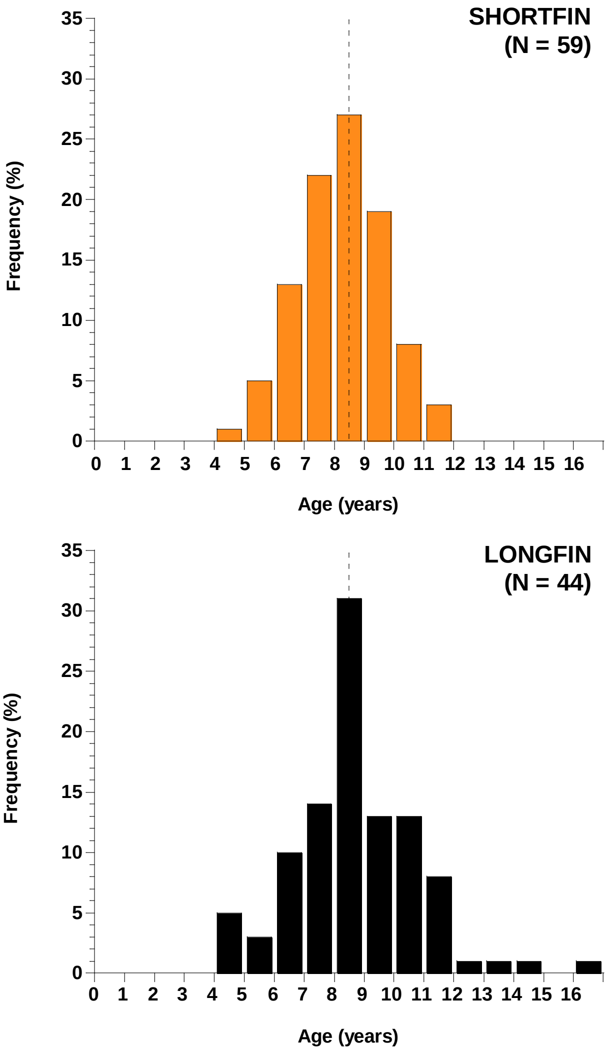

Figure 14. Estimated age frequency (%) for eels > 300 mm in length from Lake Omapere and Utakura River, November 2008. Dotted line indicates median age.

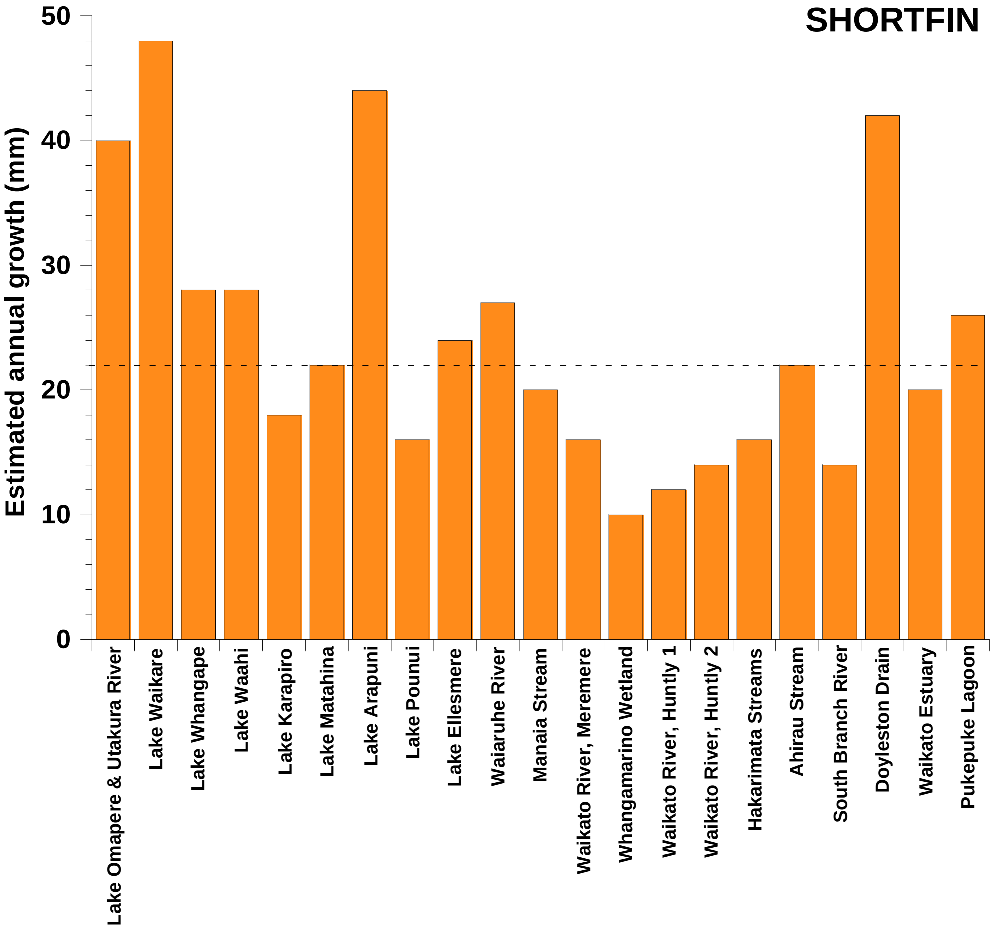

Figure 15. Comparison of shortfin eel growth rates from the Lake Omapere and Utakura River catchment to other parts of New Zealand. Comparative data from Jellyman (1997) and Rowe & Chisnall (1997). Dotted line indicates the median of this dataset.

4.5 Sex composition and maturity

Sex composition was determined through the field observation of eel gonads (Table 11). Initially we had presumed that based on the research of Jellyman & Todd (1982) it was possible to assign sex based on size (i.e., shortfin > 55 cm and longfin eels > 75 cm were all be females). However, although one longfin that was more than 75 mm was confirmed as a female, seven shortfin eels ranging in length between 520–705 mm were found to be males (Table 11). Therefore the Jellyman & Todd (1982) length criteria used to separate male from females in the field may not be applicable in this catchment.

Until this issue is resolved and assuming our visual observation is correct the female to male ratio of mature shortfin eels was approximately 5:1, and 1:4 for longfin eels

(Table 11). However, as only one shortfin female (843 mm in length, 13 years old) captured in Lake Omapere had begun to exhibit features typical of migratory tuna (i.e., enlarged eyes and pectoral fin, flatter and slender head) it would be important to examine more migrating eels in future to confirm this sex ratio.

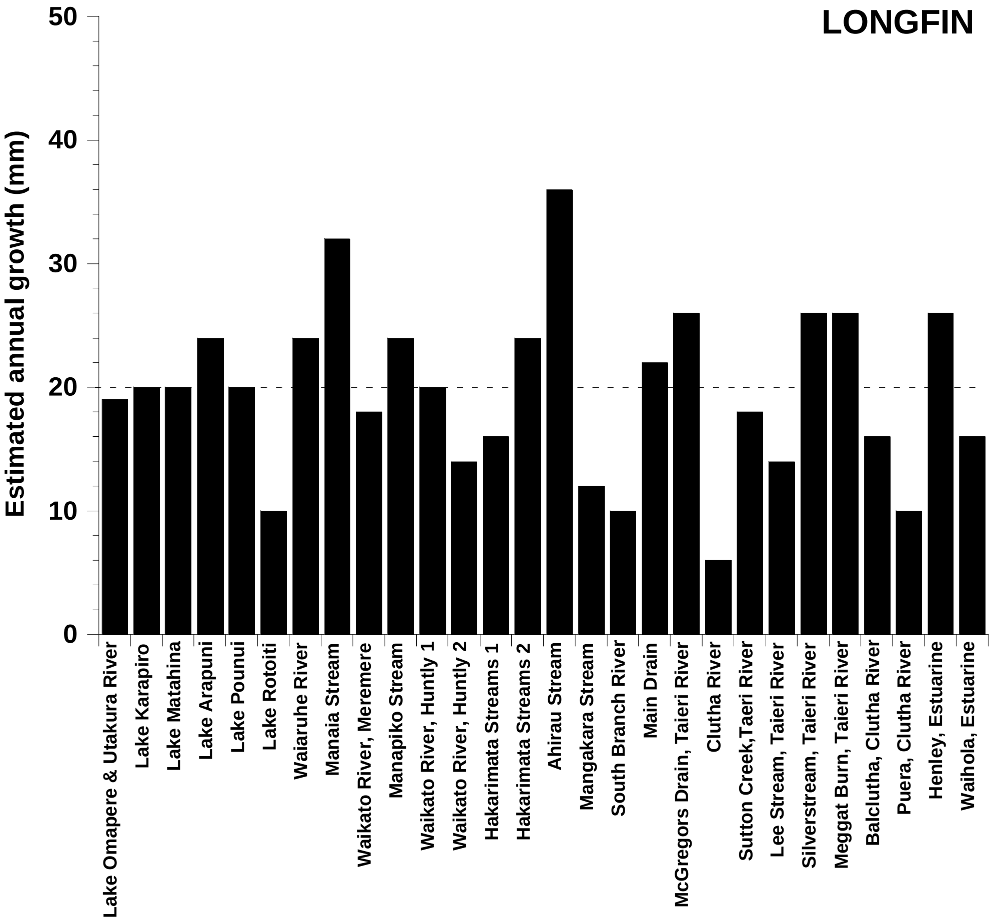

Figure 16. Comparison of longfin eel growth rates from the Lake Omapere and Utakura River catchment to other parts of New Zealand. Comparative data from Jellyman (1997) and Rowe & Chisnall (1997). Dotted line indicates the median of this dataset.

Table 11. Sex composition of tuna examined from the Lake Omapere and Utakura River catchment, November 2008.

	Shortfin[a] (length, mm)			Longfin[a] (length, mm)		
	Total examined (%)	**Average length ± SD**	**Range**	**Total examined (%)**	**Average length ± SD**	**Range**
All tuna	47	594 ± 134	268–843	36	465 ± 101	270–745
Immature	6 (13%)	342 ± 75	268–458	21 (58%)	406 ± 72	270–523
Male	7 (15%)	601 ± 66	520–705	12 (33%)	531 ± 43	455–606
Female	34 (72%)	637 ± 99	430–843	3 (8%)	609 ± 144	459–745

[a], Shortfin examined from Lake Omapere only; Longfin examined from Lake Omapere (N = 30), Waikirikiri Stream (N = 1), Waihoanga Stream (N = 3) and Utakura River (N = 2).

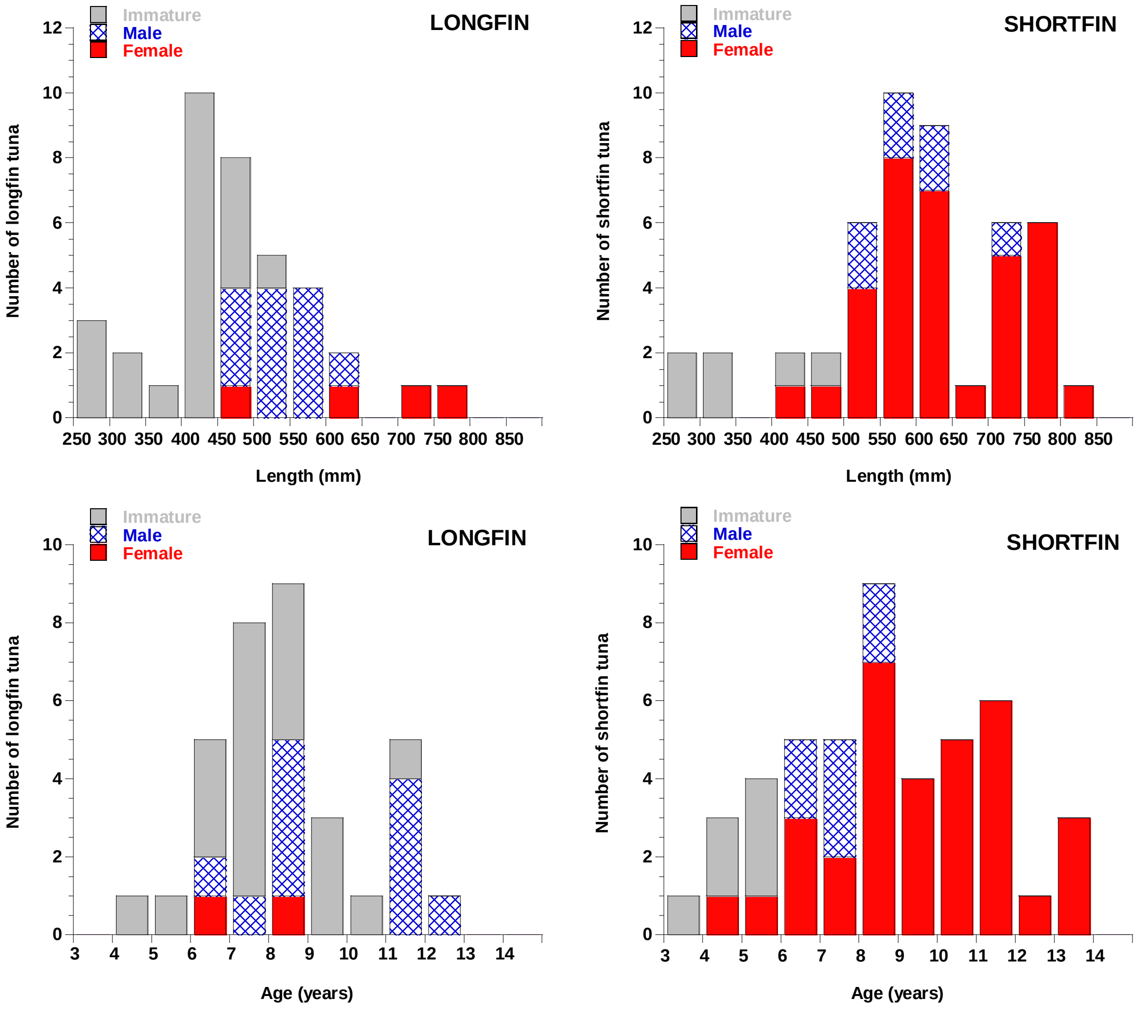

Figure 17. Sex composition (no.) by length (top) and age (bottom) of longfin and shortfin eels examined from the Lake Omapere and Utakura River catchment.

4.6 Diet composition

A qualitative visual assessment of tuna stomach contents was undertaken on a selected number of tuna captured from the Lake Omapere and Utakura River catchment. Diet items of aquatic origin observed included ‘fish’ (i.e., mosquitofish, goldfish, unidentified fish and goldfish eggs), ‘insects’ (i.e., juvenile and adult chironomids, dragonfly larvae, mayfly, caddisfly) and ‘molluscs’ (i.e., snails). Diet items of terrestrial origin observed included ‘insects’ (i.e., unidentified beetles, honey bee) and ‘vegetation/debris’.

Forty-five shortfin eel stomachs from Lake Omapere were examined, 60% of which were empty (Table 12). The stomachs of 35 longfin tuna captured from Lake Omapere (N = 29), Waikirikiri Stream (N = 1), Waihoanga Stream (N = 3) and the Utakura River (N = 2) were examined, 20% of which were empty (Table 13). There was no obvious relationship between the incidence of empty stomachs and eel size.

The most commonly observed prey item in shortfins were chironomid larvae (bloodworms) and adults (midges) which were present in 61% of the stomachs examined that contained some food. Goldfish eggs (44%) and snails (33%) were the next most prevalent items. With the exception of two of the largest eels which contained goldfish in their stomachs, no clear patterns of size related piscivory (i.e., eating fish) was observed.

As was observed for shortfins, the most commonly observed prey item in longfins were chironomid larvae and adults (present in 54% of the stomach examined with food present) and goldfish eggs (36%). Compared with shortfins a wider variety of prey items were observed in the stomachs of longfins. However, this is somewhat a reflection of the two overarching habitat types that the eels were examined from where the stomachs from the Utakura River catchment contained snails (N = 1), caddisfly larvae (N = 3), mayfly (N = 1) and a terrestrial beetle (N = 1). Terrestrial insects were observed in three longfin stomachs overall. No clear patterns of size related prey consumption was observed, but the sample size was too small to successfully assess this.

4.7 Parasites

The internal organs of tuna examined for sex and diet composition were also checked for the presence of any parasites (e.g., common parasitic nematode, *Hedruris spinigera*). Nematodes were observed in only two longfin eels captured in the Waihoanga Stream (355 mm length, 10 years old) and the Utakura River (440 mm length, 10 years old).

Table 12. Dietary items observed in shortfin eel stomachs captured in Lake Omapere, November 2008.

Diet item	No. of shortfin tuna (length range, mm)							
	200–299	300–399	400–499	500–599	600–699	700–799	800–899	Total
No. stomachs examined	2	4	3	14	9	12	1	45
No. empty stomachs	1	2	2	9	6	6	1	27
AQUATIC								
Mosquitofish								0
Goldfish						2		2
Goldfish eggs		1		5	2			8
Unidentified fish								0
Chironomid larvae & adults	1	2	1	2	2	2		11
Dragonfly larvae								0
Snails (e.g., *Potamopyrgus*)		1		1	1	3		6
Caddisfly larvae				1				1
Mayfly								0
TERRESTRIAL								
Vegetation/debris						1		1
Unidentified beetle								0
Honey bee								0

Table 13. Dietary items observed in longfin eel stomachs captured in Lake Omapere and the Utakura River catchment, November 2008.

Diet item	No. of longfin tuna (length range, mm)							
	200–299	300–399	400–499	500–599	600–699	700–799	800–899	Total
No. stomachs examined	2	4	19	8	1	1	0	35
No. empty stomachs	0	1	4	1	1	0	0	7
AQUATIC								
Mosquitofish			1					1
Goldfish								0
Goldfish eggs	1		7	2				10
Unidentified fish			2	1				3
Chironomid larvae & adults			10	5				15
Dragonfly larvae				3				3
Snails (e.g., *Potamopyrgus*)			3	2		1		6
Caddisfly larvae	1		1			1		3
Mayfly		1						1
TERRESTRIAL								
Vegetation/debris		2	4	2				8
Beetle		1	1					2
Honey bee			1					1

4.8 Other freshwater fish species

In Lake Omapere (i.e., above the Utakura River waterfalls) the bycatch captured in the fyke nets were all introduced fish species. Goldfish (*C. auratus*) were by far the most dominant species, followed by mosquitofish (*G. affinis*) and grass carp (*C. idella*). A diverse native freshwater fish assemblage was sampled downstream of the waterfalls on the Utakura River, which included redfin bully (*G. huttoni*), inanga (*G. maculatus*), banded kōkopu (*G. fasciatus*), kōaro (*G. brevipinnis*), torrentfish (*Cheimarrichthys fosteri*), common smelt (*R. retropinna*), and shortjaw kōkopu (*G. postvectis*) (Table 14, Photo 9). No common bullies were observed during this survey.

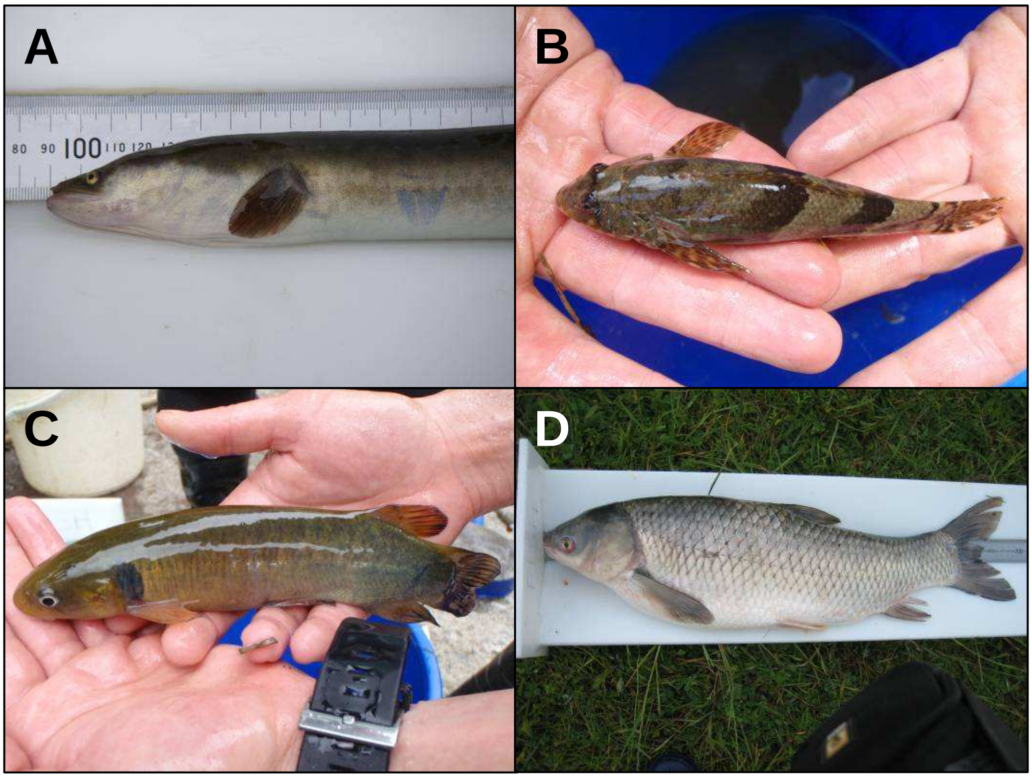

Photo 9. Selection of freshwater fish species caught from Lake Omapere and Utakura River. (A) Shortfin eel, (B) Torrentfish, (C) Shortjaw kōkopu, (D) Grass carp. (Photos - A: Jacques Boubée; B & C: Bruce Davison; D: Wakaiti Dalton).

The gill net was by far the most successful method of catching goldfish (22.5 goldfish/gill net/night) followed by fine mesh fyke nets (average CPUE of 5.8 goldfish/fine mesh fyke/night). Coarse mesh fyke nets were relatively ineffectual at catching goldfish (average CPUE of 0.3 goldfish/coarse mesh fyke/night). At the request of Lake Omapere Trust members, all of the introduced fish species (i.e., goldfish, grass carp and mosquitofish) captured were removed from Lake Omapere.

This tally included a minimum of 389 goldfish (Figure 18) and 5 mosquitofish. Only 3 grass carp were captured and removed from the lake in November 2008.

The commercial eel fisherman who periodically fishes the lake also removes the goldfish that he catches. From time to time the goldfish population has been observed to significantly increase (e.g., 2004) and, in some past years, it was common for this fisherman to catch 30 kg in one net at a time (Ian Mitchell, pers. comm.).

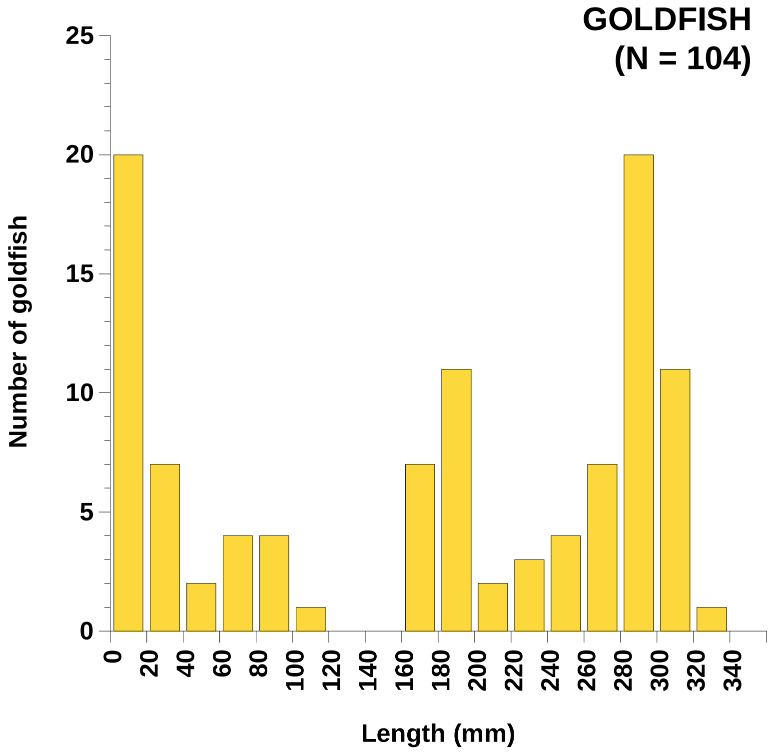

Figure 18. Length distribution of 27% of the goldfish removed from Lake Omapere.

Table 14. By-catch species composition from the Lake Omapere catchment.

Site location[1]	Number of fish captured									
	Goldfish	**Mosquitofish**	**Grass carp**	**Smelt**	**Inanga**	**Banded kōkopu**	**Shortjaw kōkopu**	**Kōaro**	**Torrentfish**	**Redfin bully**
Lake Omapere	389	5	3	–	–	–	–	–	–	–
Lake Omapere tributaries	–	–	–	–	–	–	–	–	–	–
Utakura River	–	–	–	2	13	–	–	–	7	8
Waikirikiri Stream	–	–	–	4	10	18	2	3	–	17
Waihoanga Stream	–	–	–	–	–	–	–	–	–	2
TOTAL	389	5	3	6	23	18	2	3	7	27
Average length ± SD (mm)	173 ± 114	35 ± 9	555 ± 99	80 ± 5	53 ± 5	42 ± 1	152 ± 73	58 ± 19	115 ± 19	61 ± 14
Range	12–320	26–47	485–625	75–90	45–65	40–44	100–203	47–80	105–130	39–87

[1], Sites were grouped as follows: Sites 1–9 = 'Lake Omapere', Sites16–19 = 'Lake Omapere tributaries', Sites 14–15 = 'Utakura River', Sites 10–12 = 'Waikirikiri River', Site 13 = 'Waihoanga Stream'.

5. Discussion & Recommendations

Limitation of the methods

Fyke nets were the main sampling method used in the survey of Lake Omapere. These nets are known to be size selective, with eels smaller than 400 mm tending to be under represented in the catch (Jellyman & Graynoth 2005), particularly when using coarse mesh fykes (Jellyman & Sykes 1998). Smaller eels can be captured by electric fishing and the data collected in the survey of the Utakura River supports this, with the average length and weight of eels captured by electric fishing being less than that of the eels captured by fyke netting. Unfortunately, electric fishing for eels is only effective in clear shallow reaches and at depths < 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 equally sample all sizes of eel across the entire catchment. Jellyman & Chisnall (1999) have shown that it is possible to use brush collectors to sample small eels in lakes and it may be interesting to further test this technique in future studies.

According to Jellyman & Graynoth (2005), depletion netting (as utilised at Sites 2 and 6) can provide an estimation of a population within a riverine area and provide an estimate of the proportion of the population that is caught by setting nets on one night only. No significant reduction in the numbers of eels captured over consecutive nights was observed in Lake Omapere, and no further analysis (i.e., population and biomass estimates) was undertaken. Therefore we confirm that it is not possible to undertake accurate low effort depletion netting in lakes (and possibly in tidal reaches) as factors such as immigration from areas outside the sampling reach is likely to be occurring.

Species composition and catch per unit effort (CPUE)

Although both shortfin and longfin tuna were captured at 83% of the sites sampled during this survey, overall the numbers of longfin tuna were low. While shortfins dominated the catch from Lake Omapere, in comparison a large proportion (> 50%) of the eels captured in the Waikirikiri and Waihoanga Streams (Sites 10, 11 & 13) were longfins. While the distributions of both these species extensively overlaps throughout New Zealand some generalisations can be made about the types of habitats each species prefer. Shortfin tuna appear to prefer less-shaded, slow-moving waters such as estuaries and the lower reaches of rivers that are closer to the sea, while longfins generally dominate at greater distances inland in faster flowing rivers and in sites that are forested (e.g., Burnet 1952, McDowall 1990, Rowe *et al.* 1999, Chisnall & Kemp

2000, McDowall & Taylor 2000). Therefore the predominance of longfins in parts of the Utakura River may be due to the increased native bush cover, tree roots and other woody debris which Burnet (1952) established as favouring longfins. This may also be the reason why very few longfin tuna were captured away from the lake margins, in ‘mid-water’ (Sites 4 & 9), where the cover was expected to be less. However, an alternate possibility to consider regarding the rarity of longfin in Lake Omapere may be due to the impacts of fishing pressure because Chisnall & Kemp (2000) and Chisnall *et al.* (2003) report that longfins are more vulnerable to overfishing compared to shortfins. The commercial fishing data and observations supplied by Ian Mitchell, in addition to the information presented in Beentjes (2008a), also indicate that a decline in the proportion of longfin eels has occurred in the lake between 2000 and 2007.

A total of 271 kg of tuna was captured during the present survey, a large proportion of which (39%) was from the site set closest to the lake outlet. Catch per unit effort (CPUE) is utilised as an index of the abundance of fish, and is commonly used to compare changes (trends) over time. The information collected in this survey will form a valuable baseline of information upon which to monitor long term trends in tuna abundance. Unfortunately there have been no previous studies of this nature with which to compare the results obtained in this survey directly.

In the Lake Omapere and Utakura River catchment the density of longfins obtained at sites that were electric fished was relatively low. For example, in their recent study of what they considered to be relatively high eel density streams, Graynoth *et al.* (2008) report densities ranging from 0.28 to 0.61 longfins/m^2 and 30.5–58.0 g/m^2. In comparison, densities obtained in Utakura River and southwestern tributaries of Lake Omapere ranged from 0.00 to 0.33 longfins/m^2, indicating that longfin densities in this catchment could be considered low. Very few longfins were captured in the southwestern tributaries, with the exception of Site 18 where 0.20 kg/m^2 was found predominately because of the presence of a single large, longfin female (775 mm, estimated weight 1.3 kg).

For shortfin eels, Graynoth *et al*. (2008) report densities between 0.48 and 0.93 shortfins/m^2. In comparison, densities of 0.09–2.18 shortfins/m^2 were observed in the Utakura River and 0.03–0.63 were captured in the southwestern tributaries of the lake. Elvers dominated the catch from the flowing 100% ‘run habitat’ sites (Sites 12 & 15) where large CPUE’s of shortfin eels were observed.

Size and sex distribution

As expected, the length-weight relationships that were derived for Lake Omapere and the Utakura River catchment indicated that longfins were heavier for their length than shortfins. However, the median length of the shortfins captured was greater than that of longfins. It is possible that longfins, being more easily caught by fishers, tend to be removed from the population first. This is because longfins are known to respond well to baited nets in comparison to shortfins (Jellyman & Graynoth 2005). They also become piscivorous at a smaller size than shortfins (Jellyman 1989) which could mean that they are more sensitive to bait. Certainly, longfins inhabiting less accessible areas tend to be larger than those from more accessible reaches due to increased fishing pressure (Broad *et al*. 2002, Beentjees *et al*. 2006). 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.

Of the close to 923 eels measured during this study only five shortfins (0.6%) were > 800 mm, and only two longfins (2%) were between 650 and 800 mm in length. Reproductive maturity of *Anguilla* species is considered to be related to length (Tesch 1977). Females of both species grow to a large size before reaching maturity which can take a long time in the wild with consequent long exposure to the fishery. The age and size of the migrating adults varies depending on the species, sex, and location. Shortfins generally migrate at a younger age than longfins, and are smaller than longfins when they migrate. Males are smaller and migrate at an earlier age than females. Within New Zealand, shortfin males migrate to sea at between 34–59 cm (6–24 years), and females 48–120 cm (10–35 years). Longfin males migrate to sea at between 48–74 cm (12–35 years) and females 74–156 cm (25–98 years) (Todd 1980, Jellyman & Todd 1982, Beentjes & Chisnall 1998, Boubee *et al.* 2001, Boubee & Williams 2006).

Jellyman & Todd’s (1982) study of the length distributions of migratory eels indicated that in general shortfin eels larger than 55 cm, and longfin eels larger than 75 cm were mostly females. The commercial fishery for shortfin eels is typically based on the harvest of immature females, as males are generally known to mature and emigrate below the commercial size (e.g., Todd 1980, Chisnall & Kemp 2000). However, in Lake Omapere this situation may not be as clear cut as observations of the gonads in the field identified seven shortfin males between 520–705 mm (260–610 g). Shortfin males longer than 598 mm have not been observed in previous research (Burnet 1952, Todd 1980, D. Jellyman pers. comm.). Although it is possible that inaccurate assessments may have been made during the field sampling, and may have benefited from microscopic examination, the characteristics of sexually mature migrant tuna heke (katua) exiting the lake requires further investigation.

In order to better understand the effect of harvest on the size and species composition of the eel population over time, robust information on harvest (commercial, recreational and customary) activities within the Lake Omapere and Utakura River catchment is required. This information should include the number of nets and number of nights fished and preferably a size structure of a representative proportion of the catch. This dataset will assist the Lake Omapere Trust to monitor long term trends in tuna abundance. As a precautionary measure, to ensure future recruitment, it is recommended that fishing pressure (including customary and recreational take) be reduced on large female tuna, an action that may benefit future eel recruitment into New Zealand waters.

In addition, further investigation is required into the survival of migrant eels exiting the catchment (e.g., do they survive the drop over the waterfalls?). There have been reports of dead and live grass carp, both in the Utakura River and in other rivers off the Hokianga Harbour (National Aquatic Pest Awareness Group 2005, G. Jamieson, pers. comm.). This implies that there may be some mortality for fish associated with the trip downstream over the waterfalls, but it is not clear if this will affect large eels.

Juvenile recruitment

In this study, 25% of longfins and 24% of shortfins were < 300 mm in length. In Lake Omapere, only 4% of longfins and 1% of shortfins in the catch were < 300 mm in length. The low number of juvenile eels captured could be a reflection of the sampling methods (i.e., largely fyke netting) employed and the habitats fished rather than an indication of poor recruitment into the lake. This is because some of these smaller size classes were found when electric fishing the southwestern tributaries (Sites 16–19) where 20% were < 300 mm in length. The size selectivity of the sampling methods becomes obvious when we compare the figures for Lake Omapere to the Utakura River catchment where only electric fishing was suitable and we observed 61% of longfins and 98% of shortfins in the catch from Sites 10–15 were < 300 mm in length.

Freshwater eels are catadromous, meaning that these fish species invade rivers from the sea as juveniles (i.e., glass eels), spend most of their lives in fresh water and returning to the sea as adults (McDowall 1998). Both shortfin and longfin eels are well known as skilled climbers and can reach locations inaccessible to other migratory species, although climbing ability declines with fish size (Jellyman 1977). It is clear that some elvers surmount the waterfalls to reach Lake Omapere, and there is some history of facilitating elver passage at the largest of these falls (NZMS260 E2579025, N6648294), by placing an old trawl net over the drop (Ian Mitchell, pers. comm.). This net has since been removed, or was damaged during a flood and no means of facilitating elver passage was visible when this site was visited in November 2008. As the bottom of the large waterfall appears very difficult to access it would probably be difficult to implement an elver trap and transfer programme or an elver ladder such as those that have been trialled at other sites (predominantly hydro dams) (e.g., Martin *et al.* 2007). Consequently we recommend re-implementation of a low cost overhanging elver rope(s) or trawl net-like structure to help facilitate as much elver passage into the lake while a more permanent solution is being investigated.

There is some kōrero about another outlet via the Waiharakeke Stream on the northeastern side of the lake through which elvers get in and migrant eels and other fish species can exit the lake when lake levels are high and surface water connectivity occurs. Therefore there could well be other pathways into the lake for migrating elvers. A better understanding of the potential upstream and downstream passage routes, including the possibility of a second lake outlet during floods is required.

Diet, age, and growth

The stomachs of 60% of shortfins and 20% of longfins, throughout the size range examined during this study, were found to be empty. High incidences of empty stomachs have been recorded in other tuna diet studies (e.g., Cairns 1942, Burnet 1952, Cadwallader 1975, Sagar & Eldon 1983, Jellyman 1989). It has been proposed that eels intermittently feed on large amounts of food and then rest while it is digested (digestion rates of wild eels range between 24–36 h, (Cairns 1942, Burnet 1952)). Eels therefore do not feed every night (Cairns 1942, Jellyman 1989). Burnet (1952) reported that there is a tendency for the number of empty stomachs to increase with increase in size of eels suggesting that large eels probably feed less frequently than small eels, but there was no obvious relationship between the incidence of empty stomachs and eel size in this study.

Prior to becoming piscivorous (i.e., eating fish), eels are generally opportunistic feeders, where their diet is reflective of the availability of food (e.g., Jellyman 1989). In this study, fish were more prevalent items in the overall diet of longfins, and supported observations made by Jellyman (1989) where longfins (in this study 400–600 mm) become piscivorous at a smaller size than shortfins (in this study 700–800 mm). Longfins from the Lake Omapere and Utakura River catchment ate a larger variety of food items than shortfins of equivalent size. The variety of prey items observed in the stomachs of longfins is somewhat a reflection of samples being taken from both the Utakura River (N = 6) and Lake Omapere (N = 29) where the benthic communities would be expected to be different. Shortfins were only sampled from

Lake Omapere. As observed in Hicks (1997) terrestrial prey items had a lower percentage occurrence in the guts of shortfin eels than in longfin eels.

In Lake Omapere the occurrence of prey items in the diet of both shortfin and longfin tuna was dominated by chironomids and goldfish eggs. Benthic invertebrates are important in the diets of eels from throughout the country (e.g., Cairns 1942, Burnet 1952, Cadawaller 1975, Jellyman 1989). Ryan (1982) and McCarter (1986) have shown that the energy content of chironomidae (range 17,592–22,152 J g^{-1}) is higher than other benthic organisms such as snails (*Potamopyrgus* and *Physa* sp.) and isopods. Sagar & Glova (1998) observed that when shortfin eels have a range of species available to them that they appear to choose soft bodied prey such as ostracods and larval chironomids, as opposed to those with hard external cases such as snails.

Goldfish, ranging in size between 12–320 mm (maximum weight recorded 960 g), were commonly encountered in Lake Omapere. Goldfish mature around the ages of 1-2 years, and they produce several hundred thousand yellow eggs (1–2 mm) that are laid amongst the aquatic vegetation (McDowall 2000). There have been few published studies on these exotic fish populations in New Zealand lakes, so life history and habitat requirements are generally inferred from overseas studies (Rowe & Graynoth 2002). Rudd spawn several times a year (in spring, summer and autumn) producing three distinct size groups in each year class (Rowe & Graynoth 2002), so other similar species (like goldfish and tench) may also do this. The eggs hatch after about one week when the young initially attach to aquatic plants while they are absorbing the yolk sac, after which they become free swimming (McDowall 2000). Pest species such as goldfish, rudd and tench may deposit eggs on wood, shells and rocks when plant material is scarce, and therefore will continue to breed in lakes where macrophytes are absent (Rowe & Champion 1994, Rowe & Graynoth 2002).

Goldfish eggs are rich in lipid reserves and contain essential fatty acids that are required in the diet of tuna. The contribution of goldfish eggs as a source of high energy food, that contains essential fatty acids in a relatively accessible form, to the seasonal and temporal growth of tuna in Lake Omapere may be important. The impact of food availability on the growth rates of New Zealand eels has not been studied, although most authors have assumed it to be important (Jellyman 1997). Future studies (e.g., fatty acid profiles, diet studies and stable isotope techniques to identify food web structure) are required to quantify the relative importance of such prey items to the overall growth of tuna (and other species which may be competing with eels for food) in this lake, as this will provide information to inform the management of pest fish populations in Lake Omapere.

Eel growth is dependent upon density, interspecific interactions, food availability and water temperature. Eel catches show a strong correlation with average water temperature, where cooler waters inhibit eel activity and therefore the ability of eels to be captured (e.g., Jellyman 1991 & 1997). Mean annual eel catches (1983–1990) for Northland were significantly higher than for other New Zealand regions during the winter period (Jellyman 1997). The Northland winters are warmer than 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 the age of 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. Chisnall & Kemp (2000) processed otoliths from commercial eel landings which included landings from the Northland Region (e.g., Kaipara Harbour, Wairoa River, Lake Tomarata, Maungaturoto), but they do not mention having issues reading otolith annual winter checks.

For both tuna species, the lowest average annual length increments were generally recorded below the falls in the Utakura River catchment. Chisnall & Kemp (2000) observed that eels in lowland lakes generally grow faster than in rivers. It is intuitive that growth rates will be higher in the lake if the food they are eating (i.e., fish and goldfish eggs) are more abundant and of higher energy content than the prey available in the Utakura River. Water temperature (generally warmer in lakes compared to streams/rivers) is also known to affect foraging and feeding activity and has been suggested as the most important factor influencing habitat-specific growth differences in longfin eels (Chisnall & Hayes 1993, Jellyman 1991).

The average annual length increments for longfin eels from the Lake Omapere and Utakura River catchment were comparable to those reported from North Island hydro-electric lakes, and higher than those reported in forested streams and most pastoral streams studied by Chisnall & Hicks (1993). For shortfin eels, the average annual length increments obtained in the Lake Omapere catchment were also higher than for all 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, Rowe & Chisnall 1997). However, the average annual length increments obtained from Lake Waikare by Chisnall & Hayes (1991) and Lake Arapuni by Chisnall (1993) were slightly higher than those from Lake Omapere. These observations indicate that shortfin tuna growth in Lake Omapere is amongst the highest recorded in New Zealand. This may be related to the reduced density of eels in Lake Omapere following the large harvests that occurred between 1999–2001.

The minimum commercial weight limit for freshwater eels is 220 g with a maximum landing weight of 4 kg. For shortfins in Lake Omapere, the minimum weight would be equivalent to 484 mm (6.7 years) and 437 mm (7.6 years old) for longfins. Using these lengths and relating them to the length frequency data, it is apparent that approximately 55% of the longfins captured in this study could legally be landed compared to 61% 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 Lake Omapere and Utakura River catchment but also further emphasises the sensitivity of the population to fishing pressure and particularly highlights the vulnerability of longfins.

The age distribution of the eels captured during this study indicated that shortfins were between 3 and 13 years of age while longfins were between 4 and 16 years. The minimum length at which female longfins can mature and emigrate is about 75 cm (Jellyman & Todd 1982), which is also the minimum preferred size for customary take (MFish 2008). Of eels sampled during this study, only about 2% of the longfin eels captured during the survey exceeded this size. The time needed for longfin females to reach the minimum reproductive size in Lake Omapere and the Utakura River catchment is estimated to take about 13 years. Consequently it appears that there are very few eels left in Lake Omapere and the Utakura River catchment which are of a size preferred for customary take. But perhaps of more concern is that these records also indicate that there are very few female longfins being supported by the catchment that could contribute to the spawning stock. These results emphasise not only the vulnerability of the population to fishing pressure but also indicate that management measures taken nationwide could take decades to show results.

This Te Wai Māori-funded research will assist the Lake Omapere Project Management Group to achieve it’s overarching vision and the successful outcome of Waiora, by providing the Lake Omapere Trust and Ngapuhi Fisheries Limited with the baseline information required to monitor and adaptively manage the long term well-being of the Lake Omapere tuna fishery. While this research has greatly increased our understanding of the tuna population in the Lake Omapere and Utakura River catchment, very little tuna population studies have been undertaken in the greater Ngāpuhi rohe. In November 2007 workshop attendees identified a number of other Tai Tokerau catchments that were significant to them, and where they require tuna population baseline information. After Lake Omapere, the Mangakahia and Taheke Rivers were identified by the group as the next priorities.

6. Summary of Recommendations

Future surveys – Factors that influence the mobility of eels (e.g., season, moon phase, prey behaviour, and weather patterns etc) will affect survey results. Capture efficiency can also be affected by various factors such as sampling method employed, immigration or emigration, net avoidance, and mesh size selectivity. The collection of comparable long-term datasets for the sustainable adaptive management of this fishery relies on controlling for these factors as much as possible. To ensure that comparable data are collected in any future tuna population surveys of Lake Omapere and the Utakura River catchment, the same sites (or a selection of) should be used and standardised survey techniques (notably mesh size and deployment method) maintained. Any additional sites and methods implemented should be considered supplementary to those used in the present study.

Catch history – In order to better understand the effect of harvest on the size and species composition of the eel population over time, robust information on harvest (commercial, recreational and customary) activities within Lake Omapere and the Utakura River catchment is required. The information collected should include the number of nets and number of nights fished and preferably the size structure of a representative proportion of the catch.

Sex and size composition of the tuna heke (katua) – Unlike the observations made in Lake Omapere, shortfin migrant males longer than 598 mm have not been observed in previous research. Although it is possible that inaccurate assessments may have been made during the field sampling, and may have benefitted from microscopic examination, the characteristics of sexually mature migrant tuna heke (katua) exiting the lake requires further investigation.

Spawning escapement – It appears that there are very few eels left in Lake Omapere and the Utakura River catchment which are of a size preferred for customary take. Perhaps of more concern is that there are very few female longfins being supported by the catchment that could contribute to the spawning stock. As a precautionary measure, to ensure future recruitment, it is recommended that fishing pressure (including customary and recreational take) on large female longfins be reduced to benefit future eel recruitment to New Zealand waters. However, further investigation is required into the survival of large migrant eels exiting the catchment (e.g., do they survive the drop over the waterfalls). Confirmation that there is another lake outlet through which juvenile and migrant eels can safely enter and exit the lake is also required.

Recruitment – Based on our observations we recommend re-implementation of a low cost overhanging elver rope(s) or trawl net-like structure over the waterfall to facilitate elver passage into the lake while a more effective solution is being investigated. As mentioned above, alternate pathways for eel recrutiment into Lake Omapere have been suggested and also require further investigation.

Diet and growth – The impact of food availability on the growth rates of New Zealand eels has not been studied. Future studies (e.g., fatty acid profiles, diet studies and stable isotope techniques to identify food web structure) are required to quantify the relative importance of prey items to the overall growth and well-being of tuna in Lake Omapere. This should be designed to identify seasonal changes in food as well as changes in the main prey species that are associated with eel size.

Acknowledgements

We are grateful for the assistance of Geraldine Baker and Dr Charlotte Severne in the preparation of the proposal and their on-going support of this project; Rex Faithful, David & Barbara Green and all of the landowners who kindly gave us permission to access the lake, rivers and streams through their properties; Tracey Dalton, Maki Dalton, and members of the Lake Omapere Trust and Te Roopu Taiao o Utakura who assisted during fieldwork; Gray Jamieson and Ian Mitchell for commercial fishing data; Shane Grayling and Catriona Stevenson for their assistance in the analysis of the otolith data; Dr Dave Rowe for his advice and expertise when reviewing the report; the November 2007 attendees of the tuna training workshop held in Kaikohe; Alan Wihongi and George Riley of Te Rūnanga a Iwi o Ngāpuhi; and finally to Te Wai Māori Trust, including Claire Nesus and Morrie Love, whom provided the core funding to complete this research. This research was also supplemented with funding from the FRST funded Taonga Species programme (C01X0511).

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8. Appendices

8.1 Appendix 1: List of workshop participants and selected contact details (Te Rūnanga A Iwi O Ngāpuhi has the full list of contact details).

Name	Affliation	Email contact details
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Harata Toms Paul	Ngāti Kura, Whangārei	
Agnes Roderich	Ngāti Kura, Whangārei	
Rebecca Reihana	Ngāti Kura, Whangārei	
Te Aroha McIntyre	Ngāti Tautahi, Ngāti Hine	
Stephan Naera	Te Roroa	
Stephen Pikaahu	Ngāpuhi	
Henare Pehi	Ngāpuhi	
John Ellis	Pārengarenga	
Morrie Love	Te Atiawa ki Pōneke, Te Wai Māori Trust	
John Thompson	Ngāti Kura	
Peter Kitchen	Ngāti Kuri	
Dawson Joyce	Ngāpuhi	
Jim Taituha	Ngāti Kawa	
Pake Taituha	Ngāti Kawa	
Sinori Loza	Ngāpuhi	
Hariata Skelton	Ngāpuhi	
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8.2 Appendix 2: Results of freshwater fish sampling demonstration at Waipapa Stream, 29–30 November 2007.

Introduction

In November 2007, a variety of scientific sampling methodologies were deployed at a location on the Waipapa Stream (Kerikeri), where the primary aim was to demonstrate a variety of methods that can be used to sample tuna populations. In addition, nets were set above and below a natural waterfall and weir structure present at this site to determine whether or not this posed a barrier to fish passage. This appendix presents a brief summary of the information that was collected by Te Runanga A Iwi O Ngapuhi members and NIWA during the field trip to Waipapa Stream.

The location on the Waipapa Stream was chosen as it contained a variety of habitats in close proximity where both electric fishing of shallow (< 0.3 m depth) and deployment of nets in deep pool (> 1.0 m depth) habitats. In addition, this site had a large bank alongside from which people could more easily observe and participate in activities. The Waipapa Stream flows from Lake Manuwai, a manmade irrigation dam which was constructed in the 1980’s for irrigation purposes to serve the Kerikeri horticultural belt. This lake is stocked annually with 400–500 rainbow trout fingerlings (Fish & Game New Zealand, n.d) and supports a tuna fishery (workshop attendees, pers comm.).

Methods

Historical freshwater fish records

The New Zealand Freshwater Fish Database (NZFFD) is an internet based tool that we can use to get an idea of what people have previously found when they have sampled our streams, rivers and lakes for freshwater fish species. This can be accessed via http://neptune.niwa.cri.nz/fwdb/. The NZFFD (established in 1977, maintained by NIWA) records the occurrence of fish in fresh waters of New Zealand, including major offshore islands. Data stored include the site location, the species present, their abundance and size, as well as information such as the fishing method used and a physical description of the site. The latter includes an assessment of the habitat type, substrate type, available fish cover, catchment vegetation, riparian vegetation, water widths and depths, and some water quality measures.

Data, which are recorded in the field on pre-printed forms are **contributed voluntarily** by organisations such as NIWA, Fish and Game Councils, the Department of Conservation, regional councils, consultants, universities, and interested individuals. **Access to the data is free** and only requires registration (although users are encouraged to contribute data in return).

Site description

Three sites on the Waipapa Stream were sampled on the 29 November 2007. All three sites were located within approx. 200 m of each other. Access to the site was gained by travelling north from Waipapa along SH10, turning (left) onto Pungaere Rd and then (right) onto Ironbark Rd (Figure A1).

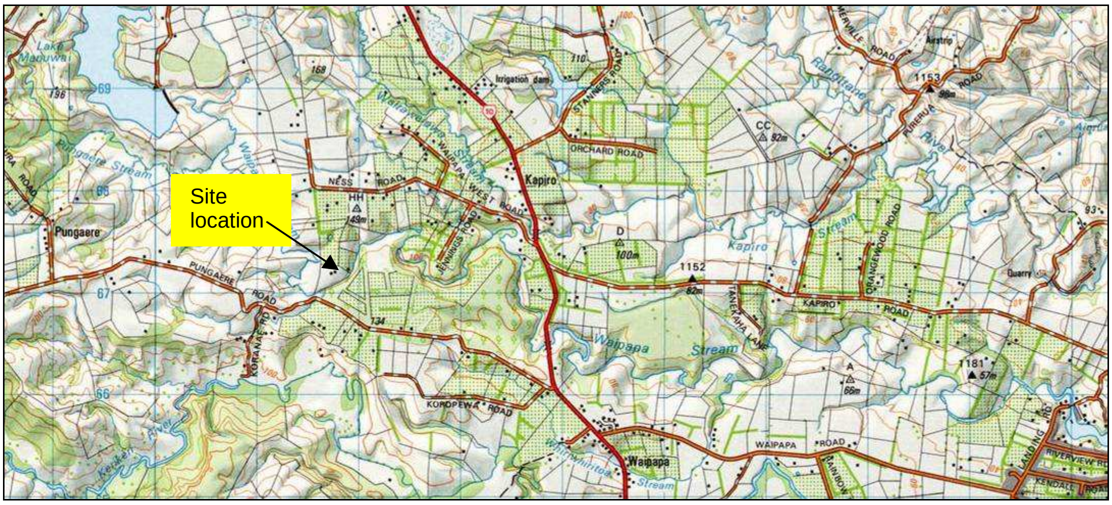


Figure A1. Location of site sampled on the Waipapa Stream, Kerikeri (Map number: NZMS260 PO5).

Two sites were located below a natural waterfall and weir structure (Photo A1), and one was located above. A diagram (not to scale) illustrating the approximate location of each site and the methodologies used at each is presented in Figure A2. A brief description of each site is as follows:

- Site 1: (NZMS260 PO5 2591900E, 6667200N). Furtherest downstream of the three sites. Downstream of waterfall and weir structure. Flowing stream section, immediately below Site two (Photo 1).

- Site 2: (NZMS260 PO5 2591850E, 6667140N). 'Middle' site. Large pool, immediately below waterfall and weir structure (Photo 2).

- Site 3: (NZMS260 PO5 2591770E, 6667100N). Immediately upstream of waterfall and weir structure. Slow moving river/pool section.

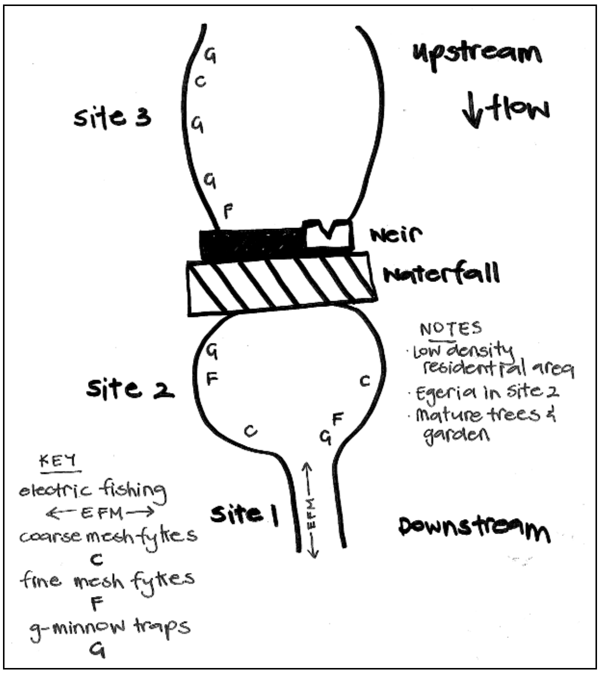


Figure A2. Diagram illustrating approximate location of sites investigated on the Waipapa Stream and the sampling methods used (not drawn to scale).

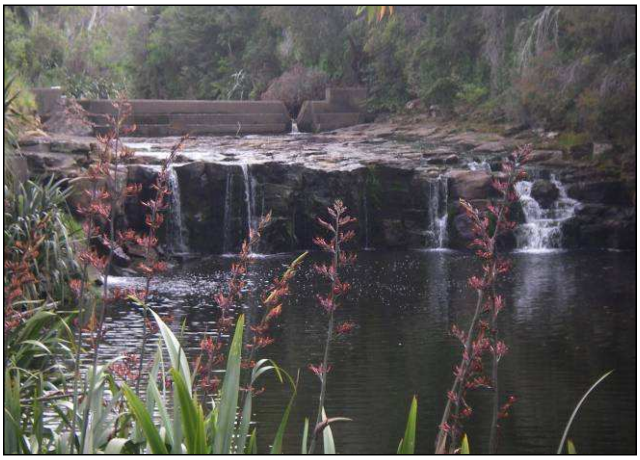


Photo A1. Looking upstream at the natural waterfall and weir structure on the Waipapa Stream. Site 2, immediately in the foreground (Photo: Jacques Boubée).

Photo A2. Electric fishing Site 1 on the Waipapa Stream (Photo: Taoho Patuawa).

Photo A3. Site 2 on the Waipapa Stream, where the pool downstream of waterfall and weir structure was sampled using fyke nets and Gee minnow traps (Photo: Taoho Patuawa).

Photo A4. Site 3 on the Waipapa Stream, upstream of waterfall and weir structure, which was sampled using fyke nets and Gee-minnow traps (Photo: Taoho Patuawa).

The in-stream cover, habitat type, and substrate composition of each site was subjectively classified according to categories outlined in the New Zealand Freshwater Fish Database (NZFFD). Stream width and maximum depth was recorded, where possible, for each reach. Site elevation and distance to the sea (i.e. inland penetration) was estimated using NZMS 260 1:50 000 topographic maps.

Sampling methods

A combination of sampling methods, primarily targeting freshwater eels, were utilised during the present survey including coarse mesh fyke nets (15 mm mesh), fine mesh fyke nets (6 mm mesh), electric fishing (Kainga EFM300, battery powered backpack) and Gee-minnow traps (3 mm mesh).

A 15 m length of stream was electric fished (single pass) at Site 1 with a back-pack EFM300 on the 29 November 2007. Baited fyke nets and Gee-minnow traps were set at Site 2 (2 fine-mesh fykes, 2 coarse-mesh fykes and 2 Gee-minnows) and 3 (3 Gee-minnows, 1 fine-mesh fyke and 1 coarse-mesh fyke) in the early afternoon on 29 November 2007 and left to fish overnight. These were lifted the next morning between 9 and 10 am.

Catch processing

The fish captured were identified, counted and the length measured (to the nearest mm). Tuna were also weighed (to the nearest g). Any visible signs of malformation or parasitism in the fish (i.e., colour of liver and gills, presence of nematodes on swim bladder and skin lesions) were noted. Three eels were sacrificed to show people how to remove the otoliths for aging. All remaining fish were returned to Waipapa Stream.

Data analysis

Catch per unit effort (CPUE) is a measure of relative fish abundance. For nets and traps, CPUE is defined as the mean number of fish caught per net per overnight set. When analysing electric fishing data, the CPUE is presented on an area basis, i.e., number of fish per m^2 fished.

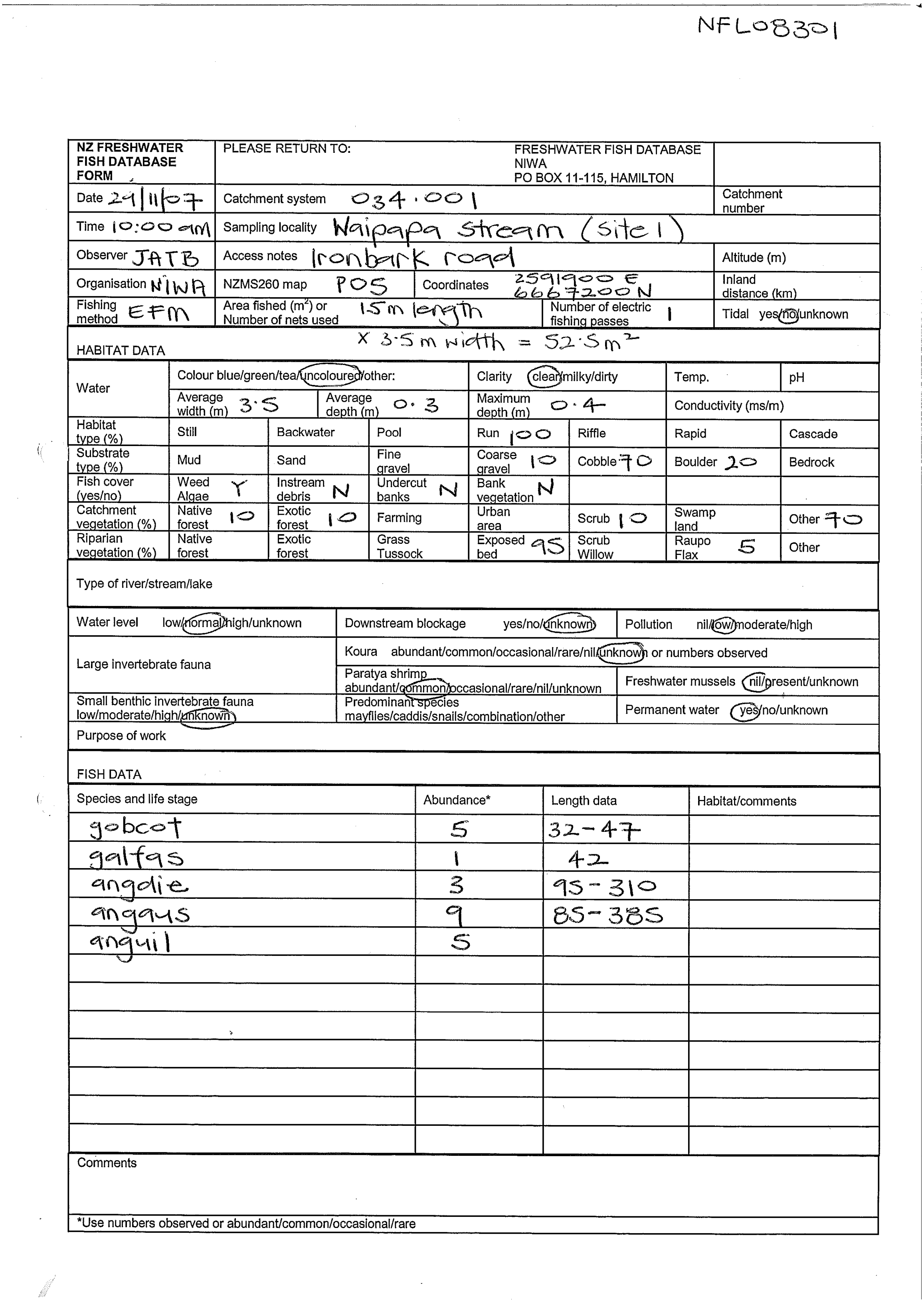
Results

Species composition

Four indigenous fish species were recorded during this study. Common bullies (*Gobiomorphus cotidianus*) (total number, N = 135) and shortfin eels (*Anguilla australis*) (N = 21) were the most common fish species captured. Longfin eels (*A. dieffenbachii*) (N = 5), banded kōkopu (*Galaxias fasciatus*) (N = 1) and the freshwater shrimp (*Paratya curvirostris*) were also present (Figures A3, A4 and A5; Table A1).

Table A1. Summary of fish (species, number and length range) captured from the Waipapa Stream, 29-30 November 2007. Note: All sampling methods combined.

Site	Species	Number	Length range (mm)
One	Common bully	5	32–47
	Longfin eel	3	95–310
	Shortfin eel	9	85–385
	Unidentified eel	5	Not recorded
	Banded kōkopu	1	42
	Freshwater shrimp	present	
Two	Common bully	112	21–86
	Unidentified bully (likely to be common bullies, eaten by tuna)	17	Not recorded
	Longfin eel	2	540, 740
	Shortfin eel	11	346–665
	Freshwater shrimp	present	
Three	Common bully	1	42
	Shortfin eel	1	430
	Freshwater shrimp	present	



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NZ FRESHWATER FISH DATABASE FORM	PLEASE RETURN TO: FRESHWATER FISH DATABASE NIWA PO BOX 11-115, HAMILTON	
Date 29/11/07	Catchment system 034.001	Catchment number
Time 10:00 am	Sampling locality Waipapa stream (site 1)	
Observer JATB	Access notes Ironbark road	Altitude (m)
Organisation NIWA	NZMS260 map P05 — Coordinates 2591900 E 6667200 N	Inland distance (km)
Fishing method EFM	Area fished (m^2) or Number of nets used 15m length x 3.5m width = 52.5m^2 — Number of electric fishing passes 1	Tidal yes/[✓ no]/unknown

HABITAT DATA

Water	Colour blue/green/tea/[✓ uncoloured]/other:			Clarity [✓ clear]/milky/dirty		Temp.	pH
	Average width (m) 3.5		Average depth (m) 0.3	Maximum depth (m) 0.4		Conductivity (ms/m)	
Habitat type (%)	Still	Backwater	Pool	Run 100	Riffle	Rapid	Cascade
Substrate type (%)	Mud	Sand	Fine gravel	Coarse gravel 10	Cobble 70	Boulder 20	Bedrock
Fish cover (yes/no)	Weed Algae Y	Instream debris N	Undercut banks N	Bank vegetation N			
Catchment vegetation (%)	Native forest 10	Exotic forest 10	Farming	Urban area	Scrub 10	Swamp land	Other 70
Riparian vegetation (%)	Native forest	Exotic forest	Grass Tussock	Exposed bed 95	Scrub Willow	Raupo Flax 5	Other

Type of river/stream/lake

Water level low/[✓ normal]/high/unknown	Downstream blockage yes/no/[✓ unknown]	Pollution nil/[✓ low]/moderate/high
Large invertebrate fauna	Koura abundant/common/occasional/rare/nil/[✓ unknown] or numbers observed	
	Paratya shrimp abundant/[✓ common]/occasional/rare/nil/unknown	Freshwater mussels [✓ nil]/present/unknown
Small benthic invertebrate fauna low/moderate/high/[✓ unknown]	Predominant species mayflies/caddis/snails/combination/other	Permanent water [✓ yes]/no/unknown
Purpose of work		

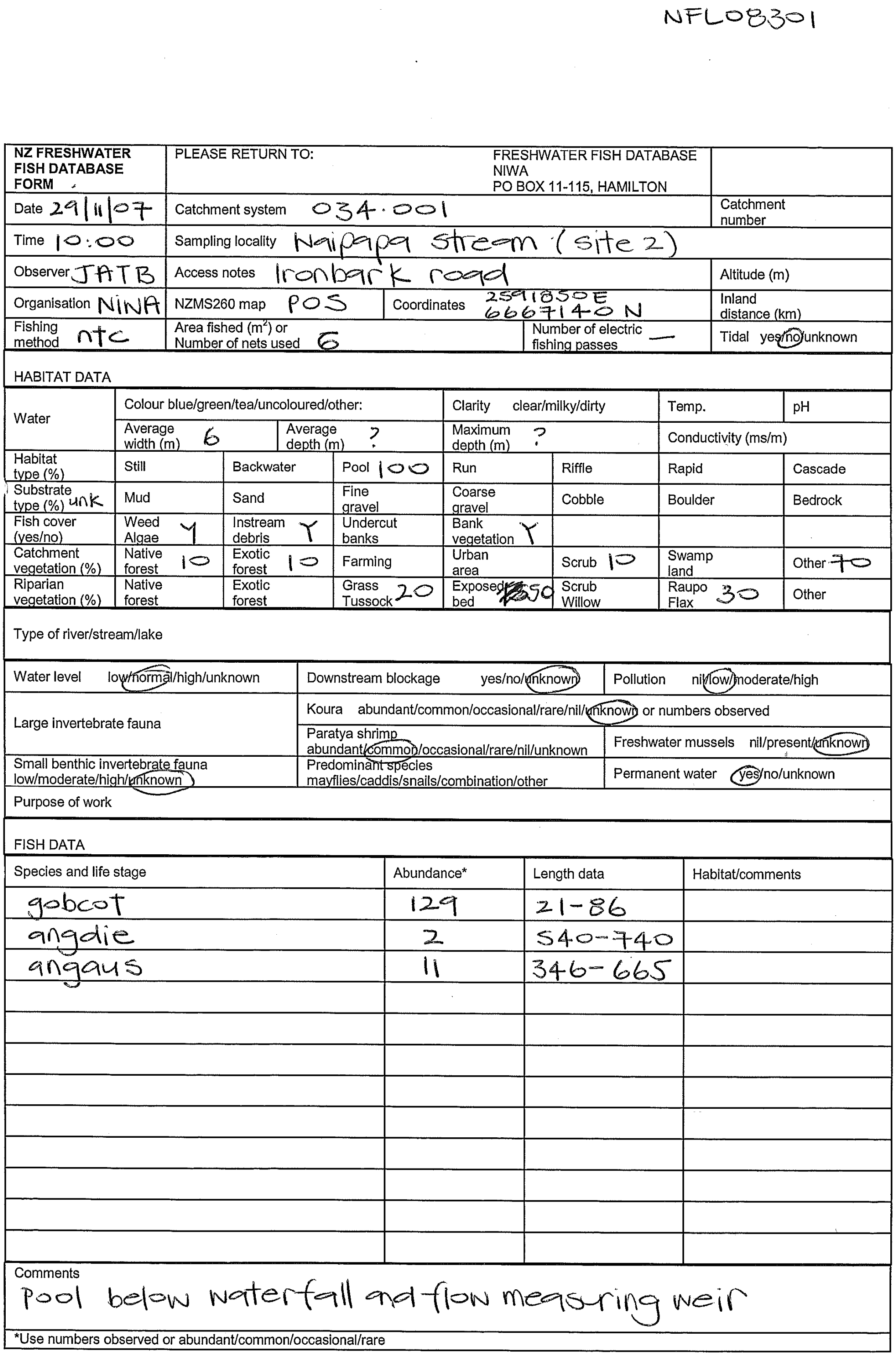
FISH DATA

Species and life stage	Abundance*	Length data	Habitat/comments
gobcot	5	32-47	
galfas	1	42	
angdie	3	95-310	
angaus	9	85-385	
anguil	5		

Comments

*Use numbers observed or abundant/common/occasional/rare

Figure A3. Raw data collected from Site 1 on the Waipapa Stream, recorded in a New Zealand Freshwater Fish Database (NZFFD) form.



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NZ FRESHWATER FISH DATABASE FORM	PLEASE RETURN TO:	FRESHWATER FISH DATABASE NIWA PO BOX 11-115, HAMILTON	
Date 29/11/07	Catchment system 034·001		Catchment number
Time 10:00	Sampling locality Waipapa stream (site 2)		
Observer JATB	Access notes Ironbark road		Altitude (m)
Organisation NIWA	NZMS260 map P05	Coordinates 2591850 E 6667140 N	Inland distance (km)
Fishing method ntc	Area fished (m^2) or Number of nets used 6	Number of electric fishing passes —	Tidal yes/[✓ no]/unknown

HABITAT DATA

Water	Colour blue/green/tea/uncoloured/other:			Clarity clear/milky/dirty		Temp.	pH
	Average width (m) 6		Average depth (m) ?	Maximum depth (m) ?		Conductivity (ms/m)	
Habitat type (%)	Still	Backwater	Pool 100	Run	Riffle	Rapid	Cascade
Substrate type (%) unk	Mud	Sand	Fine gravel	Coarse gravel	Cobble	Boulder	Bedrock
Fish cover (yes/no)	Weed Algae Y	Instream debris Y	Undercut banks	Bank vegetation Y			
Catchment vegetation (%)	Native forest 10	Exotic forest 10	Farming	Urban area	Scrub 10	Swamp land	Other 70
Riparian vegetation (%)	Native forest	Exotic forest	Grass Tussock 20	Exposed bed 50	Scrub Willow	Raupo Flax 30	Other

Type of river/stream/lake

Water level low/[✓ normal]/high/unknown	Downstream blockage yes/no/[✓ unknown]	Pollution nil/[✓ low]/moderate/high
Large invertebrate fauna	Koura abundant/common/occasional/rare/nil/[✓ unknown] or numbers observed	
	Paratya shrimp abundant/[✓ common]/occasional/rare/nil/unknown	Freshwater mussels nil/present/[✓ unknown]
Small benthic invertebrate fauna low/moderate/high/[✓ unknown]	Predominant species mayflies/caddis/snails/combination/other	Permanent water [✓ yes]/no/unknown

Purpose of work

FISH DATA

Species and life stage	Abundance*	Length data	Habitat/comments
gobcot	129	21-86	
angdie	2	540-740	
angaus	11	346-665	

Comments
Pool below waterfall and flow measuring weir

*Use numbers observed or abundant/common/occasional/rare

Figure A4. Raw data collected from Site 2 on the Waipapa Stream, recorded in a New Zealand Freshwater Fish Database (NZFFD) form.

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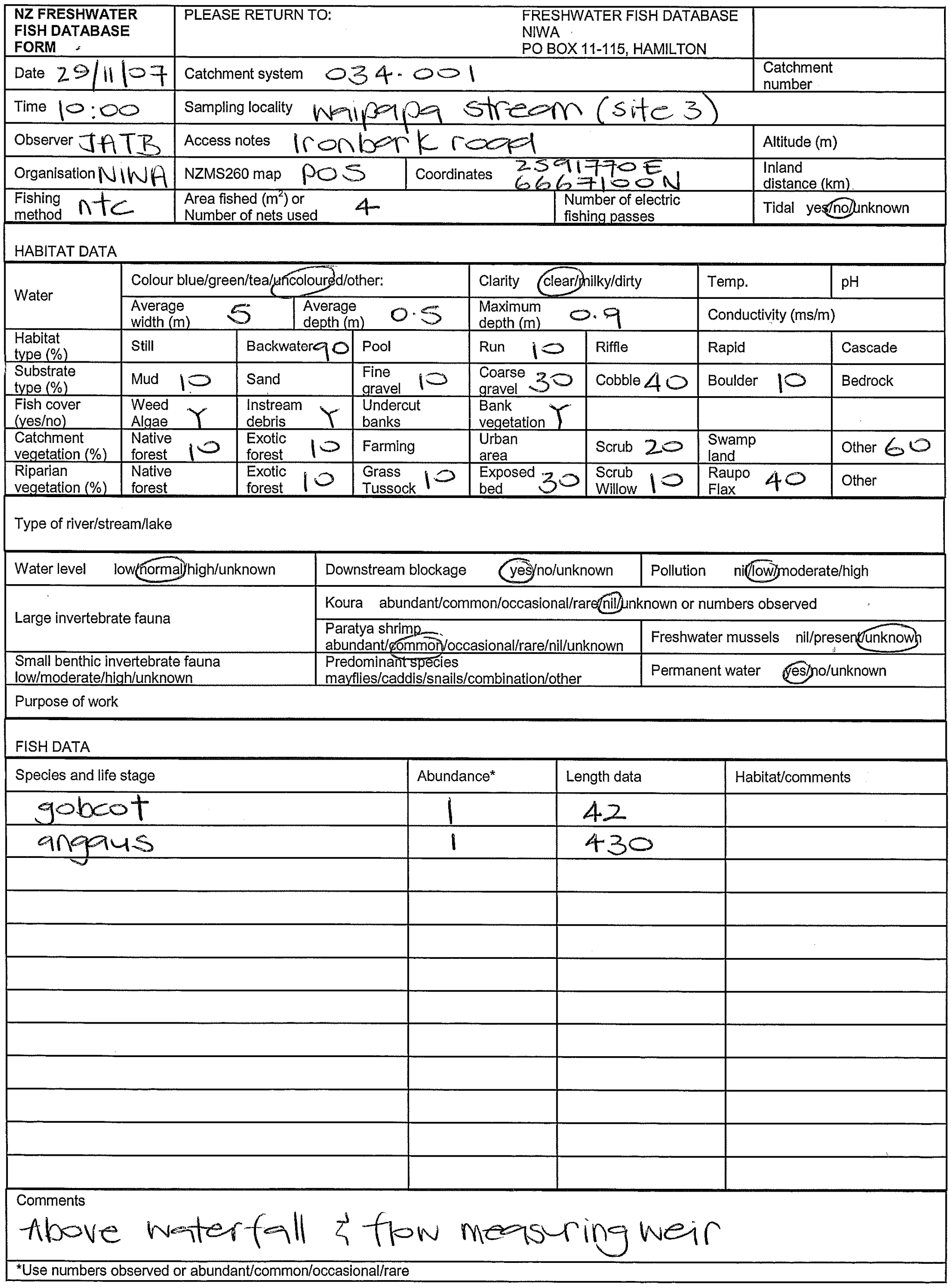


NZ FRESHWATER FISH DATABASE FORM	PLEASE RETURN TO:	FRESHWATER FISH DATABASE NIWA PO BOX 11-115, HAMILTON	
Date 29/11/07	Catchment system 034.001		Catchment number
Time 10:00	Sampling locality waipapa stream (site 3)		
Observer JATB	Access notes Ironbark road		Altitude (m)
Organisation NIWA	NZMS260 map P05	Coordinates 2591770E 6667100N	Inland distance (km)
Fishing method ntc	Area fished (m^2) or Number of nets used 4	Number of electric fishing passes	Tidal yes/[✓ no]/unknown

HABITAT DATA

Water	Colour blue/green/tea/[✓ uncoloured]/other:			Clarity [✓ clear]/milky/dirty		Temp.	pH
	Average width (m) 5		Average depth (m) 0.5	Maximum depth (m) 0.9		Conductivity (ms/m)	
Habitat type (%)	Still	Backwater 90	Pool	Run 10	Riffle	Rapid	Cascade
Substrate type (%)	Mud 10	Sand	Fine gravel 10	Coarse gravel 30	Cobble 40	Boulder 10	Bedrock
Fish cover (yes/no)	Weed Algae Y	Instream debris Y	Undercut banks	Bank vegetation Y			
Catchment vegetation (%)	Native forest 10	Exotic forest 10	Farming	Urban area	Scrub 20	Swamp land	Other 60
Riparian vegetation (%)	Native forest	Exotic forest 10	Grass Tussock 10	Exposed bed 30	Scrub Willow 10	Raupo Flax 40	Other

Type of river/stream/lake

Water level low/[✓ normal]/high/unknown	Downstream blockage [✓ yes]/no/unknown	Pollution nil/[✓ low]/moderate/high
Large invertebrate fauna	Koura abundant/common/occasional/rare/[✓ nil]/unknown or numbers observed	
	Paratya shrimp abundant/[✓ common]/occasional/rare/nil/unknown	Freshwater mussels nil/present/[✓ unknown]
Small benthic invertebrate fauna low/moderate/high/unknown	Predominant species mayflies/caddis/snails/combination/other	Permanent water [✓ yes]/no/unknown
Purpose of work		

FISH DATA

Species and life stage	Abundance*	Length data	Habitat/comments
gobcot	1	42	
angaus	1	430	

Comments

Above waterfall & flow measuring weir

*Use numbers observed or abundant/common/occasional/rare

Figure A5. Raw data collected from Site 3 on the Waipapa Stream, recorded in a New Zealand Freshwater Fish Database (NZFFD) form.

Although the methodology that we used was not as comprehensive as a full scientific survey (i.e., would have been better to have used a consistent set of net types deployed at each location, and electric fished upstream of the waterfall/weir also) we can start to see how we can use CPUE to compare the distribution of fish between sites, above and below the waterfall/weir (Table A2).

Table A2. Catch per unit effort (CPUE) for fyke nets and Gee-minnow traps set overnight in Waipapa Stream.

Species	Method	CPUE (mean number of fish caught per net set overnight) Downstream of waterfall (Site 2)	Upstream of waterfall (Site 3)
Common bully	Coarse-mesh fyke	0	0
	Fine mesh-fyke	45.5	1
	Gee-minnow trap	19	0
Shortfin eel	Coarse-mesh fyke	3.5	1
	Fine mesh-fyke	2	0
	Gee-minnow trap	0	0
Longfin eel	Coarse-mesh fyke	1	0
	Fine mesh-fyke	0	0
	Gee-minnow trap	0	0

The majority of the common bullies were caught in the fine-mesh fyke nets set downstream (i.e., Site 2) of the natural waterfall and weir structure. Gee-minnow traps were also successful at catching common bullies, but mesh size of the coarse fyke nets was too big to catch these smaller fish species successfully. Although the number of eels captured was fairly low, the majority were caught in the coarse-mesh fyke nets. No eels were caught in the Gee-minnow traps.

Common bullies and both tuna species were more common below the waterfall and weir structure when compared to the results obtained upstream. Shortfin tuna were more common than longfin tuna (Tables 2 and 3).

Although we can not directly compare the CPUE results that we got from the electric-fishing to those observed in the nets and traps (as we would be comparing different units - number per net per night versus number of fish caught per square metre fished), this method gives us some different types of information (Table A3 and Figure A6).

Table A3. Catch per unit effort (CPUE) for electric fishing.

Site	**Species**	**CPUE (number of fish per m^2)**
One	Common bully	0.10
	Longfin eel	0.06
	Shortfin eel	0.17
	Unidentified eel	0.10
	Banded kōkopu	0.02

Length distribution

The length distribution of the two most common species (i.e., common bullies and shortfin eels) are presented in the following graph (Figure A6). The most obvious feature is that both common bullies and shortfin tuna were very rare upstream of the waterfall. The large pool below the waterfall supports a fairly healthy common bully and shortfin tuna population, where a large range of size classes were present.

We can see that the electric fishing (Site 1) was the most successful method for capturing smaller size classes of fish, like elvers (< 100 mm) (Figure A6). However, we can’t rule out the possibility of elvers occurring at Sites 2 and 3 because it may be due to the methods that we used (i.e., traps and nets) that we didn’t capture them at these sites. In deeper waters there are very few reliable methods available for sampling elvers and glass eels at present.

Age distribution

The otoliths of two tuna captured during the workshop (from below the waterfalls) were taken back to the laboratory to determine the age of these eels (Table A4). The eels ranged between 13 and 16 years of age. Although we only have a very small sample of tuna, we can use these measurements to work out how fast they are growing in a year (i.e., annual growth increment), and we can use this information to compare growth between populations living in different places. To work out the annual growth increment, a length of 63 mm was subtracted from the total length of the longfins, being the average length of glass eels at arrival. This is then divided by the age (i.e., ((length – 63) / age)). As a comparison, Rowe & Chisnall (1997) recorded mean annual growth rates of between 24 mm/yr and 32 mm/yr in the Waiaruhe River and Manaia Stream (Waitangi River catchment) respectively.

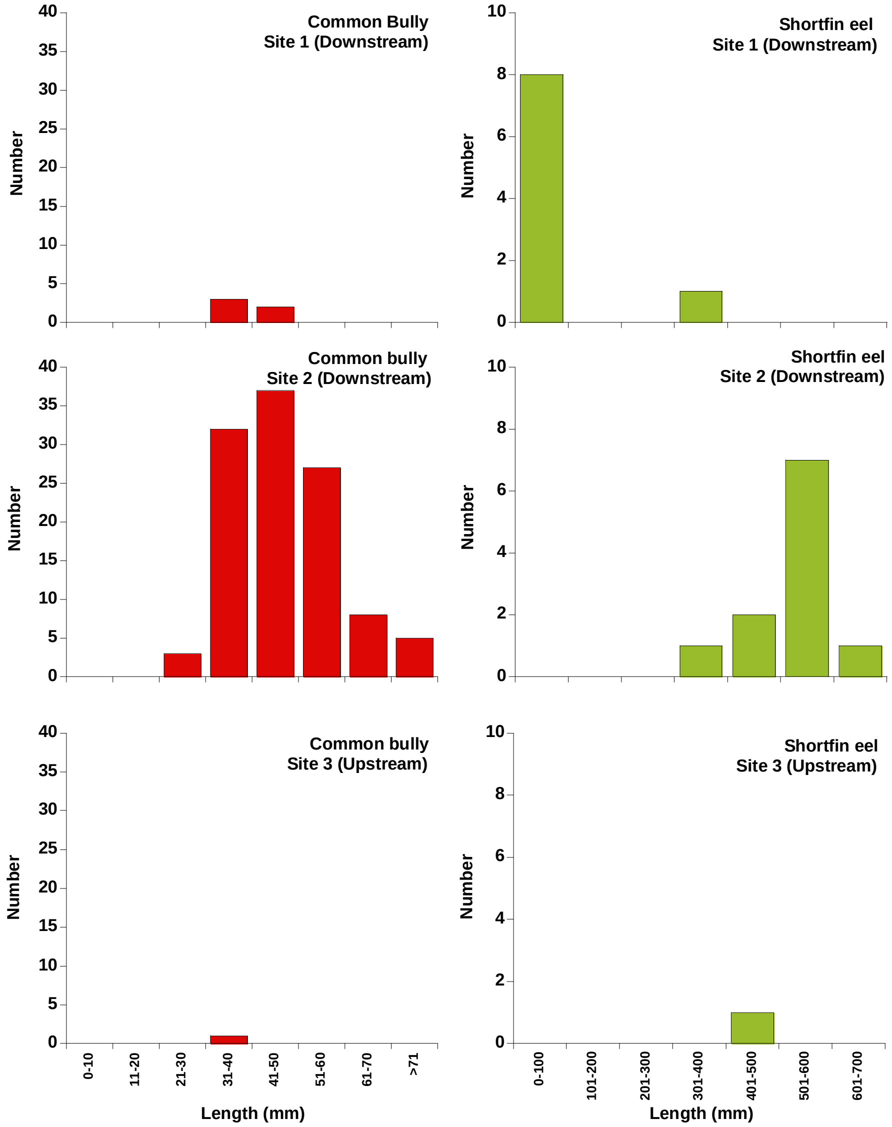


Figure A6. Length distribution of common bullies and shortfin tuna caught from Waipapa Stream both downstream (Site 1 & 2) and upstream (Site 3) of the waterfall and weir structure.

Table A4. Age of longfin tuna captured from the Waipapa Stream.

No.	Species	Length (mm)	Weight (g)	Age (yr)	Annual growth increment (mm / yr)
1	Longfin	530	460	13	35.9
2	Longfin	665	780	16	37.6

Historical records

The NZFFD was searched for any records pertaining to the Waipapa Stream and the neighbouring Kerikeri River to provide a reference point (from a western science perspective) regarding the status of freshwater fisheries information.

Only one other record exists in the NZFFD for the Waipapa Stream itself. A site downstream of where we fished during the workshop was sampled in 2002 by the Department of Conservation using a mixture of net types. They observed abundant numbers of common bullies and the introduced pest species, mosquitofish.

Sixty-seven records (between 1962 and 2007) exist in the NZFFD for the Kerikeri River catchment (predominantly sampled by DoC and NIWA). In the Kerikeri River catchment there are a variety of both indigenous (79%) and introduced species (21%) present. Banded kōkopu, Burgundy mudfish, and the introduced pest species mosquitofish were the ones most frequently encountered in the Kerikeri catchment. No fish species were recorded at 21% of the sites sampled in this catchment. The relatively high number of sites where no fish species (and Burgundy mudfish) were observed may be due to the fairly recent "discovery" (i.e., 1993) of the Burgundy mudfish in the vicinity of the Kerikeri airport and near Ngāwhā – and their attempts to establish the extent of their distribution (Table A4).

For the Kerikeri River catchment, the abundance of shortfin tuna is recorded as 0.16 ± 0.10 eels/ Gee-minnow traps (N = 10) for, 0.4 eels/Kilwell bait trap (N = 1); and 0.01 eels/m^2 using electric fishing (N = 1). The abundance of longfin tuna was estimated to be 0.16 ± 0.12 eels/G-minnow trap (N = 2) and 0.05 eels/m^2 using electric fishing (N = 1).

Discussion

Below the waterfall and weir structure we observed a four types of native freshwater fish species (both eel species, banded kōkopu and common bullies) the majority, over a range of size classes (with the exception of banded kōkopu where we only caught 1). Using the NZFFD records from the neighbouring Kerikeri River we might have also expected to see mosquitofish, kōura, redfin bully, inanga and possibly smelt below the waterfall/weir structure considering the habitats that we sampled.

Below the waterfall/weir we observed a wide range of sizes classes for the two most abundant species, shortfin eels and common bullies. Above the waterfall/weir we observed only one common bully and shortfin eel. As we all expected, these results indicate that the waterfall-weir structure is a partial barrier, restricting the upstream movement of freshwater fish species in the Waipapa Stream. Tuna and some type of whitebait species are likely to surmount the waterfall and weir structure when they are very small using the wetted margins.

Table A4. Summary of NZFFD information for records from the Kerikeri River catchment Introduced species are shown in italics.

Species	Occurrence / total 67 records (%)	Relative abundance[1]	Min–max length (mm)
Grey mullet	1	rare	–
Unidentified salmonid	*1*	*rare*	–
Bluegill bully	1	rare	–
Smelt	3	occasional	87–93
Torrentfish	3	common	52–98
Crans bully	3	occasional-common	53–58
Goldfish	*3*	*rare–common*	*235–250*
Koi carp	*3*	*rare*	*700–752*
Kōura	4	rare	–
Estuarine cockabully	6	occasional–abundant	44–60S
Common bully	7	rare-abundant	
Giant bully	7	rare-occasional	75–124
Unidentified eels	7	rare-common	–
Inanga	9	occasional	73–115
Redfin bully	9	rare-abundant	39–95
Longfin eel	12	rare-abundant	320–1000
Shortfin eel	19	occasional	250–600
Burgundy mudfish	21	rare-common	20–113
No species present	21	–	–
Mosquitofish	*21*	*occasional–abundant*	*21–45*
Banded kōkopu	31	rare–abundant	37–198

1, where numbers of each species are not measured, “abundance” is assigned as either: rare (r), occasional (o), common (c) or abundant (a).

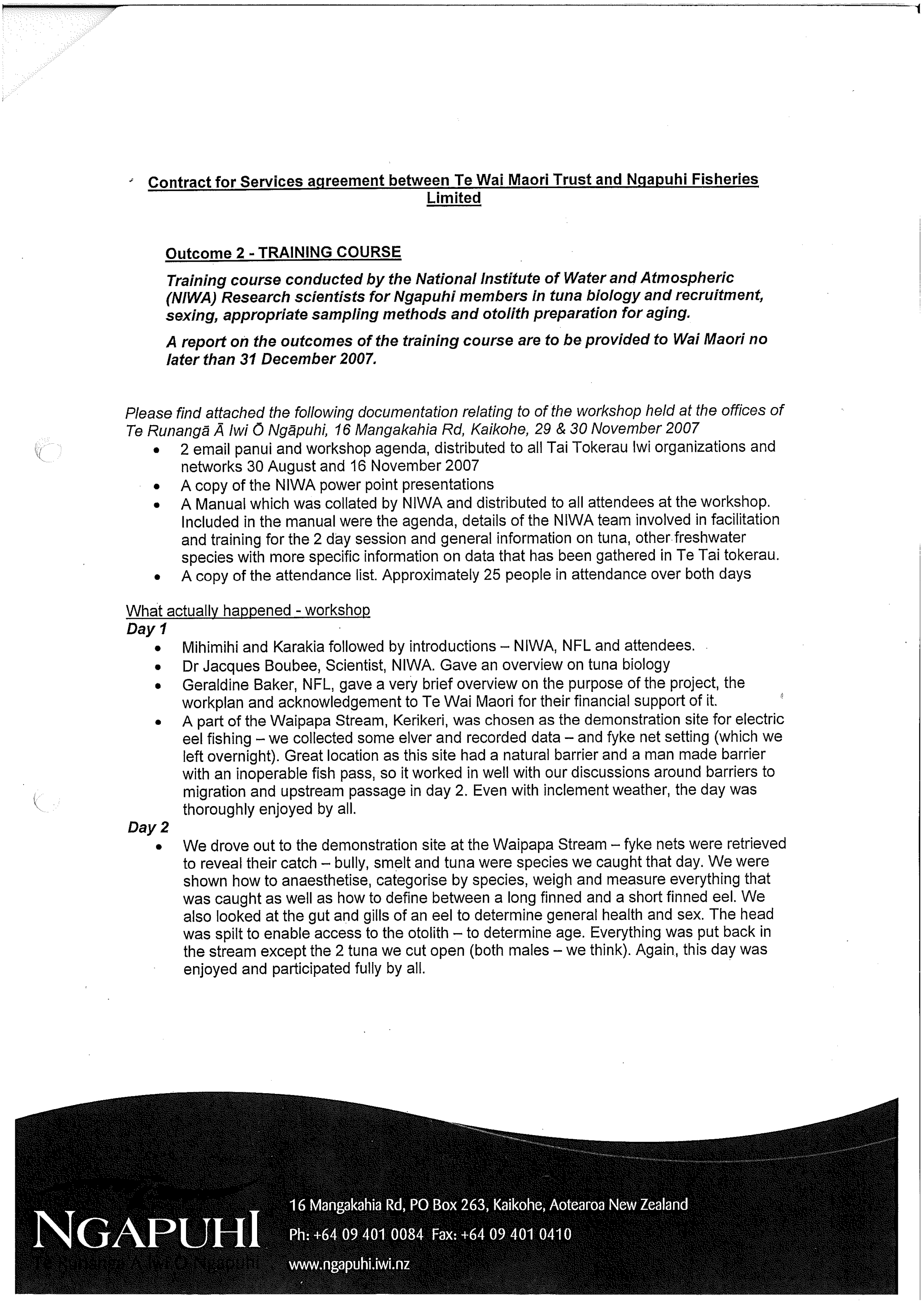
If the overall goal of our research was, for example, to assess the recruitment of eels into Lake Manuwai, then the focus and methodologies we should use would be different to that demonstrated during our workshop. For example, we would be able to increase the accuracy of our observations by increasing the number of sites both upstream and downstream of the waterfall/weir structure that were sampled. We would also sample the lake itself to get an idea about the numbers of tuna reaching the lake, the age and growth rate of these fish. It would also be useful to walk the length of the stream to locate and describe any other in-stream barriers to fish passage so as to identify structures that may require retrofitting to better facilitate passage. If you remember, there was a kind of fish passage structure on the weir when we visited, however no water was running through it. These would be some of the things you might do in order to help you understand, in this example, tuna recruitment into the lake, as well as identifying potential solutions to increase lake tuna populations should that be the goal.

References

Fish & Game New Zealand. (n.d). Reservoir fishing in Northland. Lake Manuwai. http://www.fishandgame.org.nz/Site/Regions/Northland/fisheries.aspx

Rowe, D. K., Chisnall, B. L. 1997. Heavy metals in muscle tissue of eels at sites near the Ngawha geothermal field. NIWA Client Report TSA07201, Hamilton, New Zealand. 23 p.

8.3 Appendix 3: Report provided to Te Wai Māori September 2007 following the completion of the training workshop (Objective 2).



Contract for Services agreement between Te Wai Maori Trust and Ngapuhi Fisheries Limited

Outcome 2 - TRAINING COURSE

Training course conducted by the National Institute of Water and Atmospheric (NIWA) Research scientists for Ngapuhi members in tuna biology and recruitment, sexing, appropriate sampling methods and otolith preparation for aging.

A report on the outcomes of the training course are to be provided to Wai Maori no later than 31 December 2007.

Please find attached the following documentation relating to of the workshop held at the offices of Te Runangā Ā Iwi Ō Ngāpuhi, 16 Mangakahia Rd, Kaikohe, 29 & 30 November 2007

- 2 email panui and workshop agenda, distributed to all Tai Tokerau Iwi organizations and networks 30 August and 16 November 2007
- A copy of the NIWA power point presentations
- A Manual which was collated by NIWA and distributed to all attendees at the workshop. Included in the manual were the agenda, details of the NIWA team involved in facilitation and training for the 2 day session and general information on tuna, other freshwater species with more specific information on data that has been gathered in Te Tai tokerau.
- A copy of the attendance list. Approximately 25 people in attendance over both days

What actually happened - workshop

Day 1

- Mihimihi and Karakia followed by introductions – NIWA, NFL and attendees.
- Dr Jacques Boubee, Scientist, NIWA. Gave an overview on tuna biology
- Geraldine Baker, NFL, gave a very brief overview on the purpose of the project, the workplan and acknowledgement to Te Wai Maori for their financial support of it.
- A part of the Waipapa Stream, Kerikeri, was chosen as the demonstration site for electric eel fishing – we collected some elver and recorded data – and fyke net setting (which we left overnight). Great location as this site had a natural barrier and a man made barrier with an inoperable fish pass, so it worked in well with our discussions around barriers to migration and upstream passage in day 2. Even with inclement weather, the day was thoroughly enjoyed by all.

Day 2

- We drove out to the demonstration site at the Waipapa Stream – fyke nets were retrieved to reveal their catch – bully, smelt and tuna were species we caught that day. We were shown how to anaesthetise, categorise by species, weigh and measure everything that was caught as well as how to define between a long finned and a short finned eel. We also looked at the gut and gills of an eel to determine general health and sex. The head was spilt to enable access to the otolith – to determine age. Everything was put back in the stream except the 2 tuna we cut open (both males – we think). Again, this day was enjoyed and participated fully by all.

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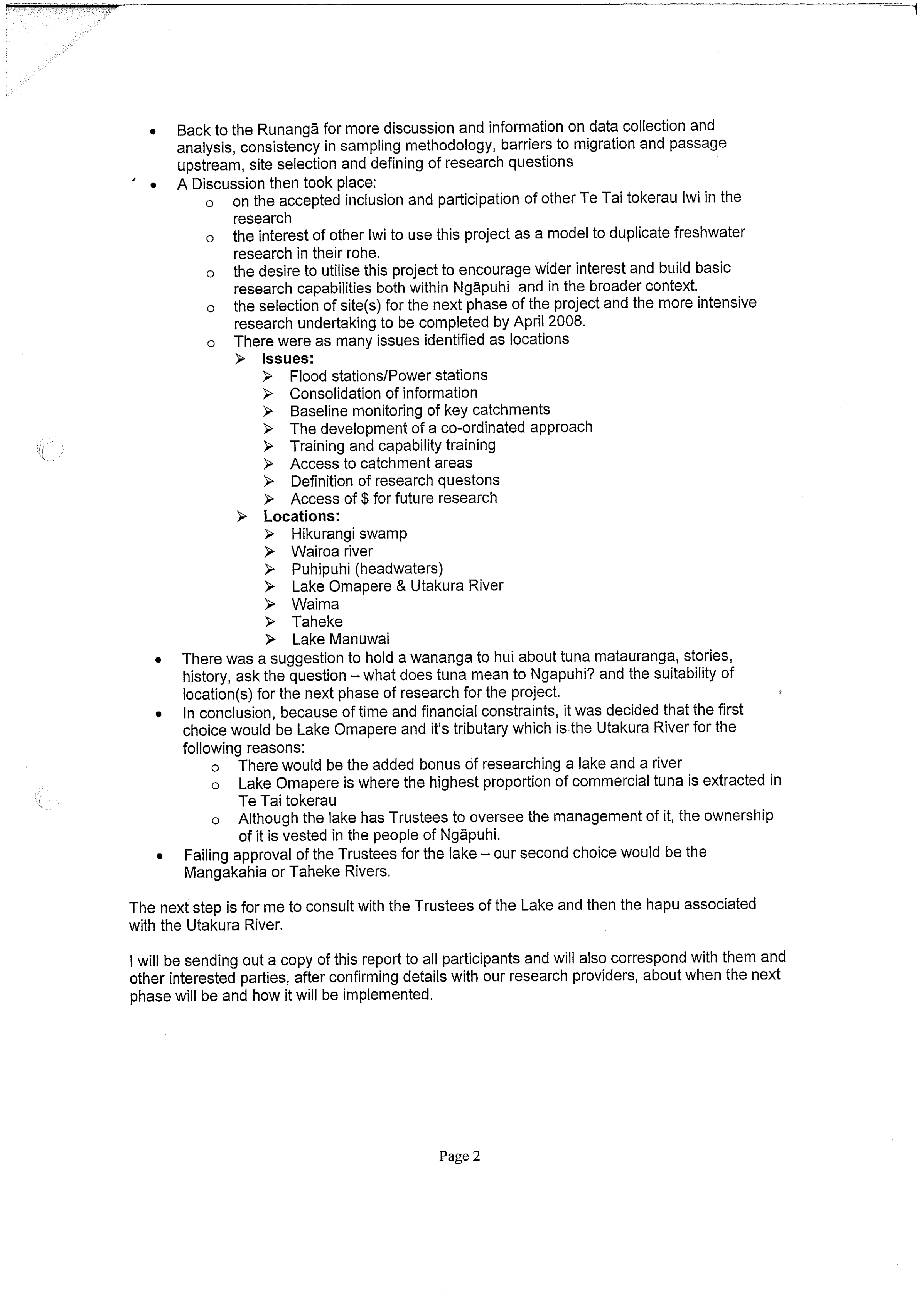

- Back to the Runangā for more discussion and information on data collection and analysis, consistency in sampling methodology, barriers to migration and passage upstream, site selection and defining of research questions
- A Discussion then took place:
  - on the accepted inclusion and participation of other Te Tai tokerau Iwi in the research
  - the interest of other Iwi to use this project as a model to duplicate freshwater research in their rohe.
  - the desire to utilise this project to encourage wider interest and build basic research capabilities both within Ngāpuhi and in the broader context.
  - the selection of site(s) for the next phase of the project and the more intensive research undertaking to be completed by April 2008.
  - There were as many issues identified as locations
    - **Issues:**
      - Flood stations/Power stations
      - Consolidation of information
      - Baseline monitoring of key catchments
      - The development of a co-ordinated approach
      - Training and capability training
      - Access to catchment areas
      - Definition of research questons
      - Access of $ for future research
    - **Locations:**
      - Hikurangi swamp
      - Wairoa river
      - Puhipuhi (headwaters)
      - Lake Omapere & Utakura River
      - Waima
      - Taheke
      - Lake Manuwai
- There was a suggestion to hold a wananga to hui about tuna matauranga, stories, history, ask the question – what does tuna mean to Ngapuhi? and the suitability of location(s) for the next phase of research for the project.
- In conclusion, because of time and financial constraints, it was decided that the first choice would be Lake Omapere and it's tributary which is the Utakura River for the following reasons:
  - There would be the added bonus of researching a lake and a river
  - Lake Omapere is where the highest proportion of commercial tuna is extracted in Te Tai tokerau
  - Although the lake has Trustees to oversee the management of it, the ownership of it is vested in the people of Ngāpuhi.
- Failing approval of the Trustees for the lake – our second choice would be the Mangakahia or Taheke Rivers.

The next step is for me to consult with the Trustees of the Lake and then the hapu associated with the Utakura River.

I will be sending out a copy of this report to all participants and will also correspond with them and other interested parties, after confirming details with our research providers, about when the next phase will be and how it will be implemented.

Page 2

8.4 Appendix 4: Habitat descriptions of sites surveyed in the Lake Omapere and Utakura River catchment, November 2008.

Site No.	Location	Average depth (m)	Average width (m)	Clarity	Temp (ºC)	Conductivity (ms/m)	Habitat type (%)	Substrate type (%)	Riparian vegetation
1–9	Lake Omapere	1.4 (1.8 max)	–	Dirty	16.3–17.7	58.2–58.9	100% still	10% boulder, 20% cobble, 70% mud	60% farming, 20% scrub/willow, 10% exotic forest, 10% raupo/flax
10	Waikirikiri Stream	0.2 (0.5 max)	2.43	Clear	16	98	55% run, 40% riffle, 5% pool	90% boulder, 10% cobble	100% native forest
11	Waikirikiri Stream	0.4	2.8	Clear	15.5	97.4	60% run, 30% riffle, 10% pool	80% boulder, 15% cobble, 5% sand	100% native forest
12	Waikirikiri Stream	0.2 (0.4 max)	1.5	Clear	15.7	106.1	100% run	30% fine gravel, 30% sand, 10% coarse gravel, 30% mud,	80% farming, 20% scrub/willow
13	Waihoanga Stream	0.4	1.5	Clear	18.4	106.3	70% pool, 15% run, 15% riffle	90% boulder, 5% fine gravel, 5% sand	40% Native bush, 35% scrub, 25% farming
14	Utakura River	0.4	1.5	Dirty	19	61	70% riffle, 30% torrent/rapids	95% boulder, 5% sand	100% native forest
15	Utakura River	1.5	2.0	Dirty	18.6	70.2	100% run	30% coarse & fine gravel, 10% mud, 20% bedrock, 20% boulder, 20% cobble,	80% farming, 20% scrub
16	Lake Omapere tributary	0.1 (0.2 max)	0.8	Clear	15.1	16.1	50% pool, 50% run	40% mud, 20% sand, 80% cobble	80% farming, 20% scrub
17	Lake Omapere tributary	0.3	0.8	Clear	–	–	20% pool, 80% run	80% mud, 20% sand	90% farming, 10% scrub
18	Lake Omapere tributary	0.1 (0.4 max)	0.6	Clear	18.6	150	20% pool, 80% run	100% mud	100% farming
19	Pararataio Stream	0.4 (0.6 max)	1.5	Clear	16.6	95.2	10% riffle, 10% pool, 80% run,	100% bedrock	100% farming