The aquatic ecology of Lake Rotokare

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Frontispiece – View of Lake Rotokare.

Abstract

The biology of three endemic and one exotic species of fish (banded kokopu, *Galaxias fasciatus*; shortfin eel, *Anguilla australis*; longfin eel, *Anguilla dieffenbachii*; and the European perch, *Perca fluviatilis*) was investigated in Lake Rotokare. Little is currently known regarding the local ecology of the lake. This study improves the understanding of the biological processes in Lake Rotokare and investigates the characteristics of the lake's water quality.

Fish sampling occurred in the lake using a combination of boat electrofishing, gill netting, and fyke netting. The tributary was sampled using night time spotlighting. Fish taken from the lake were used to determine length-weight relationships, size frequencies, CPUE, abundance estimations, fish biomass, stable isotope analyses, trophic levels, and perch diet. Water quality sampling was also undertaken to further build upon data from previous studies.

The majority of fish sampled in Lake Rotokare were perch, with a mixture of size classes, but dominated by a large juvenile size class. Perch density was high (16.55 fish 100 m^{-2}). Longfin eels showed a cohort of large individuals with no evidence of recruitment occurring; while shortfin eels exhibited a distribution of size ranges with evidence of juvenile recruitment occurring.

Electrofishing showed evidence of banded kokopu inhabiting the lake, even at distance from the tributary outlet, suggesting the possibility of a lake fringe population of kokopu. Spotlight sampling in June and December revealed a stable kokopu and kōura population residing in the lakes' main tributary. Water quality data showed an overall decrease in total nitrogen and phosphorus loads within the lake since 1979. However, the lake has shown strong thermal stratification over summer over multiple years (1977, 2013, February 2017 and December 2017), and remains in poor condition, with a eutrophic TLI_4 rating of 4.1. Frequent cyanobacterial blooms continue to occur during the summer season, resulting in closure of the lake for contact recreation.

Both dietary and stable isotope analyses showed indications that chironomid larvae and *Daphnia* sp. constituted the bulk of the primary production of the food web;

juvenile perch were found to be the predominant food source of the three resident fish species. The lake food web was trophically adjusted for higher-level consumers and compared with chironomid larvae, dragonfly larvae, and juvenile perch as end members. Lipid treatment techniques were examined in this study to compare the bias between eel fin and muscle tissue. The results indicate that lipid treatment is needed for ^{13}C isotope values for both longfin and shortfin muscle, and longfin fin tissue for accurate results. Mathematical equations were constructed to correct untreated fin tissue values into treated muscle values for ^{13}C and ^{15}N; avoiding the necessity for future lethal sampling methods.

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Chapter 1: Introduction

1.1 Overview

Human incursion into natural environments has become common practice in the last century. The acquisition of natural resources to fulfil human needs often comes at the expense of degrading the surrounding environment (Foley et al., 2005). Exploitation of aquatic ecosystems is nothing new, humans have exploited these environments since the dawn of civilization for a variety of reasons. However, manipulation of ecosystems (particularly aquatic environments) has become increasingly complicated in recent times – as society has learned to appreciate that lakes and rivers provide essential ecosystem goods and services (Arthington et al., 2006). Over time, freshwater ecosystems have generally continued to exhibit a trend of decline; through withdrawal of water, degradation of water quality, changing the flow patterns of waterways and other various anthropogenic stressors (Gleick, 2003; Foley et al., 2005).

This trend of decline is also apparent on a localized scale. New Zealand's freshwater environments are under severe pressure from a number of destabilising and damaging activities (Collier & Grainger, 2015). Nationally, freshwater lakes and rivers have been showing steady rates of decline for decades. This coupled with management approaches tailored at maintaining the bottom line of acceptable environmental conditions; or maximum pollutant loads, has led to poor national standards and severe ecological degradation (Baron et al., 2002; Howard-Williams et al., 2010). In addition to problematic environmental management, other anthropogenic influences have further degraded natural freshwater ecosystems. For instance, primarily land-use intensification, water extraction for irrigation leading to habitat reduction and loss, and biosecurity threats such as unwanted organisms and diseases are significant contributors towards ecological degradation (Collier & Grainger, 2015). Furthermore, both global and regional signals point towards climate change exacerbating these drivers even more dramatically in the future.

Although there are many drivers of environmental degradation, in recent years the unsuccessful management paradigm in New Zealand has shifted, as both the local and national governing bodies, and the wider public have recognized the need for further improvement of water quality and freshwater ecosystems (Hughey et al., 2013; Julian et al., 2017).

1.2 Study site

This study focuses on a freshwater lake; Lake Rotokare, situated in the Taranaki region, on the west coast of the North Island, New Zealand. Lake Rotokare (39°27'12.1"S, 174°24'40.0"E; Figure 1.1) is a small (17.8 ha), natural-peat lake, formed roughly 1900 years ago through the damming of a major stream channel below a confluence of two streams as a result of a substantial landslide event near the current outflow located at the southwest end (Taranaki Catchment Commission, 1980; Lowe & Green, 1992). The lake is situated within the 230 ha Rotokare Scenic Reserve and is 37 km from the sea at an elevation of 200 m, with a catchment area of roughly 265 ha (Figure 1.1; Hicks et al., 2013). The reserve is located in the eastern Taranaki region, 12 km east of Eltham.

The lake has a variable maximum depth of 10 m (Taranaki Catchment Commission, 1980) and consists of two dominant arms. The northern arm, with a distance from the central N – S points of 772 m; and the eastern and western branches, with a distance of roughly 670 m between branches. The maximum width of the lake never reaches more than 200 m at any point (Turner et al., 2009). The lake consists of one main basin located within the centre of the lake, with two arms varying in depth between 5-9 m (Figure 1.2), with an average depth of approximately 6 m (Taranaki Catchment Commission, 1980). The banks of the lake are steep inclines, often greater than 3 m from the water’s edge, this is largely due to the expanse of vegetation growth outwards at all points surrounding the lake; with the exception of the developed area surrounding the boat ramp (Taranaki Catchment Commission, 1980).

There is minimal amount of inflow or outflow of the lake. Water enters the lake from a number of sources, including discharge from indirect overland flow, direct precipitation, ground water and surface runoff, it is primarily fed by one main inlet stream however (Figure 1.1). The lake has an average annual flow of 50 L s^{-1}, with an average annual low flow of 3 L s^{-1}. Most of the stream inflows appearing on topographical maps are ephemeral, and completely dependent on rainfall for their existence. However, the north-western stream inflow adjacent to the jetty is a continuous source of surface water, with populations of adult banded kokopu residing there (Hicks et al., 2013). The lake drains via the Ararata Stream, which flows into the Tangahoe River, with a 37 km distance to travel before reaching the sea (Figure 1.1). Lake Rotokare has significantly higher sedimentation rates than surrounding lakes within the Taranaki region; Turner et al. (2009) attribute this to the lake waters mixing only throughout the winter period, becoming strongly stratified during spring and summer, leading to a long sedimentation residency time. This is primarily attributed to the depth of the lake, and the lack of external mixing sources.

Lake Rotokare is used extensively for recreational purposes as the surrounding region has few other accessible freshwater lakes. Therefore, Rotokare is a highly popular destination for locals, for a range of water-based activities – powerboating, kayaking, water-skiing, wind surfing, and angling; however, this popularity creates issues, as the stratification of the lake over summer leads to frequent phytoplankton blooms of blue-green algae (cyanobacteria). Cyanobacterial blooms are recognized as a public health hazard due to their ability to produce cyanotoxins, these toxins can be a threat to humans and animals if consumed in drinking water or through incidental contact during recreational activities, and pose a potential threat to anyone using the lake. Therefore the blooms at Rotokare often cause frequent closure of the lake during the powerboating season, which ties in closely with the algal growth period. Due to the high level of public interaction with the lake, it is important to establish detailed ongoing ecological research in order to establish the biotic and abiotic parameters of this lake to help advise on any potential future lake restoration.

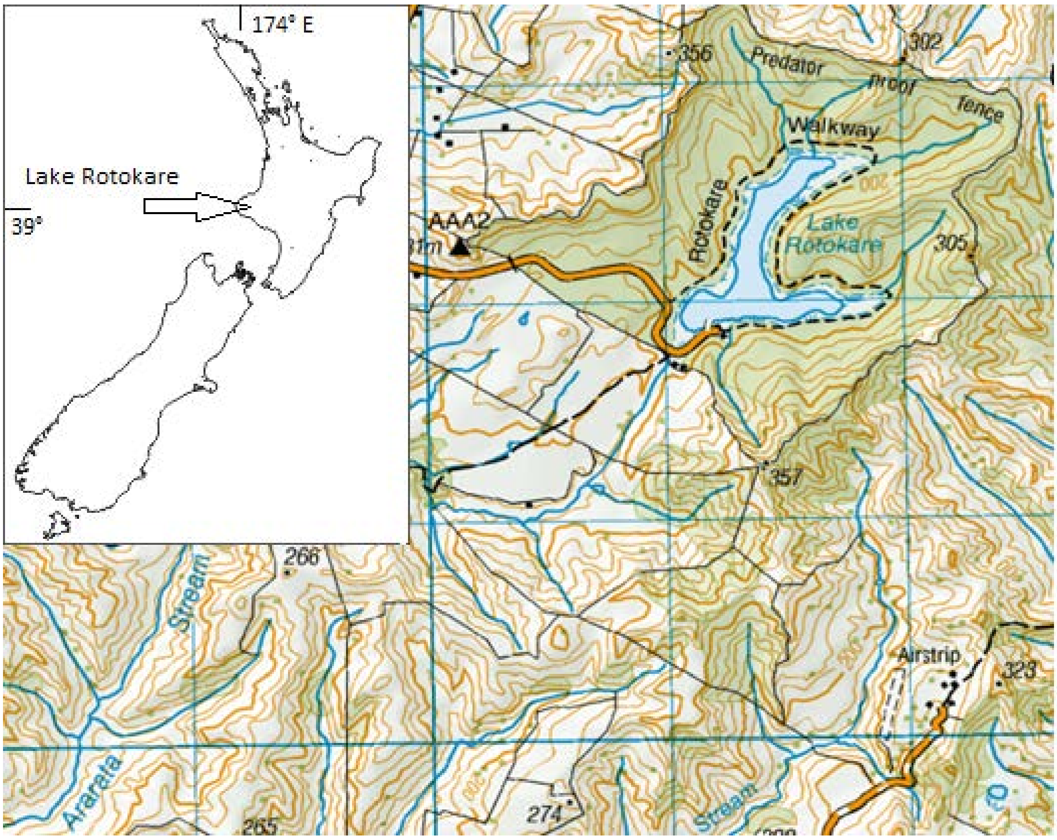
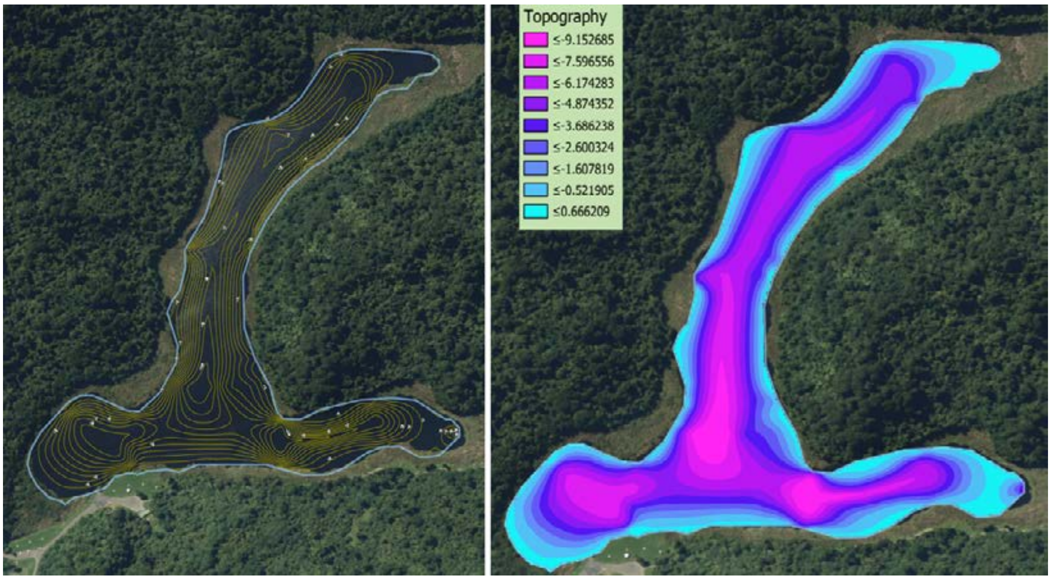


Figure 1.1: Topographical map and location of Lake Rotokare in the Tangahoe River catchment with reference to location within New Zealand (Lake Rotokare/Taranaki Topographical map, (2017).



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1.3 History of ecological change

Lake Rotokare frequently has cyanobacterial blooms, and has suffered from past agricultural practices (mainly farming) from the early-mid 20th century when the land surrounding the lake was grazed by cattle. It has relatively few inputs for a lake its size, and hence, remains a relatively stable environment. In terms of the fish population, the lake currently has a population of European Perch (*Perca fluviatilis*; henceforth referred to as perch). Hicks et al., (2013) attribute the past introduction and establishment of a known invasive freshwater fish within Lake Rotokare; the perch, to potentially having a detrimental impact on the lakes ecology.

Additionally, there have also been changes in Lake Rotokare's macrophyte and zooplankton population, due to the invasion of exotic species. A report issued by the Taranaki Catchment Commission in 1980, indicated that the driving factor attributed to one of the macrophyte invasions was likely the development of Sanger road in 1975, the sole road leading into the reserve. Open access led to the transportation of *Lagarosiphon major* (oxygen weed) into the lake; presumably brought in by boats from other infested lakes. There has also been a documented shift of species composition in the planktonic community sometime between 1980 and 2013. Hicks et al. (2013) carried out a basic ecological assessment of the lake, and found there was shift in the dominant species of zooplankton. Originally, the lake was dominated by *Boeckella* sp., *Ceriodaphnia dubia* and *Bosmina meridionalis* at the time the Catchment Commission conducted their study; between 1978 and 1980 (Taranaki Catchment Commission, 1980). However, at some point in the 33 year window, *Daphnia galeata* (a North American invader) managed to successfully establish itself and became the dominant species. These invasions are highly significant as changes to macrophyte and plankton communities in other lakes have been documented to contribute to biodiversity losses (Kelly & Hawes, 2005); additionally, modifications to the composition of primary consumers in lakes can potentially have drastic negative effects on lake food webs (Duggan et al., 2006).

1.4 Flora and fauna of Lake Rotokare

Four species of fish are currently known to reside within Lake Rotokare; three native species, and one exotic species (Table 1.1). Both longfin and shortfin eels have been recorded in this lake. According to F. Gordon (personal communication, 21 February 2017), deliberate introductions of longfin eels have occurred on several occasions in the past, through a series of translocations from other water bodies throughout the region over the last few decades. It is likely that shortfin eels comprise the bulk of eel population within the lake, as previous attempts of sampling eel populations yielded almost exclusively shortfin eels (Taranaki Catchment Commission, 1980; Hicks et al., 2013), with results showing only one longfin captured during the 2013 survey, this 2013 study addresses the gap in knowledge of the dynamics of the eel population within the lake, and presents a quantitative population and biomass estimate of both species. There were also previous accounts of a native galaxiid being present in the lake, Inanga (*Galaxias maculatus*); however, subsequent sampling from Hicks et al. (2013) and sampling during this project failed to locate or identify any inanga within the lake. However, as highlighted by Hicks et al., (2013), the absence of inanga may be due to the fact the species does not typically travel long distances upstream. Given the distance from the coast to the lake, it is more likely that these fish were juvenile banded kokopu mistaken as inanga, due to the similarity in the two species appearances.

Table 1.1: Fish species found within Lake Rotokare on 9 Feb 2013 (Hicks et al., 2013).

Common name	Scientific name
Exotic:	
European perch	*Perca fluviatilis*
Native:	
Longfin eel	*Anguilla dieffenbachii*
Shortfin eel	*Anguilla australis*
Banded kokopu	*Galaxias fasciatus*

1.4.1 Perch

On arrival in New Zealand, the early European settlers found a freshwater fish fauna which was low in diversity, with few fish of any angling or culinary value (Wise, 1990). Because of this, during the earlier stages of colonization, European settlers brought 19 species of exotic fish into New Zealand for liberation in lakes, streams and rivers. Perch were intentionally introduced into New Zealand in 1868;

at the time of introduction the perch were believed to be a valuable commodity for freshwater anglers (McDowall, 1990). Unfortunately, the introduction of this species into New Zealand waterways poses a significant potential threat to freshwater ecosystems (Chadderton et al. 2001).

The founding population of perch originated from Tasmania and was introduced into the eastern South Island and Lake Mahinapua (McDowall, 1996). Further attempts to acclimate the species were undertaken, and the species was subsequently introduced into other regions (Canterbury, Taranaki, Wanganui and Wellington) between 1870 and 1877. Since that time, perch have further radiated out into many of the country's waterways (Figure 1.3). The fish was introduced into the Lake Rotokare by an unknown source sometime in the early 1900s; possibly through the people that owned the surrounding countryside for angling.

Perch are an endemic species throughout much of Europe and Northern Asia; which has subsequently spread, establishing self-sustaining populations in Spain, Central/Southern Italy, Australia, South Africa and New Zealand (Thorpe, 1977). Perch have been categorised as a 'sports fish' under the Freshwater Fisheries Regulations of 1983, and they are rarely targeted for recreational fishing purposes. However, their viability as a commercial fisheries option failed largely because populations are often dense, with a small average size of fish compared to endemic populations from England (Jellyman, 1980).

Perch are a robust species of fish that exhibit relatively deep body forms. They have proportionately large heads, and display bumps at the base of the skull; a feature most prominent in larger individuals of the species. Perch also have large jaws proportional to size and body mass with moderately sized eyes. The lateral line arches over pectoral fins, with the first pectoral fin being considerably taller than any sub-sequential fins. The first dorsal fin is supported by strong, sharp spines, exhibited in perch throughout all life stages. The second dorsal fin is smaller and separate from the first. The anal fin lies directly beneath the second dorsal fin and somewhat similar in characteristic and shape. The slightly forked caudal fin is supported by a caudal peduncle. The pelvic fins are smaller in shape and size and located just forward of the pectoral fins. The outer exterior of the fish is covered in a layer of thick ctenoid scales.

Perch are also considerably colourful compared to freshwater endemic species. Their body is olive-green, paling to a silvery white sheen around the stomach. Both juveniles and adults exhibit a series of black vertical bands (usually 4–6), broadest at the front, and pale from fin to belly. The caudal fin exhibits a lower red region, and both anal and pelvic fins are typically red and orange. They have a thermal maximum of 31˚C and are therefore theoretically capable of establishing a population anywhere within New Zealand (Weatherly, 1977; Wise, 1990).

Perch are typically found in gently flowing or still waters (Le Cren, 1958). Juvenile perch, or young of the year have been found to distribute themselves amongst the littoral zone of lakes and rivers, particularly where areas retain a depth range of ≤ 3 m (Karas, 1996). Juveniles also exhibit congregation behaviour, forming into high density shoals in the shallows; adults tend to disperse and become solitary, distributing themselves among both the littoral and limnetic zones (Karas, 1996; Thorpe, 1977). Adults distribute themselves differently and tend to congregate in deeper waters and become solitary, entering shallow waters primarily to feed.

Perch are unique in the fact that they can behave autonomously within an ecosystem, through the modulation and control of its own density through food resources (Holcik, 1977). Feeding behaviour is primarily dominated by the species unique ontogenetic life history; undertaking several shifts in feeding behaviour throughout its growth cycle (Thorpe, 1977). These shifts can be categorized into three major niche shifts during its life history (Hjelm et al., 2000). The first ontogenetic stage begins with juveniles subsisting on a diet comprised mainly of zooplankton; particularly *Daphnia* sp. (Alm, 1946; Persson & Greenburg, 1990). As growth occurs, a transition in ontogeny occurs and their diet changes (primarily due to metabolic demands), shifting prey dependency mainly towards macroinvertebrates (Bronmark, 1994). Finally, as the larger individuals begin reaching a minimum of length ≥ 120 mm, a noticeable shift occurs in their diets (Hargeby et al., 2005). Adults become increasingly dependent on fish as their primary diet and once perch reach sizes above 250 mm, their diet consists almost entirely of fish (Le Cren, 1992; Pekcan-Hekim et al., 2013).

Perch have been shown to exert influence over their freshwater environments in New Zealand. Perch have been implicated in the decline of several native fish species, and are capable of significantly altering native freshwater communities (Closs et al., 2001; McDowall, 1996). Perch are unique in an ecological context to New Zealand, as they are both controlled by, and exert control over trophic interactions at multiple levels; with juveniles being susceptible to competition and adults exerting significant predatory top-down control over native species (Cadwaller & Backhouse, 1983). Perch have been shown to exert a disproportionately large effect on smaller bodies of water when compared to that of larger waterbodies, due to population density factors being less intense (Collier & Grainger, 2015). Smith and Lester (2006) found stunted zooplanktivorous perch were decreasing water clarity and increasing cyanobacterial levels in the Karori reservoir, Wellington. Four species of *Anabaena* (cyanobacteria) were found within the catchment. Smith and Lester's study further indicated that addition of nutrients, had no significant effect on cyanobacterial densities. Community composition of both phytoplankton and zooplankton species were also found to be altered by the addition of juvenile perch, via reduction in algal grazing zooplankton. Romare (2000) found similar evidence in their studies, with multiple lakes showing a clear negative association between water clarity and the presence of exotic fish (including perch), independent of lake depth.

Ludgate and Closs (2003) found that perch have been found to heavily predate on the native common bully (*Gobiomorphus cotidianus*), throughout various regions in New Zealand. They further demonstrated that populations of common bully declined in ponds, lakes and tarns across the country in the presence of perch, and Kane (1995) found that the common bully had disappeared both from the perch's diet and Hamilton Lake in his study. These findings implicate that perch, in association with other invasive species, have potentially removed bully from the lake entirely. Additionally, research by Rowe and Smith (2001) suggest that the presence and high density of perch in Lake Wainamu (Auckland) was responsible for the absence of two native species; the common smelt (*Retropinna retropinna*) and inanga (*Galaxias maculatus*). The authors highlighted the fact that even though both species had readily available access into the lake, there was a complete absence of either species during sampling.

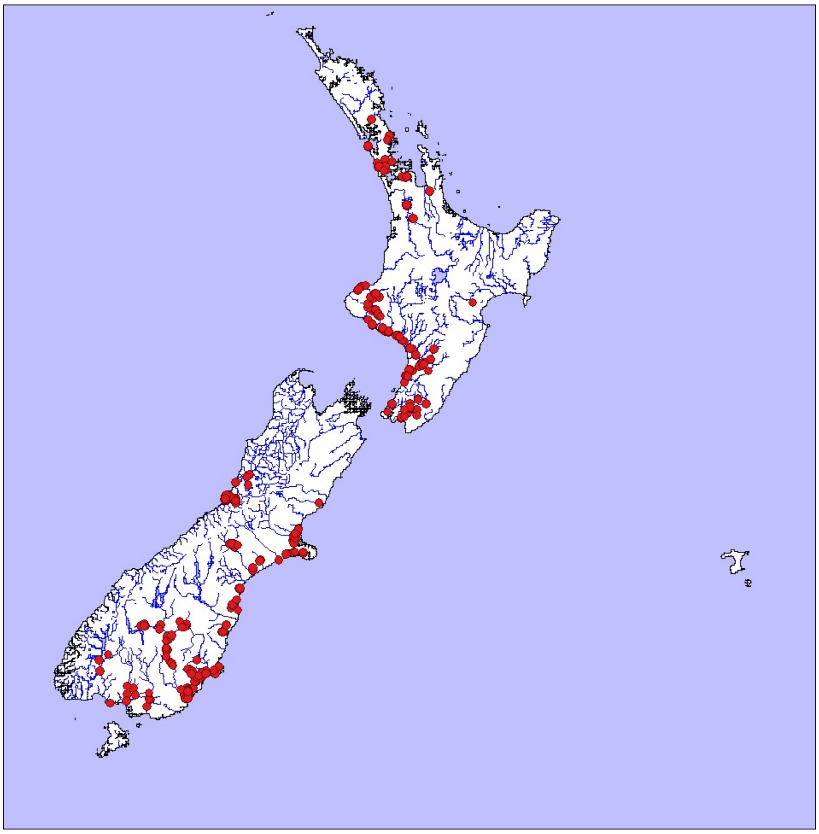

Figure 1.3: Distribution of European Perch in New Zealand (NIWA, 2016a).

1.4.2 Shortfin and Longfin eels

Shortfin and Longfin eels are both native freshwater fish species residing in New Zealand. Both species of eel are nocturnal, slow growing (averaging 2-3 cm year^{-1}) and omnivorous, both are unique as they are the only native carnivorous species in New Zealand freshwater systems (Jellyman, 1997). Shortfin eels are widely distributed throughout both the North and South Island and have also have been located on both Stewart and the Chatham Islands (Figure 1.4). They are also located within other South Pacific nations such as Australia, Fiji, New Caledonia, Norfolk and Lord Howe Island. Shortfin eels inhabit a wide range of habitat, they have been found in numerous levels in lowland lakes, wetlands, and streams, and shortfin eels form the basis of the commercial eel fishery that has existed for over 20 years in New Zealand (Jellyman, 1987). Shortfins from Australia and New Zealand show small but significant differences in morphology (Jellyman, 1987; Watanabe et al., 2006), but have genetic homogeneity between populations (Dijkstra & Jellyman, 1999; Smith et al., 2001).

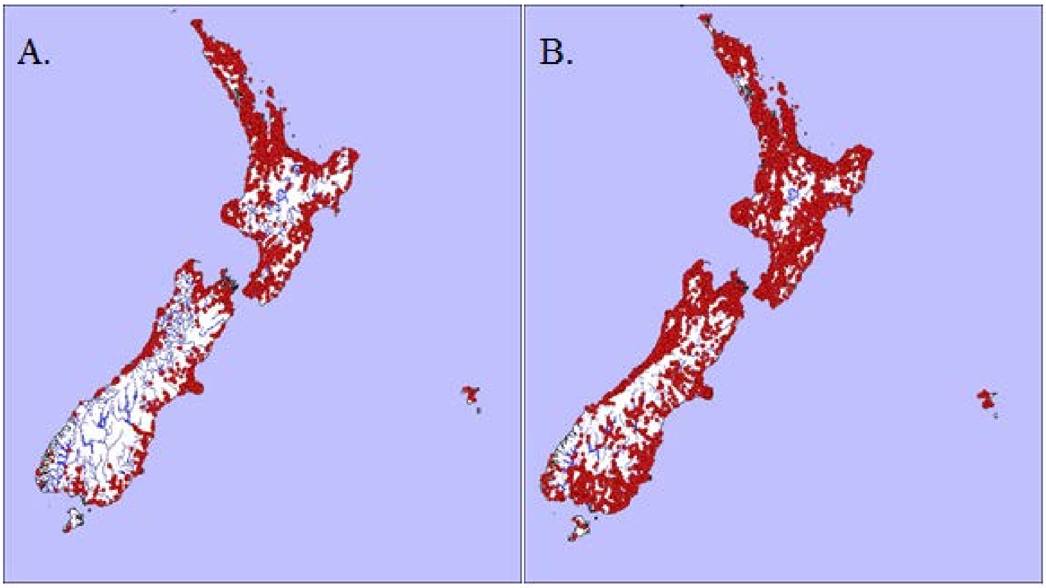

Figure 1.4: Distribution of the **(A).** Shortfin eel in New Zealand (NIWA, 2016b) and **(B).** Longfin eel in New Zealand (NIWA, 2016c).

Longfin eels are endemic to New Zealand and have managed to occupy many freshwater reaches within the country (Figure 1.4). These eels have also sustained a large freshwater fishery for several decades and remain a source of cultural importance to Maori, as they are present in several Maori legends, and remain a source of whakapapa (identity) to tribes throughout the country.

Both species frequently coexist, but the shortfin is principally a lowland species, dominating populations in lowland lakes, estuaries and the lower reaches of rivers. The shortfin eel reaches a maximum size of roughly 1.1 m and 3 kg, compared with that of the longfin, which reaches upwards of 2 m and ≥ 25 kg (Jellyman, 2003). The two species have different habitat preferences (Jellyman et al., 2003). Longfins prefer flowing water and hence, are found extensively in large, deep flowing waterways; they penetrate long distances inland and inhabit high country lakes and rivers. Adults of both species prefer deep, slow-moving water, but shortfins prefer finer substrata (mud) than longfins, which prefer coarse gravel and boulders (Jellyman, 2012). There is experimental evidence of shortfin glass eels making specific olfactory choices about the types of waterways they invade, but longfins appear indifferent to water type, a response in keeping with their broader habitat preferences (McCleave & Jellyman, 2002).

Records of juvenile recruitment for both species remain poor (Jellyman, 2012); however, the population of longfin eel currently shows symptoms of decline and has been declared at risk. Due to damming of major waterways access to inland habitat has been severely reduced. Furthermore, additional modifications in freshwater environments such as river channelization, wetland drainage, modification of flow pathways and deforestation has also led to a significant reduction in suitable eel habitat.

Eels are elongate, slender-bodied fishes, almost tubular. When they are small, they have relatively smooth heads; but as they grow, the head becomes bulbous (particularly longfin), with a prominent muscular dome behind the eyes (Figure 1.5). They physiologically morph when preparing for migration to their breeding grounds. The head becomes much more slender and tapered, almost bullet-like and the eyes enlarge to up to twice their normal size. The main way to distinguish between these two species is by comparing the colour, skin plasticity, and shape of dorsal fin. Longfin eels tend to have wrinkled skin compared their shortfin counterparts, and can be kinked if pacified to reveal skin folds; shortfin eels remain smooth. Longfin eels also tend to be darker in texture, however, this can be a misleading identification method as shortfin eels can also be dark in texture. The most reliable method is to check the dorsal fin – if the dorsal fin is vertically above the anus, then the species is a shortfin, if the dorsal fin continues further ahead of the anus then the fish is a longfin (see Figure 1.6).

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Figure 1.5: Identification chart for distinguishing Longfin and shortfin eels apart (Science Learning Hub, 2014).

Both species of eel are omnivorous. Jellyman (1989) analysed the diets of the two eel species and determined that both species probably feed intermittently, and tend to act as opportunistic feeders consuming a wide range of food items. Jellyman also found that individual eels' feeding behaviour was normally selective for single prey items. The diet of each species changes with size. The smallest eels of both species are typically known to feed primarily on amphiphods and insect larvae; whereas Longfin eels > 40 cm were primarily piscivorous. Whereas, fish did not become an important part of shortfin eel diet until eels were > 70 cm. Thus, at similar sizes, the two species had different diets and the transition between insectivorous feeding towards a piscivorous diet occurs at much different stages in each species' development.

The overall life cycle of both species of eel is not completely understood. Current knowledge of the eels' spawning patterns has determined that eels only breed once, and die sometime shortly after. In autumn, the adults leave New Zealand freshwater systems and migrate north for thousands of kilometres, with the hypothesized spawning grounds somewhere near Tonga (Jellyman, 2003). Females can lay between 1-20 million eggs; the eggs float, hatch into larvae known as leptocephali and then drift in currents back towards New Zealand and return to coastal waters. The whole process is believed to take 15-17 months however, there is currently no data to verify this theory.

Juvenile eels tend to spend their first year in fresh water in the upper estuarine tidal area, juveniles usually have a growth period of 1-3 years, migrate upstream at the beginning of summer (Jellyman, 1977). Both longfin and shortfin eels are renowned climbers (Ryan, 2007), and this has partially led to their success in colonizing so far inland (Jellyman, 1977). Surface tension allows the elvers to hold to rock faces, and elvers have been observed climbing the Patea River dam which is 75 m tall, demonstrating how efficient juveniles are as climbers. They lose their climbing ability once reaching roughly 12 cm; becoming too heavy to be held by surface tension. Elvers can also navigate overland through wet grass to continue migration upwards, with demonstrated migration distances of over 130 km inland over the period of one summer (Jellyman, 1977).

1.4.3 Banded kokopu

The banded kokopu (*Galaxias fasciatus*) is one of the more common species of freshwater native galaxid endemic to New Zealand and found throughout the mainland and a few of surrounding offshore islands (McDowall, 1990). Much like the longfin and shortfin eel, the banded kokopu is an accomplished climber (West, 1989). While it can climb quite effectively, its overall penetration inland remains limited, with population abundances typically highest in areas near the coast (West, 1989; Figure 1.6).

Being one of the larger galaxiids of New Zealand, the banded kokopu has a maximum length of roughly 260 mm (McDowall, 1990). Banded kokopu habitat commonly consists of slow flowing pools, small 1st-order headwater streams and tributaries, with reasonably extensive riparian vegetation (many characteristic small streams in native bush). Undercut banks, instream woody material and tree roots all appear to be strongly desired features for habitat –rapidly becoming absent from streams when they begin to flow through deforested reaches (e.g. streams leaving native forest and entering pastoral reaches below) (McCullough, 1998). Research indicates that population abundance and distributions are high in forested areas of the country, and other areas with a paucity of tall woody riparian cover (e.g. the anthropogenic deforestation of much of the historically forested Waikato region) often exhibit a complete absence of banded kokopu (West, 1989; Hicks & McCaughan, 1997). Most populations throughout the country are diadromous, although lacustrine populations are also known to exist in lakes and reservoirs both with and without streams allowing sea access (McCullough, 1998). Lake Rotokare is most likely one such population, as access to the sea is limited due to river alterations and farmland modifications undertaken on areas adjacent to the stream connecting Lake Rotokare to the Arawata River. Therefore, it is likely the population is lacustrine and self-recruiting.

Behaviourally, the species is shy and recluse, often disappearing quickly when any disturbance within their stream of occupation occurs (McCullough, 1998). The juveniles are planktivorous, feeding on zooplankton, whereas adults tend to become opportunistic insectivores, feeding largely on invertebrates of terrestrial origin falling from overhanging vegetation onto the water’s surface (Main, 1988; McDowall, 1990; Swales & West, 1991; Hicks, 1997). Banded kokopu contribute towards a significant freshwater fishery in New Zealand - Whitebait. This and other galaxid fry contribute towards the whitebait fishery, and banded kokopu have been shown to contribute large proportions of fry towards this fishery (Rowe et al., 1992). Currently this species remains non-threatened under the conservation status of New Zealand freshwater fish series published in 2013.

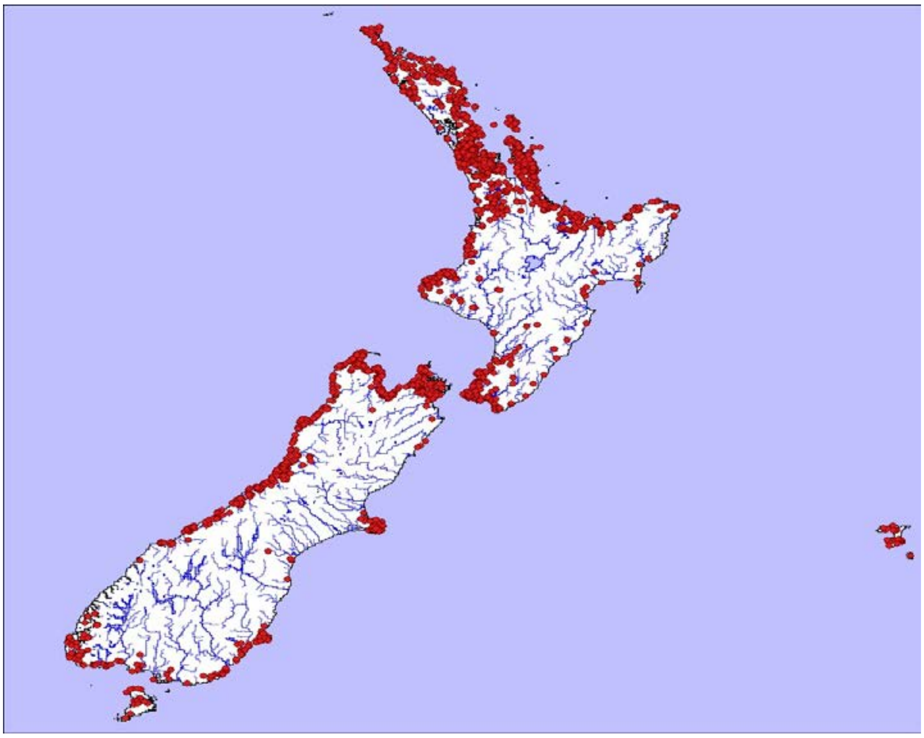


Figure 1.6: Distribution of banded kokopu (*Galaxias fasciatus*) in New Zealand. (NIWA, 2016d).

1.4.4 Invertebrates:

Collaborating the research from the Taranaki Catchment Commissions report, and this study's findings regarding invertebrate sampling – Table 1.2 highlights the current known species list of invertebrates present within Lake Rotokare. Three new species were discovered during sampling in 2017, most noticeably *Radiospongilla sceptroides*; a freshwater sponge that is known to inhabit some parts of Eastern Australia and New Zealand (Figure 1.7), although its true distribution remains relatively unknown. Two species of dragonfly were identified, and a cautionary note should be made in regards to the discovery of the species *Latia neritoides* in 1979 by the Taranaki Catchment Commission. It is probable that the person who identified *Latia neritoides* may have mistaken the sample for *Pisidium* sp. during identification, as the two species have a high similarity in physical external appearances.

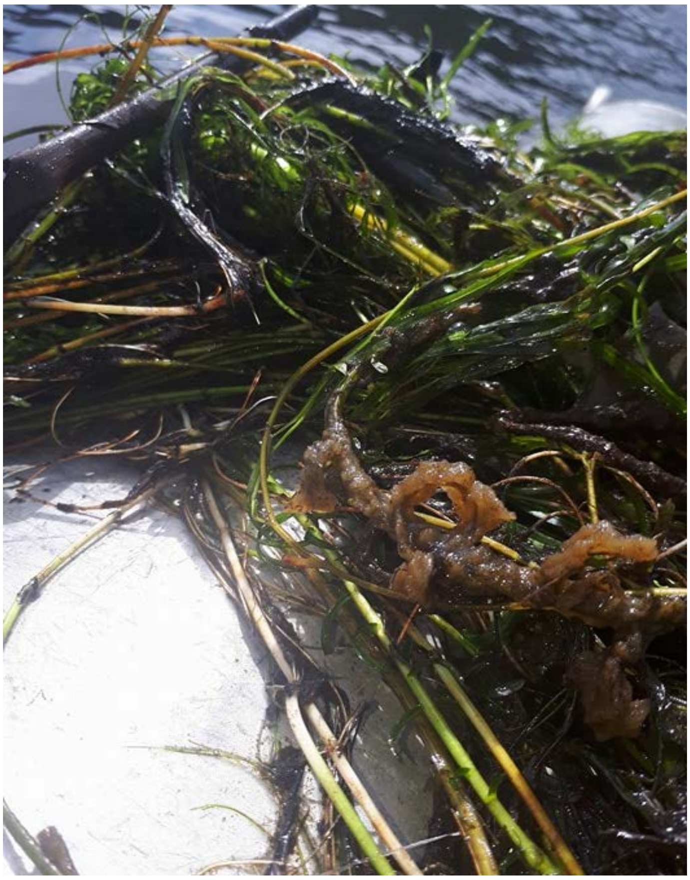


Figure 1.7: *Radiospongilla sceptroides*, a species of freshwater sponge discovered residing within Lake Rotokare on 9 June 2017.

Table 1.2: Invertebrate species found within Lake Rotokare (Taranaki Catchment Commission, 1980) and newly identified species during sampling in 2017.

Scientific name	**Common name**
Chironomus zealandicus	Chironomids
Pycnocentrodes sp.	Caddisfly
Potamopyrgus sp.	Mud snail
Latia neritoides	Freshwater limpet
Pisidium sp.	Pea clam
Tubificidae	Oligochaete worms
Hemiptera	True bugs
Zygoptera	Damselfly
Physa	Freshwater snail
Lymnaea	Freshwater snail
Gyraulus sp.	Freshwater snail
Hirudinae	Leech
Newly identified species:	
Antipodochlora braueri	Dusk dragonfly
Aeschna brevistyla	Australian lancer dragonfly
Radiospongilla sceptroides	Freshwater sponge

1.4.5 Plankton community:

The planktonic community was not surveyed in detail during this study. This was primarily due to the fact that Hicks et al. (2013) compiled a detailed report of the micro community during their analysis of the lake - Table 1.3 highlights their findings of the plankton community residing within the lake.

Table 1.3: Planktonic species found within Lake Rotokare (Hicks et al., 2013).

Phytoplankton:	**Zooplankton:**
Chlorophyta	**Cladocerans**:
Botryococcus sp.	*Daphnia galeata*: North American invader
Closterium sp.	*Ceriodaphnia dubia*
Cosmarium sp.	**Copepods:**
Eudorina sp.	*Calamoecia lucasi*
Nephrocytium sp.	*Mesocyclops* sp.
Oocystis sp.	**Rotifers:**
Sphaerocystis sp.	*Trichocerca similis*
Staurastrum sp.	*Asplanchna priodonta*
Volvox sp.	*Synchaeta pectinata*
Euglenophyta	*Polyarthra dolichoptera*
Trachelomonas sp.	*Keratella procurva*
Euglena sp.	*Pompholyx complanata*
Euglena texta	**Water mites (Acari: Hydrachnidae):**
Diatoms	Unidentified water mites, most likely *Piona* sp.
Asterionella sp.	
Aulacoseira sp.	
Fragilaria sp.	
Navicula sp.	
Dinoflagellates	
Ceratium sp.	
Ankyra sp.	
Cyanobacteria	
Anabaena planktonica	
Anabaena circinalis	
Aphanocapsa sp.	
Microcystis sp.	
Pseudanabaena sp.	
Pseudanabaenaceae	

1.5 Study objectives

Due to the current lack of knowledge surrounding the biotic and abiotic components of Lake Rotokare, the overall ecological aspects of this lake remain poorly understood. Therefore, this research project aims to further study both the fish communities within the lake, as well as the wider food web as a whole. It also intends to assess the water quality of the lake, and evaluate the nutrient status of Lake Rotokare. Additionally, this study aims to address this gap in knowledge through examining:

Population dynamics:

- Determine the weight-length relationships of the perch, shortfin, and longfin present within the lake.
- Establish length-frequency models of the perch, shortfin and longfin eel populations.
- Estimate the population size and density of shortfin and longfin eel through mark-recapture methods in order to determine the absolute abundance and density of these two species.
- Estimate the density and relative abundance of perch within the lake through the use of CPUE methods.
- Estimate the biomass of each of the three species present.
- Finally obtain a relative abundance estimation of banded kokopu and kōura present in the streams flowing into the lake through spotlight counting.

Food web dynamics:

- To study the lakes trophic interactions of plants, microorganisms, vertebrates and invertebrates residing within the lake, through obtaining each species average stable isotope signature and developing a lake mixing model.
- Check the validity of the isotopic readings of perch and eels against their respective diets through a dietary analysis of their stomach contents – allowing a comparison between the observed dietary patterns and the results of the stable isotope analysis indicating the accuracy of the isotope readings (in regards to diet versus growth).

- Compare the values of eel fin and muscle tissue, and determine whether lipid correction is necessary.
- Create mathematical equations to correct stable isotope fin values into muscle values.

Physical conditions:

- Assess the temperature and oxygen profile within the lake and determine the presence and depth of the summer thermocline, and re-evaluate the temperature profile in winter, to establish the breakdown of the thermocline and subsequent oxygenation of the lake.
- Employ Secchi disks and light meters to obtain a vertical ambient light profile and water clarity reading.
- Take a series of vertical water samples to establish a water profile, and compare the results to previous water profiles taken to assess any changes in nitrogen and phosphorus in regards to vertical gradients and changes over time.
- Compare our results to those taken in previous studies and determine if any trends are occurring.

1.6 References:

Alm, G. 1946. Reasons for the occurrence of stunted fish populations with special regard to perch. - *Rep. Swed. State Inst. Freshwat. Fish. Res*. Drottningholm, 25.

Arthington, A. H., Bunn, S. E., Poff, N. L., & Naiman, R. J. (2006). The challenge of providing environmental flow rules to sustain river ecosystems. *Ecological Applications*, 16(4), pp. 1311-1318.

Baron, J. S., Poff, N. L., Angermeier, P. L., Dahm, C. N., Gleick, P. H., Hairston, N. G., ... & Steinman, A. D. (2002). Meeting ecological and societal needs for freshwater. *Ecological Applications*, 12(5), pp. 1247-1260.

Bronmark, C. (1994). Effects of tench and perch on interactions in a freshwater, benthic food chain. *Ecology,* 75(6), pp. 1818-1828.

Cadwallader, P. L., & Backhouse, G. N. (1983). *A guide to the freshwater fish of Victoria*. US Government Printing Office.

Chadderton, L., Kelleher, S., Brow, A., Shaw, T., Studholme, B., & Barrier, R. (2001). Testing the efficacy of rotenone as a piscicide for New Zealand pest fish species. Managing invasive freshwater fish in New Zealand. Proceedings of a workshop hosted by Department of Conservation, pp. 10-12).

Closs, G. P., Ludgate, B., & Goldsmith, R. J. (2001). Controlling European perch (*Perca fluviatilis*): lessons from an experimental removal. In Proceedings of the workshop: Managing invasive freshwater fish in New Zealand, pp. 10-12).

Collier, K. J., & Grainger, N. P. J. (2015). New Zealand Invasive Fish Management Handbook. Lake Ecosystem Restoration New Zealand (LERNZ; The University of Waikato) and Department of Conservation, Hamilton, New Zealand. 212 p.

Dijkstra L.H.; & Jellyman, D.J. (1999). Is the subspecies classification of the freshwater eels *Anguilla australis australis* Richardson and *A. a. schmidtii* Phillipps still valid? New *Zealand journal of Marine and Freshwater Research*, 50: pp. 261-263.

Duggan, I. C., Green, J. D., & Burger, D. F. (2006). First New Zealand records of three non-indigenous Zooplankton species: *Skistodiaptomus pallidus,* *Sinodiaptomus valkanovi*, and *Daphnia dentifera*. *New Zealand Journal of Marine and Freshwater Research*, 40(4), pp. 561-569.

Foley, J. A., DeFries, R., Asner, G. P., Barford, C., Bonan, G., Carpenter, S. R., & Helkowski, J. H. (2005). Global consequences of land use, *Science*, 309(5734), pp. 570-574.

Gleick, P. H. (2003). Global freshwater resources: soft-path solutions for the 21st century. *Science*, 302(5650), pp. 1524-1528.

Hargeby, A., Blom, H., Blindow, I., & Andersson, G. (2005). Increased growth and recruitment of piscivorous perch, *Perca fluviatilis*, during a transient phase of expanding submerged vegetation in a shallow lake. *Freshwater Biology*, 50(12), pp. 2053-2062.

Hicks, B. J., & McCaughan, H. M. (1997). Land use, associated eel production, and abundance of fish and crayfish in streams in Waikato, New Zealand. *New Zealand Journal of Marine and Freshwater Research*, 31(5), pp. 635-650.

Hicks, B. J. (1997). Food webs in forest and pasture streams in the Waikato region, New Zealand: a study based on analyses of stable isotopes of carbon and nitrogen, and fish gut contents. *New Zealand Journal of Marine and Freshwater Research*, 31(5), pp. 651-664.

Hicks, B. J., Bell, D. G., Duggan, I. C., Wood, S. A., & Tempero, G. W. (2013). Aquatic ecology of Lake Rotokare, Taranaki, and options for restoration. Environmental Research Institute, The University of Waikato.

Hjelm, J., Persson, L., & Christensen, B. (2000). Growth, morphological variation and ontogenetic niche shifts in perch (*Perca fluviatilis*) in relation to resource availability. *Oecologia*, 122(2), pp. 190-199.

Holčík, J. (1977). Changes in fish community of Klíčava reservoir with particular reference to Eurasian perch (*Perca fluviatilis*), 1957–72. *Journal of the Fisheries Board of Canada*, 34(10), pp. 1734-1747.

Howard-Williams, C., Davies-Colley, R., Rutherford, K., & Wilcock, R. (2010). Diffuse pollution and freshwater degradation: New Zealand perspectives. *Issues and Solutions to Diffuse Pollution*, OECD, Paris, pp. 126-140.

Hughey, K. F., Kerr, G. N., & Cullen, R. (2013). Public perceptions of New Zealand's environment: 2013. *EOS Ecology*.

Jellyman, D.J. (1977). Summer upstream migration of juvenile freshwater eels in New Zealand.

Jellyman, D. J. (1980). Age, growth, and reproduction of perch, *Perca fluviatilis* L., in Lake Pounui. *New Zealand journal of marine and freshwater research*, 14(4), 391-400.

Jellyman D.J. (1987). Review of the marine life history of Australasian temperate species of *Anguilla*. *American Fisheries Society Symposium,* 1: pp 276-285.

Jellyman, D. J. (1989). Diet of two species of freshwater eel (*Anguilla spp*.) in Lake Pounui, New Zealand. *New Zealand Journal of Marine and Freshwater research*, 23(1), pp 1-10.

Jellyman, D. J. (1997). Variability in growth rates of freshwater eels (*Anguilla spp*.) in New Zealand. *Ecology of Freshwater Fish*, 6(2), 108-115.

Jellyman, D. J. (2003). The distribution and biology of the South Pacific species of *Anguilla*. Pp. 275-292. *Eel Biology*. Aida, K.; Tsukamoto, K.; Yamauchi, K. (Ed.). Tokyo, Springer.

Jellyman, D. J., Bonnett, M. L., Sykes, J. R. E., & Johnstone, P. (2003). Contrasting use of daytime habitat by two species of freshwater eel Anguilla spp. in New Zealand Rivers. pp. 63-78. In: *Biology, Management, and Protection of Catadromous Eels*. Dixon, D.A. (Ed.). American Fisheries Society Symposium, 33.

Jellyman, D. J. (2012). The status of longfin eels in New Zealand - an overview of stocks and harvest. *Report for the parliamentary Commissioner for the Environment*. NIWA. Christchurch, New Zealand.

Julian, J. P., de Beurs, K. M., Owsley, B., Davies-Colley, R. J., & Ausseil, A. G. E. (2017). River water quality changes in New Zealand over 26 years: response to land use intensity. *Hydrology and Earth System Sciences*, 21(2), pp. 1149.

Kane, D. S. (1995). The status of fish in Hamilton Lake (Lake Rotoroa). Unpublished MSc thesis. University of Waikato. Hamilton, New Zealand.

Karås, P. (1996, January). Basic abiotic conditions for production of perch (*Perca fluviatilis L.*) young-of-the-year in the Gulf of Bothnia. In *Annales Zoologici Fennici* (pp. 371-381). Finnish Zoological and Botanical Publishing Board.

Kelly, D. J., & Hawes, I. (2005). Effects of invasive macrophytes on littoral-zone productivity and foodweb dynamics in a New Zealand high-country lake. *Journal of the North American Benthological Society*, 24(2), pp. 300-320.

Le Cren, E. D. (1958). Observations on the growth of perch (*Perca fluviatilis L.*) over twenty-two years with special reference to the effects of temperature and changes in population density. *The Journal of Animal Ecology*, pp. 287-334.

Lowe, D. J., & Green, J. D. (1992). Lakes. In J. M. Soons & M. J. Selby (Eds.), *Landforms of New Zealand*: 2, pp. 107-143. Auckland, New Zealand: Longman Paul.

Ludgate, B. G., & Closs, G. (2003). Responses of fish communities to sustained removals of perch (*Perca fluviatilis*). Wellington,, New Zealand: *Department of Conservation*.

Main, M. R. (1988). Factors influencing the distribution of kokopu and koaro (Pisces: Galaxiidae).

McCleave, J. D., Jellyman D. J. (2002). Discrimination of New Zealand stream waters by glass eels of *Anguilla australis* and *Anguilla dieffenbachii*. *Journal of Fish Biology*, 61: pp. 785- 800.

McCullough, C. D. (1998). Abundance, behaviour, and habitat requirements of the banded kokopu (*Galaxias fasciatus* Gray)(Pisces: *Galaxiidae*). Unpublished MSc thesis, The University of Waikato, Hamilton, New Zealand.

McDowall, R. M. (1990) New Zealand freshwater fishes: a natural history and guide. Heinemann Reed, Auckland.

McDowall, R. M. (1996). Volcanism and freshwater fish biogeography in the northeastern North Island of New Zealand. *Journal of biogeography*, 23(2), pp. 139-148.

NIWA. (2016a). *Perch*. Retrieved from: https://www.niwa.co.nz/freshwater-and-estuaries/nzffd/NIWA-fish-atlas/fish-species/perch.

NIWA. (2016b). *Shortfin eel*. Retrieved from: https://www.niwa.co.nz/freshwater-and-estuaries/nzffd/NIWA-fish-atlas/fish-species/shortfin_eel.

NIWA. (2016c). *Longfin eel*. Retrieved from: https://www.niwa.co.nz/freshwater-and-estuaries/nzffd/NIWA-fish-atlas/fish-species/longfin_eel.

NIWA. (2016d). Banded kokopu. Retrieved from: https://www.niwa.co.nz/our-science/freshwater/tools/kaitiaki_tools/species/banded-kokopu.

Persson, L., & Greenberg, L. A. (1990). Juvenile competitive bottlenecks: the perch (*Perca fluviatilis*) - roach (*Rutilus rutilus*) interaction. *Ecology*, 71(1), pp. 44-56.

Romare, P. (2000). Growth of larval and juvenile perch: the importance of diet and fish density. *Journal of Fish Biology,* 56(4), pp. 876-889.

Ryan, P. (2007). Eels. Te Ara - the Encyclopedia of New Zealand, retrieved online from http://www.TeAra.govt.nz/en/eels/print (accessed 31 January 2018).

Rowe, D. K., Saxton, B. A., & Stancliff, A. G. (1992). Species composition of whitebait (*Galaxiidae*) fisheries in 12 Bay of Plenty rivers, New Zealand: evidence for river mouth selection by juvenile Galaxias brevipinnis (Günther). *New Zealand Journal of Marine and Freshwater Research*, 26(2), 219-228.

Rowe, D. K., & Smith, J. P. (2001). The role of exotic fish in the loss of macrophytes and increased turbidity of Lake Wainamu, Auckland. *NIWA Client Report*, New Zealand, 32pp.

Science Learning Hub. (2014). *Longfin eels*. Retrieved from: https://www.sciencelearn.org.nz/resources/441-longfin-eels.

Smith, P.J.; Benson, P.G.; Stanger, C.; Chisnall, B.L.; Jellyman, D.J. (2001). Genetic structure of New Zealand eels *Anguilla dieffenbachii* and *A. australis* with allozyme markers. *Ecology of Freshwater Fish*, (10): 132-137.

Smith, K. F., & Lester, P. J. (2006). Cyanobacterial blooms appear to be driven by top-down rather than bottom- up effects in the Lower Karori Reservoir (Wellington, New Zealand). *New Zealand Journal of Marine and Freshwater Research*, 40(1), pp. 53-63.

Swales, S., & West, D. W. (1991). Distribution, abundance and conservation status of native fish in some Waikato streams in the North Island of New Zealand. *Journal of the Royal Society of New Zealand,* 21(4), pp. 281-296.

Taranaki Catchment Commission. (1980). Lake Rotokare water management plan. Unpublished report, Taranaki Catchment Commission, Stratford, New Zealand.

Thorpe, J. E. (1977). Morphology, physiology, behavior, and ecology of *Perca fluviatilis* L. and *P. flavescens* Mitchill. *Journal of the Fisheries Board of Canada*, 34(10), pp. 1504-1514.

Turner, M. B., Bebbington, M. S., Cronin, S. J., & Stewart, R. B. (2009). Merging eruption datasets: building an integrated Holocene eruptive record for Mt Taranaki, New Zealand. *Bulletin of Volcanology*, 71(8), pp. 903-918.

Watanabe, S.; Aoyama J.; Tsukamoto K. (2006). Confirmation of morphological differences between *Anguilla australis australis* and *A. australis schmidtii*. *New Zealand Journal of Marine and Freshwater Research*, 40, pp. 325-331.

Weatherley, A. H. (1977). *Perca fluviatilis* in Australia: Zoogeographic expression of a life cycle in relation to an environment. *Journal of the Fisheries Board of Canada*, 34(10), pp. 1464-1466.

West, D. W. (1989). The ecology of native and introduced fish in some Waikato streams. MSc thesis, University of Waikato. Hamilton, New Zealand.

Wise. (1990). The biology of three exotic fish species in Hamilton Lake. Unpublished MSc thesis, University of Waikato. Hamilton, New Zealand.

Chapter 2: Water quality

2.1 Introduction

Cultural eutrophication has been identified as the primary problem affecting surface water quality in both lakes and river systems globally (Smith & Schindler, 2009). New Zealand is not exempt from this phenomenon; the country has experienced over a century of environmental freshwater degradation - primarily due to urban land use modification, development, non-point source pollution from pastoral farming activities, and the expansion of forestry plantations (Douglas et al., 2016). Aquatic degradation has become acute since the late 1970s, as agricultural practices have intensified in many areas of New Zealand, due to increasing pressure from economic demands (Monaghan et al., 2007). This transition in agriculture has led to higher stocking rates and yields, increased use of fertiliser and pesticides, and the nationwide transition to more intensive forms of agriculture, such as dairy and cattle ranching (Ministry for the Environment & Stats, 2017). This is cause for concern, as these drivers of change have resulted in nationwide over-enrichment of surface waters with nitrogen (N) and phosphorus (P), leading to enhanced growth of phytoplankton and aquatic plants; deoxygenation of deeper waters, and a range of adverse impacts to freshwater biota (Carpenter et al., 1998; Monaghan et al., 2007; Adrian et al., 2009; Douglas et al., 2016). These factors combined with climate change, will only become more problematic in the future (Adrian et al., 2009; IPCC, 2014).

New Zealand remains committed to the halt of environmental decline and restoration of freshwater systems throughout the country (Ministry for the Environment, 2017). Central government has recently developed a National Policy Statement for Freshwater Management (NPS-FM) as well as national water quality guidelines to improve national water standards (Ministry for the Environment, 2014). Variations in land use practice or environmental cues can have impacts on water quality (Hamilton et al., 2016) and New Zealand lakes and reservoirs around are rarely static in their water quality or ecological condition (Ministry for the Environment & Stats NZ; 2017). The best way to mitigate this is by obtaining a better understanding of the nutrient loads within degraded lakes, to discover the rate of change that is occurring, with a focus on nitrogen and phosphorus levels.

Lake Rotokare is an elevated lake (184 m), and therefore deemed to be at less risk of degradation then other catchments at lower elevations, which often show extreme vulnerability to degradation (Larned et al., 2004). However, the lake has been negatively impacted by multiple stressors, particularly due to the lake's history of previous agricultural use. This has resulted in the lake developing a nutrient legacy, resulting in elevated levels of nitrogen and phosphorus (Taranaki Catchment Commission, 1980). The lake regularly suffers from severe surface water stratification and cyanobacterial algal blooms over the spring-summer period annually, subsequently leading to closure of the lake.

Little has been done to monitor the nutrient loads in Lake Rotokare. The Taranaki Regional Council (TRC) has focused primarily on bacterial loads as a form of water quality monitoring (Taranaki Regional Council, 2010-2017). Therefore, obtaining the nutrient status of Lake Rotokare is critical, as having this information will allow stakeholders the information to tailor effective strategies to reduce algal blooms and nutrient loads to manageable levels. The aim of this study is to carry out water samples on the lake to establish a Trophic Level Index (TLI); a popular management tool across the country, typically used to provide a numerical, and cost-effective indicator of the trophic status of New Zealand lakes' (Burns et al., 1999). This has yet to be ascertained for Lake Rotokare and will provide a basis for future studies. Second, to obtain total and dissolved N & P measurements, complimented with other basic indicators of water quality such as phosphate, nitrate and ammonium level, allowing a comparison of past recorded nutrient levels, to set a baseline for future water quality studies on the lake. Light measurements and refraction rates from down-welling, and Secchi disc sampling. Finally, this study aims to sample temperature and oxygen levels within Lake Rotokare to determine lake stratification and severity of detachment between the epilimnion and hyperlimnion in summer.

2.2 Methods

2.2.1 Location

The deepest part of the lake (Figure 2.1) was chosen as the most suitable location for water sampling. This was primarily to obtain the best vertical water profile, as it was considered to be the deepest part of the lake, but also because this method remained consistent with previous sampling efforts (Taranaki Catchment Commission, 1980; Hicks et al., 2013).

Figure 2.1: Lake Rotokare sampling water quality sampling site 22 Feb 2017.

2.2.2 *Conductivity, Secchi disc depth*

Electrical conductivity was measured with an YSI 3200 conductivity meter for both ambient and specific conductivity (i.e., corrected water temperature of 25°C), during the summer sampling period; this was taken at the water surface, and then in 5 L water samples collected at 0.5 m intervals between the surface and the lake bed with a Schindler-Patalas trap. During the winter sampling period, this was simplified down to only incorporate specific conductivity using the YSI Pro 2030. Water clarity was measured at the same location (Fig. 2.1). Secchi disc depth was used to measure water clarity; where the distance at which a 20 cm disc with black and white quadrants disappears from view.

2.2.3 Dissolved oxygen and temperature

Using the recommended guidelines from Bryers (2000), the dissolved oxygen (DO) concentration was measured as both percent saturation and absolute values expressed as mg L^{-1}, and temperature (°C) were captured with a YSI Pro 2030 meter at the water's surface and then at 0.5 m intervals until reaching the lake bed. Additionally, samples were also taken for conductivity at the same time. This was also repeated in June and again in December; this allowed both a consistent profile to match previous samples and provided a comparative analysis of temperature and DO for both summer and winter. Data was also retrieved from two previous studies from the Taranaki Catchment Commission report (1980) and Hicks et al. (2013) allowing a comparison of four summer's worth of water column profiling to be compared; 1979, 2013, February 2017 and December 2017.

2.2.4 Light measurements

Light measurements were recorded during water quality sampling on the 23 February 2017 at 14:42 h using the same location as was used for water quality sampling (Figure 2.1). The device used was a Li-Cor LI-1400 data logger equipped with a double sided light sensor array, to detect photosynthetically active radiation (or PAR) from both upwelling and downwelling. Measurements were taken periodically at depths at the surface, 0.5 m, 1 m and every meter subsequently until reaching the bottom to obtain a vertical light profile. Down-welling data was deemed unusable, and only upwelling data was kept.

2.2.5 Dissolved nutrients & chlorophyll a

To effectively monitor the current nutrient status of Lake Rotokare, a similar method of water quality sampling was used to that of Hicks et al. (2013), and the Taranaki regional council's water testing during the summer period of 1979–1980 (Taranaki Catchment Commission 1980). Water quality sampling occurred on 22 February 2017 at the lake's centre (Figure 2.1). A 60 mL subsample was extracted from Schindler-Patalas trap samples with a syringe and then filtered through a 0.45 µm filter and placed on ice. Dissolved nutrients in each subsample were then taken back to the University of Waikato, and measured with an Aquakem nutrient analyser. These results were then compared with previous water quality analyses and measurements conducted in 2013 by Hicks et al., (2013) and the original water profile taken by the Taranaki Catchment Commission (Taranaki Catchment Commission, 1980); the TRC report had multiple sites, for the purpose of this study, Site 5 from the TRC report was chosen for comparative data analysis as it was in a similar location to this study's (Figures 2.1, 2.3). This analysis quantifies the lakes total N, total P, dissolved N & P, phosphate levels, nitrogen oxide (NO_x), nitrogen dioxide (NO_2), nitrate (NO_3), and ammonium levels (NH_4). Chlorophyll *a* levels were retrieved in a similar fashion to dissolved nutrients; two 60 mL water samples were taken from the lake's surface on the 19 December 2017. These samples were taken back to the university to be analysed using a spectrometer.

2.2.6 Trophic Level Index

Using the equations from Burns et al., (1999), measurements of chlorophyll *a* concentration (chl *a*), Secchi disc depth (SD), total phosphorus (TP) and total nitrogen (TN) were extracted from nutrients data obtained on 22 February and 19 December 2017 in order to quantify the TLI 3 and TLI 4 value of Lake Rotokare. The equations and modifications necessary to normalise the data into standardized units are as follows:

$$\mathbf{TLc} = 2.22 + 2.54\,Log(chla)$$
$$\mathbf{TLs} = 5.10 + 2.27\,Log(1/SD - 1/40)$$
$$\mathbf{TLp} = 0.218 + 2.92\,Log(TP)$$
$$\mathbf{TLn} = -3.61 + 3.01\,Log(TN)$$

Using these equations to transform these variables, the overall TLI value can be obtained using the following equation:

$$\mathbf{TLI} = 0.25\,(TLc + TLs + TLp + TLn)$$

The TLI 3 equation was possible to be applied to the February 2017 and December 2017 data. Due to the lack of chl *a* samples in February, TLI 4 was only possible in December.

2.2.7 Cyanobacterial count data and overall water quality index data

Other basic water quality indicators such as *Escheria coli* levels, cyanobacterial level counts, turbidity, temperature and conductivity were measured by the Taranaki Regional Council (TRC) during their annual water quality reports. Data was published and made available online through their website (Taranaki Regional Council, 2010-2017), and was then retrieved and summarised. The dataset for cyanobacteria counts was split into two data sets due to the change in methods of cyanobacterial counts used by the TRC from 2014-2017 from cells ml^{-1} to biovolume expressed as cyanobacteria present mm^{-3} L^{-1}.

2.3 Results:

2.3.1 Thermal and oxygen stratification:

Water column sampling undertaken in the lakes central point (Figure 2.1) determined that temperature on the lake surface did increase over time. Between the two data sets taken from February 1977–2013 there was a 1.1°C increase, from February 2013–2017 there was a further temperature increase of 1.3°C. Overall, from 1977 to present there has been an increase of 2.4°C increase between years; 20.5°C to 22.9°C (Figure 2.2; Table 2.1). While this data is limited due to the minimal number of samples conducted over such a large timeframe, it does suggest there has been an overall temperate increase over this period.

All four seasons sampled showed strong thermal stratification. While temperature generally increased, the thermocline; defined as the point where temperature drops > 1°C (Hicks et al., 2013) varied over time (Figure 2.2; Table 2.1). In February 1977, the lakes thermal profile gradually declined from the surface (20.5°C) to 4 m (18.5°C), with the thermocline establishing at a depth between 4-5 m deep (Figure 2.2; Table 2.1). The vertical temperature gradient dropped from surface to bottom by 8.7°C, with an average temperature of 16.6±2.35°C (95% confidence interval). The lake showed severe stratification, with dissolved oxygen levels (%) starting at 116.9% at the surface (indicating a possible lack of machine calibration), then dropping rapidly at the thermocline (3-5 m deep) from 81.5% to 48.4%, declining to ≤ 3.1% from 6 m onwards.

2013 showed a less pronounced drop in temperature. From the surface to 6 m, the temperature showed minimal variation, the thermocline established between 6-7 m deep (Table 2.2). The vertical temperature profile of the lake dropped by 6.6°C in 2013, with an average temperature of 18.65±1.66°C. The dissolved oxygen profile was less stratified in 2013, and much higher below the thermocline than in 1977 (21.4-26.7%). Above the thermocline the oxygen rate diffused much slower throughout the water column with high values above the thermocline, varying between 96.2-78.1%. Past this point DO levels dropped rapidly from 64.7% to 39.9% oxygen saturation. Overall stratification was less extreme in 2013 than any other season.

2017 varied, the rate of change differed between February and December. February had the most extreme thermocline, with a surface temperature of 22.8°C, the thermocline establishing between 2-3 m deep (Figure 2.2). From that point little variation in temperature occurred, 20.7-18.7°C After dipping below the thermocline, the temperature a decreased a further 3.2°C, with a total decrease in the vertical temperature profile of 9°C. The average temperature in February 2017 was the highest recorded, with a value of 19.27±2.02°C. The water column showed extreme decreases in oxygen levels, with a surface value of 110.5%, declining sharply at the thermocline by half to 56.4%, and further dropping to 21.4% below the thermocline (Table 2.1). There were spikes in dissolved oxygen between 5-7 m deep (Table 2.1). From 8 m onwards DO values dropped to < 15%.

December 2017 showed a similar thermal trend. The surface water remained stable for the first 3 m, establishing the thermocline between 3-4 m, with a water temperature of 17.3°C at 4 m (Table 2.1). From there it decreased rapidly towards the bottom with a final temperature of 12.5°C at 9 m deep; with an overall decrease of 10.4°C. The average temperature was 17.67±3.37°C. Dissolved oxygen in December showed a similar trend to 1977, with a surface value of 88.9% dropping to 78.4% at the 3 m thermocline, then rapidly dropping to 3.6% (Table 2.1). From that point the dissolved oxygen ratio fails to show any variation; with 0.2% change in oxygen at 9 m deep.

The depth profile of water temperature in winter showed a very different trend, the lake had become fully mixed with minimal variation from the surface to the lake bed; 11.3-11.2°C (Figure 2.2; Table 2.1). The dissolved oxygen profile becomes fully mixed during the winter season, with a dissolved oxygen decrease from surface to bottom of only 20.6% (Table 2.1).

Table 2.1: Dissolved oxygen and temperature values from 1977-2017 for Lake Rotokare. Sources: Taranaki Catchment Commission (1980); Hicks et al. (2013).

	2 Feb 1977			9 Feb 2013			23 Feb 2017		
Depth	Dissolved oxygen		Temperature	Dissolved oxygen		Temperature	Dissolved oxygen		Temperature
(m)	%	mg L^{-1}	(°C)	%	mg L^{-1}	(°C)	%	mg L^{-1}	(°C)
0	116.9	10.5	20.5	96.2	8.5	21.6	110.5	9.45	22.8
1	104.4	9.5	19.7	98.2	8.6	21.4	107.8	9.41	22.5
2	88.3	8.1	19.5	81.9	7.4	20.9	101.0	8.85	22.2
3	81.5	7.5	19.1	78.1	7.0	20.8	56.4	5.04	20.7
4	48.4	4.5	18.5	64.7	5.8	20.5	21.4	1.90	20.3
5	3.1	0.3	16.6	44.6	4.0	20.1	32.0	2.90	20.1
6	3.0	0.3	15.0	39.9	3.6	19.3	10.6	1.05	18.7
7	2.8	0.3	13.2	30.1	2.9	17.4	34.8	3.18	19.1
8	2.8	0.3	12.6	26.7	2.6	16.3	14.7	1.43	17.0
9	2.8	0.3	11.8	25.0	2.4	15.8	12.7	1.28	14.8
10				25.0	2.5	14.9	12.9	1.36	13.8
11				21.4	2.1	14.9			

	9 June 2017			19 Dec 2017		
Depth	Dissolved oxygen		Temperature	Dissolved oxygen		Temperature
(m)	%	mg/L	(°C)	%	mg/L	(°C)
0	93.7	9.45	11.3	88.9	7.67	22.9
1	93.2	9.43	11.3	87.2	7.57	23.0
2	91.4	9.41	11.3	88.9	7.55	22.9
3	91.3	8.85	11.3	78.4	6.5	22.8
4	89.6	8.83	11.3	3.6	0.34	17.3
5	86.6	8.42	11.3	3.6	0.36	15.4
6	84.1	8.37	11.3	3.7	0.38	14.2
7	82	8.21	11.3	3.5	0.38	13.0
8	79.8	8.01	11.2	3.4	0.36	12.7
9	77.4	7.92	11.2	3.4	0.35	12.5
10	74.3	7.77	11.3			
11	73.1	7.56	11.2			

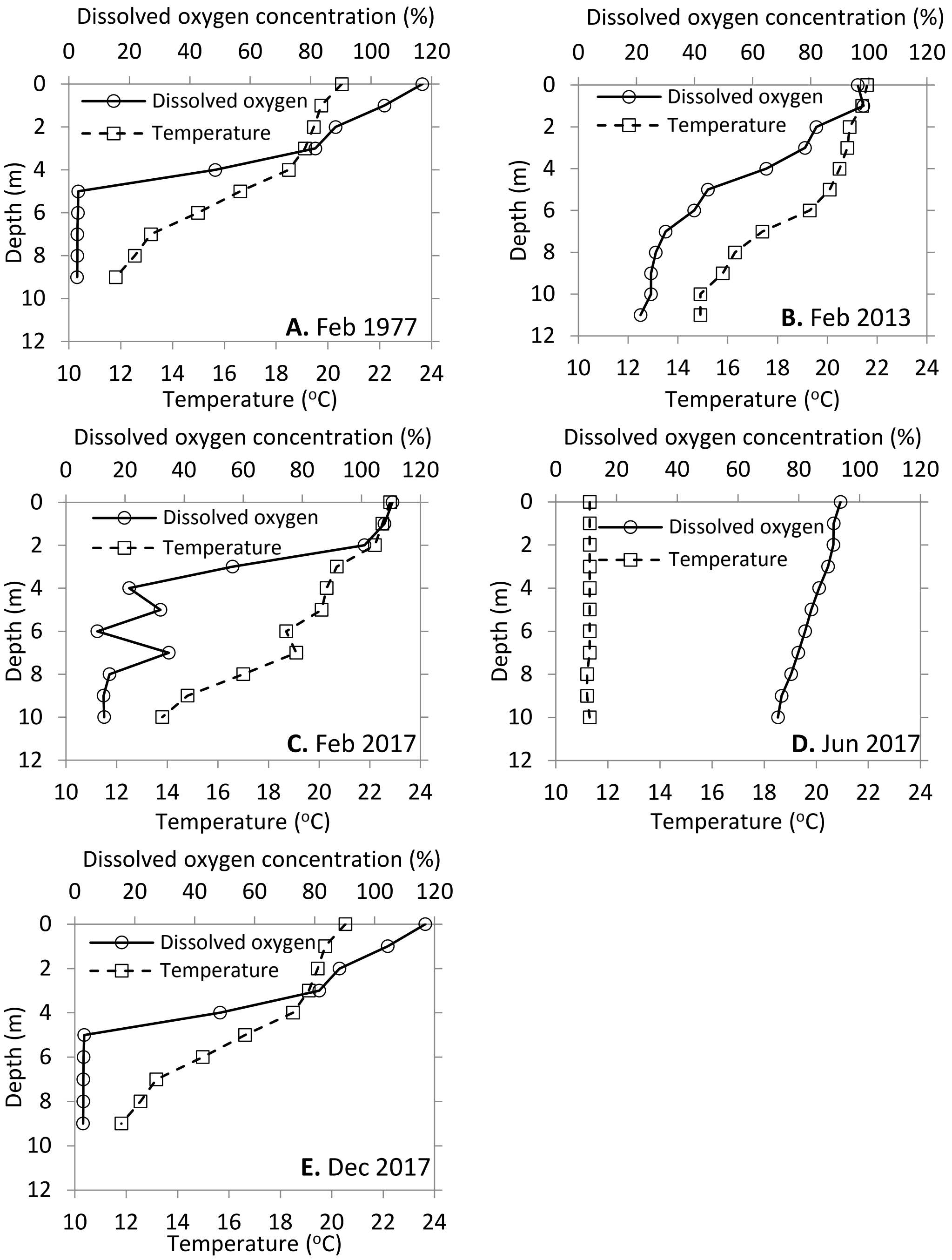


Figure 2.2: Dissolved oxygen and temperature profiles in Lake Rotokare in **A.** 1977, **B.** 2013, **C.** Feb 2017, **D.** Jun 2017, and **E.** Dec 2017. Sources: Taranaki Catchment Commission (1980); Hicks et al. (2013).

Overall, it remains hard to distinguish any year to year trends. Figure 2.3 shows all four water samples compared together, overall it appears that 1977 and December 2017 share similar trends of lake stratification in both DO and temperature. Whereas 2013 and February 2017 show a different trend in temperature and very different trends in dissolved oxygen. The overall averages in temperature did not significantly differ from one another, the February 2013 average did differ significantly from February 1977, with the average of 16.6°C falling outside of the 18.65±1.66°C sample range; the mean confidence interval (95%) of 1977 (±2.35°C) did overlap with 2013 however. February 2017 does remain significantly different from 1977 also, with a value of 19.27±2.02°C, neither set of confidence intervals overlap.

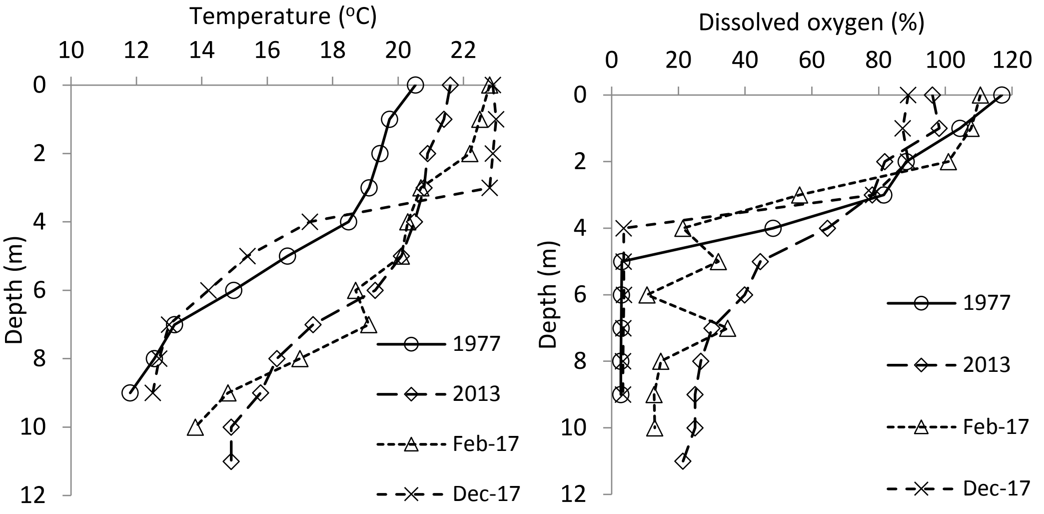


Figure 2.3: Temperature and dissolved oxygen profiles of Lake Rotokare during periods in Feb 1977-2017 and Dec 2017. February 1977-2013 data extracted from: (Taranaki Catchment Commission, 1980; Hicks et al., 2013).

2.3.2 Conductivity and Secchi disc depth

Surface conductivity in 1976 and 1977 was 116±13 µS cm^{-1} (mean±1SD; Taranaki Catchment Commission, 1980). As Hicks et al., (2013) highlighted in their study, it is not clear whether the conductivity was ambient or specific. Hicks et al. (2013) had a similar conductivity measurement, taken on 9 February 2013, ambient conductivity for 2013 was 112.8 µS cm^{-1} and specific conductivity of 123.1 µS cm^{-1} (temperature adjusted to 25°C). 2017 data was similar, with an electrical ambient conductivity of 120.5 µS cm^{-1}, and a specific conductivity of 123.5 µS cm^{-1}.

Water clarity appears to be improving. While issues remain for the sampling methods between the 1980 and 2013-2017 data, there appears to an improvement in water clarity in 2017. The TRC report surveyed four sites within the lake and obtained an overall mean Secchi disc clarity. However, these sites were not the same location as our sampling site. The TRC report used sites 1-4 in the lake (Figure 2.4), which did not align with our sampling site in the lake centre (Figure 2.1). The data in 1979-1980 was highly variable. Between December 1979 and January 1980 and Feb-March 1980 there was a significant increase in water clarity from 1.5 m to 1.9-2.18 m (1.76±0.55 m; mean 95% confidence interval). Secchi sampling in this study and Hicks et al. (2013) showed a more consistent pattern with a Secchi depth of 1.92 m in February 2013, 1.95 m in February 2017, 1.92 m deep in June 2017, and 2.2 m in December 2017 (Figure 2.5). The mean Secchi depth in 2017 was 2.01±0.09 m. This suggests water clarity has overall improved in the last 35-40 years, and that water clarity may not vary in winter, even with the breakdown of lake stratification (Figure 2.2).

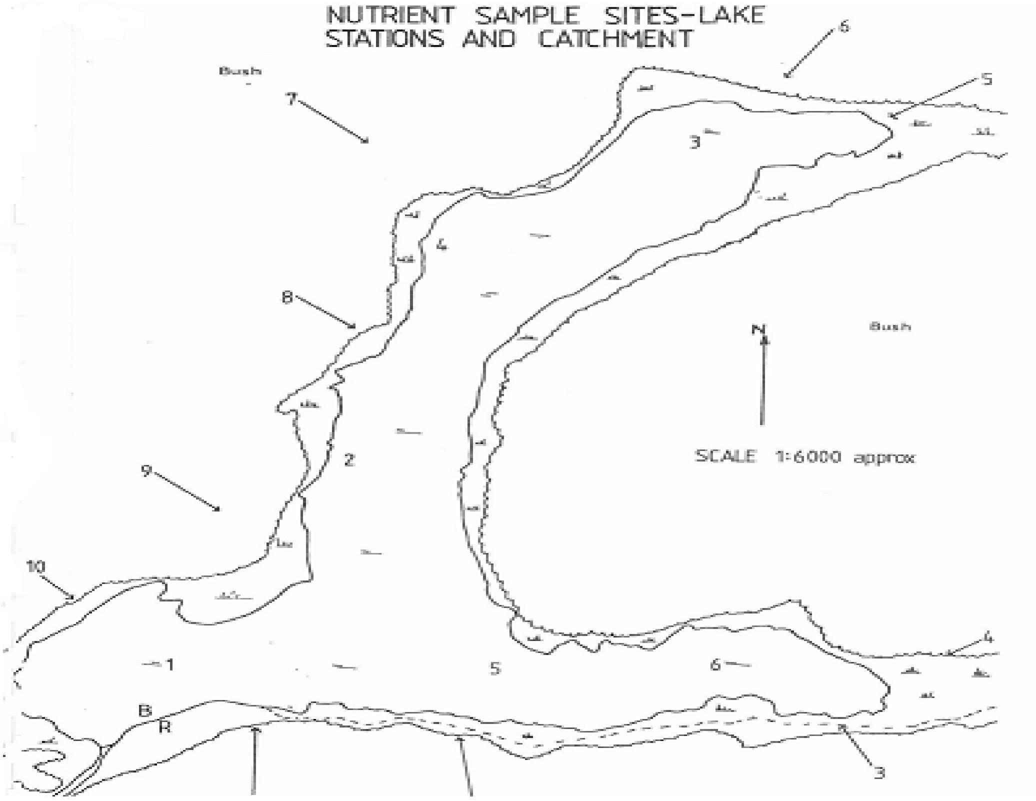


Figure 2.4: Sampling site locations for Secchi disc sampling and water quality samples taken by the TRC between 1979 and 1980 (Taranaki Catchment Commission 1980).

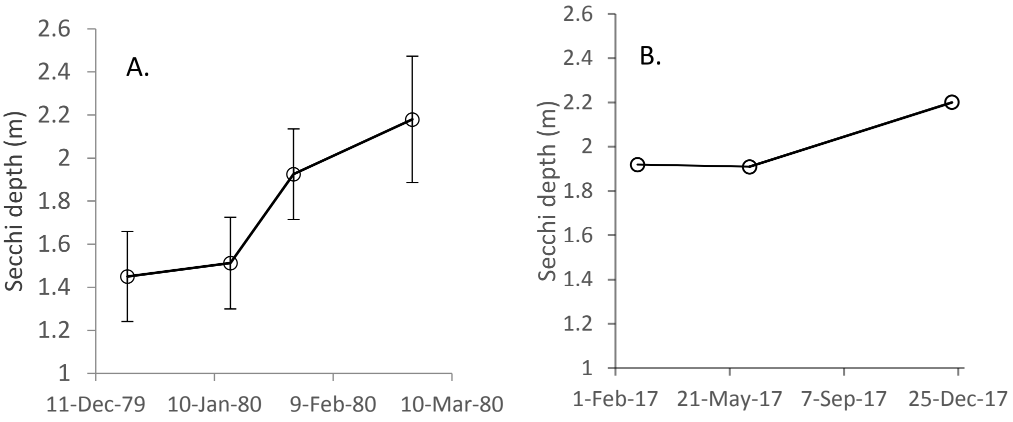


Figure 2.5: A. Mean Secchi depth measured at four sites in Lake Rotokare in summer 1979-1980 (Error bars 95% confidence interval). **B.** Single measurement Secchi depth data from the same water quality profile used in this study (Figure 2.1) from 2017.

2.3.3 Light extinction

Light extinction occurred rapidly within Lake Rotokare. Diffuse attenuation coefficient of photosynthetically active radiation (K_d(PAR)) maximum penetration distance of LnPAR into the water column was 5 m. Natural logarithm (Ln) 1% of surface PAR was 1.87 m and the compensation depth (1% light extinction depth) was 3.42 m (Figure 2.6). K_d measured (0-4 m) was 1.36 m, PAR µmol extinction occurred at 4.77 m (Figure 2.7), therefore, the calculated K_d value (0-4.77 m) was 1.36 m. These values match up closely with the lake stratification occurring in February (Figure 2.2).

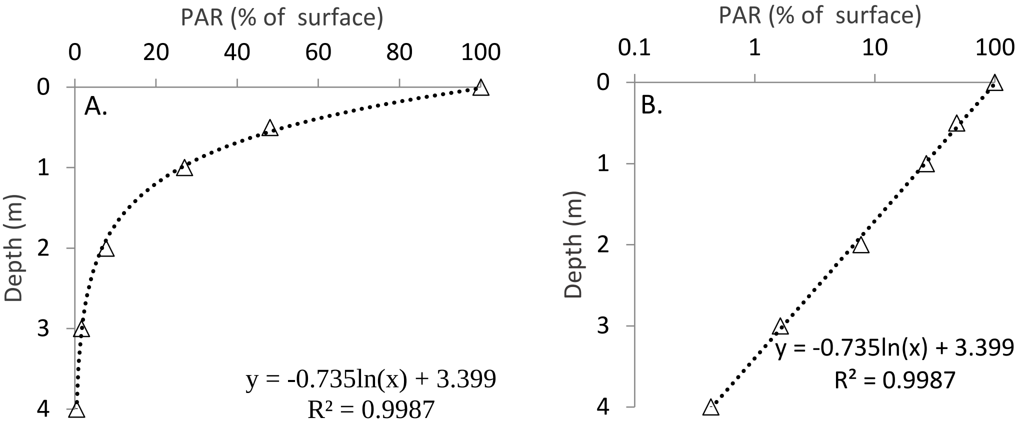


Figure 2.6: A. Light extinction coefficient curve represented by photosynthetically active radiation saturation from surface (100% PAR saturation) to the maximum penetration depth of 4 m depth (0% PAR saturation). **B.** Log value graph of the light extinction coefficient from the surface.

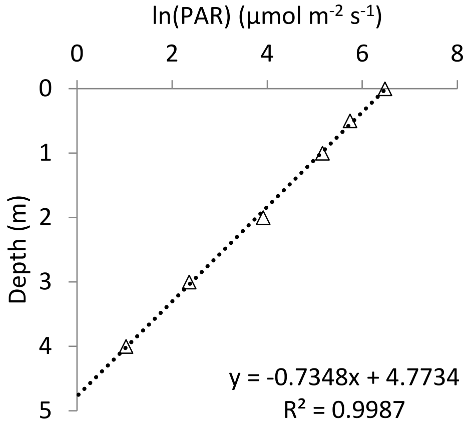


Figure 2.7: Light extinction coefficient curve represented by photosynthetically active radiation saturation represented by a linear model of PAR from the surface to the maximum depth of PAR penetration (4.77 m).

2.3.4 Nutrient sampling

Dissolved nutrient sampling was the most useful measurement for comparing water quality between years. Dissolved reactive phosphorus (DRP) was sampled in 1976-1977, and compared against phosphate (PO_4) values sampled in 2013 and 2017. PO_4 exhibited a large trend of decline between 1976 and 2017 (Table 2.2). However, the middle water PO_4 values also showed a slight decrease over the same time-frame (Table 2.2). Nitrogen was more difficult to compare, as water nutrient data was inconsistent in nutrients sampled between years. The best comparable data available for 1977 was nitrate (NO_3-N) which can be compared to NO_3 samples in 2017. There was no sample measured in 2013 that could be directly compared to 1977 and 2017. Therefore, NO_3 was calculated for 2013 water quality values by taking NO_x and NO_2 from Hicks et al. (2013), subtracting from each other. Dissolved nitrogen nutrient levels show a significant decrease between 1977 and the 2013 and 2017 water samples, with large decreases in NO_3 at each depth sample. There were negligible differences between 2013 and 2017, suggesting NO_3 levels have since stabilized (Table 2.2).

Table 2.2: Comparison of dissolved nutrient available for cross-referencing between years for Lake Rotokare. Data represents single sample values of each nutrient (except where data modification was necessary (read above). Surface represents a depth of 0.2 m, middle; 5 m, and the bottom; 9 m. Blank cells indicate no data (Data retrieved from Table 2.3; Table 2.4; Table 2.5).

	DRP & PO_4 mg L^{-1}			NO_3-N mg L^{-1} & NO_3 mg L^{-1}		
Date	Surface	Middle	Bottom	Surface	Middle	Bottom
2-Sep-76	0.165	0.050	0.170			
1-Feb-77	0.145	0.040	0.425	0.010	0.060	0.310
9-Feb-13	0.059	0.088	0.121	0.001	< 0.001	< 0.001
23-Feb-17	0.012	0.019	0.031	0.009	0.007	0.006

Table 2.3: Dissolved nutrient concentrations measured in Lake Rotokare on 2 Sep 1976 and 1 Feb 1977. Blank cells indicate no data. (Source: Taranaki Catchment Commission 1980).

	Depth	DRP mg m^{-3}		NO_3-N mg m^{-3}		pH	Alkalinity	Total hardness
Site	sampled	2-Sep-76	1-Feb-77	2-Sep-76	1-Feb-77	1-Feb-77	(g m^{-3} as $CaCO_3$)	(g m^{-3} as $CaCO_3$)
Outlet		405		1500				
Ramp		350		1120				
A			950		1220	7.3	80	63
1	surface	260	100	240	80	6.9	30	32
1	middle	50	10	250	70	6.8	20	31
1	bottom	245	10	330	310	6.5	40	31
2	surface	255	0		90	7.1	30	27
2	middle	70	25	310	90	7.1	30	29
2	bottom	260	15		100	6.8	30	29
3	surface	195	15		70	7.3	30	28
3	middle	120	335	330	80	7.2	30	28
3	bottom	40	10		70	7.2	30	27
4	surface	175	10		70	8.8	40	27
4	middle	195	135	270	70	8.5	30	28
4	bottom	320	1		50	8.3	20	28
5	surface	165	135		10	7.3	30	27
5	middle	50	40	260	60	7	30	28
5	bottom	170	425		310	5.3	30	34
6	surface	260	160		70	8.3	60	27
6	middle	175	80		70	8.1	40	29
6	bottom	45	15		50	8	20	28

Table 2.4: Dissolved nutrient data extracted from Hicks et al. (2013). Data measured on 9 Feb 2013.

	Dissolved nutrient concentration (mg m^{-3})			
Depth (m)	NH_4	NO_2	NO_x	PO_4
0.2	43	1	5	59
5.0	248	1	1	88
9.0	1173	< 0.1	< 0.1	121
9.0	1274	< 0.1	< 0.1	98
9.0	1342	< 0.1	< 0.1	97

2.3.5 2017 nutrient results

In February Nitrogen oxide (NO_x), Nitrogen dioxide (NO_2), Nitrate (NO_3), and phosphate (PO_4) levels were negligible (Table 2.5). Concentrations of NO_x, NO_2, and NO_3 were all less than ≤ 0.013 mg L^{-1} with no noticeable changes between surface waters and the bottom of the lake (Table 2.5). PO_4 levels were higher, varying between 0.012-0.053 mg L^{-1}. Ammonia (NH_4) was present in low levels throughout the upper-middle water column (≤ 0.5 mg L^{-1}), bottom hypolimnion had extremely high levels of NH_4 present; this may have been due to the spikes of oxygen present throughout the middle of the water column in February, lowering the potential for ammonia production exclusively to the bottom 3 m (Figure 2.2). Total nitrogen (TN) was present in extremely high quantities throughout the water column. The surface value was 0.582 mg L^{-1}, increasing roughly eightfold (4.5 mg L^{-1}) at the bottom, with intermittent spikes in between. Total phosphorus showed a similar trend to TN, starting with a surface value of 0.032 mg L^{-1}, increasing 50-fold at the lake bed (1.587 mg L^{-1}), with spikes in TP appearing throughout the water column. Dissolved N/P (expressed as NH_4/PO_4) showed massive imbalances starting at a surface ratio of 3.6, rising to 11.75 below the thermocline, and spiking at 126.75 difference in dissolved N/P ratio (Figure 2.8). Total N/P was high above the thermocline (8.51-17.92), with more modest values below the thermocline of 8.29-2.83. Both solid and dissolved nitrogen and phosphorus concentrations showed a similar trend of increase from the epilimnion to the hypolimnion (Figure 2.8).

Table 2.5: Water nutrients concentrations measured in Lake Rotokare on 23 Feb 2017.

Depth (m)	NO$_x$ mg L^{-1}	NO$_2$ mg L^{-1}	NO$_3$ mg L^{-1}	PO^4 mg L^{-1}	NH^4 mg L^{-1}	TN mg L^{-1}	TP mg L^{-1}	N/P Dissolved	N/P Total
0.2	0.013	0.004	0.009	0.012	0.033	0.582	0.032	3.60	17.92
0.5	0.011	0.004	0.007	0.011	0.031	0.564	0.041	3.47	13.78
1	0.012	0.004	0.007	0.011	0.035	1.682	0.198	3.85	8.51
2	0.012	0.004	0.008	0.012	0.035	0.614	0.053	3.55	11.68
3	0.011	0.004	0.007	0.013	0.042	0.863	0.114	3.75	7.54
4	0.013	0.004	0.008	0.013	0.148	1.915	0.231	12.41	8.29
5	0.011	0.004	0.007	0.019	0.199	0.701	0.085	10.61	8.20
6	0.011	0.004	0.007	0.023	0.332	0.898	0.162	14.98	5.53
7	0.011	0.004	0.006	0.034	0.455	0.824	0.148	13.51	5.57
8	0.011	0.005	0.006	0.053	1.171	1.245	0.529	22.19	2.36
9	0.011	0.004	0.006	0.031	2.329	3.392	1.119	75.05	3.03
10	0.012	0.005	0.007	0.035	4.421	4.499	1.587	126.94	2.83

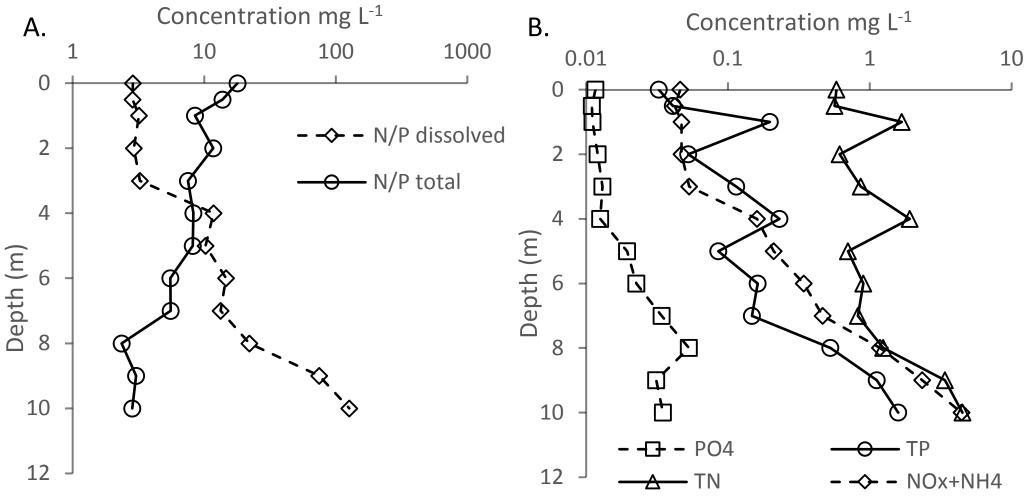


Figure 2.8: **A**. Depth profiles of N:P ratios in Lake Rotokare on 23 Feb 2017.**B.** Phosphate (PO_4), total phosphorus (TP), ammonium (NH_4), and total nitrogen (TN) levels in Lake Rotokare on 22 Feb 2017.

2.3.6 *Trophic Level Index*

Using Chlorophyll *a* concentration (chl *a*), Secchi disc depth, total phosphorus and total nitrogen, it was possible to construct a Trophic Level Index (TLI) for Lake Rotokare using the formula given from Burns et al., (1999). The TLI was constructed using the chlorophyll a and Secchi depth data, as well as the surface TP and TN values from Table 2.5. The following values were estimated for the construction of a lake TLI value using the data from Table 2.5. TLc = 5.13, TLs = 4.38, TLp = 4.63, and TLn =2.55. Using these conversion values, the TLI was estimated: 0.25(TLc + TLs + TLp + TLn) giving a final value of 4.12. This value shows that under the New Zealand standardized lake nutrient measurement, Lake Rotokare is classified as a eutrophic lake (Table 2.6). The only exception worth noting is the Chl *a* values reflected a supertrophic lake (mean = 14.01 mg m^{-3}; Table 2.6) rather than a eutrophic lake chl *a* value (Table 2.7).

Table 2.6: Lake Trophic Index data used to determine the Lake Rotokare TLI 4 score in 19 December 2017.

	Lake Trophic Index data (TLI 4)			
	Chl *a*	Secchi depth	TP	TN
Date	(mg m^{-3})	(m)	(mg m^{-3})	(mg m^{-3})
19-Dec-17	14.01	2.20	28	110

Table 2.7: Values of TLI variables that define the boundaries of different trophic levels (source: Burns et al., 1999).

Lake type	Trophic level	Chl *a* (mg m^{-3})	Secchi depth (m)	TP (mg m^{-3})	TN (mg m^{-3})
Ultra-microtrophic	0.0 - 1.0	0.13 - 0.33	33 - 25	0.84 - 1.8	16 - 34
Microtrophic	1.0 - 2.0	0.33 - 0.82	25 - 15	1.8 - 4.1	34-73
Oligotrophic	2.0 - 3.0	0.82 - 2.0	15 - 7.0	4.1 - 9.0	73-157
Mesotrophic	3.0 - 4.0	2.0 - 5.0	7.0 - 2.8	9.0 - 20	157 - 337
Eutrophic	4.0 - 5.0	5.0 - 12.0	2.8 - 1.1	20 - 43	337 - 725
Supertrophic	5.0 - 6.0	12.0 - 31.0	1.1 - 0.4	43 - 96	725 - 1558
Hypertrophic	6.0 - 7.0	>31	<0.4	>96	>1558

TLI 3 scores varied significantly between February (4.54) and December (3.71) in 2017. This was primarily due to the massive reduction in lake surface TN loading between seasons, dropping from 582.1 to 110 mg m^{-3}. This caused Lake Rotokare's TLI classification to change between seasons, from Eutrophic in February, to Mesotrophic in December (Tables 2.7, 2.8).

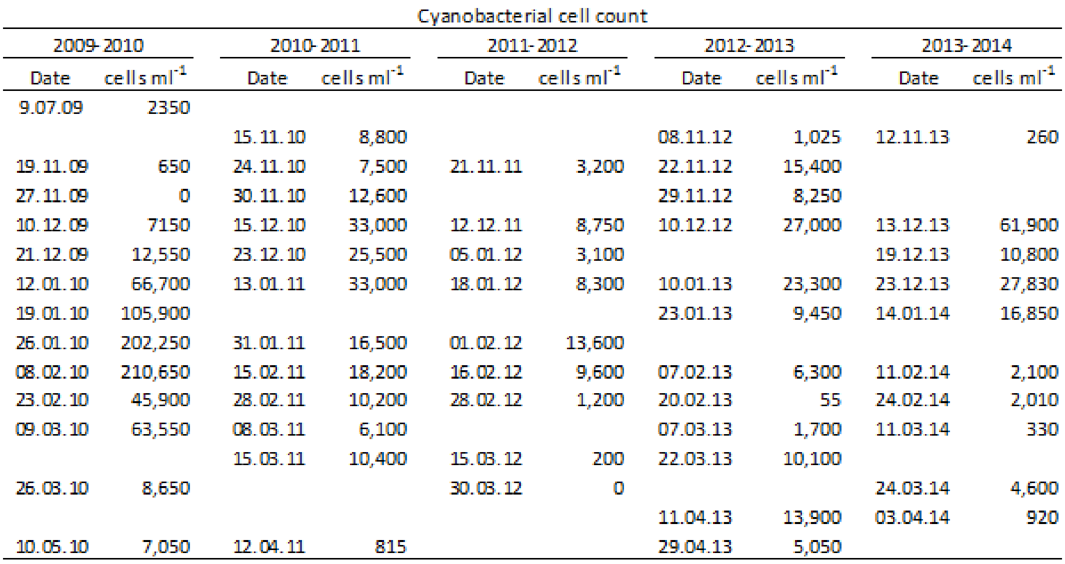
Table 2.8: Lake Trophic Index data used to determine the Lake Rotokare TLI 3 scores for 22 Feb 2017 and 19 December 2017.

Lake Trophic Index data (TLI 3)			
Date	Secchi depth (m)	TP (mg m^{-3})	TN (mg m^{-3})
22-Feb-17	1.92	32.48	582.10
19-Dec-17	2.20	28.00	110.00

2.3.7 Cyanobacterial data and lake quality index

Regular state-of-the-environment monitoring for cyanobacteria and water quality index reports have been issued by the Taranaki Regional Council since 2009 (Cyanobacteria data: Tables 2.9, 2.10; water quality report: Table 2.11). The predominant genus of cyanobacteria has been *Dolichospermum* (*Anabaena*), with low levels of *Microcystis* appearing intermittently over summer, with peak abundance from late December through to mid-February (Table 2.9; Table 2.10). It appears the duration of hazardous levels of bacteria appearing is increasing. As in 2014-2017 the hazardous level limit was exceeded in all three years all the way through to late March and early April in most cases (with the exception of 4 Feb 2016 and 26 Jan 2017; Table 2.10). Compared to 2009-2014, where the limits were sporadically exceeded in most seasons (Table 2.9), algal blooms have occurred more severely in the last few years. 2012 was an exception, with a season were cells mL^{-1} never exceed the danger level imposed by the council. Table 2.9 shows measurements of turbidity, surface temperatures, conductivity, and *E.coli* levels. Turbidity, surface temperatures, and conductivity are generally poor indicators of water quality to make any assumptions from. However, the water quality reports do indicate that the lake has consistently low levels of *E.coli*, with only one alert in *E.coli* levels of 340 100 ml^{-1}; nos; safety limit ≥ 550 *E. coli* 100 ml^{-1} (2016-2017) over the 9-year sampling period.

Table 2.9: Cyanobacterial cell counts between Oct-Apr for Lake Rotokare from 2009-2014. Safe level counts > 15,000 cells ml^{-1} (source: Taranaki Regional Council 2010, 2011, 2012, 2013, 2014).



Cyanobacterial cell count									
2009-2010		2010-2011		2011-2012		2012-2013		2013-2014	
Date	cells ml^{-1}	Date	cells ml^{-1}	Date	cells ml^{-1}	Date	cells ml^{-1}	Date	cells ml^{-1}
9.07.09	2350								
		15.11.10	8,800			08.11.12	1,025	12.11.13	260
19.11.09	650	24.11.10	7,500	21.11.11	3,200	22.11.12	15,400		
27.11.09	0	30.11.10	12,600			29.11.12	8,250		
10.12.09	7150	15.12.10	33,000	12.12.11	8,750	10.12.12	27,000	13.12.13	61,900
21.12.09	12,550	23.12.10	25,500	05.01.12	3,100			19.12.13	10,800
12.01.10	66,700	13.01.11	33,000	18.01.12	8,300	10.01.13	23,300	23.12.13	27,830
19.01.10	105,900					23.01.13	9,450	14.01.14	16,850
26.01.10	202,250	31.01.11	16,500	01.02.12	13,600				
08.02.10	210,650	15.02.11	18,200	16.02.12	9,600	07.02.13	6,300	11.02.14	2,100
23.02.10	45,900	28.02.11	10,200	28.02.12	1,200	20.02.13	55	24.02.14	2,010
09.03.10	63,550	08.03.11	6,100			07.03.13	1,700	11.03.14	330
		15.03.11	10,400	15.03.12	200	22.03.13	10,100		
26.03.10	8,650			30.03.12	0			24.03.14	4,600
						11.04.13	13,900	03.04.14	920
10.05.10	7,050	12.04.11	815			29.04.13	5,050		

Table 2.10: Cyanobacterial biovolume for Lake Rotokare for Oct-Apr 2014-2017. Safety level ≤ 1.88 mm^{-3} L^{-1} (source: Taranaki Regional Council 2015, 2016, 2017).

Biovolume danger level: 1.8 mm^{-3} L^{-1}								
2014-2015			2015-2016			2016-2017		
Date	Biovolume	Hazard	Date	Biovolume	Hazard	Date	Biovolume	Hazard
10/10/14	0.12	Low	04/11/15	0.7	Med	03/11/16	0.6	Med
18/11/14	0.18	Low	20/11/15	1.9	High	22/11/16	4.6	High
03/12/14	4.5	High	21/12/15	18.7	High	07/12/16	2.5	High
15/12/14	9.6	High	19/01/16	11.2	High	21/12/16	15	High
15/01/15	43.3	High	01/02/16	2.2	High	05/01/17	6.3	High
27/01/15	17.9	High	04/02/16	1.3	Med	26/01/17	1.8	Med
12/02/15	16.7	High	15/02/16	2.4	High	07/02/17	4.1	High
26/02/15	35.5	High	04/03/16	7.6	High	07/03/17	0	High
20/03/15	5.5	High	16/03/16	9	High	20/03/17	0.08	High
25/03/15	5.2	High	01/04/16	1.1				

Table 2.11: Taranaki Regional Council water quality index monitoring report data from 2009-2017. Retrieved from eight TRC technical reports (Taranaki Regional Council 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017).

Water quality index (2009-2017)

	Parameter	Unit	Sample size	Min	Max	Median	range - comments
2009-2010	Conductivity	mS/m	9	11.2	12.9	11.8	1.7mS/m - stable
	Temperature	°C	9	15.9	22.7	20.9	6.8°C - moderate range
	Turbidity	NTU	9	1.7	28	8	26NTU - high tubidity
	E.*coli*	nos/100mL	9	1	13	3	Safe levels
2010-2011	Conductivity	mS/m	11	11.6	18.8	11.8	1.2 mS/m - stable
	Temperature	°C	11	17.8	23.7	20.3	5.9°C - moderate range
	Turbidity	NTU	11	0.8	8.8	3.4	8 NTU - moderate
	E.*coli*	nos/100mL	9	1	37	5	Safe levels
2011-2012	Conductivity	mS/m	8	10.6	11.8	11.1	1.2 mS/m - stable
	Temperature	°C	9	17.5	20.9	20.2	3.4°C
	Turbidity	NTU	9	0.8	8.8	3.4	8 NTU - moderate
	E.*coli*	nos/100mL	9	1	220	7	Safe levels
2012-2013	Conductivity	mS/m	10	11.4	12.1	11.6	0.7mS/m - stable
	Temperature	°C	11	17.1	23.9	20.3	6.8°C - moderate range
	Turbidity	NTU	10	0.9	6.8	3.3	5.9 NTU - moderate
	E.*coli*	nos/100mL	10	<1	69	3	Safe levels
2013-2014	Conductivity	mS/m	9	11.5	12.8	11.9	1.3mS/m - stable
	Temperature	°C	9	18.5	21.2	19.9	2.7°C - narrow range
	Turbidity	NTU	8	1.2	14	2.3	12.8NTU - moderate with spike
	E.*coli*	nos/100mL	9	7	170	17	Safe levels
2014-2015	Conductivity	mS/m	8	11.6	13.3	12.1	1.7mS/m
	Temperature	°C	9	16	25.5	21	9.5°C - warm, wide range
	Turbidity	NTU	8	3.2	35	20	32NTU - High turbidity
	E.*coli*	nos/100mL	8	8	240	21	Safe levels
2015-2016	Conductivity	mS/m	7	11.9	14.6	12.2	2.5mS/m - high variability
	Temperature	°C	10	16.5	24.9	21.2	8.4°C - warm, wide variability
	Turbidity	NTU	7	3	13	7.2	10NTU - moderate
	E.*coli*	cfu/100mL	7	11	290	80	Safe levels
2016-2017	Conductivity	mS/m	10	12	12.6	12.2	0.6mS/m - stable
	Temperature	°C	10	17.6	22.4	20	4.8°C
	Turbidity	NTU	10	1.5	14	5.7	12NTU - high
	E.*coli*	cfu/100mL	10	7	340	73	Safe - one alert (340cfu/100mL)

2.4 Discussion:

Overall, Lake Rotokare has poor water quality. The lake has high levels of phosphorus and nitrogen do not appear to have improved since 1977. The only exception to this is dissolved phosphorus (PO_4) which has consistently dropped throughout each sampling period, with a large difference between concentrations. 1976 was the lowest of the two samplings years in the TRC report, with an average water-column phosphate concentration of 0.16±0.04 mg L^{-1} (mean 95% confidence interval). 2013 showed a decrease of 0.4 mg L^{-1} with a mean water-column PO_4

concentration of 0.09±0.02 mg L^{-1} and our data dropped further to an average PO_4 concentration of 0.02±0.01 mg L^{-1}. Caution should be taken when comparing water samples from 1976-1980, given the differences in sampling and analytical methods. Comparing dissolved nitrogen was not possible between 1976 and 1980 with the 2013 and 2017 data. However, there was minimal change in mean ammonia (NH_4) between 2013 and 2017. Mean water column ammonium in 2013 was 0.81±0.76 mg L^{-1} and in 0.77±0.85 mg L^{-1} in 2017. Secchi disc remained similar between 1980 and 2017; with an increase in the Secchi disc depth of 0.25 m. There was no significant difference between the two years, suggesting that the lakes water clarity may not be improving. PAR may have been low due to the large availability of nutrients and high algal biomass (the lake had a cyanobacterial bloom at the time of sampling), which may have forced greater light dispersal (Brown, 1984).

The lake likely remains hypoxic throughout the entire summer period and therefore, has an annual nutrient flux of phosphorus; which can be seen with the high levels of ammonia and total nitrogen levels below the thermocline - driven by nutrient release from N and P rich sediments exposed to deoxygenation. Total phosphorus concentrations under the thermocline were also high, and this was probably a response to anoxic conditions resulting in the phosphorus molecules unbinding from the lake sediment and rising into the water column. The burial efficiency of phosphorus decreases with decreasing oxygen concentrations and under anoxic conditions, instead of net burial, phosphorus is released from the sediment to the water column (Vant, 1987; Nurnberg, 1984).

While it is impossible to accurately compare TP and TN of the lake from the 2017 samples to earlier water quality tests, it is likely that TN and TP were higher in 1976 to 1980. The limited water testing results for TP from 1977 are highly suspect, with results well outside of expected values or trends. The decrease in dissolved phosphorus concentrations is likely to be a result of fencing off the scenic reserve, exclusion of grazing livestock, and the discontinued use of fertilizer for agricultural practices around the lake. Re-establishing the dense, intact forest layer would have also reduced sediment run-off rates greatly and also improved bacterial levels of *E.coli* and other harmful organisms by stopping urine and faeces from entering the lake (Hicks et al., 2013).

Light penetration and the lakes' thermocline had similar depth regimes, suggesting that only algae above the lake thermocline in 2017 (4 m) were capable of absorbing sufficient solar radiation to survive. This would mean algal biomass would be restricted to the epilimnion, and therefore only serve to increase the biomass of blue-green algal species. The lake exhibited a very low surface dissolved N/P ratio, which favours the persistence and domination of cyanobacterial species above the lake's thermocline. Cyanobacterial species are fully capable of utilizing the available dissolved P nutrients available, while fixing nitrogen through photosynthesis (Lindenschmidt & Chorus, 1997). The fact that cyanobacterial blooms were dominated by *Anabaena* and *Microcystis* species is not surprising. Ganf and Oliver (1982) found both species are capable of fully exploiting thermal stratification.

Additionally, both species of algae can maintain position in the water column through buoyancy control (Lindenschmidt & Chorus, 1997). Unlike other algal species, species of cyanobacteria would be able to migrate below the 1% light extinction region of 4.77 m and gain access to the higher nutrient levels present in the lower water column. The lake is experiencing annual cyanobacterial blooms, and this phenomena appear to be increasingly in duration and severity over time. This would favour the dominance of cyanobacterial species as opposed to other species of algae, as the ability to shift between nutrient rich waters below the thermocline would give the two species a massive advantage. Johnston & Jacoby (2003) found that *Microcystis* populations were 2-10 times higher in vertical migration rates in shallower lakes (≥ 10 m) than deeper lakes. Lake Rotokare is small and shallow (Figure 1.2) and has very few external sources of mixing due to its position in the middle of a valley surrounded by dense native forest, therefore, the summer water column would remain highly stable. The data from the dissolved oxygen-temperature analysis of the lake over successive years and months (December-February) supports this idea, as the water column shows extreme stratification and detachment of oxygen enriched surface waters from lower anoxic layers. This is likely to become worse in the future, as climate change is only going to further exacerbate this process, with cyanobacteria having both the physiological and physical factors to exploit warming climates, leading to the persistence and duration of blooms in the future (O'Neil et al., 2012; Paerl & Paul, 2012).

The average concentration of dissolved oxygen in the bottom water was 5.9 mg L^{-1}, with 20% of those values falling below ≤ 1 mg L^{-1} (Verburg et al., 2010). These results ranged from 0.3-2.1 mg L^{-1} in summer, suggesting Lake Rotokare is one of the most deoxygenated lakes in the country during the summer period. When stratification was not present in samples however, the average became 7.3 mg L^{-1}, and Rotokare was above this with an average of 7.56 mg L^{-1}. Low concentrations of dissolved oxygen in the hypolimnion can accelerate the flux of nutrients from lake sediments, resulting in a positive feedback loop, accelerating eutrophication (Verburg et al., 2010).

The lake also has several species of invasive aquatic plants; with a large section of the lake being colonized by *Lagarosiphon major,* a species of exotic oxygen weed. Invasive plant communities have been shown to reduce the recovery time of lakes significantly due to the uptake and release cycle of nutrients, limiting the release of nutrients out of the system (Kufel & Kufel, 2002). Furthermore, the presence of perch in the lake can act as a control mechanism on zooplankton through predation; this coupled with climate change set to favour the ontogenic plankti-benthivorous life stage; resulting in favourability for increased algal growth (Jeppesen et al., 2008).

There is minimal water movement between systems within and outside of the lake. The lake inflow remains low year-round, with lake inflow being restricted to one stream inlet and a few ephemeral streams appearing during high rainfall events. The lake outflow varies, with a mean annual flow of 50 L s^{-1}, with a mean annual low flow of 3 L s^{-1}, a relatively low rate of movement. This would lead Lake Rotokare to have a very long retention time, and this coupled with the fact the basin of the lake is located in is sheltered by dense forest cover and minimal fetch would contribute to decreasing the rate at of removal of these nutrients from the lake. Therefore the retention time of phosphorus in Lake Rotokare could potentially be massive.

The TLI indicates the lake is likely eutrophic, the TLI 4 score of 4.12 considered eutrophic by national, standards, and was above the national average of 3.8 (Verburg et al., 2010). The TLI 3 score between February (4.54) and December (3.71) indicated a different outcome. Surface TN levels between February and

December 2017 were significantly different (Feb = 582.1 mg L^{-1} vs. 110 mg L^{-1}) causing the differences in scores. December's TLI 3 value falls below the national average TLI score of 3.8. However, caution should be stipulated here, as the TLI 4 value reflects a more accurate assessment (Burns et al., 1999), falling between the two TLI values - suggesting the TLI 4 value best represents lake quality. Therefore, with the limited data available it is likely the lake would be considered eutrophic. The TLI is a highly useful tool for lake management approaches in New Zealand, and it is a common and cheap method of monitoring the general decline-improvement ratio of the lake and to quickly assess changes and trends of eutrophication in lakes over time (Burns et al., 1999). There are great variations in the annual fluctuations of TN, TP and Secchi among lakes. Therefore, it is important to consider further TLI studies are necessary, in order to compensate for seasonal variation and obtain an accurate TLI representation of the lake.

Both TN and TP are in high levels and both are attributable to phytoplankton growth in lakes. There are rigorous arguments for both N and P being the limiting factor for controlling phytoplankton biomass, thus leading to different outcomes for controlling eutrophication of lakes. Schindler et al., (2008) used a 37-year study on a large lake system in Canada, concluding that P-reduction would be the best source of action in managing lake eutrophication. Other arguments (as previously mentioned above) include the role of cyanobacterial N fixation likely making up N deficits in lake systems (Burger et al., 2007; Carpenter, 2008; Patterson et al., 2011; Muller & Mitrovic, 2014). The proliferation of N-fixing cyanobacteria is often associated with the presence of anoxia in bottom waters, which enhances both P-release from bottom sediments and N losses from denitrification (Downing & McCauley 1992; Smith 2003; Dodds et al., 2002; Ma et al., 2015); resulting in low water column N:P ratio (Bergstrom et al., 2015). Our results support the theory this lake is driven by the availability of phosphorus. It should be noted however that surface TN and NH_4 where high. Ultimately both elements are needed in abundance to supply the building blocks necessary for sustaining enhanced phytoplankton production (Douglas et al., 2016), therefore, it is likely remedial action for lake nutrient loads will require a multi-targeted approach.

2.5 Conclusion

Without proper management the condition of Lake Rotokare will likely show no improvement. Temperature-mediated phosphorus release from the sediment (which we can presume is highly enriched due to 2017 results) will likely increase in the future. This would lead to higher levels of TP in the lake bottom water column; this coupled with increasing hypolimnetic anoxia being driven by climate warming, may further drive lake eutrophication by enhancing internal loading of nutrients from the sediments (Adrian et al., 2009). The retention time of the lakes’ water will also likely make management options difficult with internal phosphorus loads unable to be removed from the lake. There are limited options available for restoring lake quality; one potential option could be the use of Alum – a substance used to lock up phosphorus, leaving it unable to be recycled into the water column.

The lake will likely see further stratification in the future and the persistence of cyanobacterial algal blooms during summer. While external sources of N and P have been removed, the damage may well have already been done with past nutrient loads being sufficient to cause issues well into the future. There is reason to be optimistic however, as PO_4 levels have significantly dropped. Nutrient sampling during winter would be a useful start to gaining a better understanding of the lakes water quality, given the fact that full nutrient mixing in the water column will have likely occurred by June (due to the breakdown of the thermocline). This would give better insights into Lake Rotokare nutrient loading, and better inform stakeholders on how improvement could be made in the future. Continuation of monitoring the lakes Trophic Level Index score would be useful for stakeholders to monitor change in lake conditions.

2.6 References:

Adrian, R., O’Reilly, C. M., Zagarese, H., Baines, S. B., Hessen, D. O., Keller, W., Livingstone, D. M., Sommaruga, R., Straile, D., Van Donk, E., Weyhenmeyer, G. A., & Winder, M. (2009). Lakes as sentinels of climate change. *Limnol. Oceanogr*, 54. pp. 2283–2297.

Bergstrom, A. K., Karlsson, D., Karlsson, J., & Vrede, T. (2015). N-limited consumer growth and low nutrient regeneration N:P ratios in lakes with low N deposition. *Ecosphere,* 61(9).

Brown, R. (1984). Relationships between suspended solids, turbidity, light attenuation, and algal productivity. *Lake and reservoir management*, 1(1), pp. 198-205

Bryers, G. (2000). Protocol for monitoring trophic levels of New Zealand lakes and reservoirs, 99(2). Lakes Consulting, Report.

Burger, D. F., Hamilton, D. P., Hall, J. A., & Ryan, E. F. (2007). Phytoplankton nutrient limitation in a polymictic eutrophic lake: community versus species-specific responses. *Fundamental and Applied Limnology/Archiv für Hydrobiologie*, 169(1), pp. 57-68.

Burns, N. M., Rutherford, J. C., & Clayton, J. S. (1999). A monitoring and classification system for New Zealand lakes and reservoirs. *Lake and Reservoir Management*, 15(4), pp. 255-271.

Carpenter, S. R., Caraco, N. F., Correll, D. L., Howarth, R. W., Sharpley, A. N., & Smith, V. H. (1998). Nonpoint pollution of surface waters with phosphorus and nitrogen. *Ecological applications*, 8(3), pp. 559-568.

Carpenter, S. R. (2008). Phosphorus control is critical to mitigating eutrophication. Proceedings of the National Academy of Sciences, 105(32), pp. 11039-11040.

Dodds, W. K., Bouska, W. W., Eitzmann, J. L., Pilger, T. J., Pitts, K. L., Riley, A. J., & Thornbrugh, D. J. (2008). Eutrophication of US freshwaters: analysis of potential economic damages.

Douglas, G. B., Hamilton, D. P., Robb, M. S., Pan, G., Spears, B. M., & Lurling, M. (2016). Guiding principles for the development and application of solid-phase phosphorus adsorbents for freshwater ecosystems. *Aquatic ecology*, 50(3), pp. 385-405.

Downing, J. A., & McCauley, E. (1992). The nitrogen: phosphorus relationship in lakes. *Limnology and Oceanography*, 37(5), pp. 936-945.

Ganf, G. G., & Oliver, R. L. (1982). Vertical separation of light and available nutrients as a factor causing replacement of green algae by blue-green algae in the plankton of a stratified lake. *The Journal of Ecology*, pp. 829-844.

Hamilton, D. P., Collier, K. J., & Howard-Williams, C. (2016). Lake Restoration in New Zealand. *Ecological Management & Restoration*, 17(3), pp. 191-199.

Hicks, B. J., Bell, D. G., Duggan, I. C., Wood, S. A., & Tempero, G. W. (2013). Aquatic ecology of Lake Rotokare, Taranaki, and options for restoration. Environmental Research Institute, The University of Waikato.

IPCC. (2014). Climate change 2014: synthesis report. Contribution of Working Groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change, pp. 151. IPCC.

Jeppesen, E., Kronvang, B., Meerhoff, M., Søndergaard, M., Hansen, K. M., Andersen, H. E., & Olesen, J. E. (2009). Climate change effects on runoff, catchment phosphorus loading and lake ecological state, and potential adaptations. *Journal of Environmental Quality*, 38(5), pp.1930-1941.

Johnston, B. R., & Jacoby, J. M. (2003). Cyanobacterial toxicity and migration in a mesotrophic lake in western Washington, USA. *Hydrobiologia*, *495*(1-3), 79-91.

Kufel, L., & Kufel, I. (2002). Chara beds acting as nutrient sinks in shallow lakes—a review. *Aquatic botany*, 72(3-4), pp. 249-260.

Larned, S. T., Scarsbrook, M. R., Snelder, T. H., Norton, N. J., & Biggs, B. J. (2004). Water quality in low-elevation streams and rivers of New Zealand: Recent state and trends in contrasting land-cover classes. *New Zealand journal of marine and freshwater research*, 38(2), pp. 347-366.

Lindenschmidt, K. E., & Chorus, I. (1997). The effect of aeration on stratification and phytoplankton populations in Lake Tegel, Berlin. *Archiv für Hydrobiologie*, 139(3), pp. 317-346.

Ma, J., Qin, B., Wu, P., Zhou, J., Niu, C., Deng, J., & Niu, H. (2015). Controlling cyanobacterial blooms by managing nutrient ratio and limitation in a large hyper-eutrophic lake: Lake Taihu, China. *Journal of Environmental Sciences*, 27, pp. 80-86.

Ministry for the Environment. (2014). *National Policy Statement for Freshwater Management 2014.* Wellington: Ministry for the Environment.

Ministry for the Environment & Stats NZ (2017). *New Zealand's Environmental Reporting Series: Our fresh water 2017*. Retrieved from www.mfe.govt.nz and www.stats.govt.nz.

Monaghan, R. M., Wilcock, R. J., Smith, L. C., Tikkisetty, B., Thorrold, B. S., & Costall, D. (2007). Linkages between land management activities and water quality in an intensively farmed catchment in southern New Zealand. *Agriculture, Ecosystems & Environment*, 118(1-4), pp. 211-222.

Müller, S., & Mitrovic, S. M. (2015). Phytoplankton co-limitation by nitrogen and phosphorus in a shallow reservoir: progressing from the phosphorus limitation paradigm. *Hydrobiologia*, 744(1), pp. 255-269.

Nurnberg, G.K. (1984). The prediction of internal phosphorus load in lakes with anoxic hypolimnia. *Limnology and Oceanography*, 29: pp. 111–124.

O'neil, J. M., Davis, T. W., Burford, M. A., & Gobler, C. J. (2012). The rise of harmful cyanobacteria blooms: the potential roles of eutrophication and climate change. *Harmful Algae*, 14, pp. 313-334.

Paerl, H. W., & Paul, V. J. (2012). Climate change: links to global expansion of harmful cyanobacteria. *Water Research*, 46(5), pp. 1349-1363.

Paterson, M. J., Schindler, D. W., Hecky, R. E., Findlay, D. L., & Rondeau, K. J. (2011). Comment: Lake 227 shows clearly that controlling inputs of nitrogen will not reduce or prevent eutrophication of lakes. *Limnology and Oceanography*, 56(4), pp. 1545-1547.

Schindler, D. W., Hecky, R. E., Findlay, D. L., Stainton, M. P., Parker, B. R., Paterson, M. J., & Kasian, S. E. M. (2008). Eutrophication of lakes cannot be controlled by reducing nitrogen input: results of a 37-year whole-ecosystem experiment. *Proceedings of the National Academy of Sciences*, 105(32), pp. 11254-11258.

Smith, V. H. (2003). Eutrophication of freshwater and coastal marine ecosystems a global problem. *Environmental Science and Pollution Research*, 10(2), pp. 126-139.

Smith, V. H., & Schindler, D. W. (2009). Eutrophication science: where do we go from here?. *Trends in ecology & evolution*, 24(4), pp. 201-207.

Taranaki Catchment Commission. (1980). Lake Rotokare water management plan. Unpublished report, Taranaki Catchment Commission. Stratford, New Zealand.

Taranaki Regional Council. (2010). Freshwater contact recreational water quality at Taranaki sites. State of the Environment Monitoring Report (2009-2010). *Technical Report 2010-01*.

Taranaki Regional Council. (2011). Freshwater contact recreational water quality at Taranaki sites. *State of the Environment Monitoring Report* (2010-2011). Technical Report 2011-01.

Taranaki Regional Council. (2012). Freshwater contact recreational water quality at Taranaki sites. *State of the Environment Monitoring Report* (2011-2012). Technical Report 2012-01.

Taranaki Regional Council. (2013). Freshwater contact recreational water quality at Taranaki sites. *State of the Environment Monitoring Report* (2012-2013). Technical Report 2013-01.

Taranaki Regional Council. (2014). Freshwater contact recreational water quality at Taranaki sites. *State of the Environment Monitoring Report* (2013-2014). Technical Report 2014-01.

Taranaki Regional Council. (2015). Freshwater contact recreational water quality at Taranaki sites. *State of the Environment Monitoring Report* (2014-2015). Technical Report 2015-01.

Taranaki Regional Council. (2016). Freshwater contact recreational water quality at Taranaki sites. *State of the Environment Monitoring Report* (2015-2016). Technical Report 2016-01.

Taranaki Regional Council. (2017). Freshwater contact recreational water quality at Taranaki sites. *State of the Environment Monitoring Report* (2016-2017). Technical Report 2017-01.

Vant, W.N. (1987). Hypolimnetic dissolved oxygen: Survey and interpretation. *Lake Managers Handbook*. NWASCA, Wellington.

Verburg, P., Hamill, K., Unwin, M., Abell J. (2010). Lake water quality in New Zealand 2010: status and trends. *National Institute of Water and Atmospheric Research (NIWA) Client report: HAM2010-107*. Prepared for the Ministry for the Environment. Wellington: Ministry for the Environment.

Chapter 3: Abundance and frequency of fish

3.1 Introduction

New Zealand freshwater fish populations remain under constant strain nationwide, due to a variety of natural and anthropogenic influences. In total, 77 species of freshwater and estuarine fish are present in New Zealand; of these, 54 species of taxa are currently listed as resident native species. At present, 40 (74%) of the 54 native fish species are considered to be 'Threatened' or 'At Risk' (Goodman et al., 2013). Endemic galaxiids are particularly vulnerable, dominating the 'Threatened' and 'At Risk' categories, with minimal signs of improvement (Allibone et al., 2010).

Previous studies undertaken by the Taranaki Catchment Commission (a regional government branch absorbed into the Taranaki Regional Council) between 1977 and 1980 established that shortfin eel (*Anguilla australis*) and European perch (*Perca fluviatilis*) populations were present Lake Rotokare. Subsequent research by other parties has also established the presence of two fish species, the longfin eels *(Anguilla dieffenbachii*) and banded kokopu (*Galaxias fasciatus*). Addiitionally, the National Freshwater Fish Database was incorporated into this study, which determined two species of crustaceans were discovered within the lake; kōura (*Paranephrops planifrons*); a native species of crayfish and *Paratya curvirostris*, a species of freshwater shrimp (Crow, 2017).

In New Zealand shortfin eels and banded kokopu are currently classified as not threatened according to New Zealand's threat classification system (Goodman et al., 2013). This is primarily because shortfin eels have exhibited nationwide increase in overall abundance between 1977 and 2015; with a 0.35±0.09% (95% confidence interval limit) increase in abundance annually (Crow et al., 2016). Comparatively, longfin eels show an overall national decline in relative abundance of 0.09±0.08% annually (Crow et al., 2016). Longfin eels are now allocated as a species at risk (Goodman et al., 2013). In a localized context, little information exists on the current status of fish populations residing in Lake Rotokare; there is minimal data on population sizes, recruitment, and fish density. Thus quantifying population dynamics of the perch, longfin and shortfin eels in Lake Rotokare is critical in understanding the ecological dynamics, giving stakeholders the ability to enhance the quality of the lake, through the decrease or removal of perch.

The morphology and behaviour of perch have been shown to influence the population dynamics and community structure in lakes (Cotterill, 2016). In particular, perch have been linked to declines in water quality through the juvenile predation on zooplankton that help regulate algal growth (Hicks et al., 2013; Collier & Grainger, 2015; Cotterill, 2016). Therefore, removing the perch in Lake Rotokare could improve and enhance water quality. They have also been implicated in multiple declining freshwater fish populations (Cadwaller & Backhouse, 1983; McDowall, 1996; Ludgate & Closs, 2003). For example, the introduction of perch into Lake Ototoa, Auckland, led to a massive reduction in kōura and common bully abundance (Collier & Grainger, 2015). Furthermore, īnanga (*Galaxias maculatus*) and smelt (*Retropinna retropinna*) were both absent in a northern New Zealand dune lake dominated by perch even though the lake was readily accessible for both species (Rowe, 2007). Therefore, removal or reduction of perch biomass within the lake may also serve to significantly enhance endemic fish populations.

In response to the current lack of knowledge around fish population dynamics within Lake Rotokare, this study aims to assess the relative abundance of banded kokopu and perch; and absolute abundance of longfin and shortfin eels. It also aims to obtain length-weight relationships and length-frequency data for perch, longfin and shortfin eels. This study will produce quantitative data on the fish community residing in Lake Rotokare, and offer fisheries managers baseline information necessary to create management action plans.

3.2 Methods

3.2.1 *Ethics statement*

All animal work was conducted in accordance with national and university guidelines to minimize discomfort to animals, and the State of Practice (SOP) 6 was adhered to throughout the duration of the project. As the project's field work was directly supervised by a technician trained and qualified to administer the anaesthetic benzocaine, the ethics committee chair decided that there were no requirements for ethics approval.

3.2.2 *Fish surveys*

In order to achieve a proper representative sample of the local fish population, several methods of capture were utilized to obtain adequate samples and are described in detail below.

3.2.3 *Electrofishing*

The University of Waikato currently has the only working electrofishing boat in New Zealand, allowing for effective fishing at night time. Hicks et al. (2007) discovered night time electro boat fishing yielded much greater catch rates of perch when compared against daytime sampling. A custom-made electrofishing boat was brought on location to survey the lake. The boat consists of a 4.5 m-long, aluminium-hulled electrofishing boat, with a 5-kilowatt pulsator (GPP, model 5.0, Smith-Root Inc, Vancouver, Washington, USA). The pulsator is powered by a 6-kilowatt custom-wound generator. Two anode poles, each with six stainless steel droppers, creates the fishing field at the bow, with the boat hull acting as the cathode (Hicks et al., 2006). This essentially paralysed the fish in such a way that the current causes nearby fish trapped within the field to swim towards to origin point, rendering them vulnerable to capture.

The measured conductivity was then used to calculate the settings on the GPP, which resulted in the lake being fished with the GPP set to low range (50-500 V direct current), and a frequency of 60 pulses per second. The GPP was then adjusted to 65% of range, giving an applied current of 3.5-amp root mean square, identical to that used by Hicks et al. (2013) during their survey. Due to the Lake Rotokare's depth profile (Figure 1.2) and previous sampling on the lake, we determined that an effective fishing field would require a depth of 2-3 m, with the anode poles roughly 2 m either side of the centre line of the boat. This equates to a transect roughly 4 m wide. This assumption was used to calculate total area fished.

Surveying occurred between 20:30–23:00 h on February the 21 and 22, 2017. Night time was selected as the most effective sampling period, due to Hicks et al. (2013) finding of a 16-fold increase in perch capture rates at night-time, when compared to daytime sampling. A total of ten sites were originally fished; however, due to a change in sampling methods (switching from mark-recapture to single pass electrofishing) part way through, only seven sites in Lake Rotokare were fished and weight/length values collected (Figure 3.1). This was due to the realization of a mark-recapture project for perch being unfeasible – given the population size. The total length fished was 1390 m, and the total area of the lake fished was 5560 m^{-2}.

Figure 3.1: Night-time boat electrofishing tracks. Night-time boat electrofishing occurred on 21-22 Feb 2017.

Fyke netting & mark-recapture

Fyke-nets are generally an effective fish sampling technique in shallow areas of ponds lakes and reservoirs, with benthic, cover seeking, mobile species being most susceptible to capture. In order to estimate the abundance of shortfin and longfin eels within Lake Rotokare, we set out a series of 15 m fyke nets with 5 m wings at indeterminate intervals around the edge of the lake to obtain mark-recapture data on both species. The placement of the nets was not predetermined due to limited availability of potential placement locations, primarily because of fragile floating plant matter surrounding the lake edge. This caused a failure of the posts used to secure the fyke nets to the substrate, therefore limiting the amount of suitable netting locations greatly.

A total 22 nets were set out overnight around the lake (Figure 3.2) between 1600–18:00 h and collected at 09:00 h the following day. This timeframe was chosen to allow for the slow moving benthivorous eels to have sufficient time to come into contact with the nets. This occurred over successive days on 8-9 February, and again on 21-23 February. Fish were then collected and brought back to shore, to record weight/length measurements, and mark individuals by removing their left pectoral fin for their subsequent release. The same process was repeated each evening and morning; where marked eels were evaluated against unmarked individuals until sufficient data was obtained to quantify the absolute abundance of both species. Population estimates (N) were made based on the adjusted Chapman method (Ricker 1975), which uses the total number of fish originally marked (M), the total number caught during recapture (C), and the number of those fish marked that were recaptured (R), as follows:

$$N = \frac{(M+1)(C+1)}{(R+1)-1}$$

Figure 3.2: Fyke net locations for the 22 fyke nets set out around the edge of Lake Rotokare between 8-9 Feb 2017, and 21-23 Feb 2017.

3.2.4 Gill netting

Gill-nets are vertical walls of netting generally set out in a straight line (Kane, 1995). Most often fish are captured swimming part way through the net, causing the net to slip behind the opercula, or become entangled by their spines fins or other body protrusions. The size selectivity of various mesh sizes is a problem in gill net sampling (Kane, 1995). Perch, the species targeted for gill-netting in Lake Rotokare have a wide size distribution (Hicks et al., 2013). To overcome this we selected two mesh sizes; 18 mm, and 25 mm (stretched); small mesh sizes were determined to most effectively sample smaller perch size classes. Nets were set out in February and June 2017, to determine CPUE for perch. February netting, undertaken on 21 February, consisted of six nets set at a mixture of depths at various points (Figure 3.3), with two nets set in each lake arm for two hours between 15:00-17:00 h. Issues with net 6 sinking below the lake's summer thermocline occurred, and this resulted in no catch due to insufficient oxygen requirements, thus, this net was discarded from the results. The final nets set in February (n = 5), were primarily used to determine if the net size was sufficient for further use, and to establish baseline biomass and CPUE values.

Winter netting was more thorough. Between June 7 and June 8, 2017 eight nets (4 x 18 mm, 4 x 25 mm) were set for 1.5 hours between 13:00 – 14:30 h and 10:45-12:00 h at various points in the lakes centre (Figure 3.2) at depths greater than 5 m. This was possible due to the breakdown of stratification of the epilimnion and hypolimnion in winter, with oxygen mixing occurring in the lake's bottom water (Figure 2.2); 10 nets (5 x 18 mm, 5 x 25 mm) were set around the littoral zone (Figure 3.4). This data was collected to compare summer to winter size classes, and CPUE ratios. It also gave a comparison between perch population dynamics between littoral perch populations and perch inhabiting deep regions of the lake.

Figure 3.3: Summer gill net locations for 6 nets set around Lake Rotokare on 21 Feb 2017.

Figure 3.4: Gill netting locations in Lake Rotokare for littoral and deep zone set nets on 8-9 Jun 2017.

3.2.5 Spotlight counting

To estimate banded kokopu relative abundance, we surveyed both the outlet and the inlet (Figure 3.3) of Lake Rotokare on 8 June 2017; and again on 19 December 2017. McCullough and Hicks (2002) found fish were less disturbed by approach after dark, suggesting that from dusk to 22:00 h is the best time for visual counts of banded kokopu by spotlight in summer months. We followed these recommendations, with spotlight counting undertaken at night between 20:30 and 22:00 h. The stream was illuminated with an Airtech RT500 spotlight and three head mounted spotlights. 80 m of stream was sampled for the outlet, and 100 m of the inlet was sampled in June. 80 m was repeated in December; however, one branch of the tributary had disappeared due to low water flow. Fish were visually measured for length, with efforts to measure more accurately with rulers where possible. However, as the terrain was difficult to navigate and often the usage of rulers spooked the fish into hiding, this method was rarely used. Banded kokopu were split into two classes; juveniles (≤ 70 mm), and adults (> 70 mm), while kōura were kept as a single class for visual observation.

Figure 3.5: Spotlight tracks for banded kokopu counts on Lake Rotokare inflow **(left)**, and outflow **(right)**. Sampling occurred on 8 Jun 2017 and 19 Dec 2017.

3.2.6 *Weight-length relationships*

Weight-length relationships were determined using data obtained from fyke netting, gill netting, and boat electrofishing. After fish were captured, eels were anesthetized using benzocaine and subsequently weighed (g) and measured (mm) on site, then released once the fish had revived. Perch were also weighed and measured. As this species is considered an invasive pest within Lake Rotokare, perch were prohibited from being released into the lake. Instead these fish were frozen and returned to the University of Waikato for later analysis.

3.3 Results

3.3.1 *Catch rates*

A total of 1498 fish were caught from Lake Rotokare in February 2017 by fyke netting, gill netting, and boat electrofishing (Table 3.1). A further 542 fish were caught in June 2017 by fyke netting and gill netting (525 perch, 10 shortfin eel, 7 longfin eel; Appendix 1). The fish capture consisted of four different species (Table 3.1). Perch consisted of over 80% of the total catch from within the lake, with both species of eels adding smaller contributions (shortfin = 12%; longfin = 6.7%), banded kokopu were found within the lake, but only a few fish were found during electrofishing (0.3%).

Table 3.1: Species, frequencies and proportion of catch for all fishing methods on 8-23 Feb 2017. Blank cells indicate no catch.

	Number of fish				Proportion of
Species	Fyke net	Gill net	Electrofishing	Total	Catch (%)
Perch	110	210	897	1217	81
Shortfin	163		13	176	12
Longfin	100		1	101	6.7
Kokopu			4	4	0.3
Total	373	210	915	1498	

The average perch length varied between sampling methods (Table 3.2), electrofishing was biased towards capturing smaller fish, with the lowest average weight (19.6±1.5 g) and length (101.9±2.1 mm) values (± represents 95% confidence interval limits) of the three capture methods. Gill netting was biased towards larger perch with the largest length-weight averages; fyke netting values were intermediate, with middle length-weight values, and a larger confidence interval range (Table 3.2). With low catch rates and a bias towards smaller eels, boat electrofishing poorly represented both shortfin and longfin eel populations (Table 3.2). Overall, fyke netting was the most accurate method for sampling, with diverse size ranges and high catch rates (longfin n = 76; shortfin n = 116). The average lengths of longfin eels were significantly different ($p < 0.05$) from shortfin eels, however, when comparing length values against weight it was clear there were real discrepancies between species in weight; longfin eels were on average over 3 times larger than shortfin eels (Table 3.2).

Table 3.2: Mean length-weight values for each fishing method used to capture four fish species sampled in Lake Rotokare from 8-23 Feb 2017. Confidence interval levels set at 95%. Blank cells represent zero catch.

	Electrofishing (N = 701)		Fyke net (N = 81)		Gill net (N = 210)	
Perch	Length (mm)	weight (g)	Length (mm)	weight (g)	Length (mm)	weight (g)
mean	101.86	19.63	121.95	37.59	163.73	67.27
std. dev	28.18	20.61	46.01	42.96	18.44	32.99
CI	2.09	1.53	10.02	9.35	4.04	7.19
	Electrofishing (N = 4)		Fyke net		Gill net	
Kokopu	Length (mm)	weight (g)	Length (mm)	weight (g)	Length (mm)	weight (g)
mean	49	0.93				
std. dev	2.74	0.20				
CI	2.68	0.20				
	Electrofishing (N = 1)		Fyke net (N = 76)		Gill net	
Longfin	Length (mm)	weight (g)	Length (mm)	weight (g)	Length (mm)	weight (g)
mean	900	2480	756.92	1838.89		
std. dev			211.14	1628.55		
CI			47.47	366.14		
	Electrofishing (N = 13)		Fyke net (N = 116)		Gill net	
Shortfin	Length (mm)	weight (g)	Length (mm)	weight (g)	Length (mm)	weight (g)
mean	195	16.11	644.91	659.85		
std. dev	67.96	16.40	126.81	398.36		
CI	36.94	8.917	23.08	72.49		

Between sampling seasons there was significant variation between all sampling periods; February 2013 and February 2017, and June 2017 for perch average length and weight values (Table 3.3). June 2017 had the largest size group of perch caught, however, this was influenced by a single large perch (433 mm; 1658 g). Shortfin values were not significantly different between seasons in 2017, but were significantly different in February 2013 compared to the 2017 sampling seasons (Table 3.3). This difference is likely due to electrofishing being the only sampling method used by Hicks et al. (2013). Additionally, longfin eels lacked sufficient data in 2013 to make an accurate assessment, however, there was no meaningful difference between length and weight averages for February and June 2017, with confidence intervals overlapping between seasons.

Table 3.3: Summary of the size and number of each fish species captured within lake Rotokare through combined fishing methods by **(A)** Hicks et al., (2013); 9–10 Feb 2013, **(B)** Smith; Feb 8-23 2017 & **(C)** Smith; 7–11 Jun 2017.

	Species	number caught	Length (mm) Range	Length (mm) Mean (±95% CI)	Weight (g) Range	Weight (g) Mean (± 95% CI)
A.	Perch	217	74 - 313	135 ± 5.96	4.6 - 553	45 ± 8.54
	Shortfinned eel	16	82 - 748	447.5 ± 98.82	7 - 915	272.8 ± 73.20
	Longfinned eel	1	1126		2582.2	
	Banded kokopu					
B.	Perch	992	66 - 286	116.6 ± 2.35	4 - 423.8	31.2 ± 2.02
	Shortfinned eel	129	105 - 995	599 ± 31.97	1.8 - 2323.4	595 ± 74.26
	Longfinned eel	77	328 - 1200	758.8 ± 48.07	87 - 7253	1847.2 ± 370.01
	Banded kokopu	4	46 - 53	49 ± 5.03	0.6 - 1.1	0.9 ± 0.38
C.	Perch	525	108 - 433	162.55 ± 2.92	18 - 1658	75.65 ± 8.47
	Shortfinned eel	11	525 - 692	619.5 ± 32.03	313 - 875	561.6 ± 111.04
	Longfinned eel	7	610 - 1110	792.49 ± 168.24	675 - 5192	2143.57 ± 1444.29
	Banded kokopu					

The total weight of fish captured was 377.9 kg. Fyke netting contributed the largest volume of weight to fish biomass (Table 3.4). It was 19.6 times greater than total weight of fish captured by boat electrofishing, and 8.1 times greater than gill netting. This is almost exclusively due to the fyke nets selectivity towards eel capture; with longfin eels having an average weight value 59 times greater than perch, and shortfin having an average weight value 19.1 times greater (Table 3.2). Gill netting contributed a larger portion of perch weight than boat electrofishing (3 times greater; Table 3.4). This further shows size selectivity of sampling techniques as the number of perch caught between techniques was much larger for boat electrofishing with 491 fish more fish caught (Table 3.2).

Table 3.4: Total weight of eels, perch and kokopu caught by each method separately and by all methods combined from Lake Rotokare from 8-23 February 2017. (Juvenile kokopu were also sampled with a total boat electrofishing weight of 3.7g but are not represented due to such a small sample size).

	Total fish weight (kg)			
Capture method	Longfin	Shortfin	Perch	Total
Electrofishing	2.480	.21	13.76	16.45
Gill Netting			39.72	39.72
Fyke Netting	208.27	112.06	1.39	321.72
total (kg):	210.75	112.27	54.88	377.90

3.3.2 Electrofishing

Boat electrofishing for 100 minutes captured 915 fish. Few eels were sampled in the 10 runs undertaken (shortfin N = 13; longfin N = 1). It should be noted that eel capture rates are underestimated due to the fact eels were considered a bycatch of fishing, due to the primary focus of sampling on perch capture. Electrofishing was most successful for targeting perch (as mentioned above) with a total of 915 perch captured during fishing (702 with site 1 & 2 removed). Perch capture rates varied between sites, sometimes greatly (i.e. Site 7 vs 9). Juvenile kokopu were also found during boat electrofishing; we did not anticipate finding kokopu residing within the lake, so this was an unexpected find (Table 3.5).

Table 3.5: Catch per unit of effort of the number of fish caught in 10 minutes at each site by boat electrofishing over the period of 21-22 Feb 2017. Blank cells indicate zero catch.

					Number of fish caught				
Site	Length fished (m)	Area fished (m^{-2})	Date	Time (h)	Shortfin	Longfin	Perch	Kokopu	Total
3	161	277	21-Feb-17	2200			70		70
4	161	183	21-Feb-17	2220			111	1	112
5	153	2355	21-Feb-17	2240			73		73
6	106	248	22-Feb-17	2105	2	1	70		73
7	133	420	22-Feb-17	2131			51		51
8	137	1917	22-Feb-17	2155	5		82		87
9	116	147	22-Feb-17	2215	5		154	3	162
10	148	74	22-Feb-17	2230	1		90		91
Total	1116	5623			13	1	701	4	719

Density was measured as fish per 100 m^{-2}. Density of fish was negligible for all species except for perch (< 1 fish per 100 m^{-2}). Perch density varied between sites (9.57-33.24 fish per 100 m^{-2}), with an average density of 16.55 per 100 m^{-2}. Sites 3 and 7 had low perch densities; whereas sites 2, 4, and 9 showed high density rates (refer to Figure 3.1 for site location). Overall, perch density was consistently high (Table 3.6).

Table 3.6: Density of fish caught by boat electrofishing in Lake Rotokare on 22-23 Feb 2017 using the fixed-time electrofishing method (10 minute shots).

					number of $fish^{-1}$ 100 m^{-2}				
Site	Length fished (m)	Area Fished (m^{-2})	Date	Time	Shortfin	Longfin	Kokopu	Perch	Total
1	152	606	21-Feb-17	2042	0.00	0.00	0.00	16.49	16.49
2	123	491	21-Feb-17	2122	0.00	0.00	0.00	19.54	19.54
3	161	644	21-Feb-17	2200	0.00	0.00	0.00	10.87	10.87
4	161	644	21-Feb-17	2220	0.00	0.00	0.16	17.24	17.40
5	153	613	21-Feb-17	2240	0.00	0.00	0.00	11.90	11.90
6	106	423	22-Feb-17	2105	0.47	0.24	0.00	16.55	17.26
7	133	533	22-Feb-17	2131	0.00	0.00	0.00	9.57	9.57
8	137	550	22-Feb-17	2155	0.91	0.00	0.00	14.91	15.82
9	116	463	22-Feb-17	2215	1.08	0.00	0.65	33.24	34.97
10	148	593	22-Feb-17	2230	0.17	0.00	0.00	15.19	15.36
Total:	1390	5560		Average:	0.26	0.02	0.08	16.55	16.92

Biomass values were estimated by obtaining the average weight of each species at each site, and multiplying by the number of fish caught then dividing against area of distance fished (biomass as grams per metre). Biomass varied greatly between sites with the exception of the single longfin eel captured (site 6; refer to Figure 3.1 for site location) during sampling skewing the value upwards (Table 3.7). Averaged out longfin eel, shortfin eel, and banded kokopu remained low (< 1 g per metre squared). Shortfin eel biomass remained consistent between sites 6 to 10. Banded kokopu varied significantly between the two sites captured; 0.02–1.42 g m^{-2}. Comparatively, perch had a high biomass compared to the other species, averaging at 12.3 g m^{-2} and there was little variation between sites, with one exception; site 3.

Table 3.7: Biomass by area of fish caught estimated from fish caught during boat electrofishing in Lake Rotokare at the 7 sampling sites with recorded weight values on 21–22 Feb 2017.

		Area	Biomass g m^{-2}				
Site	Length fished (m)	Fished (m^{-2})	Longfin eel	Shortfin eel	Perch	Kokopu	Total
3	161	644	0.00	0.00	6.78	0.00	6.78
4	161	644	0.00	0.00	10.89	0.00	10.89
5	153	613	0.00	0.00	11.43	0.00	11.43
6	106	423	5.86	0.19	16.57	0.00	22.62
7	133	533	0.00	0.15	13.16	0.00	13.31
8	137	550	0.00	0.15	12.75	0.00	12.90
9	116	463	0.00	0.17	15.13	1.42	16.72
10	148	593	0.00	0.14	11.83	0.00	11.97
Average	139	558	0.73	0.10	12.32	0.18	13.33
Total	1116	4462	5.86	0.80	98.54	1.42	106.62

3.3.3 *Gill netting capture rates and biomass*

A total of 735 perch were caught between February (N = 210) and June (N = 595) 2017. A total of 276 m of gill net were set for a total of 25.5 hours. Catch per unit effort (CPUE) was expressed as the number of fish per metre per hour of fishing; a measurement of the relative abundance of perch within the lake. Catch rates were consistently highest in 18 mm mesh sizes, and CPUE was larger in winter compared to summer (Table 3.8).

Table 3.8: Capture rates for 18 and 25 mm gill nets for perch caught in Lake Rotokare between 22 Feb 2017 and 7-8 Jun 2017**.**

Catch per unit effort (fish h^{-1} m^{-1} net set^{-1})		
Summer	Perch	Total length of net (m)
18 mm	4.500	18
25 mm	2.000	12
Winter		
18 mm	4.728	54
25 mm	4.222	54
Combined		
18 mm	4.614	72
25 mm	3.111	66
All sites combined	3.863	276

Relative fish abundance varied greatly between sites (Table 3.9), especially in summer with values ranging from 0.83–9.58 between sites. In summer site 2, 3, and 4 had low abundance rates. Site 5 had a CPUE value close to the combined gill net CPUE (Table 3.9), and the highest perch capture rates were recorded at site 1. Winter CPUE rates increased, with two sites from littoral netting showing almost non-existent catch rates (sites 3 and 6), and two deep (sites 4 and 7). Littoral zone gill nets had greater catch rates in general then other sampling regions, with half the sites CPUE values above the average mean (3.863). Deep zone CPUE were low in general, with exception to nets 1, 2, and 8, which were primarily in the lake's eastern arm (Figure 3.2). Overall, it appears that the western arm of the lake had the highest catch rates of perch, with higher CPUE yields recorded for all netting sessions (Table 3.9).

Table 3.9: Mean catch rates (CPUE) of perch caught with 6 m long (18-25 mm mesh size) gill nets in Lake Rotokare at the 23 sampling sites between 22 February and 7-8 June 2017. Mixed nets set (N = 5), Littoral nets set (N = 10), and deep nets set (N = 8).

	fish h^{-1} m^{-1} net		
	Summer	Winter	
Site	Mixed	Littoral	Deep
1	9.58	2.22	4.67
2	1.42	4.78	3.56
3	2.33	0.56	2.33
4	0.83	2.89	0.11
5	3.33	5.78	3.11
6	0.00	0.11	3.22
7		5.78	0.22
8		3.44	4.44
9		5.33	
10		5.89	

Biomass results varied between sites (Table 3.8). Biomass and catch rates did not align in many cases (Tables 3.7, 3.8). Site 1 in summer had the highest catch rate of any net, yet a comparatively low biomass yield compared to littoral winter sampling. Deep set nets had low biomass values when compared to the yields littoral set nets in winter, which had much greater biomass, probably due to the larger number of fish caught (N = 325). Overall, the summer average gill net biomass was almost half that of deep set nets in winter, and 3 times lower than littoral set nets in winter. Total biomass results for summer were negligible compared to winter, 3 times lower than deep set nets and 6 times lower than littoral set nets. This could be attributed to the growth time between sampling seasons the perch, with an increase in the density of larger individuals in winter compared to summer.

Table 3.10: Biomass CPUE estimation of perch caught during 2 hour sets by gill netting in summer; 21 Feb 2017, and 1.5 hour sets in winter; 7-8 Jun 2017.

	biomass g m^{-1} net $^{-1}$				
	Summer	Winter			
Site	Mixed	Site	Littoral	Site	Deep water
1	2.26	1	1.35	1	2.04
2	0.16	2	4.25	2	2.81
3	0.71	3	0.26	3	1.02
4	0.26	4	1.00	4	0.60
5	0.63	5	4.06	5	1.77
6		6	0.06	6	0.80
7		7	5.12	7	0.99
8		8	2.79	8	2.04
9		9	2.93	9	
10		10	4.02	10	
Total	4.02		25.84		12.07
Average	0.80		2.58		1.51

3.3.4 *Fyke nets*

Fyke nets were set overnight at least twice, with average sitting time of 16.3 hours per night at each of the 23 sampling sites, giving a total of 1059.5 hours. Fyke net CPUE is expressed simply as fish caught per night, per net set. Catch rates varied greatly between species and sites. Perch capture rates were low, with 9 out of 23 nets recording no perch during any sampling set. Other sites mostly had low capture rates; with the exception to site 2, 10, and 21 which had at one night of high perch yields (≥10 fish). Eel capture rates also varied between sites, with shortfin eels having the overall highest capture rates, with 0-15 shortfin eels captured per night.

Longfin eel capture rates were similar in variability to shortfin catch rates, with between 0-12 individuals captured per night. Sampling site 21 had the highest catch rate (N = 40), site 23 had the lowest yield, with one longfin eel caught over a period of two nights (Table 3.11).

Table 3.11: Average catch rates (CPUE) of fish caught per day with fyke nets in Lake Rotokare at the 23 sampling sites between 8-23 Feb 2017 (Three sampling nights occurred on: Night 1: 8-9 Feb; Night 2: 21-22 Feb 2017; Night 3: 22-23 Feb 2017).

		Fish per night^{-1}						Fish per night^{-1}			
Site	Night in water	Shortfin	Longfin	Perch	Total	Site	Night in water	Shortfin	Longfin	Perch	Total
1	1			1	1	12	1				0
1	2			3	3	12	2		1		1
1	3	1	4	6	11	13	1	3	7	1	11
2	1	5	1	21	27	13	2		1		1
2	2	6	3		9	13	3	2		1	3
2	3	1	1		2	14	1		3		3
3	1		1	7	8	14	2	5		5	10
3	2				0	14	3	4	1		5
3	3		1		1	15	1	1	10		11
4	1		1		1	15	2	3	2		5
4	2	2			2	15	3				0
4	3				0	16	1			6	6
5	1				0	16	2		1	4	5
5	2	3			3	16	3	2	1	4	7
5	3	1		1	2	17	1	3			3
6	1	8	2		10	17	2	2	1		3
6	2	10	1		11	17	3				0
6	3	2	2	6	10	18	1	6			6
7	1	3		2	5	18	2				0
7	2	3			3	18	3			1	1
7	3	1	1	4	6	19	1	2	9		11
8	1	4			4	19	2	7	5	1	13
8	2	5	1		6	19	3				0
8	3	2	1		3	20	1	7			7
9	1	4	1		5	20	2		1	1	2
9	2	8			8	20	3	3	3		6
9	3	10		2	12	21	2	13	12	15	40
10	1			18	18	21	3				0
10	2	1	5		6	22	2	1			1
10	3	5	7		12	22	3	4	2		6
11	1	4			4	23	2	3	8		11
11	2	1			1	23	3	1	2		3
11	3	2			2						

3.3.5 Mark-recapture

114 shortfin and 69 longfin eels were captured during fyke netting over the period of 21-23 February 2017 (Table 3.12). Mark-recapture return rates were high for longfin eels (25%; 17/69 recaptures) and low for shortfin eels (5%; 6/114 recaptures). Absolute abundance values for shortfin eel estimates the population at 853, and the longfin population at 143 (Table 3.12). Biomass (kg) per hectare was also calculated at 31.4 kg ha^{-1} for shortfin, and 14.8 kg ha^{-1} for longfin eels. In total shortfin eels contributed 560 kg to the lake biomass (69%) and longfin contributed 263 kg (31%).

Table 3.12: Eel abundance estimates based of the modified Chapman method (Ricker, 1975) mark-recapture method within Lake Rotokare. Biomass per hectare estimations are also included. Estimated from fyke net data collected on 22-23 Feb 2017.

							Errors for population estimate (N)						Biomass (kg ha^{-1})		
Species	Number of fish originally marked (M)	Number of fish caught during recapture (C)	Number of marked recaptures (R)	Recaptured fish as a proportion of marked fish (R/C)	Chapman population estimate (N=(M+1)(C+1) /(R+1)) -1	MC>4N ? 1 = yes, 2 = no	Lower 95% CL	Upper 95% CL	Error distribution	Mean fish weight (g)	Standard error of population estimate	Whole-lake biomass (kg)	Estimate	Lower 95% CL	Upper 95% CL
Shortfin eel	51	114	6	0.05	853	1	424	1867	Poisson	656.1	272.3	560	31.4	20.3	89.5
Longfin eel	36	69	17	0.25	143	1	99	218	Binomial	1838.9	24.7	263	14.8	0.8	1.8
Total												823	46	21	91

3.3.6 Spotlight counts

Spotlight counts of banded kokopu in the streams outlet were conducted once on 9 June 2017, and twice for the main tributary on 9 June and 19 December 2017 (Refer to Figure 3.3 for site locations). Relative banded kokopu and kōura abundance estimates are expressed as density per 100 m^{-2}. There was variation between inlet and outlet abundance (Table 3.13). Very low numbers of kokopu were spotted in the lake's outlet, with no kōura present whereas the lake inlet had high numbers of both species present (Table 3.13B). Density increased in December for kokopu by 34% (61/100 m^{-2} to 81/100 m^{-2}) and increased threefold for kōura (Table 3.13A; Table 3.13C). This is likely due to the low stream level from lack of rainfall over the summer period, resulting in smaller habitat reaches. The stream did stop consistently flowing through sections 4 through to 6 in December, with the stream breaking down into pools on several occasions; leading to the area m^{-2} values decreasing ($\geq$15 m^{-2}).

Table 3.13: Banded kokopu and kōura abundance estimation in **A.** main tributary, **B.** The outflow of Lake Rotokare estimated by spotlight counts of 20 m reaches on 8 Jun 2017. **C.** The inflow of Lake Rotokare estimated by spotlight counts of 20 m reaches on 19 Dec 2017.

A.	Spotlight count - Number of fish						
	Habitat means			Banded kokopu			Other
Section	Area (m^{-2})	Depth (m)	Width (m)	Juvenile	Adult	Total	Koura
1	20	1.5	1	3	15	18	0
2	20	1	1	5	3	8	6
3	30	1.5	1.5	3	5	8	5
4	20	2	1	9	12	21	3
5	30	1	1.5	13	5	18	0
Total	120			33	40	73	14
Density (100 m^{-2})				27.5	33	61	12
B.							
1	40	3	2	8	2	10	
2	50	4	2.5	4	0	4	
3	100	4	5	3	0	3	
Total	190			15	2	17	0
Density (100 m^{-2})				8	3	11	0
C.							
1	20	0.15	1	1	20	21	1
2	20	0.1	1	11	3	14	16
3	30	0.05-0.1	1.5	9	2	11	11
4	10	0.05	1	5	3	8	8
5	15	0.2	1	6	13	19	5
6	5	0.4	1	0	8	8	1
Total	100			32	49	81	42
Density (100 m^{-2})				32	49	81	42

3.3.7 Length-weight relationships

Length-weight relationships (LWR) were used to back calculate fish weights (Table 3.14). Natural logarithm weight-length values from fish captures (fyke net, gill net, and boat electrofishing) were used to determine LWR for summer catches. Parameters *a* and *b* were applied to the equation

$$\text{Ln } Y = a \text{ Ln } X * b$$

Weight-length regressions (ln(Y) = ln(a) + ln(X), where Y = weight in g and X = length in mm; fork length for perch, total length for eels) allow weights to be calculated from lengths in future. Individual weight-length graphs (and calculations can be seen on Figure 3.6). Site by site LWR figures for gill netting and boat electrofishing in summer, and littoral and deep zone gill netting can be viewed in the appendix 1.

Table 3.14: Length-weight relationship table of shortfin eels, longfin eels and perch. Data obtained from the total summer catch across gill netting, fyke netting and night-time electrofishing converted into natural log values ($p < 0.05$). Winter perch LWR values were taken from total gill net capture data (7-8 Jun 2017).

Species	*a*	*b*	r^2	*N*
Summer perch	-11.507	3.052	0.984	992
Winter perch	-11.981	3.167	0.986	525
Shortfin eel	-14.698	3.256	0.995	129
Longfin eel	-14.755	3.318	0.994	77

Figure 3.4 shows a difference in the LWR values of perch, with an increase in length and weight in winter, resulting in an increase in *b* (Ln length; Table 3.14). Variance in length-weight values around the lake were checked by breaking down electrofishing shots into general locations, and compared against each other by using a simplistic approach of ±2 times the standard error to *a* and *b* values to compare locations against one another (Table 3.15A). Comparing *a* values between locations showed that the northern arm of the lake was different from other regions of the lake, while the eastern arm of the lake was almost identical to the centre but different to the northern arm. Boat electrofishing *b* values showed differences in the northern arm to all other locations, the western arm was different to the eastern arm and lake’s centre, and the lake centre and eastern arm were similar (Table 3.15B).

Comparison between summer and winter perch LWR values across seasons was achieved by comparing summer and winter gill net catches (Table 3.16A). There were a significant difference in LWR values between summer and winter gill net *a* and *b* values between each sample session in summer and winter for *a* and *b* (p = < 0.001). This indicates there are significant differences in length and weight measurements between different arms of the lake and between seasons (Table 3.16B).

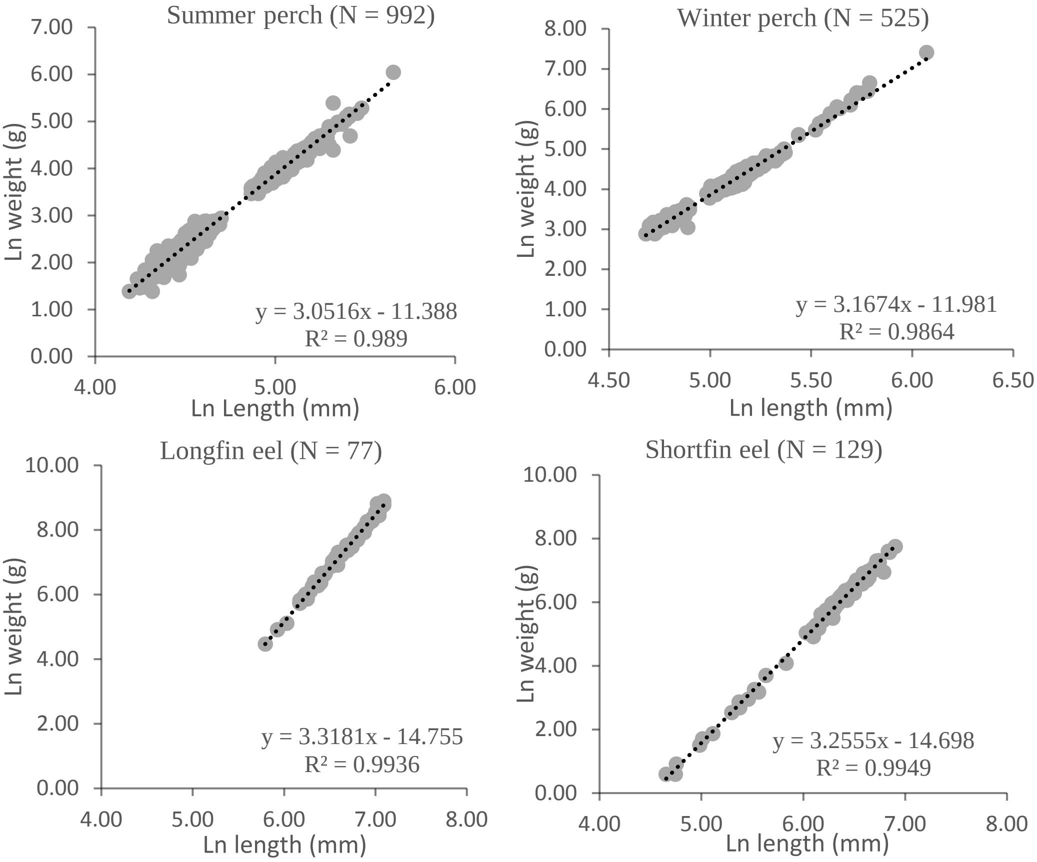


Figure 3.6: Weight-length relationships of perch, banded kokopu, shortfin eel and longfin eel sampled from all fishing methods (fyke netting, gill netting and boat electrofishing) on 8-23 Feb 2017. Weight-length relationships of perch caught in winter sampled from gill netting undertaken on the 7-8 Jun 2017.

Table 3.15: A. Length-weight relationship for perch captured during night-time electrofishing on 21-22 Feb 2017 divided into separate locations of the lake. **B.** Similarities between sites for length and weight were checked using the ±2 SE method.

A. Site	*n*	*Ln a*	SE ± *(Ln a)*	*b*	SE ± (*b*)	*Ln R*^{2} adjusted	*p* value	*Equation (ln y=ln a + b*ln x)*
North arm	254	-11.120	0.100	3.006	0.022	0.987	<0.001	-11.120 + 3.006*x*
West arm	70	-12.051	0.172	3.185	0.037	0.991	<0.001	-12.051 + 3.185x
East arm	287	-11.590	0.118	3.091	0.026	0.980	<0.001	-11.590 + 3.091x
Lake centre	90	-11.591	0.178	3.088	0.039	0.986	<0.001	-11.591 + 3.088*x*
Total	701	-11.469	0.071	3.070	0.015	0.982	<0.001	-11.469 + 3.070*x*

B. Site	*n*	*Ln a*	SE ± *(Ln a)*	*Ln a* + 2SE	*Ln a* - 2SE	*b*	SE ± (*b*)	*b + 2SE*	*b* - 2SE
North arm	254	-11.120	0.100	-11.019	-11.220	3.006	0.022	3.028	2.984
West arm	70	-12.051	0.172	-11.879	-12.223	3.185	0.037	3.221	3.148
East arm	287	-11.590	0.118	-11.472	-11.708	3.091	0.026	3.117	3.065
Lake centre	90	-11.591	0.178	-11.413	-11.769	3.088	0.039	3.127	3.050
Total	701	-11.469	0.071	-11.398	-11.541	3.070	0.015	3.086	3.055

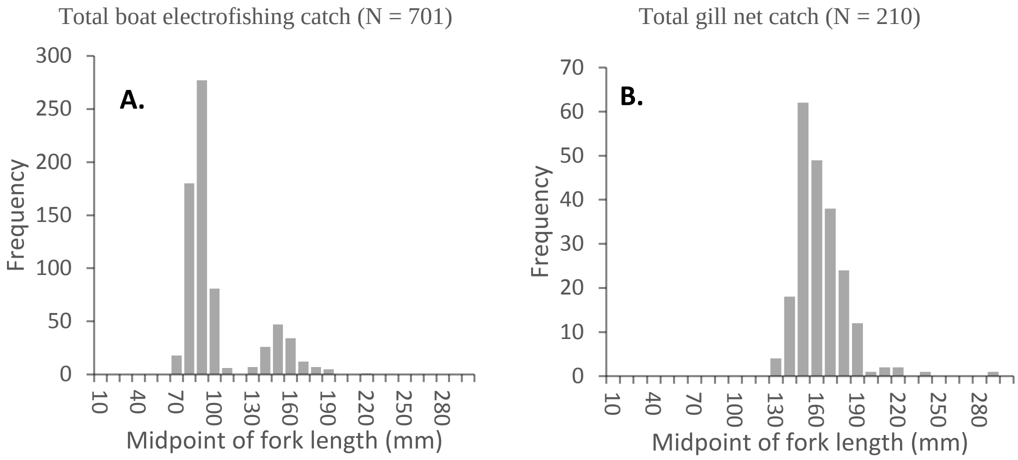
Table 3.16: A: Length-weight relationship for perch captured during gill netting on 21 of Feb 2017 divided into separate locations of the lake. **B:** Similarities between sites for length and weight were checked using the ±2 SE method.

A. Season/location	*n*	*Ln a*	SE ± *(Ln a)*	*b*	SE (*b*)	*Ln R*^{2} adjusted	*p* value	*Equation (ln y=ln a + b*ln x)*
Summer / mixed	210	-10.873	0.238	2.950	0.047	0.950	<0.001	- 10.873 + 2.950x
Winter / Littoral	330	-11.823	0.124	3.136	0.024	0.981	<0.001	-11.823 + 3.136x
Winter / Deep	195	-12.158	0.116	3.204	0.023	0.990	<0.001	-12.158 + 3.204x
Total combined catch	735	-11.868	0.078	3.145	0.015	0.983	<0.001	-11.868 + 3.145*x*

B. Season/location	*n*	*Ln a*	SE ± *(Ln a)*	*Ln a* + 2SE	*Ln a* - 2SE	*b*	SE ± (*b*)	*b + 2SE*	*b* - 2SE
Summer / mixed	210	-10.873	0.238	-10.634	-11.111	2.950	0.047	2.996	2.903
Winter / Littoral	330	-11.823	0.124	-11.699	-11.947	3.136	0.024	3.160	3.112
Winter / Deep	195	-12.158	0.116	-12.042	-12.275	3.204	0.023	3.227	3.181
Total combined catch	735	-11.868	0.078	-11.789	-11.946	3.145	0.015	3.160	3.130

3.3.8 Length-frequency

Two clear cohorts of perch were apparent in the perch population (Figure 3.7A). These are likely to represent two age groups; age 0 perch (70-100 mm fork length), and age 1 perch (140-180 mm fork length). As previously shown in Table 3.2, gill netting shows a clear proclivity towards sampling larger perch, whereas boat electrofishing is useful for targeting juvenile perch (Figure 3.7A & 3.7B).


Total boat electrofishing catch (N = 701)

Total gill net catch (N = 210)

Figure 3.7: A. Length-frequency distribution of perch caught by boat electrofishing in Lake Rotokare sampled on the 21-22 Feb 2017. **B.** Length-frequency distribution of perch caught by gill netting on 21 Feb 2017 (site by site data can be viewed in Appendix 1).

Combining the data sets from all fishing types shows the dominance of year 0-1 perch classes within Lake Rotokare. Larger perch were found, but remained rare (Figure 3.8).

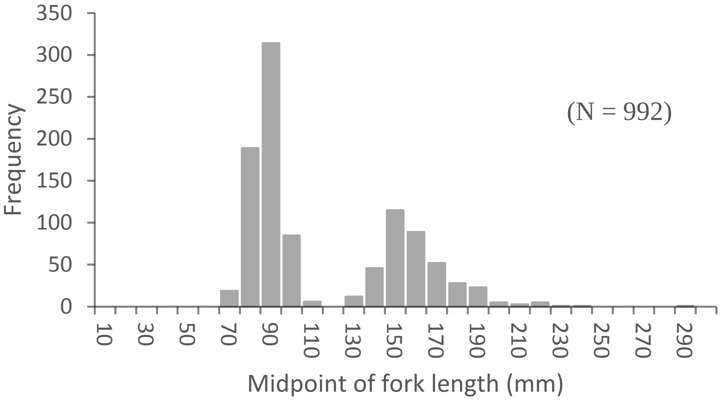


Figure 3.8: Total combined perch length-frequency distribution from fish sampled from 8 -22 Feb 2017 through a combination all fishing techniques.

Winter perch showed the same two-tiered cohort distribution to a lesser effect, with a slight breakdown in size distribution. Larger individuals were captured in June and sampled more frequently compared to summer catches (Figures 3.8, 3.9).

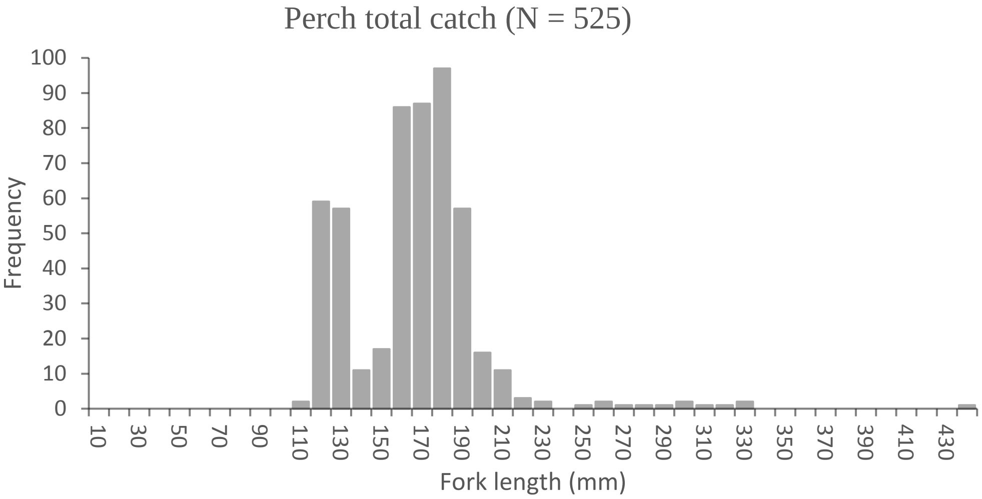


Figure 3.9: Winter perch length-frequency distribution of perch caught from gill netting in Lake Rotokare on 8-9 Jun 2017 (site by site data can be viewed in Appendix 1).

Longfin eel length frequency distribution was dominated by large size classes, there is little indication of recruitment occurring due to the lack of smaller size classes (≤ 300 mm). The lack of juvenile eels found suggests that the population within the lake is not self-recruiting (Figure 3.10A). Shortfin eel distribution was more scattered (Figure 3.10B). Much like longfin eels, there was a dominance in the lake of larger sized adults (≥ 500 mm). However, there is clear evidence of juveniles shortfin eels existing in the lake, suggesting that the population is showing juvenile recruitment to some extent.

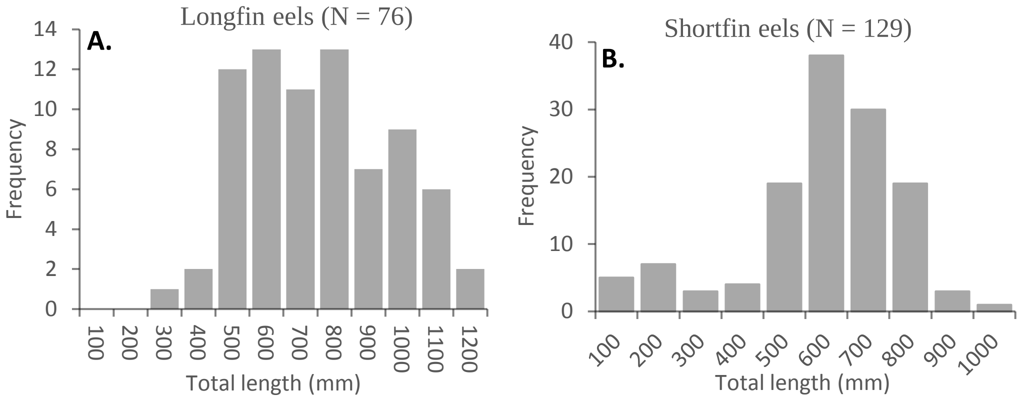


Figure 3.10: Length-frequency distribution of longfin **(A)** and shortfin eels **(B)** in Lake Rotokare captured through combined methods on the 8-22 Feb 2017.

3.4 Discussion

3.4.1 Longfin and shortfin eels

Hicks et al., (2013) originally estimated shortfin eel biomass per hectare to be 8 kg ha^{-1} in Lake Rotokare through single pass boat electrofishing. However, after extensive fieldwork, we now estimate the biomass is much higher (31.4 kg ha^{-1}). Our results reflect a more accurate representation of the eel population within Lake Rotokare as trials have shown a single night of fyke net fishing can harvest 75% of the estimated eel population within the fished area (Jellyman, 2012). To generate robust estimates of total populations from tagged–untagged ratios, several assumptions need to be met; i.e. populations must be closed, tagged fishes must move randomly back into the population and the likelihood of catching a tagged fish is similar over time (Jellyman & Crow, 2016). Lake Rotokare remains a closed environment, with minimal chance of fish entering the system. These assumptions were met in this study; by ensuring fish were released in the lake centre to maximize the probability of population mixture. Also, limiting the time-period of mark-recapture while using a set number of nets throughout sampling, ensured fish encounter rates with fyke nets remained consistent. Therefore, the population estimation inferred by the mark-recapture project is a strong estimation of absolute eel abundance in the lake.

Results for shortfin eel biomass were similar to Lake Mangahia (37 kg ha^{-1}; Hicks et al., 2015) and Lake Ohinewai (14-41 kg ha^{-1}; Hicks & Tempero, 2017), but higher than Waikato average of 23 kg ha^{-1} for shortfin eels (Hicks et al., 2015). They were also lower than Lake Milicich; 74 kg ha^{-1}, and well below shortfin biomass of 170 kg ha^{-1} of Groynes Lake (Jellyman & Crow, 2016). Longfin eel biomass for Lake Rotokare was 14.8 kg ha^{-1} when sampled in February, and this value is 14 times greater than the Waikato average of 1 kg ha^{-1}; this suggests that stocking of longfin within the lake is much higher for Lake Rotokare. When comparing longfin biomass in Rotokare to Lake Milicich, Rotokare values are over 14 times greater than Milicich (0.9 kg ha^{-1}; Hicks et al., 2015), but below the generic figure of 60 kg ha^{-1} figure for littoral zone biomass values for lakes nationwide (Graynoth et al., 2008). The ratio of longfin/shortfin biomass values is also worth noting, as shallow lakes in the Waikato typically have longfins contributing 0-17% of the total eel biomass (Hicks et al., 2015). Lake Rotokare has a much higher biomass value (31.22%).

With an absolute abundance estimation of 853 shortfin and 143 longfin eels in Lake Rotokare, the longfin population has a hugely disproportionate biomass contribution to the lake's total eel biomass.

The longfin eel biomass results may be a consequence of the lack of self-recruitment within the lake. The length-frequency data indicates that self-recruitment is unlikely. These results, in conjunction with personal communications from staff working for the Rotokare Scenic Reserve which detail translocations of longfin eels into Lake Rotokare in the past, makes it likely that the length-frequency data is accurate. With the population seemingly landlocked, it is likely the entire population of longfin in the lake are old (≥ 30 years) fish that continue to grow and reside within the lake until death. Jellyman (1995) studied longfin eel populations in Lake Rotoiti and found a slow growing longfin eel population with a sample range of 231-1203 mm were estimated to be between 20-106 years of age. With a similar size range in Rotokare (328-1200 mm) this would suggest the two populations share a similar age composition. Shortfin eel length-frequency data showed evidence to suggest there is self-recruitment occurring, with the capture of multiple juvenile eels during sampling.

Boat electrofishing appears to be a poor method of eel sampling, at least in context to Lake Rotokare. Shortfin eel density estimates from electrofishing remained low in 2013 (0.28 fish 100 m^{-2}; Hicks et al., 2013) and 2017 (0.08 fish 100 m^{-2}). Longfin eel capture remained virtually non-existent over both sampling periods. Fyke netting is recommended in the future for any further eel population studies within the lake.

3.4.2 Perch

Perch numerically dominated the fish community in Lake Rotokare (81% of total fish capture in February). Perch density was much greater in this study than in 2013 (Hicks et al., 2013); the 2013 density averaged at 4.49 fish 100 m^{-2}, whereas 2017 boat electrofishing yielded an average density of 16.55 100 m^{-2}. The number of fish captured was also much larger (217 compared to 701) even though fishing effort was similar. This provides further evidence that night-time fishing is highly effective for electrofishing perch. Comparing boat electrofishing catch rates between lakes shows that perch catch rates are much higher in Lake Rotokare then elsewhere. Collier & Grainger (2015) compared catch rates of perch caught between 2003 and 2010 in the North Island from boat electrofishing which equalled 0.71 fish min^{-1}. They also found an average catch rate of 0.03 fish min^{-1} for Lake Waahi; this compared with our average value at Rotokare of 8.97 fish min^{-1} suggesting that Lake Rotokare has a much larger perch population. Perch average biomass in Lake Rotokare was 123.2 kg ha^{-1} and had a density of 16.55 fish 100 m^{-2}. Converting relative abundance values from fish 100 m^{-2} into fish ha^{-1} gives a total of 1665 fish ha^{-1}, or 29,459 perch within the lake.

Lake Rotokare 2013 electrofishing results (Hicks et al., 2013) support this estimation, with a single night-time boat electrofishing shot yielding 12.5 fish min^{-1}. The size structure of the perch cohorts in the lake does not appear to have changed in between years either; this suggests the lake has stable biotic factors for perch development, with a population that has that is driven by density factors (Thorpe, 1977; Craig, 1982; Karas, 1996; Hjelm et al., 2000; Heibo et al., 2005; Hicks et al., 2007; Barbtels et al. 2012).

Gill netting CPUE values of 3.2 fish net^{-1} in lake Rotokare for 25 mm mesh were similar to the Lake Rotoroa's CPUE average value of 3.1 (Wise, 1990), and larger than the average CPUE value for the lower Kaori; 2.59 (Hicks et al., 2007). Mesh size clearly impacts catch rates and catch size distribution, and in order to best avoid it for future studies, a variety of net sizes from 18-45 mm mesh should be used to effectively target all size classes. CPUE results from winter also show that there is a large difference in abundance levels between littoral zones and deep zones of the lake, and that in summer perch are limited to the upper few metres of the lake due to oxygen depletion below the thermocline.

Caution should be used when making comparisons of CPUE between sites as the assumption that catch efficiency remains constant is likely to be violated in many situations. If between-site comparisons are made it is important to be mindful of differences in variables that affect catch efficiency such as electrical conductivity and habitat complexity. Given that CPUE rates varied so much in this study with all species sampled and all sampling methods, particularly with gill net CPUE; gill net 4 in summer and littoral gill net 3 and deep gill net 4 in winter were all in similar locations and had a low CPUE (< 1), this suggests that this area of the lake is unsuitable habitat for perch. Therefore, it is sensible to assume that a range of unknown biological factors could be influencing these values. With no known data on substrata or other biological parameters, making assumptions off relative abundance data needs to be exercised with care.

3.4.3 Banded kokopu and kōura

There is a large population of kōura and banded kokopu within the tributary however, the reduction of perch populations could lead to Lake Rotokare's population increasing. Hicks et al. (2013) estimated banded kokopu density to be 150 fish/100 m^{-2}. This survey was more thorough, with on average 4x time the distance covered on each spotlighting trip, the results from June and December were modest in comparison, with somewhere between 61 to 81 fish 100 m^{-2}. On both occasions during sampling, individuals recorded were estimated upwards of 250 mm), a value high for this species (McCullough, 1998). McCullough & Hicks (2002) analysed the reliability of spotlight counts related to population estimates over a range of densities, and found on average, spotlight counts accounted for 64% of the population estimates. With repeated trips over successive seasons and years, it is likely this estimate is relatively accurate. Juveniles of both species were also present, although size differences in kōura were not recorded, the size range varied from 30-90 mm. Therefore, this suggests there is recruitment within the lake for both banded kokopu and Kōura.

While there was an instance of a native species of freshwater shrimp being surveyed during spotlighting in the national freshwater database (NZFFDB), there is no evidence to support this from spotlighting surveys in 2013 or 2017. The species may have been present in the past, but it is likely to have either been a mistake; or has become locally extinct since. Inanga failed to appear in any form of fish sampling undertaken in 2017, supporting the assumption Hicks et al. (2013) made that, the identification of the species in the lake was an error made by the Taranaki Catchment Commission (1980), mistaking juvenile banded kokopu for inanga.

3.4.4 Perch interactions with other species

With such large densities it is likely that the perch are forcing banded kokopu and kōura in-lake to such small numbers, that they barely register. Until now there has been no evidence that either species was present within Lake Rotokare, however, it is likely that the surrounding fringe of dense vegetation on the lake's edges is acting as a buffer zone for cover for these two species. The presence of juvenile banded kokopu in the outlet of the lake supports this theory. The juveniles would have most likely come from the inlet, after having to travel the width of the lake to reach the outlet. With such a large population of perch, it is difficult to believe any kokopu would survive the journey without adequate cover.

The perch may also be supplying a rich food source for shortfin and longfin eels. Jellyman (1989) found evidence to show that nutrient rich diets for both species of eel leads to an increase in growth rates, and with warm lake water temperatures and rich food sources, this may accelerate eel growth within the lake considerably (Jellyman, 1997). This could also lead to high predation rates on elvers; with individuals sampled as large as 430 mm in length, it is possible the perch may target small eels as part of their diets. Another factor to consider is the self-regulation of large perch cannibalizing the young of year class (70-100 mm). Perch are unique in the fact that they can behave autonomously within an ecosystem, modulating resources, and generally control its own density through their food resources (Holcik, 1977). Cannibalism is common among European perch populations, and cannibalistic behaviour can become the predominant source of food for large perch, particularly in monospecific populations (Holcik, 1977).

There has been a clear negative association found between water clarity and the presence of perch. (Romare et al., 1999; Rowe, 2007). Stunted populations of perch can contribute to reduced water clarity through consumption of zooplankton and consequent reduction in algal grazing (Romare et al., 1999; Rowe 2007). This mechanism was proposed as a contributing factor to cyanobacterial blooms in Karori Reservoir, Wellington (Smith & Lester, 2006). Hicks et al., (2005) found a wide-ranging size class; similar to Lake Rotokare, suggesting that perch within Lake Rotokare will be impacting water clarity. This is indicative in the lake already, with frequent cyanobacterial blooms, which are quite likely attributed to such high perch numbers.

3.5 Conclusion

Lake Rotokare supports a moderately large population of shortfin and longfin eels, which are much larger in length and weight then other lakes with similar population sizes. Perch are numerous in the lake and comprised the bulk of the catch for both 2013 and 2017 sampling seasons. With such high estimated density rates of this invasive species, removal will be difficult (Closs et al., 2001). A follow up survey using multiple netting or boat electrofishing depletion rates may provide absolute abundance values, however, caution is issued for attempting mark-recapture surveys on the perch; due to their large population size.

There is evidence to suggest that shortfin eel, banded kokopu, and kōura populations are self-recruiting. Longfin eels are not. Further studies to address the presence/absence of kōura and banded kokopu within the lake should be undertaken to assess whether there is a stable population. Establishing relative abundance in lake would also be useful for a complete understanding of Lake Rotokare’s in-lake population dynamics.

3.6 References

Allibone, R., David, B., Hitchmough, R., Jellyman, D., Ling, N., Ravenscroft, P., & Waters, J. (2010). Conservation status of New Zealand freshwater fish, 2009. *New Zealand Journal of Marine and Freshwater Research*, *44*(4), 271-287.

Bartels, P., Hirsch, P. E., Svanbäck, R., & Eklöv, P. (2012). Water transparency drives intra-population divergence in Eurasian perch (*Perca fluviatilis*). *PLoS One*, *7*(8), e43641.

Cadwallader, P. L., & Backhouse, G. N. (1983). *A guide to the freshwater fish of Victoria*. US Government Printing Office.

Closs, G. P., Ludgate, B., & Goldsmith, R. J. (2001). Controlling European perch (*Perca fluviatilis*): lessons from an experimental removal. In Proceedings of the workshop: Managing invasive freshwater fish in New Zealand,pp. 10-12.

Collier, K. J., & Grainger, N. P. J. (2015). New Zealand Invasive Fish Management Handbook. *Lake Ecosystem Restoration New Zealand (LERNZ; The University of Waikato) and Department of Conservation*, Hamilton, New Zealand. 212 p.

Cotterill, V. (2016). The effects of fish removal on a European perch (*Perca fluviatilis*) populations' growth, abundance and size over time in the Lower Karori Reservoir, Wellington, New Zealand. Unpublished report by the University of Waikato, Hamilton.

Craig J (1982) Population dynamics of Windermere perch.

Crow, S., Snelder, T., Jellyman, P., Greenwood, M., Booker, D., & Dunn, A. (2016). Temporal trends in the relative abundance of New Zealand freshwater fishes, analysis of New Zealand Freshwater Fish Database Records. *Client report prepared by NIWA for Ministry for the Environment*. Christchurch, New Zealand.

Crow, S. K., & Jellyman, D. J. (2014). Assessment of the eel fishery in the Pouto Lakes in Northern Kaipara. *New Zealand Fisheries Assessment Report*, 21.

Crow, S. (2017). New Zealand Freshwater Fish Database. Version 1.2. *The National Institute of Water and Atmospheric Research* (NIWA). Occurrence Dataset. Retrieved from: https://doi.org/10.15468/ms5iqu

Goodman, J., Dunn, N. R., Ravenscroft, P. J., Allibone, R. M., Boubee, J. A., David, B. O., & Rolfe, J. R. (2014). *Conservation status of New Zealand freshwater fish, 2013* (p. 16). Publishing Team, Department of Conversation.

Graynoth, E., Jellyman, D. J., & Bonnett, M. (2008). Spawning escapement of female longfin eels. *New Zealand Fisheries Assessment Report*, *7*, 57.

Heibo, E., Magnhagen, C., & Vøllestad, L. A. (2005). Latitudinal variation in life-history traits in Eurasian perch. *Ecology*, *86*(12), pp. 3377-3386.

Hicks, B.J., Ling, N., Osbornem, M.W., Bell, D.G. & Ring, C.A. (2005). Boat electrofishing survey of the lower Waikato River and its tributaries. CBER Contract Report No. 39, *client report prepared for Environment Waikato*. Hamilton, New Zealand: Centre for Biodiversity and Ecology Research, Department of Biological Sciences, The University of Waikato.

Hicks, B. J., Osborne, M. W., & Ling, N. (2006). Quantitative estimates of fish abundance from boat electrofishing. Conference held 11-15 July 2005, Darwin, Northern Territory, Australia.

Hicks, B. J., Hamilton, D. P., Ling, N., & Wood, S. A. (2007). Top down or bottom up? Feasibility of water clarity restoration in the lower Karori Reservoir by fish removal.

Hicks, B. J., Bell, D. G., Duggan, I. C., Wood, S. A., & Tempero, G. W. (2013). *Aquatic ecology of Lake Rotokare, Taranaki, and options for restoration*. Environmental Research Institute, The University of Waikato.

Hicks, B. J., Brijs, J., Daniel, A. J., Morgan, D. K., & Ling, N. (2015). Biomass estimation of invasive fish. Section 6.2 in Collier K. J. & Grainger N. P. J. eds. *New Zealand Invasive Fish Management Handbook*. Lake Ecosystem Restoration New Zealand (LERNZ; The University of Waikato) and Department of Conservation, Hamilton, New Zealand. pp. 116-122.

Hicks, B. J., Tempero, G. W., & Powrie, W. S. (2017). *Fish population and biomass estimates from mark-recapture for Lake Milicich, a shallow Waikato peat lake* (No. 88, pp. 4-4). ERI Report.

Hjelm J, Persson L, and Christensen B (2000) Growth, morphological variation and ontogenetic niche shifts in perch (*Perca fluviatilis*) in relation to resource availability. *Oecologia*. (122), pp. 190-199.

Holcik, J. (1977). Changes in fish community of Klicava Reservoir with particular reference to Eurasian Perch (*Perca*-fluviatilis), 1957-72. *Journal of the Fisheries Research Board of Canada*, *34*, 1734-1747.

Jellyman, D. J. (1989). Diet of two species of freshwater eel (*Anguilla spp*.) in Lake Pounui, New Zealand. *New Zealand Journal of Marine and Freshwater research*, 23(1), pp. 1-10.

Jellyman, D. J. (1995). Longevity of longfinned eels *Anguilla dieffenbachii* in a New Zealand high country lake. *Ecology of Freshwater Fish*, *4*(3), pp. 106-112.

Jellyman, D. J. (1997). Variability in growth rates of freshwater eels (Anguilla spp.) in New Zealand. *Ecology of Freshwater Fish*, *6*(2), pp. 108-115.

Jellyman, D. J. (2012). The status of longfin eels in New Zealand - an overview of stocks and harvest. *Report for the parliamentary Commissioner for the Environment*. NIWA. Christchurch, New Zealand.

Jellyman, D. J., & Crow, S. K. (2016). Population size, growth and movements of Anguilla australis in a small lake. *Journal of fish biology*, *88*(6), pp. 2157-2174.

Kane, D. (1995). The status of fish in Hamilton Lake (Lake Rotoroa). Unpublished thesis. University of Waikato, Hamilton, New Zealand.

Karås P. (1996). Basic abiotic conditions for production of perch (*Perca fluviatilis L.*) young-of-the-year in the Gulf of Bothnia. Pages 371-381 *Annales Zoologici Fennici*. JSTOR

Ludgate, B. G., & Closs, G. (2003). *Responses of fish communities to sustained removals of perch (Perca fluviatilis)*. Wellington, New Zealand: Department of Conservation.

McCullough, C. D. (1998). Abundance, behaviour, and habitat requirements of the banded kokopu (*Galaxias fasciatus* Gray) (Pisces: *Galaxiidae*). Unpublished MSc thesis, The University of Waikato, Hamilton, New Zealand.

McCullough, C. D., & Hicks, B. J. (2002). Estimating the abundance of banded kokopu (*Galaxias fasciatus* Gray) in small streams by nocturnal counts under spotlight illumination. *New Zealand Natural Sciences*, *27*, pp. 1-14.

McDowall, R. M. (1996). *Freshwater fishes of south-eastern Australia*. Reed books, Chatswood, Sydney, Australia. pp 52-77.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. *Fisheries Research Board of Canada Bulletin*, 191.

Romare, P., Bergman, E., & Hansson, L. A. (1999). The impact of larval and juvenile fish on zooplankton and algal dynamics. *Limnology and Oceanography*, *44*(7), pp. 1655-1666.

Rowe, D. K. (2007). Exotic fish introductions and the decline of water clarity in small North Island, New Zealand lakes: a multi-species problem. *Hydrobiologia*, *583*(1), pp. 345-358.

Smith, K. F., & Lester, P. J. (2006). Cyanobacterial blooms appear to be driven by top-down rather than bottom- up effects in the Lower Karori Reservoir (Wellington, New Zealand). *New Zealand Journal of Marine and Freshwater Research*, *40*(1), pp. 53-63.

Taranaki Catchment Commission. (1980). Lake Rotokare water management plan. Unpublished report, Taranaki Catchment Commission, Stratford, New Zealand.

Thorpe, J. E. (1977). Morphology, physiology, behavior, and ecology of *Perca fluviatilis* L. and *P. flavescens* Mitchill. *Journal of the Fisheries Board of Canada*, 34(10), pp. 1504-1514.

Wise. (1990). The biology of three exotic fish species in Hamilton Lake. Unpublished MSc thesis, University of Waikato. Hamilton, New Zealand.

Chapter 4: Trophic Interactions

4.1 Introduction

Understanding an organism's trophic status within an ecosystem can be key to identifying how that organism (or species) interacts with its environment. Stomach content analysis is standard practice in aquatic ecology for determining fish diets; however, stomach content analyses does have its limitations. Gut contents can be difficult to identify, and seasonal variation of diets can occur; and/or individuals or groups can show preferential selectively towards prey items (Sunderland, 1988, Sheppard & Harwood, 2005). An alternative method involves incorporating stable isotope analysis into diet studies to effectively track consumer diets at a molecular level (Parnell et al., 2013).

Stable isotope ratios of carbon (C) and nitrogen (N) reported here in standard δ-notation with units of ‰ (ratios for C and N are reported as $\delta^{13}C$, $\delta^{15}N$ henceforth), are used to trace pathways of organic matter among consumers (Peterson & Howarth, 1987; Hesslein et al., 1992). $\delta^{13}C$ ratios provide information on the primary energy source (O'Reilly et al., 2002) and isotope ratios of consumers usually are similar to isotopic ratios of their diets (DeNiro & Epstein, 1978). Nitrogen is a useful method of determining an organism's trophic status within food webs, because it is preferentially incorporated into the tissues of an animal relative to its diet - resulting in an enrichment of $\delta^{15}N$ at successive trophic levels, thereby allowing estimations of an organism's trophic position (DeNiro & Epstein, 1981; Minagawa & Wada, 1984; Vander Zanden & Rasmussen, 1999).

The isotope ratio between diet and consumer shifts between trophic levels. Originally, DeNiro & Epstein (1978, 1981) determined the mean trophic shift for C ($\Delta\ \delta^{13}C$; Δ denotes the change in isotope ratio between diet and consumer) was +1‰, and the mean $\Delta\delta^{15}N$ was +3‰. It is widely accepted that the average $\Delta\delta^{13}C$ values are ca. 0 and average $\Delta\delta^{15}N$ values are ca. +3‰ (Peterson & Fry 1987; McCutchan et al., 2003). However, these values ($\Delta\delta^{13}C$ and $\Delta\delta^{15}N$) can vary considerably depending on diet and life-history traits. Ratios of stable isotopes can also change between diet and consumer due to differential digestion or fractionation during assimilation (McCutchan et al., 2003). Metabolic fractionation may also cause isotope ratios of different tissues to vary substantially within individual consumers (DeNiro & Epstein, 1981; Hobson & Clark, 1992). Additionally, classes of compounds from a single consumer may differ considerably in stable isotope ratio from other compounds (Focken & Becker, 1998).

Variation in lipid content is derived from differences in foraging dynamics and life history constraints, and hence can be of considerable interest to ecologists and evolutionary biologists (Schultz & Conover 1997; Gasser et al., 2000; Post & Parkinson, 2001; Arrington et al., 2006). The potential for lipids to influence $\delta^{13}C$ analyses comes from two sources of variation - First, fractionation of $\delta^{13}C$ during lipid synthesis results in differences in $\delta^{13}C$ between lipids and other tissues due to differences in tissue carbon uptake time (DeNiro & Epstein, 1977; McConnaughey & McRoy, 1979). Secondly, there exists considerable heterogeneity in lipid content among aquatic and terrestrial organisms (McCutchan et al., 2003). These differences influence trophic positioning studies. One method of correcting this, is applying lipid removal treatments to isotope samples to homogenize the tissue samples (Post et al., 2007).

Isotopic sampling of fish is achieved through the utilization of fin-clips, or (more commonly) white muscle tissue sampling (Kelly et al., 2006; Hanisch et al., 2010; Willis et al., 2013). White muscle tissue is usually selected for analysis because it has lower isotopic variability relative to other tissues (Pinnegar & Polunin, 1999). Furthermore, muscle tissue analysis has a (comparatively) well-understood fractionation behaviour (Sweeting et al., 2007), an extended dietary integration period (Hesslein et al., 1993), and large available tissue biomass (Willis et al., 2013). White muscle tissue typically requires euthanisation of the subject for sufficient muscle (Sanderson et al., 2009; Hanisch et al., 2010; Jardine et al., 2011; Willis et al., 2013). In contrast fin-clip tissue sampling is a non-lethal process. Hence, there is a growing call for a shift in fish sampling protocol towards reliance on fin-clip tissue.

In this study, the trophic status of multiple organisms within Lake Rotokare was evaluated, to determine the food-web structure of the lake, and how the invasive perch population tied into the lake ecology on a larger scale. Secondly, this study examined the differences between non-lethal fin clips and destructive muscle tissue samples - by examining the differences in isotopic ratios of shortfin and longfin eels within Lake Rotokare. This determines whether lipid correction is necessary for $\delta^{13}C$ and $\delta^{15}N$ samples for both fin clips and muscle tissue. Finally, we looked at the feasibility of creating mathematical correction equations, forgoing the need for lipid correction models. This would allow further studies to transform non-lethal fin clip isotopic values into treated muscle tissue values and precluding further lethal sampling methods in future research.

4.2 Methods:

4.2.1 Ethics statement

All animal work was conducted in accordance with national and university guidelines to minimize discomfort to animals, State of Practice (SOP) 6 was adhered to throughout the duration of the project. Since the project's field work was directly supervised by a trained technician who was qualified to administer the anaesthetics benzocaine and AQUI-S, the ethics committee chair decided that there were no requirements for ethics approval.

4.2.2 Stomach contents

The stomach contents of 194 *Perca fluviatilis* (perch) were sampled to analyse their diets, the stomach contents were based on two factors; occurrence, and the volumetric contribution of the contents in percent. The perch were split into three size classes, 72-110 mm, 111-180 mm, and 181-249 mm to explore differences in dietary patterns against size transitions. Perch were selected from a range of sites around the lake to ensure an event spread of information. Both gill-netting and boat electrofishing captured perch (see Chapter 3) were analysed (Boat electrofishing N = 144, gill-netting N = 50). Stomach fullness was also measured, assigning a subjective visual assessment of stomach fullness by assigning values between 1-5; as an indicator of fullness: 1 = empty, 2 = 25%, 3 = 50%, 4 = 75%, and 5 = 100%; similar to recommendations suggested by Hyslop's methods (1980).

4.2.3 Sampling and laboratory analyses

Lake Rotokare was sampled in late February, early June and late December over three 5-day periods in 2017. The lake was used as the general site, as collecting invertebrate and plant samples required careful consideration due to the depth profile of the lake (Figure 1.2). Fin-clip samples taken from the mark-recapture project in February (see Chapter 3) which were collected, frozen and brought back to the University of Waikato for later isotopic analysis (n = 17). In June 11 fyke nets were set out at intervals around the lake overnight for three consecutive days, to capture more eels for fin clip analysis (n = 17). Perch were captured in February through boat electrofishing and littoral gill-netting techniques were also selected for isotope analysis (n = 20). Fish were euthanized and brought back to the University of Waikato for isotopic analysis. More perch were retrieved in June by a mixture of littoral and euphotic zone gill-netting, and ten more perch were used to search for seasonal variability in isotope ratios. Dorsal muscle tissue of the perch was selected for isotopic analysis. Perch were split into three size classes during analysis, due to ontogenic shifts in dietary behaviour during growth (Hicks et al., 2007). A limited number of banded kokopu (*Galaxias fasciatus*) (n = 4) were collected from the boat electrofishing in February, the fish were euthanized and the whole body (minus head and gut contents) were used for stable isotope analysis.

Plants *(Potamogeton*, *Lagarosiphon* and *Charophyta*), snails (*Physa*, and *Lymnaea*), and dragonfly nymphs (*Antipodochlora braueri* and *Aeschna brevistyla*) were collected in June using sweep nets around the lakes edge. Samples were chilled and brought back to the University of Waikato for analysis. Whole specimens of dragonfly larvae were used for isotopic analysis, and snails were extracted from their shells to avoid contamination from non-dietary carbon (Hicks, 1997), while plant tissue was left unmodified. Phytoplankton and zooplankton samples were taken during July and December by using plankton nets; 45 µm mesh was selected for phytoplankton, and 125 µm mesh was used to sample zooplankton. Following the recommendations of Smyntek et al. (2007), two horizontal tows (50 m in length) were undertaken from the littoral and pelagic zone of the lake’s surface; planktonic samples were extracted from the filter, chilled and returned to the laboratory for analysis. Sediment samples were collected in December, and chironomids were collected during all three sampling periods using a Ponar grab.

Samples were dried for 48 hours at 40°C and ground into a fine powder. Samples were pulverized by a mortar and pestle and surgical scissors, or softer tissue was processed using a coffee grinder. Powdered material was sent off to the stable isotope unit at the University of Waikato, where samples were analysed with the Europa Scientific Tracermass mass spectrometer with a precision of c. 0.1‰ for ^{13}C and 0.3‰ for ^{15}N.

4.2.4 Lipid correction and fin-muscle tissue corrections

Based on the findings of Post et al. (2007), aquatic vertebrate tissue with a C:N ratio of ≥ 4 required lipid treatment for accurate $\delta^{13}C$ results. Furthermore, Pingram et al. (2014) found discrepancies between fin and muscle tissue values in shortfin eels - requiring lipid correction for fin and muscle tissue for $\delta^{13}C$ values. Due to high C:N ratio results from February sampling (4.09 for longfin eels, and 3.97 for shortfin eels), it was necessary to further explore the potential for lipid correction for the isotopic values of both eel species, to obtain more reliable results. This study then explored the feasibility of using mathematical corrections to convert untreated fin isotopic values into treated muscle values.

Fyke netting was undertaken on Lake Rotokare on December 19, 2017. A total of 10 nets were set around the lakes edge; 8 longfin eels, and 16 shortfin eels were collected and euthanized. Fin clippings and muscle tissue samples (from the dorsal region) were collected. Duplicates were taken from each fish to compare treated and untreated samples. Lipid-corrected samples were treated in a 1:1 methanol:chloroform solution for three 10 minute intervals following the work of Beaudoin et al. (2001), with the minor exception of using a convection drier rather than freeze drying the samples.

4.2.5 Isotopic food web model

An adjusted trophic consumer food web model was incorporated into this study to provide an estimate of relative isotopic contribution of various organisms residing within the lake. This model incorporates the variability (Standard error) of each species isotopic values, providing insight into each species positioning within the food web. The model incorporates the values of the isotope values from all species sampled, and encompasses the results from February, June and December 2017. Fractionation factors between resources and their consumers were assumed as $\delta^{13}C$: 0.4±0.17‰ and $\delta^{15}N$: 2.3±0.28‰, based off the analysis of McCutchan et al., (2003).

4.3 Results:

4.3.1 Stomach content analysis

Prey item occurrence and relative food item volume of perch stomach contents revealed that Zooplankton was the most abundance food source utilized by perch in all size classes. Zooplankton were found within 78% of all perch sampled (Table 4.1) and consisted of 70.47±5.86% (95% confidence interval limit) of stomach total volume (Table 4.2). Chironomid larvae were the second most abundant food source, with a 37% occurrence and a lower volumetric contribution (Table 4.1; Table 4.2). Detritus was present in 18% of perch stomachs but constituted only 3.09±1.13% of stomach volume. Unidentifiable insect species were present in 11% of stomachs, with a 4.21±2.41% volume ratio. Algae, Diptera, dragonfly nymphs, macrophytes, and snails offered negligible contributions to perch diets, with $\leq$ 3% occurrence, and contribution to stomach volume values were as follows: algae; 0.1%, Diptera; 0.53%, dragonfly nymph; 1.22%, and snail; 0.03% respectively (Table 4.2).

The most noticeable changes in diet occurred in the transitional shifts between size classes. Chironomid larvae occurrence increased threefold between the 72-110 mm size class and the 111-180 mm class; and fourfold was exhibited in the 181-249 mm size class. Volumetrically the stomach increase was significant, with increases in chironomid contribution ranging from 3.29±2.25% in the 72-110 mm, through to 27.42±7.48% (110-180 mm class), and 50.28±11.72% in individuals larger than 180 mm (Table 4.2). Zooplankton consumption shifted between classes, occurring in almost all juvenile perch stomachs (72-110 mm - 97% occurrence), decreasing in the mid-range class to 72%, and declining further to 35% occurrence in stomach contents in individuals larger than 180 mm (Table 4.1). Volumetrically this trend remained consistent with occurrence, with significant drops between classes. Perch between 72-110 mm showed an average stomach zooplankton volume of 93%, this decreased to 60.3%, and further dropped to 34.44% in larger perch ($\geq$ 180 mm; Table 4.2). There were also increases in occurrence and stomach volume between classes in detritus contribution, with no occurrence in the lowest class, 26% occurrence, and 45% occurrence, detritus contributed little to stomach volume (Table 4.2). No other food item showed any significant trends or increases. In total there were 5 perch out of 194 with empty stomachs, with the average stomach fullness between size classes was 85%, 74%, and 72% (Appendix 2).

Table 4.1: Mean frequency of occurrence (percentage of perch) for food items in perch stomachs taken from Lake Rotokare for three size classes; 80-110 mm, 110-180 mm, and ≥ 180 mm (fork length measurement) between 21-22 Feb 2017.

	Frequency of occurrence			
Food item	72-110	111-180	181-249	Combined
Algae	0	4	0	2
Chironomid larvae	16	48	60	37
Detritus	0	26	45	18
Diptera	0	0	5	1
Dragonfly nymph	0	6	0	3
Macrophyte	0	2	0	2
Snail	1	0	0	1
Unidentified insect	11	11	15	11
Zooplankton	97	72	35	78

Table 4.2: Volumetric comparison of three size classes of perch from lake Rotokare, 80-110 mm, 110-180 mm, and ≥ 180 mm (fork length measurement) caught on 21-22 Feb 2017.

	Size range (fork length measured in mm)											
	72-110			111-180			181-249			Combined		
Food item	n	average	CI (95%)	n	average	CI (95%)	n	average	CI (95%)	n	average	CI (95%)
Algae	0			3	0.19	0.23	0			3	0.10	0.12
Chironomid larvae	16	3.29	2.25	47	27.42	7.48	12	50.28	21.82	75	20.28	4.87
Detritus	0			26	4.74	1.98	9	6.67	3.81	35	3.10	1.13
Diptera	0			0			1	5.56	11.72	1	0.53	1.04
Dragonfly nymph	0			6	2.35	2.37	0			6	1.22	1.23
Macrophyte	1	0.07	0.14	2	0.10	0.23	0			3	0.08	0.09
Snail	1	0.07	0.14	0			0			1	0.03	0.05
Unidentified insect	7	3.56	3.71	11	4.90	3.73	3	3.06	3.92	21	4.21	2.41
Zooplankton	69	93.01	4.37	73	60.30	8.70	7	34.44	22.38	149	70.47	5.86

4.3.2 Eel muscle vs. fin tissue comparison

There was variation between both longfin and shortfin stable isotope values between seasons. Longfin eels sampled in December for untreated fin tissue had a lower mean C:N ratio, and a similar value to June for untreated fin tissue compared to samples taken from February (Table 4.3). The average length range was different, with eels taken in February and June, ranging between 500-1140 mm, and December; 474-872 mm, skewing towards smaller individuals (Table 4.3). $\delta^{13}C$ values of varied somewhat between sampling seasons, with an average $\delta^{13}C$ of -27.30±0.49‰ (95% mean confidence interval limit) in February, $\delta^{13}C$ equalled -26.65±0.46‰ in June, and -26.74±0.57‰ in December. February remained different from June and December values (Table 4.3). $\delta^{15}N$ was similar between February and June, there was a significant difference in December from the other months (Table 4.4).

Shortfin eels showed a different trend, with average C:N ratios falling below 4 in each sampling season (Table 4.3). February had a larger size range (615-930 mm) and arithmetic mean (746 mm) then June (525-785 mm, $\mu = 635$ mm) or December (500-871 mm, $\mu = 627$ mm). $\delta^{13}C$ remained similar between February and June (-26.84±0.62‰; -26.32±0.62‰), but different to December (-27.67±0.69‰). $\delta^{15}N$ was significantly higher in shortfin samples in February (8.70±0.24‰) then in June (7.77±0.47‰) or December (-27.67±0.69‰).

Table 4.3: Size classes and isotopic values for untreated fin tissue for Lake Rotokare; Feb-Dec 2017.

	Longfin			**Shortfin**		
Data	21-23 Feb	7-9 Jun	19 Dec	21-23 Feb	7-9 Jun	19 Dec
N	10	7	8	6	11	16
length range	520 - 1140	500 - 1110	474 - 872	615-930	525-785	500-871
Weight range	352 - 6690	675-5192	343 - 2484	465-2001	313 - 1189	287-1650
Average length (mm)	908	794	650	746	635	627
Average weight (g)	2924	2144	1070	1052	615	670
Untreated $\delta^{15}N$ mean	9.10	8.85	8.71	8.70	7.77	7.63
Confidence level (95%)	0.29	0.42	0.30	0.24	0.47	0.45
Untreated $\delta^{13}C$ mean	-27.30	-26.65	-26.74	-26.84	-26.32	-27.67
Confidence level (95%)	0.49	0.46	0.57	0.62	0.62	0.69
C:N mean	4.09	3.82	3.85	3.97	3.71	3.79

Variation for both species between untreated fin and muscle tissue $\delta^{15}N$ in December was minimal, both average values remained within confidence interval ranges, $\delta^{15}N$ for longfin untreated muscle was 8.82±0.23‰, untreated fin equalled 8.71±0.30‰ (Table 4.4). Shortfin values were roughly 1 delta unit lower, with untreated muscle = 7.87±0.39‰ and fin = 7.63±0.45‰. $\delta^{13}C$ values were variable between species; muscle tissue had a lower value than fin, with a $\Delta\delta^{13}C$ -1.91 between means in longfin (muscle $\delta^{13}C$ = 28.65±0.58‰, fin $\delta^{13}C$ = -26.74±0.57‰), and a $\Delta\delta^{13}C$ -2.42 in shortfin (muscle $\delta^{13}C$ = -30.09±0.86‰, fin $\delta^{13}C$ = -27.67±0.69‰).

Table 4.4: Shortfin and longfin eel stable isotope average values for $\delta^{13}C$ and $\delta^{15}N$ fin and muscle average values taken from eels captured during fyke netting on 19 Dec 2017.

Shortfin eel	$\delta^{15}N$ muscle	$\delta^{15}N$ fin	$\delta^{13}C$ muscle	$\delta^{13}C$ fin
Mean	7.87	7.63	-30.09	-27.67
Standard error	0.18	0.21	0.41	0.33
Confidence level (95%)	0.39	0.45	0.86	0.69
Range	2.11	2.67	5.26	4.14
Minimum	6.77	6.44	-33.00	-29.83
Maximum	8.87	9.11	-27.75	-25.69
Longfin eel				
Mean	8.82	8.71	-28.65	-26.74
Standard error	0.10	0.13	0.25	0.24
Confidence level (95%)	0.23	0.30	0.58	0.57
Range	0.85	1.16	2.20	1.76
Minimum	8.36	8.01	-29.39	-27.45
Maximum	9.21	9.18	-27.19	-25.69

Pairwise comparison between untreated fin and muscle tissue for longfin eels showed generally fin was more enriched in $\delta^{13}C$ then muscle (Figure 4.1). $\delta^{15}N$ showed an opposite trend, with a modest increase in muscle values in the lower range of samples, compared to fin tissue. Both $\delta^{13}C$ ($R^2 = 0.58$; $p \leq 0.05$) and $\delta^{15}N$ ($R^2 = 0.84$; $p < 0.05$) dual plots had moderate relationships between fin and muscle.

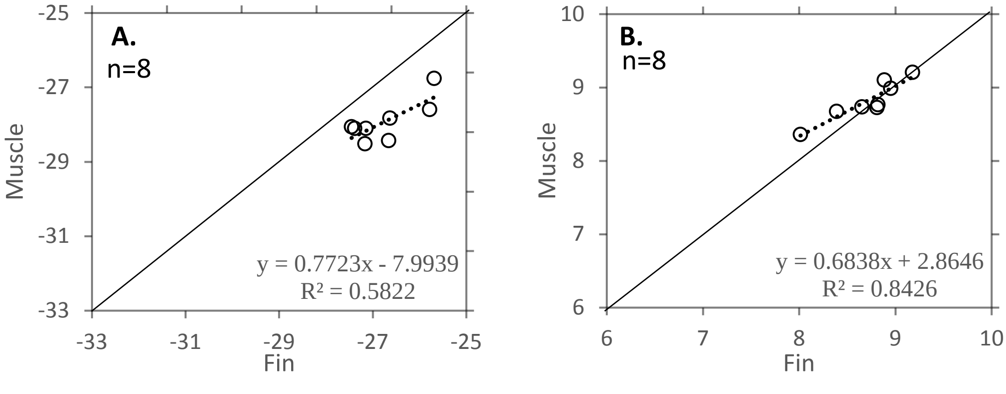


Figure 4.1: A. Pairwise comparison of stable isotope $\delta^{13}C$ values for longfin eel muscle vs. fin tissue samples. **B.** Pairwise comparison of longfin $\delta^{15}N$ muscle vs. fin tissue samples, data came from eels caught from Lake Rotokare on 20 Dec 2017. The line represents a 1:1 ratio between treated and untreated samples.

Shortfin pairwise comparison between tissue types revealed a much larger variety in shortfin isotopic values (Figure 4.2). Generally, $\delta^{13}C$ was highly enriched in fin tissue compared to muscle tissue, but the relationship was much weaker in longfin due to the variation in data points ($R^2 = 0.36$; $p < 0.05$). $\delta^{15}N$ followed the same pattern as in longfin, muscle samples were enriched compared to fin, particularly with values in the lower delta unit values (7‰), equalizing at ca. 8‰. The relationship between muscle and fin was strong ($R^2 = 0.76$; $p < 0.05$).

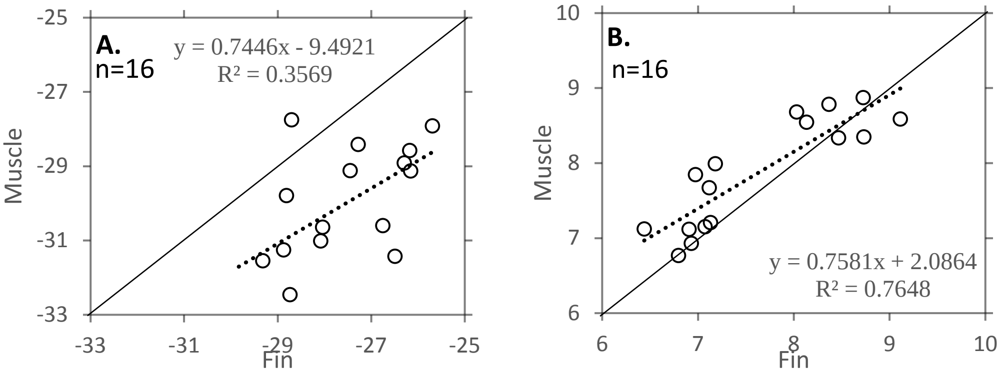


Figure 4.2: **A.** Pairwise comparison of stable isotope δ^{13}C values for shortfin eel muscle vs. fin tissue samples. **B.** Pairwise comparison of shortfin δ^{15}N muscle vs. fin tissue samples, data came from eels caught from Lake Rotokare on 20 December 2017. The line represents a 1:1 ratio between treated and untreated samples.

4.3.3 Lipid correction (δ^{13}C)

Comparison of pairwise samples from individual eels (Figure 4.3) showed that muscle and fin for longfin eels was imbalanced, untreated fin tissue compared to treated fin tissue showed a strong bias towards treated values, therefore fin tissue required lipid correction to homogenize results ($R^2 = 0.96$; $p < 0.05$). Muscle tissue also showed higher treated δ^{13}C values compared to untreated samples. While the regression between treated-untreated samples was moderate ($R^2 = 0.50$; $p < 0.05$), it still exhibited that muscle tissue samples required lipid correction.

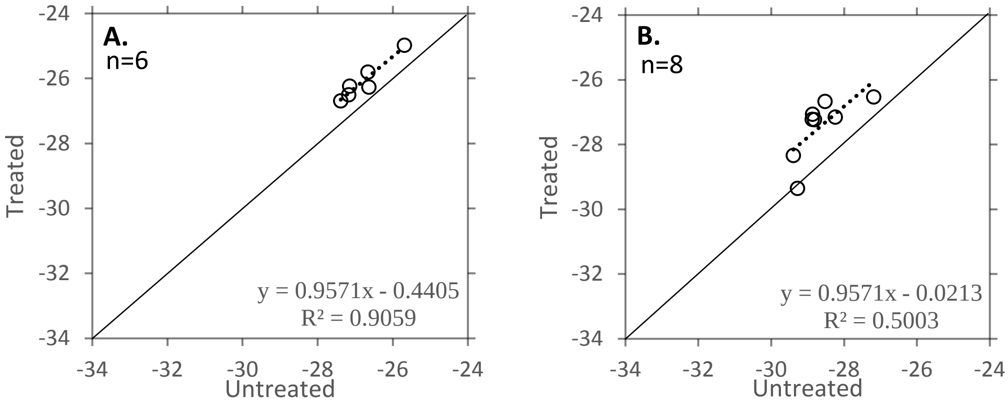


Figure 4.3: **A.** Pairwise comparison of stable isotope δ^{13}C values for Longfin eel treated vs. untreated fin tissue samples. **B.** Pairwise comparison of longfin treated vs. untreated muscle tissue samples, data came from eels caught from Lake Rotokare on 20 Dec, 2017. The line represents a 1:1 ratio between treated and untreated samples.

Shortfin required lipid correction for muscle tissue but not for fin tissue (Figure 4.4). Fin treatment showed no relationship between treated and untreated samples, and overall it appeared fin tissue remains highly heterogeneous regardless of treatment ($R^2 = 0.02$; $p < 0.05$). Muscle tissue showed lower values in δ^{13}C when exposed to lipid treatment, muscle responded strongly to fin treatment and required lipid correction for the best results ($R^2 = 0.63$; $p < 0.05$).

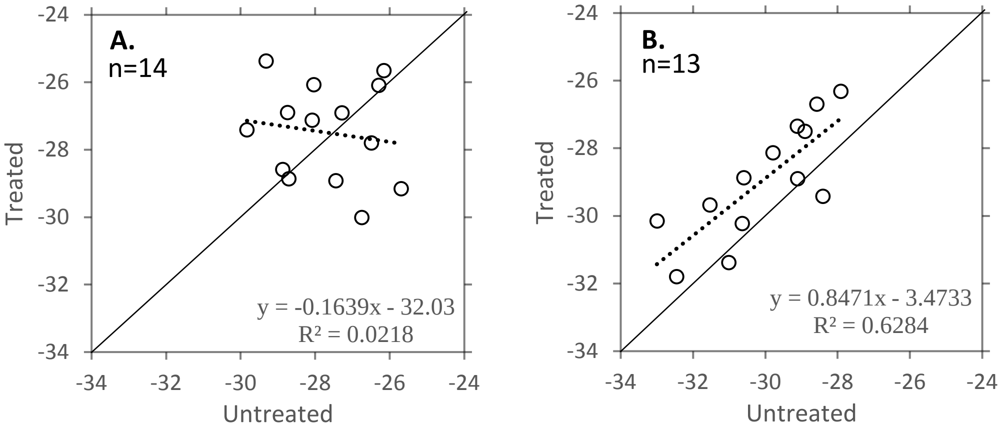


Figure 4.4: **A.** Pairwise comparison of stable isotope δ^{13}C values for Shortfin eel treated vs. untreated fin tissue samples. **B.** Pairwise comparison of shortfin treated vs. untreated muscle tissue samples, data came from eels caught from Lake Rotokare on 20 Dec, 2017. The line represents a 1:1 ratio between treated and untreated samples.

4.3.4 *Lipid correction ($\delta^{15}N$)*

Lipid correction did little to change δ^{15}N values in both species. Longfin eels in particular showed almost no change in values between treated and non-treated samples for both fin and muscle samples (Figure 4.5), with the majority of pairwise values falling on the 1:1 line. Therefore, δ^{15}N did not need require treatment for longfin eels.

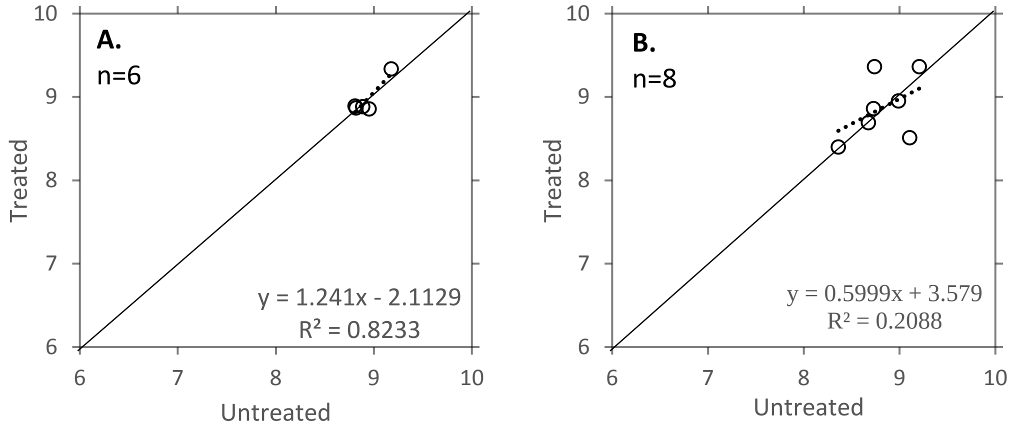


Figure 4.5: A. Pairwise comparison of stable isotope δ^{15}N values for longfin eel treated vs. untreated fin tissue samples. **B.** Pairwise comparison of longfin treated vs. untreated muscle tissue samples, data came from eels caught from Lake Rotokare on 20 Dec 2017. The line represents a 1:1 ratio between treated and untreated samples.

Shortfin did not require correction for either fin or muscle (Figure 4.6). While the regression line for fin tissue was skewed slightly above the 1:1 ratio line with a strong R^2 value (0.77; $p < 0.05$), the majority of values remained close to the 1:1 line, therefore it was deemed to be natural variation in samples, and treatment was not necessary. Muscle tissue showed a much wider spread in pairwise comparisons, once again most values fell around the 1:1 ratio line, and the overall relationship between treated and untreated samples was weak ($R^2 = 0.22$; $p < 0.05$).

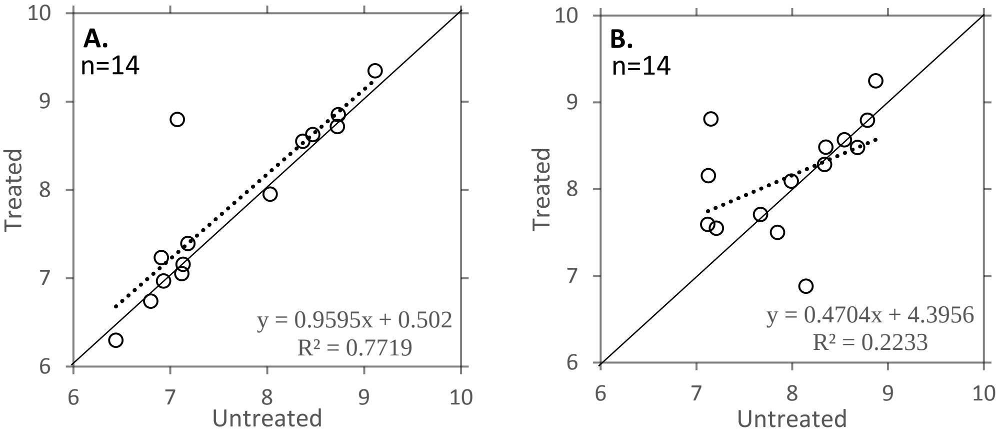


Figure 4.6: A. Pairwise comparison of stable isotope $\delta^{15}N$ values for shortfin eel treated vs. untreated fin tissue samples. **B.** Pairwise comparison of shortfin treated vs. untreated muscle tissue samples, data came from eels caught from Lake Rotokare on 20 Dec, 2017. The line represents a 1:1 ratio between treated and untreated samples.

4.3.5 Mathematical correction

Longfin eel:

A series of mathematical equations was devised to standardize untreated fin tissue into treated muscle tissue values. The following steps were used to achieve correction:

Using the regression model (Figure 4.7A); the following equation converted $\delta^{13}C$ untreated fin into untreated muscle (Figure 4.7B):

$$\delta^{13}C \text{ untreated muscle} = 0.7917\ (\delta^{13}C \text{ untreated fin}) - 7.3765$$

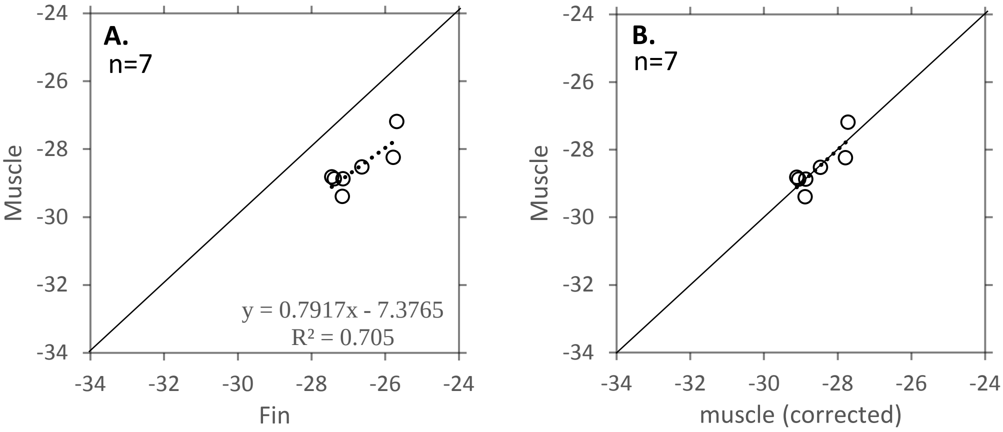


Figure 4.7: A. Longfin untreated muscle vs. untreated fin $\delta^{13}C$ values, with regression equation attached. **B.** Untreated muscle vs. mathematically corrected untreated muscle. Samples retrieved from Lake Rotokare on 20 Dec, 2017. The line represents the 1:1 ratio between X and Y values.

Once converted, the next step is to convert untreated muscle; in this case mathematically corrected untreated value (Figure 4.8A) into treated muscle values (Figure 4.8B). This is achieved by applying the following correction:

$$\delta^{13}\text{C treated muscle} = 0.6357\ (\delta^{13}\text{C untreated muscle}) - 9.0128$$

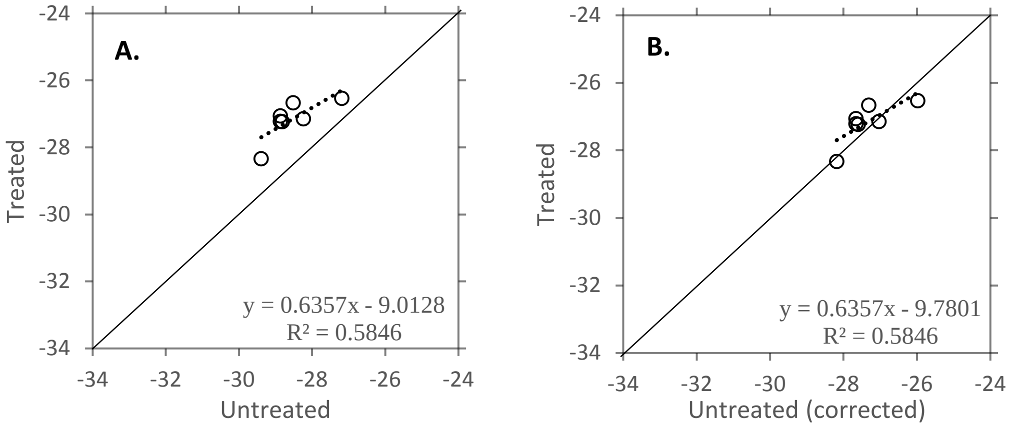


Figure 4.8: A. Longfin treated muscle vs. untreated muscle (mathematically corrected) δ^{13}C values, with regression equation attached. **B.** Treated muscle vs. mathematically corrected treated muscle. Samples retrieved from Lake Rotokare on 20 Dec, 2017. The line represents the 1:1 ratio between X and Y values.

The final equation converting δ^{13}C untreated fin directly into treated muscle is as follows:

$$\delta^{13}\text{C treated muscle} = 0.6357\ (0.7917 \text{ x } \delta^{13}\text{C untreated fin} - 7.3765) - 9.0128$$

Shortfin eel:

The regression model (Figure 4.9A) had a weak regression ($R^2 = 0.36$; $p < 0.05$), therefore it was determined the average value of the differences between (muscle minus fin) was used (-2.425) as a proxy. The following equation will convert δ^{13}C untreated fin into untreated muscle (Figure 4.9B):

$$\delta^{13}\text{C untreated muscle} = \delta^{13}\text{C Untreated fin} - 2.425$$

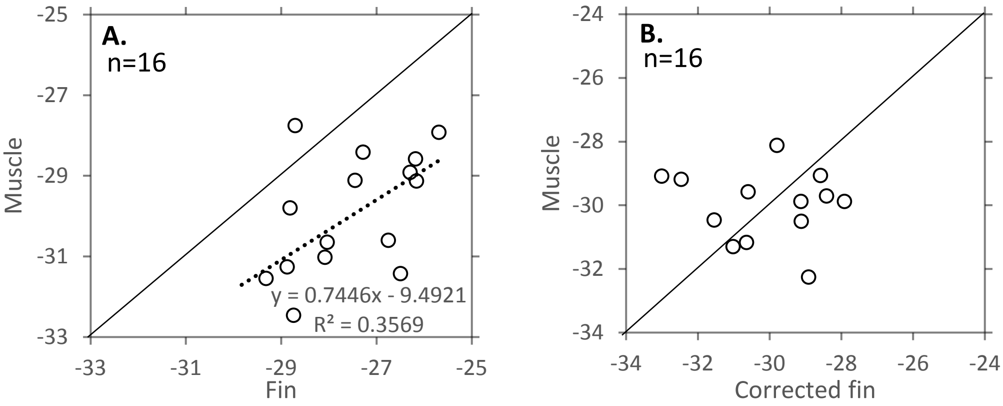


Figure 4.9: A. Shortfin untreated muscle vs. untreated fin δ^{13}C values, with regression equation attached. **B.** Untreated muscle vs. mathematically corrected untreated muscle. Samples retrieved from Lake Rotokare on 20 Dec, 2017. The line represents the 1:1 ratio between X and Y values.

Once converted, the next step is to convert untreated muscle (in this case mathematically corrected untreated values) into treated muscle values. This is achieved by applying the following correction (Figure 4.10A) to correct the values to closer to the 1:1 ratio (Figure 4.10B).

$$\delta^{13}\text{C treated muscle} = 0.8471 \cdot (\delta^{13}\text{C untreated muscle}) - 3.4733$$

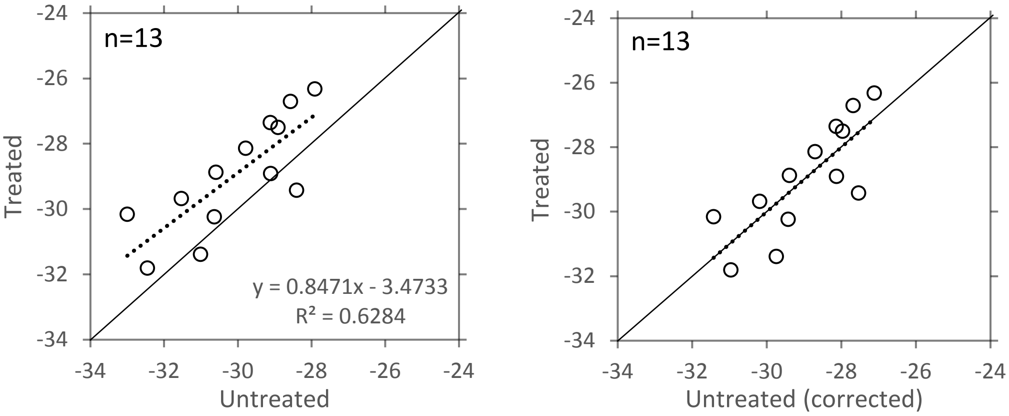


Figure 4.10: A. Shortfin treated muscle vs. untreated muscle (mathematically corrected) δ^{13}C values, with regression equation attached. **B.** Treated muscle vs. mathematically corrected treated muscle. Samples retrieved from Lake Rotokare on 20 Dec, 2017. The line represents the 1:1 ratio between X and Y values.

The final equation converting $\delta^{13}C$ untreated fin directly into treated muscle is as follows:

$$\delta^{13}C \text{ treated muscle} = 0.8471 \cdot (\delta^{13}C \text{ untreated fin } -2.425) - 3.4733$$

4.3.6 Stable isotope analysis

In total, 4 banded kokopu, 2 charophytes, 4 chironomid samples, 6 dragonfly nymphs, 2 *Lagarosiphon major*, 25 longfin eels, 37 perch, 3 phytoplankton samples, 2 Potamogeton, 2 sediment samples, 34 shortfin eels, 3 snails, and 6 zooplankton samples were used for isotopic analysis. Potamogeton, a plant species appeared to be heavily depleted, with average values of $\delta^{13}C$; -42.15±0.02, and $\delta^{15}N$; -2.41±0.02 (± values represent 1SE, $P < 0.05$). Oxygen weed and charophytes were much more enriched in $\delta^{13}C$ with average values of -28.65±1.02 and -25.56±0.23 respectively. Both were nitrogen depleted, however charophytes appear to be the most nitrogen depleted plant species of the three, with an average $\delta^{15}N$ value of -4.71. All three species appear to be disassociated with the food web, also winter phytoplankton appear to be detached from the food web, showing carbon depletion compared to summer samples. Phytoplankton had a winter $\delta^{13}C$ value of -38.21 (single sample collected), and a $\delta^{15}N$ value of -0.61. Zooplankton collected during the same season showed a similar trend, with a winter average $\delta^{13}C$ value of -39.31±1.74, although $\delta^{15}N$ did not appear different between winter (4.51±0.96) and summer (5.10±0.54). The rest of the food web appeared closely tied together, with all other isotope values falling closely within each other (Figure 4.11).

4.3.7 Adjusted trophic consumer chain results

Perch showed three successive trophic shifts, with juvenile perch (80-100g) having an average $\delta^{15}N$ value of 7.07±0.05, and a $\delta^{13}C$ value of -27.06. Perch between 100-407g were close to 1 $\delta^{15}N$ unit above their juvenile counterparts, with a $\delta^{15}N$ value of 7.95±0.19, $\delta^{13}C$ remained similar however, with a slight decrease; -27.38±0.41. A singular perch was caught much larger than the other fish, therefore it was included into the food web, it did show a 1.2 increase in $\delta^{15}N$ ($\delta^{15}N = 9.15$). It also was enriched in carbon compared to its smaller counterparts ($\delta^{13}C = -26.45$). Shortfin and longfin eels were originally uncorrected fin tissue isotopic values. However, these values have been corrected to treated muscle tissue values for $\delta^{13}C$ and $\delta^{15}N$ using the equations created in this study. Longfin eels and large shortfin eels had similar values in both $\delta^{13}C$ and $\delta^{15}N$. Shortfin heavier than 800g had $\delta^{15}N$ values of 8.73±0.10, longfin were almost identical, with $\delta^{15}N$ =8.64±0.08. Smaller shortfin showed a difference in $\delta^{15}N$ enrichment, with a $\delta^{15}N$ value of 7.98±0.10. $\delta^{13}C$ values remained similar between all three groupings, with $\delta^{13}C$ equalling -27.74±0.50, -27.35±0.12, and -28.19±0.33 respectively.

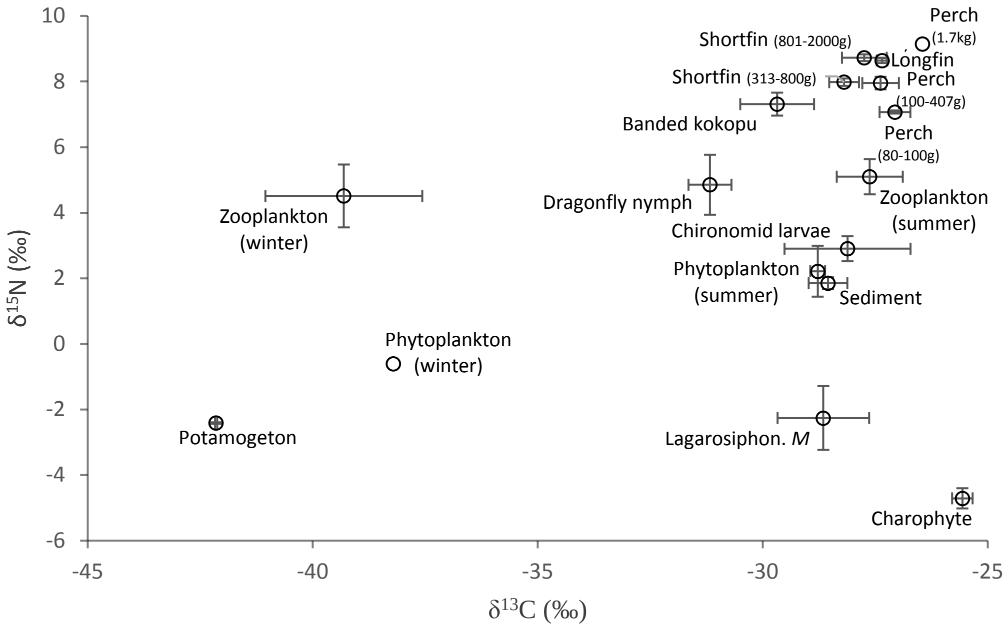


Figure 4.11: Stable isotope food web analysis of Lake Rotokare examining $\delta^{13}C$ and $\delta^{15}N$. Values represent the mean data point of each species, and error bars represent 1SE from the mean. Isotopes were collected between Feb-Dec, 2017.

Using the stable isotope baseline values, it was determined the best model would have three end members; chironomid larvae, dragonfly nymphs and juvenile perch (80-100 g). Using the meta-analysis from McCutchan et al., (2003), and their correction model of $\Delta\delta^{13}C = 0.4‰$ and $\Delta\delta^{15}N = 2.3‰$, the stable isotope data was readjusted to determine the viability of each member in the food web. Figure 4.12 shows the three end-member polygon; trophically adjusted values for shortfin eels, longfin eels, banded kokopu, 100-400 g perch and snails fell within the polygon. There were two exceptions to this however, with zooplankton falling just outside of the polygon, but the error bars correct for both C and N and therefore, can be considered within the food chain. The large perch also fell outside of the model, the $\delta^{15}N$ value was lower than the juvenile perch $\delta^{15}N$ once corrected (6.85 vs. 7.07), however the $\delta^{13}C$ corrected value of -26.85‰ remained within acceptable parameters.

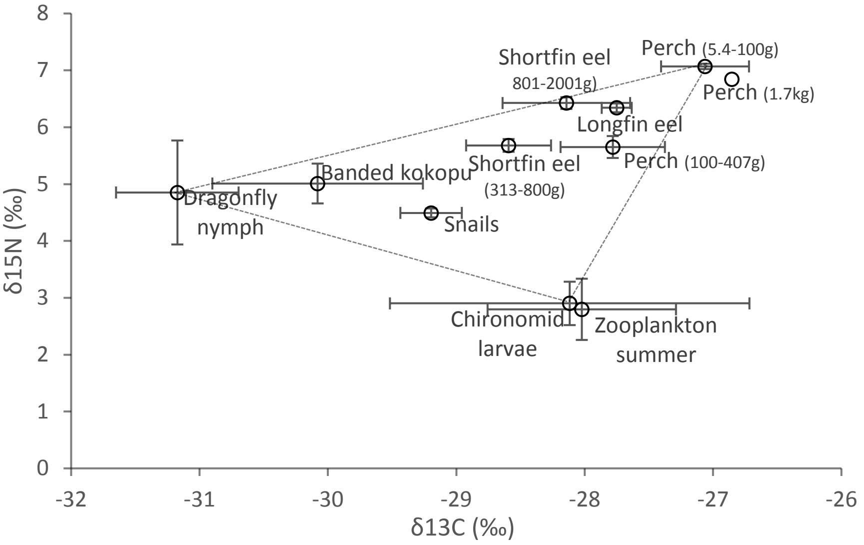


Figure 4.12: Adjusted trophic consumer model of various species within Lake Rotokare. Each species has been corrected in $\delta^{13}C$ and $\delta^{15}N$ values according to McCutchan et al. (2003)'s guidelines.

4.4 Discussion:

4.4.1 Stability of diet:

Isotope ratios of C, N, for consumers may change gradually in response to changes in diet. Fry & Arnold (1982) found that shrimp approached isotopic equilibrium with a new diet only after their mass had quadrupled. Rate of turnover for some tissues has been found to be very slow (MacNeil et al., 2006). Estimates of trophic shift from diet-switching may be influenced by the isotope ratio of the initial diet even after a consumer has been maintained for a long period of time on the same diet (McCutchan et al., 2003). However, in context to Lake Rotokare it appears that the dietary uptake of perch remains stable year round with evidence from both stable isotopes and stomach contents that chironomid larvae and zooplankton are the primary nutritional food source of the perch within the lake. The isotopic values of the lake food web show both food items well within the bounds of the perch's potential diet. Applying the corrections of De Niro & Epstein (1978, 1981) of 3‰

for $\delta^{15}N$; 1‰ for $\delta^{13}C$, and McCutchan et al., (2003) of 2.4‰ for $\delta^{15}N$; 0.4‰ for $\delta^{13}C$ zooplankton with an average $\delta^{15}N$ of 5.10 falls well within trophic shift correction limits for both juvenile and adult perch (average: 7.07 and 7.95 respectively). Chironomid values fall outside of the limits, with an average $\delta^{15}N$ of 2.98, however there does exist a high level of variation in chironomid $\delta^{15}N$, with a 1.21‰ ± 95% confidence interval limit, suggesting that there may be variation between seasons, possibly attributing to a low $\delta^{15}N$ average. Grey et al. (2004) studied the variability of chironomid larvae $\delta^{13}C$ and $\delta^{15}N$ values in lakes, and found a high level of intraspecific variation within chironomid populations ($\delta^{13}C$ range: 35‰; $\delta^{15}N$ range: 16‰), suggesting that this study failed to incorporate enough samples to effectively account for the variation.

Zooplankton and phytoplankton showed significant variation in isotopic values between seasons. Winter zooplankton and phytoplankton were significantly different in $\delta^{13}C$ values. Winter isotope values showed an average -10‰ shift in zooplankton, and -12‰ shift in phytoplankton. Zohary et al., (1994) exhibited modest shifts in $\delta^{13}C$ values between summer and winter, and large shifts in $\delta^{13}C$ for zooplankton, with significant $\delta^{13}C$ depletion in winter, contributing the differences in phytoplankton to a reduction in DIC and photosynthetic isotope fractionation. Vuorio et al. (2006) studied multiple lakes and found a similar seasonal pattern in a wide range of phytoplankton species. Grey et al. (2001) found seasonal variation of zooplankton $\delta^{13}C$, attributing these seasonal shifts as a dietary switch from a reliance on allochthonous carbon from POM during winter and early spring, to heavy dependence on algal production during summer.

The difference in shortfin eel isotopic data between the 313-800 g class, and the 801-2001g is likely due to a transitional shift in diet from juveniles being primarily insectivores up until 700 mm, where they become primarily piscivorous (Jellyman, 1997), longfin eel's exhibit diet shifts at 400 mm, with the smallest individual sampled for isotope analysis above the transition length (474 mm). This could also be attributed to ectothermic organism's life history traits; isotopic change is generally attributed to growth rather than metabolism (Logan et al., 2008). It does appear that the lakes food web is relatively small, with a low diversity of members (n = 8 different members).

McCutchan et al. (2003) investigated the uncertainties in isotopic variation between samples and individuals, and concluded much of the variation in trophic shift can be explained by differences in diet or method of sample preparation. They found that the best estimate of $\Delta\delta^{13}C$ for consumers analysed whole is +0.3±0.14‰; for consumers analysed as muscle tissue, the best estimate is +1.3±0.30‰. $\delta^{15}N$ was found to be significantly lower for consumers raised on invertebrate diets (+1.4±0.20‰) than for those raised on other high-protein diets; +3.3±0.26‰. This may account for eel values, and for the large $\delta^{15}N$ value exhibited by perch; each species would be feeding primarily off perch, and therefore requiring a larger trophic shift to equalize nitrogen values with their likely dietary source; juvenile perch.

4.4.2 Fin vs muscle tissue:

Similar heterogeneity exists among tissue types within a single organism (McConnaughey & McRoy 1979; Hobson & Clark 1992; Sweeting et al., 2006). Considerable bias in analyses based on $\delta^{13}C$ could be introduced by the combination of both relatively large differences in $\delta^{13}C$ between lipids and other tissue types and by the considerable heterogeneity in lipid content among samples (McCutchan et al., 2003; Post et al., 2007). This study found that both muscle and fin tissue were homogenous in $\delta^{15}N$ values for longfin eels, and homogenous for shortfin eels with $\delta^{15}N$ values above 8‰. Both species exhibit variation in fin-muscle values below this threshold, most likely due once again to the shift in dietary behaviour that eels undertake, with both species likely feeding almost exclusively on perch once shifting to piscivory. The effect of growth rate on isotope ratios may also explain this, as juvenile growth rates are much greater than individuals smaller than 30 cm, with growth rates typically slowing down to 2–3 cm per year and linear, with females generally growing faster than males (Jellyman, 1977). This may also be attributed to the quality of dietary sources between size classes. Webb et al. (1998) and Adams & Sterner (2000) both concluded that the high trophic shift for N associated with diets of low quality (i.e. very low protein content) may have resulted from internal recycling of N, which occurs in starving animals. Thus, it is possible that $\Delta\delta^{15}N$ is high when dietary N either exceeds or is well below requirements for optimal growth, and that $\Delta\delta^{15}N$ is low when dietary N is near the requirements for optimal growth (McCutchan et al., 2003). With a decrease in growth rates in larger eels, that would act as a stabilizing factor for $\delta^{15}N$ values, which both species show.

This study did manage to achieve correction equations between muscle and fin tissue values, allowing for future study on eels within the lake to rely on fin tissue alone. However, both fin and muscle tissue values should be used in conjunction, as previously mentioned different tissue types have different isotopic turnover rates, and reliance on a single tissue type may miss any shifts in isotopic values the eels are undergoing. MacNeil et al. (2006) suggest that multi-tissue sampling can overcome problems associated with muscle tissue sampling alone, and lead to a more robust evaluation of trophic dynamics for individual species. Sanderson et al. (2009) also caution the use of fin tissue isotope values, as fin clips is not a viable option for smaller fish (< 50 mm) because the majority of the caudal fin is necessary for analysis. This analysis was based around salmon, and these species are reliant on caudal fins to stabilize movement, whereas eels have much different body forms, possibly rendering this recommendation invalid. With a population of endangered species such as longfin eels, it is highly recommended to use non-lethal sampling techniques to offset mortality.

4.5 Conclusion:

Stable isotopes are excellent tools for the study of trophic relationships in aquatic ecosystems. While it is highly probable that not all links in the mid-level trophic region were assessed here in this study, it remains clear that there exists a three-way split in basal resources between larger consumers; large perch, large shortfin and longfin eels. Isotope and stomach content results also show the importance of both chironomid and zooplankton contributions to the food web. It also appears that juvenile perch are acting as a large food source for the eel populations within the lake. Given the fact that perch are an invasive species this is interesting as it is hard to determine whether the introduction of the perch was a positive factor for eels or not. This study also highlights the need for lipid correction in stable isotope studies for large aquatic vertebrates, with both shortfin and longfin requiring lipid correction for homogenous $\delta^{13}C$ values. While these correction values are not applicable to other locations around the country, it does show that establishing mathematical equations can save unnecessary euthanisation of subjects. This is particularly useful when dealing with species like longfin eels, where the species is in an overall decline, and populations are often present in small quantities. The lake appears to have a stable food web, with seasonal differences coming from variation in $\delta^{13}C$ and $\delta^{15}N$ values within species due to physiological factors, rather than dietary shifts.

4.6 References:

Adams, T. S., & Sterner, R. W. (2000). The effect of dietary nitrogen content on trophic level ^{15}N enrichment. *Limnology and Oceanography*, *45*(3), pp: 601-607.

Arrington, D. A., Davidson, B. K., Winemiller, K. O., & Layman, C. A. (2006). Influence of life history and seasonal hydrology on lipid storage in three neotropical fish species. *Journal of Fish Biology*, 68(5), pp: 1347-1361.

Beaudoin, C. P., Prepas, E. E., Tonn, W. M., Wassenaar, L. I., & Kotak, B. G. (2001). A stable carbon and nitrogen isotope study of lake food webs in Canada’s Boreal Plain. *Freshwater Biology*, 46(4), pp: 465-477.

DeNiro, M. J., & Epstein, S. (1978). Influence of diet on the distribution of carbon isotopes in animals. *Geochimica et cosmochimica acta*, 42(5), pp: pp: 495-506.

DeNiro, M. J., & Epstein, S. (1981). Influence of diet on the distribution of nitrogen isotopes in animals. *Geochimica et cosmochimica acta*, 45(3), pp: 341-351.

Focken, U., & Becker, K. (1998). Metabolic fractionation of stable carbon isotopes: implications of different proximate compositions for studies of the aquatic food webs using δ^{13}C data. *Oecologia*, 115(3), pp: 337-343.

Fry, B., & Arnold, C. (1982). Rapid 13 C/12 C turnover during growth of brown shrimp (*Penaeus aztecus*). *Oecologia*, 54(2), pp: 200-204.

Gannes, L. Z., O’Brien, D. M., & Del Rio, C. M. (1997). Stable isotopes in animal ecology: assumptions, caveats, and a call for more laboratory experiments. *Ecology*, 78(4), pp: 1271-1276.

Gasser, M., Kaiser, M., Berrigan, D., & Stearns, S. C. (2000). Life-history correlates of evolution under high and low adult mortality. *Evolution*, 54(4), pp: 1260-1272.

Grey, J., Jones, R. I., & Sleep, D. (2001). Seasonal changes in the importance of the source of organic matter to the diet of zooplankton in Loch Ness, as indicated by stable isotope analysis. *Limnology and Oceanography*, 46(3), pp: 505-513.

Grey, J., Kelly, A., & Jones, R. I. (2004). High intraspecific variability in carbon and nitrogen stable isotope ratios of lake chironomid larvae. *Limnology and Oceanography*, 49(1), pp: 239-244.

Hanisch, J. R., Tonn, W. M., Paszkowski, C. A., & Scrimgeour, G. J. (2010). δ^{13}C and δ^{15}N signatures in muscle and fin tissues: nonlethal sampling methods for stable isotope analysis of salmonids. *North American Journal of Fisheries Management,* 30(1), pp: 1-11.

Hesslein, R. H., Hallard, K. A., & Ramlal, P. (1993). Replacement of sulfur, carbon, and nitrogen in tissue of growing broad whitefish (*Coregonus nasus*) in response to a change in diet traced by δ^{34}S, δ^{13}C, and δ^{15}N. *Canadian Journal of Fisheries and Aquatic Sciences*, 50(10), pp: 2071-2076.

Hicks, B. J. (1997). Food webs in forest and pasture streams in the Waikato region, New Zealand: a study based on analyses of stable isotopes of carbon and nitrogen, and fish gut contents. *New Zealand Journal of Marine and Freshwater Research*, 31(5), pp: 651-664.

Hicks, B. J., Hamilton, D. P., Ling, N., & Wood, S. A. (2007). Top down or bottom up? Feasibility of water clarity restoration in the lower Karori Reservoir by fish removal.

Hobson, K. A., & Clark, R. G. (1992). Assessing avian diets using stable isotopes II: factors influencing diet-tissue fractionation. *Condor,* pp: 189-197.

Jackson, M. C., Donohue, I., Jackson, A. L., Britton, J. R., Harper, D. M., & Grey, J. (2012). Population-level metrics of trophic structure based on stable isotopes and their application to invasion ecology. *PloS one*, 7(2), e31757.

Jardine, T. D., Hunt, R. J., Pusey, B. J., & Bunn, S. E. (2011). A non-lethal sampling method for stable carbon and nitrogen isotope studies of tropical fishes. *Marine and Freshwater Research,* 62(1), pp: 83-90.

Jellyman, D. J. (1989). Diet of two species of freshwater eel (*Anguilla* spp.) in Lake Pounui, New Zealand. *New Zealand journal of marine and freshwater research*, 23(1), pp; 1-10.

Jellyman, D. J. (1997). Variability in growth rates of freshwater eels (*Anguilla* spp.) in New Zealand. *Ecology of Freshwater Fish*, 6(2), pp: 108-115.

Kelly, M. H., Hagar, W. G., Jardine, T. D., & Cunjak, R. A. (2006). Nonlethal sampling of sunfish and slimy sculpin for stable isotope analysis: how scale and fin tissue compare with muscle tissue. *North American Journal of Fisheries Management*, 26(4), pp: 921-925.

Logan, J. M., & Lutcavage, M. E. (2008). A comparison of carbon and nitrogen stable isotope ratios of fish tissues following lipid extractions with non-polar and traditional chloroform/methanol solvent systems. *Rapid Communications in Mass Spectrometry*, 22(7), pp: 1081-1086.

MacNeil, M. A., Drouillard, K. G., & Fisk, A. T. (2006). Variable uptake and elimination of stable nitrogen isotopes between tissues in fish. *Canadian Journal of Fisheries and Aquatic Sciences*, 63(2), pp: 345-353.

McConnaughey, T., & McRoy, C. P. (1979). Food-web structure and the fractionation of carbon isotopes in the Bering Sea. *Marine Biology*, *53*(3), 257-262.

McCutchan, J. H., Lewis, W. M., Kendall, C., & McGrath, C. C. (2003). Variation in trophic shift for stable isotope ratios of carbon, nitrogen, and sulfur. *Oikos*, 102(2), pp: 378-390.

Minagawa, M., & Wada, E. (1984). Stepwise enrichment of ^{15}N along food chains: further evidence and the relation between δ^{15}N and animal age. *Geochimica et cosmochimica acta*, 48(5), pp: 1135-1140.

O'reilly, C. M., Hecky, R. E., Cohen, A. S., & Plisnier, P. D. (2002). Interpreting stable isotopes in food webs: recognizing the role of time averaging at different trophic levels. *Limnology and oceanography*, *47*(1), 306-309.

Parnell, A. C., Inger, R., Bearhop, S., & Jackson, A. L. (2010). Source partitioning using stable isotopes: coping with too much variation. *PloS one*, 5(3), e9672.

Peterson, B. J., & Howarth, R. W. (1987). Sulfur, carbon, and nitrogen isotopes used to trace organic matter flow in the salt-marsh estuaries of Sapelo Island, Georgia. *Limnology and Oceanography*, 32(6), pp: 1195-1213.

Pingram, M. A., Collier, K. J., Hamilton, D. P., Hicks, B. J., & David, B. O. (2014). Spatial and temporal patterns of carbon flow in a temperate, large river food web. *Hydrobiologia*, 729(1), pp: 107-131.

Pinnegar, J. K., & Polunin, N. V. C. (1999). Differential fractionation of δ^{13}C and δ^{15}N among fish tissues: implications for the study of trophic interactions. *Functional ecology,* 13(2), pp; 225-231.

Post, J. R., & Parkinson, E. A. (2001). Energy allocation strategy in young fish: allometry and survival. *Ecology*, 82(4), pp: 1040-1051.

Post, D. M., Layman, C. A., Arrington, D. A., Takimoto, G., Quattrochi, J., & Montana, C. G. (2007). Getting to the fat of the matter: models, methods and assumptions for dealing with lipids in stable isotope analyses. *Oecologia*, 152(1), pp: 179-189.

Sanderson, B. L., Tran, C. D., Coe, H. J., Pelekis, V., Steel, E. A., & Reichert, W. L. (2009). Nonlethal sampling of fish caudal fins yields valuable stable isotope data for threatened and endangered fishes. *Transactions of the American Fisheries Society*, 138(5), pp: 1166-1177.

Schultz, E. T., & Conover, D. O. (1997). Latitudinal differences in somatic energy storage: adaptive responses to seasonality in an estuarine fish (*Atherinidae: Menidia menidia*). *Oecologia*, 109(4), pp: 516-529.

Sheppard, S. K., & Harwood, J. D. (2005). Advances in molecular ecology: tracking trophic links through predator–prey food-webs. *Functional Ecology*, 19(5), pp: 751-762.

Smyntek, P. M., Teece, M. A., Schulz, K. L., & Thackeray, S. J. (2007). A standard protocol for stable isotope analysis of zooplankton in aquatic food web research using mass balance correction models. *Limnology and Oceanography*, 52(5), pp: 2135-2146.

Sunderland, K. D. (1988). Quantitative methods for detecting invertebrate predation occurring in the field. *Annals of Applied Biology*, 112(1), pp: 201-224.

Sweeting, C. J., Barry, J. T., Polunin, N. V. C., & Jennings, S. (2007). Effects of body size and environment on diet-tissue δ^{13}C fractionation in fishes. *Journal of Experimental Marine Biology and Ecology*, 352(1), pp: 165-176.

Vuorio, K., Meili, M., & Sarvala, J. (2006). Taxon-specific variation in the stable isotopic signatures (δ^{13}C and δ^{15}N) of lake phytoplankton. *Freshwater Biology*, 51(5), pp: 807-822.

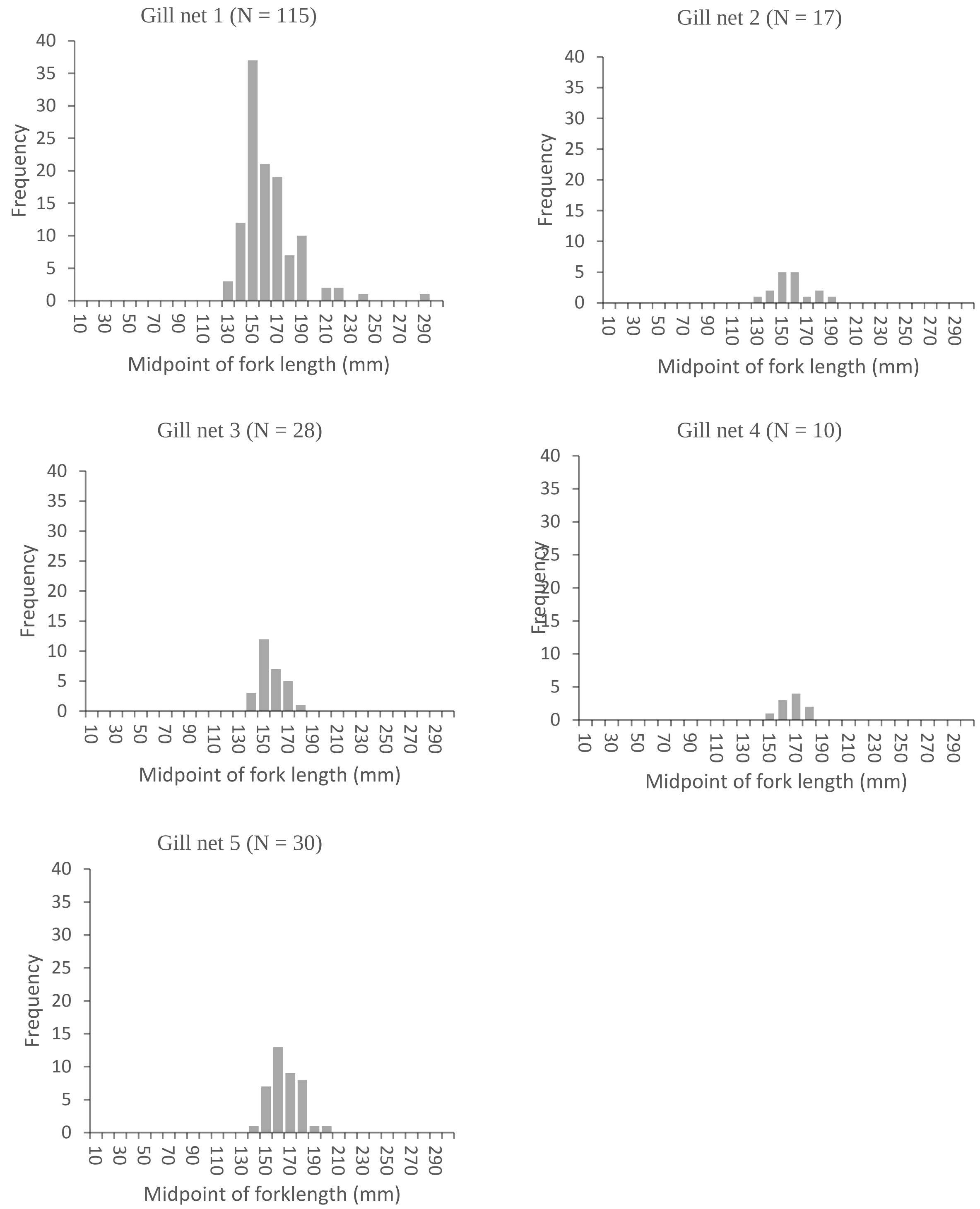
Vander Zanden, M. J., Casselman, J. M., & Rasmussen, J. B. (1999). Stable isotope evidence for the food web consequences of species invasions in lakes. *Nature*, *401*(6752), 464.

Webb, S. C., Hedges, R. E., & Simpson, S. J. (1998). Diet quality influences the $\delta^{13}C$ and $\delta^{15}N$ of locusts and their biochemical components. *Journal of Experimental Biology*, 201(20), pp: 2903-2911.

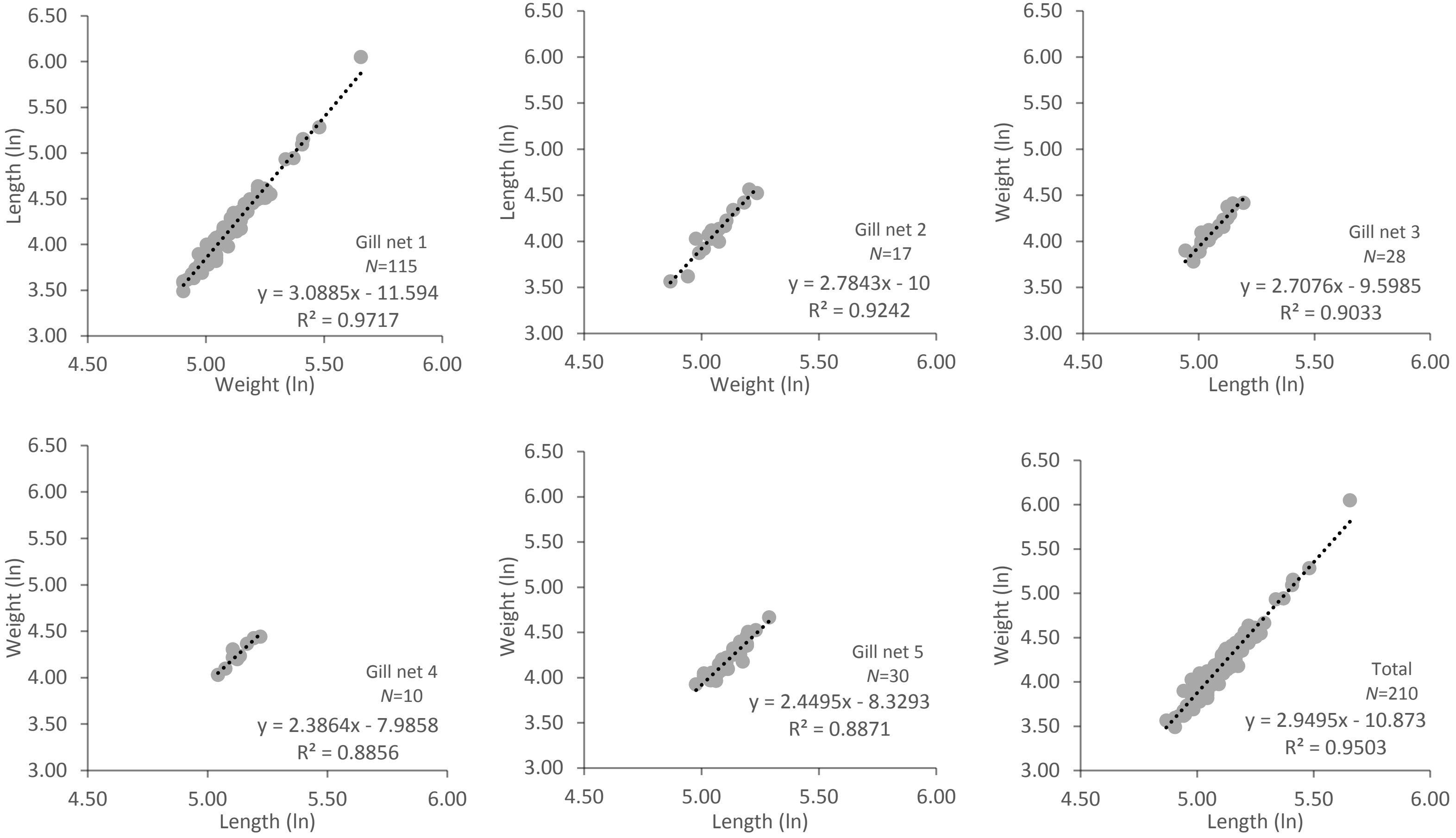
Willis, T. J., Sweeting, C. J., Bury, S. J., Handley, S. J., Brown, J. C., Freeman, D. J., & Page, M. J. (2013). Matching and mismatching stable isotope ($\delta^{13}C$ and $\delta^{15}N$) ratios in fin and muscle tissue among fish species: a critical review. *Marine biology*, 160(7), pp: 1633-1644.

Zohary, T., Erez, J., Gophen, M., Berman-Frank, I., & Stiller, M. (1994). Seasonality of stable carbon isotopes within the pelagic food web of Lake Kinneret. *Limnology and Oceanography*, *39*(5), 1030-1043.

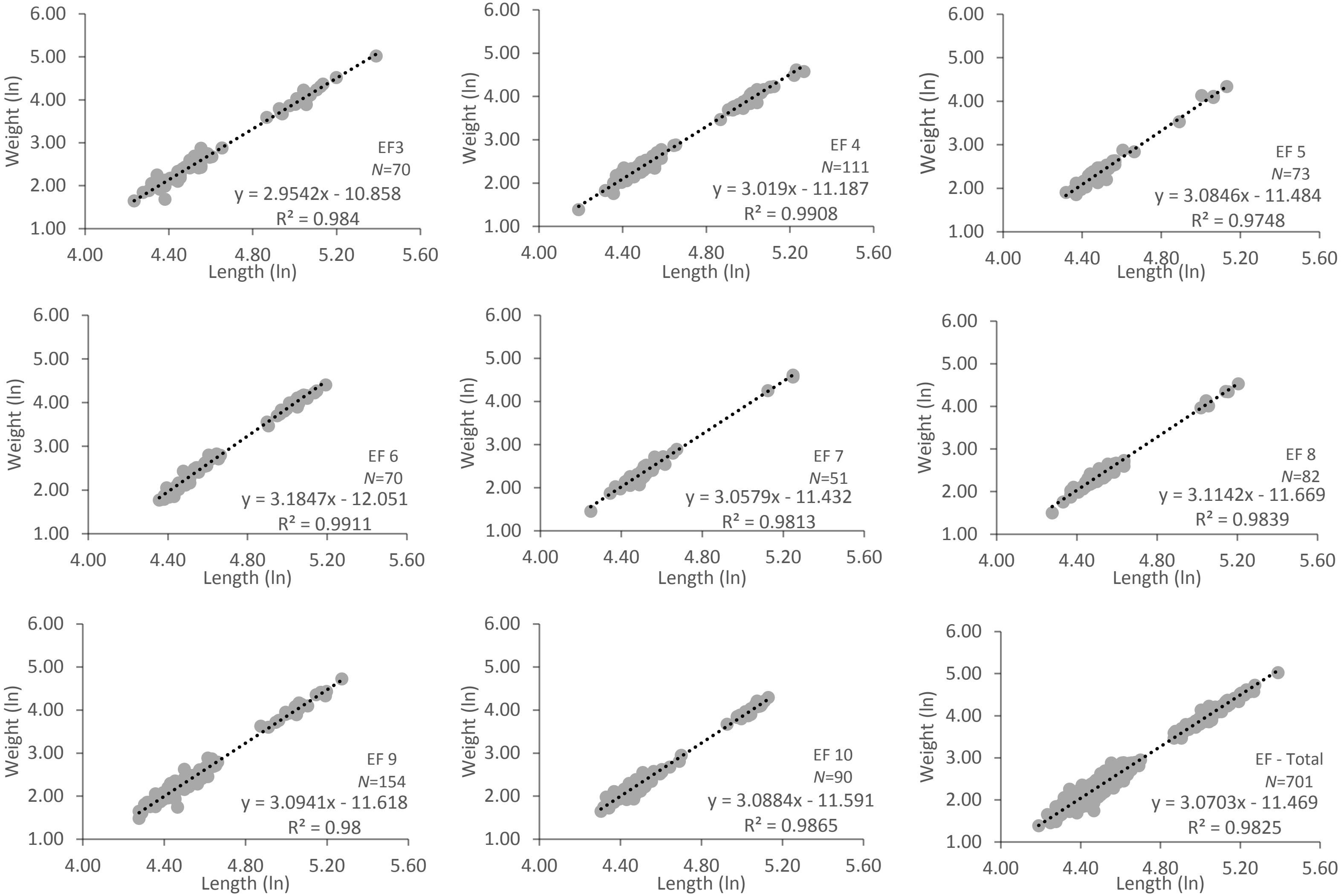
Appendix 1:



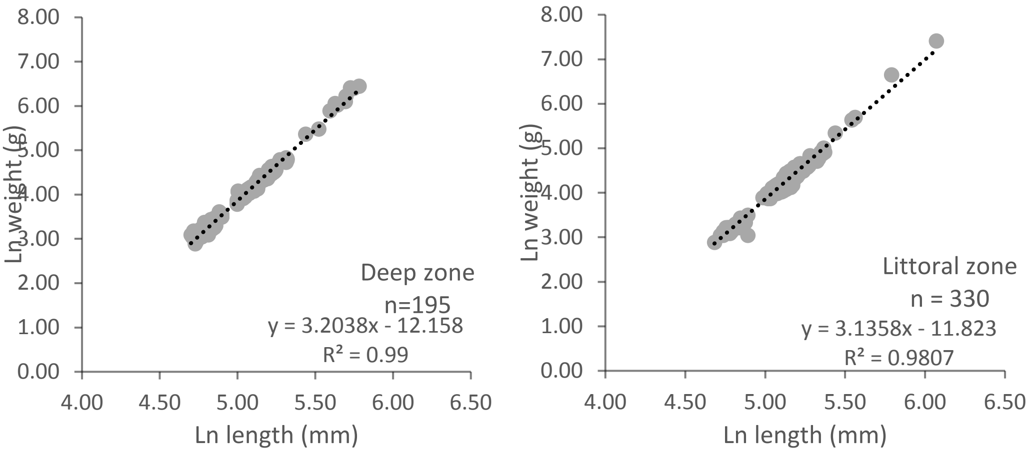
Appendix 1; Figure 1: Length-frequency distribution of perch caught using gill nets in Lake Rotokare () caught on the 21 Feb 2017.



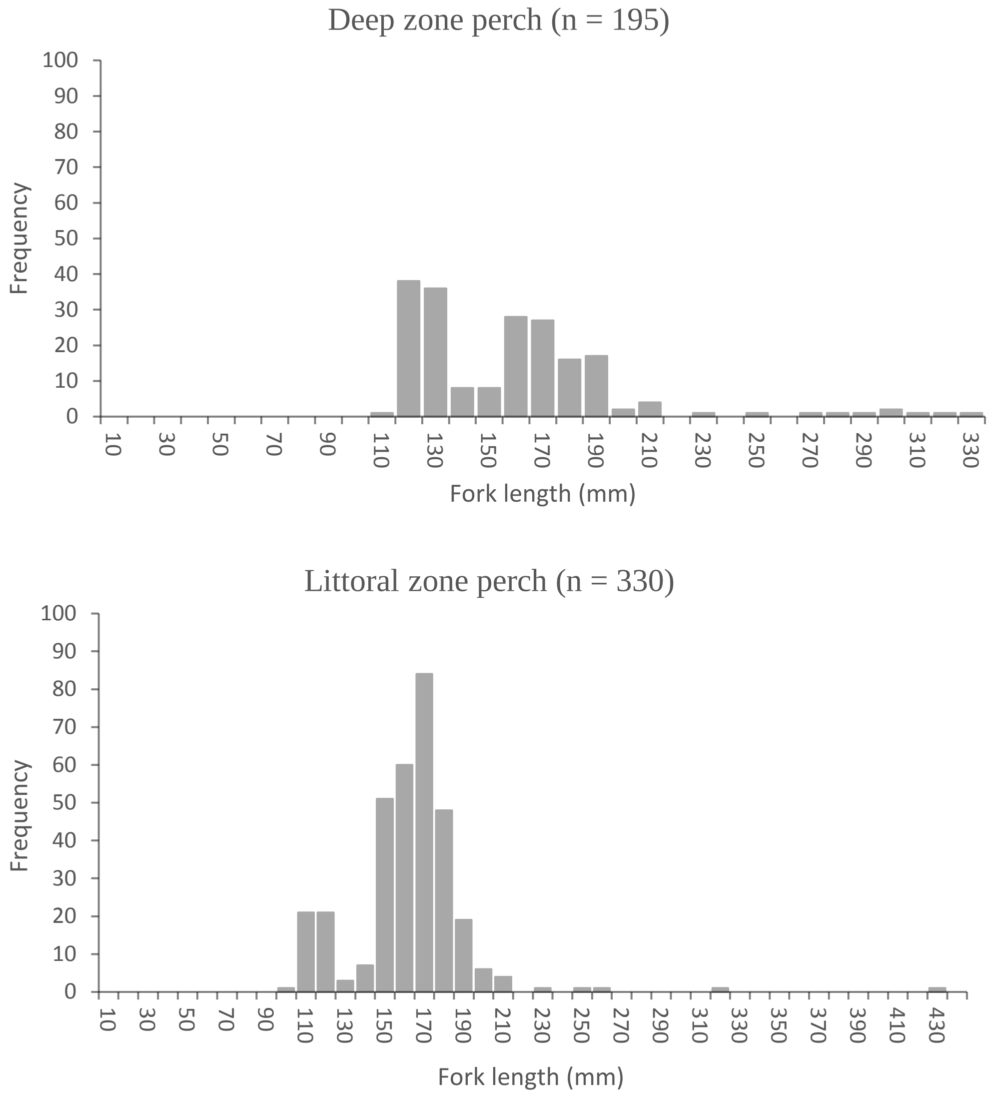
Appendix 1; Figure 2: Site by site length/weight relationships of perch caught by gill netting in Lake Rotokare on 21 Feb 2017.



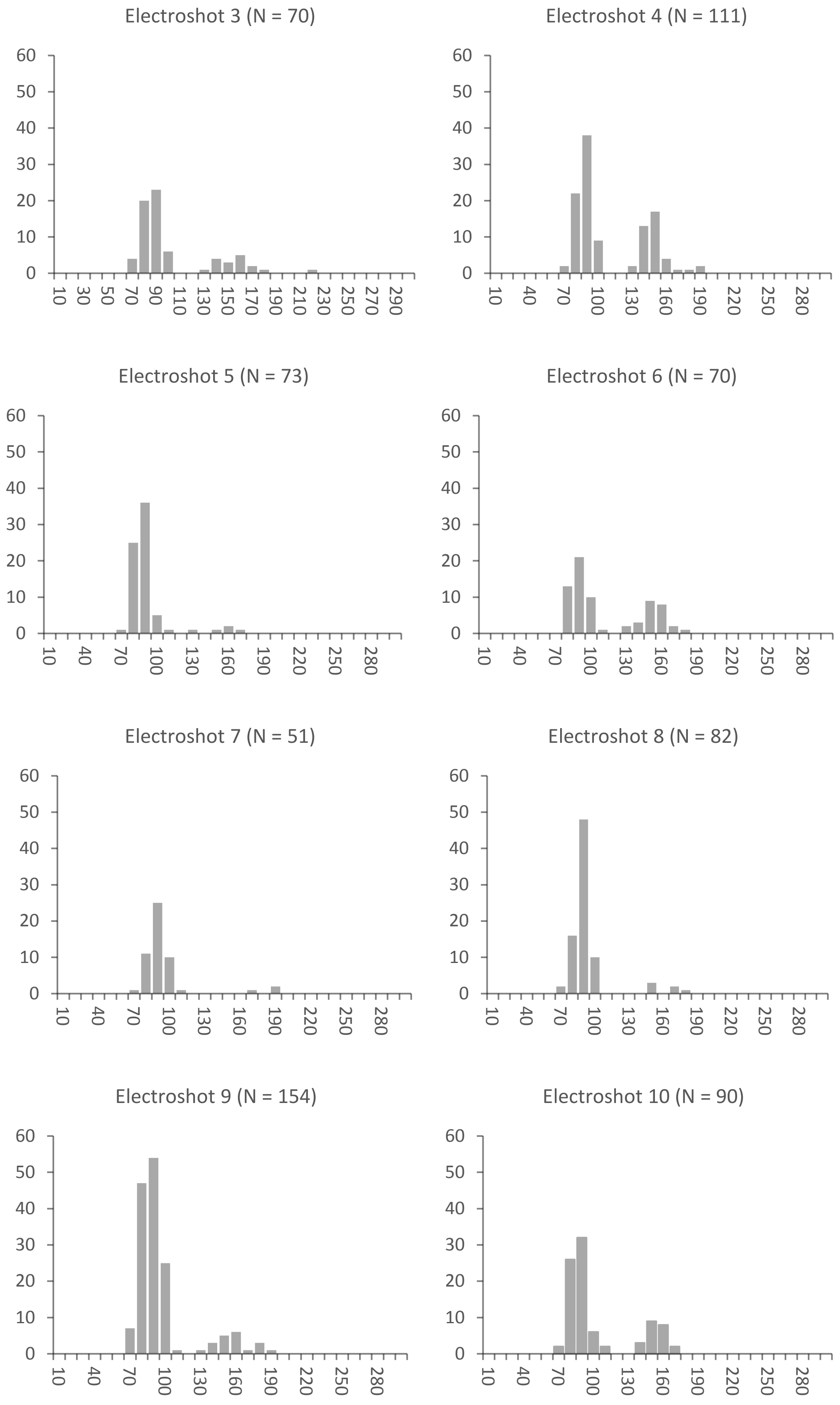
Appendix 1; Figure 3: Site-by-site length/weight relationships of perch caught by boat electrofishing in Lake Rotokare on 21-22 Feb 2017.



Appendix 1; Figure 4: Weight-length relationships of perch sampled from gill netting undertaken on the 7-8 Jun 2017.



Appendix 1; Figure 5: Length-frequency distribution of perch caught by gill netting on 7-8 Jun 2017.



Appendix 1; Figure 6: Length-frequency distribution of perch caught boat electrofishing in Lake Rotokare (see figure 1 for sample locations) caught on 21-22 Feb 2017.

Appendix 1: Results from the fish sampling in Lake Rotokare between 9 February and 23 February 2017.

Date	Fishing_type	Fishing_type_mesh	Phase	Net_shot_number	Net_mesh_mm	Species	Count_of_fish	Length_mm	Weight_g	Mark_recapture	ln_len	ln_weight	order
9-Feb-17	Fyke net	Fyke net	Marking	1	3	Perch	1		55	unmarked		4.01	1
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	240	197	unmarked	5.48	5.28	1
9-Feb-17	Fyke net	Fyke net	Marking	2	3	Longfin eel	1	688.58	1020	unmarked	6.53	6.93	2
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	286	423.8	unmarked	5.66	6.05	2
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	195	94.6	unmarked	5.27	4.55	3
9-Feb-17	Fyke net	Fyke net	Marking	2	3	Shortfin eel	5		3761	unmarked			3
9-Feb-17	Fyke net	Fyke net	Marking	2	3	Perch	20			unmarked			4
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	208	138.7	unmarked	5.34	4.93	4
9-Feb-17	Fyke net	Fyke net	Marking	2	3	Perch	1		35	unmarked		3.56	5
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	190	90.9	unmarked	5.25	4.51	5
9-Feb-17	Fyke net	Fyke net	Marking	3	3	Longfin eel	1	626.12	744	unmarked	6.44	6.61	6
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	190	100.7	unmarked	5.25	4.61	6
9-Feb-17	Fyke net	Fyke net	Marking	3	3	Perch	7			unmarked			7
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	224	172.9	unmarked	5.41	5.15	7
9-Feb-17	Fyke net	Fyke net	Marking	4	3	Longfin eel	1	1000	3870	unmarked	6.91	8.26	8
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	215	140.5	unmarked	5.37	4.95	8
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	223	162.9	unmarked	5.41	5.09	9
9-Feb-17	Fyke net	Fyke net	Marking	6	3	Shortfin eel	8		3430	unmarked			9
9-Feb-17	Fyke net	Fyke net	Marking	6	3	Longfin eel	2		8400	unmarked			10
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	185	98.3	unmarked	5.22	4.59	10
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	185	100	unmarked	5.22	4.61	11
9-Feb-17	Fyke net	Fyke net	Marking	7	3	Shortfin eel	3		1084	unmarked			11
9-Feb-17	Fyke net	Fyke net	Marking	7	3	Perch	2			unmarked			12
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	187	90.7	unmarked	5.23	4.51	12

21-Feb-17	Gill net	Count	NA	1	18	Perch	1	174	75.5	unmarked	5.16	4.32	13
9-Feb-17	Fyke net	Fyke net	Marking	8	3	Shortfin eel	4		1735	unmarked			13
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	164	61.4	unmarked	5.10	4.12	14
9-Feb-17	Fyke net	Fyke net	Marking	9	3	Shortfin eel	4		3042	unmarked			14
9-Feb-17	Fyke net	Fyke net	Marking	9	3	Longfin eel	1	538.08	450	unmarked	6.29	6.11	15
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	170	66.6	unmarked	5.14	4.20	15
9-Feb-17	Fyke net	Fyke net	Marking	10	3	Perch	18			unmarked			16
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	155	45.6	unmarked	5.04	3.82	16
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	164	67.3	unmarked	5.10	4.21	17
9-Feb-17	Fyke net	Fyke net	Marking	11	3	Shortfin eel	4		2104	unmarked			17
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	144	49.1	unmarked	4.97	3.89	18
9-Feb-17	Fyke net	Fyke net	Marking	13	3	Shortfin eel	3		4532	unmarked			18
9-Feb-17	Fyke net	Fyke net	Marking	13	3	Perch	1			unmarked			19
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	148	46.6	unmarked	5.00	3.84	19
9-Feb-17	Fyke net	Fyke net	Marking	13	3	Longfin eel	7		8932	unmarked		9.10	20
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	154	52.6	unmarked	5.04	3.96	20
9-Feb-17	Fyke net	Fyke net	Marking	14	3	Longfin eel	1	1100	5179	unmarked	7.00	8.55	21
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	141	37.8	unmarked	4.95	3.63	21
9-Feb-17	Fyke net	Fyke net	Marking	14	3	Longfin eel	1	1200	7253	unmarked	7.09	8.89	22
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	172	73.4	unmarked	5.15	4.30	22
9-Feb-17	Fyke net	Fyke net	Marking	14	3	Longfin eel	1	1009.08	3625	unmarked	6.92	8.20	23
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	155	53.4	unmarked	5.04	3.98	23
9-Feb-17	Fyke net	Fyke net	Marking	15	3	Longfin eel	10		27680	unmarked			24
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	154	52.3	unmarked	5.04	3.96	24
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	172	70.8	unmarked	5.15	4.26	25
9-Feb-17	Fyke net	Fyke net	Marking	15	3	Shortfin eel	1	715.15	800	unmarked	6.57	6.68	25

9-Feb-17	Fyke net	Fyke net	Marking	16	3	Perch	1		318	unmarked		5.76	26
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	145	43.6	unmarked	4.98	3.78	26
9-Feb-17	Fyke net	Fyke net	Marking	16	3	Perch	3			unmarked			27
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	146	43.8	unmarked	4.98	3.78	27
9-Feb-17	Fyke net	Fyke net	Marking	16	3	Perch	2			unmarked			28
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	160	61.1	unmarked	5.08	4.11	28
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	146	40.1	unmarked	4.98	3.69	29
9-Feb-17	Fyke net	Fyke net	Marking	17	3	Shortfin eel	3		2093	unmarked			29
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	155	47.1	unmarked	5.04	3.85	30
9-Feb-17	Fyke net	Fyke net	Marking	18	3	Shortfin eel	6		5790	unmarked			30
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	155	54.8	unmarked	5.04	4.00	31
9-Feb-17	Fyke net	Fyke net	Marking	19	3	Shortfin eel	1	738.33	883	unmarked	6.60	6.78	31
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	189	93.6	unmarked	5.24	4.54	32
9-Feb-17	Fyke net	Fyke net	Marking	19	3	Shortfin eel	1	679.96	687	unmarked	6.52	6.53	32
9-Feb-17	Fyke net	Fyke net	Marking	19	3	Longfin eel	9		19630	unmarked		9.88	33
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	158	57.3	unmarked	5.06	4.05	33
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	164	61.6	unmarked	5.10	4.12	34
9-Feb-17	Fyke net	Fyke net	Marking	20	3	Shortfin eel	7		3278	unmarked			34
22-Feb-17	Fyke net	Fyke net	Recapture	1	3	Perch	1	210	146	marked	5.35	4.98	35
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	169	68.7	unmarked	5.13	4.23	35
22-Feb-17	Fyke net	Fyke net	Recapture	1	3	Perch	1	170	70	unmarked	5.14	4.25	36
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	167	77.1	unmarked	5.12	4.35	36
22-Feb-17	Fyke net	Fyke net	Recapture	1	3	Perch	1	75	4	unmarked	4.32	1.39	37
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	154	57.3	unmarked	5.04	4.05	37
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	156	57.7	unmarked	5.05	4.06	38
22-Feb-17	Fyke net	Fyke net	Recapture	2	3	Shortfin eel	1	660	605	unmarked	6.49	6.41	38

21-Feb-17	Gill net	Count	NA	1	18	Perch	1	149	51.2	unmarked	5.00	3.94	39
22-Feb-17	Fyke net	Fyke net	Recapture	2	3	Shortfin eel	1	805	1178	unmarked	6.69	7.07	39
22-Feb-17	Fyke net	Fyke net	Recapture	2	3	Longfin eel	1	970	3234	unmarked	6.88	8.08	40
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	150	47.7	unmarked	5.01	3.86	40
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	153	49.6	unmarked	5.03	3.90	41
22-Feb-17	Fyke net	Fyke net	Recapture	2	3	Shortfin eel	1	670	729	unmarked	6.51	6.59	41
22-Feb-17	Fyke net	Fyke net	Recapture	2	3	Longfin eel	1	760	1380	unmarked	6.63	7.23	42
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	172	78.7	unmarked	5.15	4.37	42
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	151	51.4	unmarked	5.02	3.94	43
22-Feb-17	Fyke net	Fyke net	Recapture	2	3	Shortfin eel	1	445	136.2	unmarked	6.10	4.91	43
22-Feb-17	Fyke net	Fyke net	Recapture	2	3	Longfin eel	1	520	352	unmarked	6.25	5.86	44
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	159	59.5	unmarked	5.07	4.09	44
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	135	36.4	unmarked	4.91	3.59	45
22-Feb-17	Fyke net	Fyke net	Recapture	2	3	Shortfin eel	1	440	145	unmarked	6.09	4.98	45
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	154	56.2	unmarked	5.04	4.03	46
22-Feb-17	Fyke net	Fyke net	Recapture	2	3	Shortfin eel	1	620	539	unmarked	6.43	6.29	46
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	145	42.9	unmarked	4.98	3.76	47
22-Feb-17	Fyke net	Fyke net	Recapture	4	3	Shortfin eel	1	600	510	unmarked	6.40	6.23	47
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	172	74.4	unmarked	5.15	4.31	48
22-Feb-17	Fyke net	Fyke net	Recapture	4	3	Shortfin eel	1	660	670	unmarked	6.49	6.51	48
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	140	39.5	unmarked	4.94	3.68	49
22-Feb-17	Fyke net	Fyke net	Recapture	5	3	Shortfin eel	1	580	477	unmarked	6.36	6.17	49
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	160	61.5	unmarked	5.08	4.12	50
22-Feb-17	Fyke net	Fyke net	Recapture	5	3	Shortfin eel	1	545	401	unmarked	6.30	5.99	50
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	170	72.1	unmarked	5.14	4.28	51
22-Feb-17	Fyke net	Fyke net	Recapture	5	3	Shortfin eel	1	540	303	unmarked	6.29	5.71	51

21-Feb-17	Gill net	Count	NA	1	18	Perch	1	135	36	unmarked	4.91	3.58	52
22-Feb-17	Fyke net	Fyke net	Recapture	6	3	Shortfin eel	1	650	570	unmarked	6.48	6.35	52
22-Feb-17	Fyke net	Fyke net	Recapture	6	3	Longfin eel	1	750	1448	unmarked	6.62	7.28	53
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	185	103.1	unmarked	5.22	4.64	53
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	165	67	unmarked	5.11	4.20	54
22-Feb-17	Fyke net	Fyke net	Recapture	6	3	Shortfin eel	1	550	338	unmarked	6.31	5.82	54
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	177	78.3	unmarked	5.18	4.36	55
22-Feb-17	Fyke net	Fyke net	Recapture	6	3	Shortfin eel	1	620	428	unmarked	6.43	6.06	55
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	172	64.9	unmarked	5.15	4.17	56
22-Feb-17	Fyke net	Fyke net	Recapture	6	3	Shortfin eel	1	505	314	marked	6.22	5.75	56
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	160	65.8	unmarked	5.08	4.19	57
22-Feb-17	Fyke net	Fyke net	Recapture	6	3	Shortfin eel	1	540	244	unmarked	6.29	5.50	57
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	164	61.7	unmarked	5.10	4.12	58
22-Feb-17	Fyke net	Fyke net	Recapture	6	3	Shortfin eel	1	615	539	unmarked	6.42	6.29	58
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	145	44	unmarked	4.98	3.78	59
22-Feb-17	Fyke net	Fyke net	Recapture	6	3	Shortfin eel	1	560	368	marked	6.33	5.91	59
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	155	58.7	unmarked	5.04	4.07	60
22-Feb-17	Fyke net	Fyke net	Recapture	6	3	Shortfin eel	1	620	572	unmarked	6.43	6.35	60
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	155	55	unmarked	5.04	4.01	61
22-Feb-17	Fyke net	Fyke net	Recapture	6	3	Shortfin eel	1	415	154	unmarked	6.03	5.04	61
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	181	85.9	unmarked	5.20	4.45	62
22-Feb-17	Fyke net	Fyke net	Recapture	6	3	Shortfin eel	1	535	330	unmarked	6.28	5.80	62
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	165	63.9	unmarked	5.11	4.16	63
22-Feb-17	Fyke net	Fyke net	Recapture	7	3	Shortfin eel	1	890	1038	unmarked	6.79	6.95	63
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	152	49.8	unmarked	5.02	3.91	64
22-Feb-17	Fyke net	Fyke net	Recapture	7	3	Shortfin eel	1	470	177	unmarked	6.15	5.18	64

21-Feb-17	Gill net	Count	NA	1	18	Perch	1	171	70.5	unmarked	5.14	4.26	65
22-Feb-17	Fyke net	Fyke net	Recapture	7	3	Shortfin eel	1	785	1089.92	unmarked	6.67	6.99	65
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	175	85	unmarked	5.16	4.44	66
22-Feb-17	Fyke net	Fyke net	Recapture	21_2	3	Shortfin eel	1	700	744	unmarked	6.55	6.61	66
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	144	40.8	unmarked	4.97	3.71	67
22-Feb-17	Fyke net	Fyke net	Recapture	21_2	3	Shortfin eel	1	722	805	unmarked	6.58	6.69	67
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	146	46	unmarked	4.98	3.83	68
22-Feb-17	Fyke net	Fyke net	Recapture	21_2	3	Shortfin eel	1	640	505	marked	6.46	6.22	68
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	148	45.3	unmarked	5.00	3.81	69
22-Feb-17	Fyke net	Fyke net	Recapture	21_2	3	Shortfin eel	1	665	557	unmarked	6.50	6.32	69
22-Feb-17	Fyke net	Fyke net	Recapture	8	3	Longfin eel	1	960	3046	unmarked	6.87	8.02	70
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	156	57	unmarked	5.05	4.04	70
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	140	39.3	unmarked	4.94	3.67	71
22-Feb-17	Fyke net	Fyke net	Recapture	8	3	Shortfin eel	1	535	385	unmarked	6.28	5.95	71
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	192	98.2	unmarked	5.26	4.59	72
22-Feb-17	Fyke net	Fyke net	Recapture	8	3	Shortfin eel	1	665	535	unmarked	6.50	6.28	72
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	150	43.8	unmarked	5.01	3.78	73
22-Feb-17	Fyke net	Fyke net	Recapture	8	3	Shortfin eel	1	720	716	unmarked	6.58	6.57	73
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	155	54.3	unmarked	5.04	3.99	74
22-Feb-17	Fyke net	Fyke net	Recapture	8	3	Shortfin eel	1	535	385	unmarked	6.28	5.95	74
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	186	96.2	unmarked	5.23	4.57	75
22-Feb-17	Fyke net	Fyke net	Recapture	8	3	Shortfin eel	1	720	766	unmarked	6.58	6.64	75
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	170	70.4	unmarked	5.14	4.25	76
22-Feb-17	Fyke net	Fyke net	Recapture	9	3	Shortfin eel	1	600	485	unmarked	6.40	6.18	76
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	151	49.8	unmarked	5.02	3.91	77
22-Feb-17	Fyke net	Fyke net	Recapture	9	3	Shortfin eel	1	490	226	unmarked	6.19	5.42	77

21-Feb-17	Gill net	Count	NA	1	18	Perch	1	146	42.3	unmarked	4.98	3.74	78
22-Feb-17	Fyke net	Fyke net	Recapture	9	3	Shortfin eel	1	760	1054	unmarked	6.63	6.96	78
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	189	97.5	unmarked	5.24	4.58	79
22-Feb-17	Fyke net	Fyke net	Recapture	9	3	Shortfin eel	1	845	1490	unmarked	6.74	7.31	79
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	150	53	unmarked	5.01	3.97	80
22-Feb-17	Fyke net	Fyke net	Recapture	9	3	Shortfin eel	1	615	463	unmarked	6.42	6.14	80
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	152	53.4	unmarked	5.02	3.98	81
22-Feb-17	Fyke net	Fyke net	Recapture	9	3	Shortfin eel	1	700	804	marked	6.55	6.69	81
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	158	59.8	unmarked	5.06	4.09	82
22-Feb-17	Fyke net	Fyke net	Recapture	9	3	Shortfin eel	1	610	580	unmarked	6.41	6.36	82
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	160	60.5	unmarked	5.08	4.10	83
22-Feb-17	Fyke net	Fyke net	Recapture	9	3	Shortfin eel	1	625	497	unmarked	6.44	6.21	83
22-Feb-17	Fyke net	Fyke net	Recapture	10	3	Longfin eel	1	916	2458	unmarked	6.82	7.81	84
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	137	37	unmarked	4.92	3.61	84
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	188	95	unmarked	5.24	4.55	85
22-Feb-17	Fyke net	Fyke net	Recapture	10	3	Shortfin eel	1	590	439	unmarked	6.38	6.08	85
22-Feb-17	Fyke net	Fyke net	Recapture	10	3	Longfin eel	1	994	3330	marked	6.90	8.11	86
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	171	64.5	unmarked	5.14	4.17	86
22-Feb-17	Fyke net	Fyke net	Recapture	10	3	Longfin eel	1	480	314	unmarked	6.17	5.75	87
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	145	41.3	unmarked	4.98	3.72	87
22-Feb-17	Fyke net	Fyke net	Recapture	10	3	Longfin eel	1	635	794	unmarked	6.45	6.68	88
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	163	53.4	unmarked	5.09	3.98	88
22-Feb-17	Fyke net	Fyke net	Recapture	10	3	Longfin eel	1	500	372	unmarked	6.21	5.92	89
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	155	52.6	unmarked	5.04	3.96	89
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	165	68.5	unmarked	5.11	4.23	90
22-Feb-17	Fyke net	Fyke net	Recapture	11	3	Shortfin eel	1	830	1475	unmarked	6.72	7.30	90

22-Feb-17	Fyke net	Fyke net	Recapture	12	3	Longfin eel	1	708	1160	unmarked	6.56	7.06	91
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	151	46.9	unmarked	5.02	3.85	91
22-Feb-17	Fyke net	Fyke net	Recapture	13	3	Longfin eel	1	810	1586	marked	6.70	7.37	92
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	184	88.9	unmarked	5.21	4.49	92
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	169	63	unmarked	5.13	4.14	93
22-Feb-17	Fyke net	Fyke net	Recapture	14	3	Shortfin eel	1	770	872	unmarked	6.65	6.77	93
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	151	53.2	unmarked	5.02	3.97	94
22-Feb-17	Fyke net	Fyke net	Recapture	14	3	Shortfin eel	1	820	1252	unmarked	6.71	7.13	94
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	154	53.4	unmarked	5.04	3.98	95
22-Feb-17	Fyke net	Fyke net	Recapture	14	3	Shortfin eel	1	835	1370	unmarked	6.73	7.22	95
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	151	48	unmarked	5.02	3.87	96
22-Feb-17	Fyke net	Fyke net	Recapture	14	3	Shortfin eel	1	930	2001	unmarked	6.84	7.60	96
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	179	89.4	unmarked	5.19	4.49	97
22-Feb-17	Fyke net	Fyke net	Recapture	14	3	Shortfin eel	1	505	310	unmarked	6.22	5.74	97
22-Feb-17	Fyke net	Fyke net	Recapture	14	3	Perch	5	95		unmarked	4.55		98
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	191	91	unmarked	5.25	4.51	98
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	149	50.8	unmarked	5.00	3.93	99
22-Feb-17	Fyke net	Fyke net	Recapture	15	3	Shortfin eel	1	755	898	unmarked	6.63	6.80	99
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	135	32.8	unmarked	4.91	3.49	100
22-Feb-17	Fyke net	Fyke net	Recapture	15	3	Shortfin eel	1	778	1087	unmarked	6.66	6.99	100
22-Feb-17	Fyke net	Fyke net	Recapture	15	3	Longfin eel	1	726	1004	marked	6.59	6.91	101
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	155	48.6	unmarked	5.04	3.88	101
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	152	49.7	unmarked	5.02	3.91	102
22-Feb-17	Fyke net	Fyke net	Recapture	15	3	Shortfin eel	1	698	783	unmarked	6.55	6.66	102
22-Feb-17	Fyke net	Fyke net	Recapture	15	3	Longfin eel	1	1140	4663	unmarked	7.04	8.45	103
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	149	45.4	unmarked	5.00	3.82	103

22-Feb-17	Fyke net	Fyke net	Recapture	16	3	Longfin eel	1	1120	6690	unmarked	7.02	8.81	104
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	148	48.1	unmarked	5.00	3.87	104
22-Feb-17	Fyke net	Fyke net	Recapture	16	3	Perch	1	165		unmarked	5.11		105
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	159	61.2	unmarked	5.07	4.11	105
22-Feb-17	Fyke net	Fyke net	Recapture	16	3	Perch	1	140		unmarked	4.94		106
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	142	41.8	unmarked	4.96	3.73	106
22-Feb-17	Fyke net	Fyke net	Recapture	16	3	Perch	1	158		unmarked	5.06		107
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	170	71.7	unmarked	5.14	4.27	107
22-Feb-17	Fyke net	Fyke net	Recapture	16	3	Perch	1	93		unmarked	4.53		108
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	149	54.4	unmarked	5.00	4.00	108
22-Feb-17	Fyke net	Fyke net	Recapture	17	3	Longfin eel	1	1040	3819	unmarked	6.95	8.25	109
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	165	72.8	unmarked	5.11	4.29	109
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	160	64.5	unmarked	5.08	4.17	110
22-Feb-17	Fyke net	Fyke net	Recapture	17	3	Shortfin eel	1	745	920	unmarked	6.61	6.82	110
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	167	68.6	unmarked	5.12	4.23	111
22-Feb-17	Fyke net	Fyke net	Recapture	17	3	Shortfin eel	1	545	357	unmarked	6.30	5.88	111
22-Feb-17	Fyke net	Fyke net	Recapture	19	3	Perch	1	234	177	unmarked	5.46	5.18	112
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	159	60	unmarked	5.07	4.09	112
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	170	68.5	unmarked	5.14	4.23	113
22-Feb-17	Fyke net	Fyke net	Recapture	19	3	Shortfin eel	1	260	24	unmarked	5.56	3.18	113
22-Feb-17	Fyke net	Fyke net	Recapture	19	3	Longfin eel	1	880	2327	unmarked	6.78	7.75	114
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	172	76.5	unmarked	5.15	4.34	114
22-Feb-17	Fyke net	Fyke net	Recapture	19	3	Longfin eel	1	719	1098	marked	6.58	7.00	115
21-Feb-17	Gill net	Count	NA	1	18	Perch	1	142	40.5	unmarked	4.96	3.70	115
21-Feb-17	Gill net	Count	NA	2	18	Perch	1	188	92	unmarked	5.24	4.52	116
22-Feb-17	Fyke net	Fyke net	Recapture	19	3	Shortfin eel	1	755	805	marked	6.63	6.69	116

21-Feb-17	Gill net	Count	NA	2	18	Perch	1	158	59.4	unmarked	5.06	4.08	117
22-Feb-17	Fyke net	Fyke net	Recapture	19	3	Shortfin eel	1	665	695	unmarked	6.50	6.54	117
22-Feb-17	Fyke net	Fyke net	Recapture	19	3	Longfin eel	1	1060	3920	unmarked	6.97	8.27	118
21-Feb-17	Gill net	Count	NA	2	18	Perch	1	150	50.3	unmarked	5.01	3.92	118
21-Feb-17	Gill net	Count	NA	2	18	Perch	1	182	95.9	unmarked	5.20	4.56	119
22-Feb-17	Fyke net	Fyke net	Recapture	19	3	Shortfin eel	1	815	1227	unmarked	6.70	7.11	119
22-Feb-17	Fyke net	Fyke net	Recapture	19	3	Longfin eel	1	685	1135	marked	6.53	7.03	120
21-Feb-17	Gill net	Count	NA	2	18	Perch	1	160	62.5	unmarked	5.08	4.14	120
21-Feb-17	Gill net	Count	NA	2	18	Perch	1	140	37.3	unmarked	4.94	3.62	121
22-Feb-17	Fyke net	Fyke net	Recapture	19	3	Shortfin eel	1	595	521	unmarked	6.39	6.26	121
22-Feb-17	Fyke net	Fyke net	Recapture	19	3	Longfin eel	1	602	580	marked	6.40	6.36	122
21-Feb-17	Gill net	Count	NA	2	18	Perch	1	170	76.7	unmarked	5.14	4.34	122
21-Feb-17	Gill net	Count	NA	2	18	Perch	1	153	58.6	unmarked	5.03	4.07	123
22-Feb-17	Fyke net	Fyke net	Recapture	19	3	Shortfin eel	1	525	301	unmarked	6.26	5.71	123
22-Feb-17	Fyke net	Fyke net	Recapture	19	3	Shortfin eel	1			unmarked			123
22-Feb-17	Fyke net	Fyke net	Recapture	20	3	Longfin eel	1	710	1277	marked	6.57	7.15	124
21-Feb-17	Gill net	Count	NA	2	18	Perch	1	160	54.3	unmarked	5.08	3.99	124
22-Feb-17	Fyke net	Fyke net	Recapture	20	3	Perch	1	95	12.2	unmarked	4.55	2.50	125
21-Feb-17	Gill net	Count	NA	2	18	Perch	1	178	83.1	unmarked	5.18	4.42	125
22-Feb-17	Fyke net	Fyke net	Recapture	21	3	Perch	1	95	13.9	unmarked	4.55	2.63	126
21-Feb-17	Gill net	Count	NA	2	18	Perch	1	145	56.1	unmarked	4.98	4.03	126
22-Feb-17	Fyke net	Fyke net	Recapture	21	3	Perch	1	87	10.1	unmarked	4.47	2.31	127
21-Feb-17	Gill net	Count	NA	2	18	Perch	1	130	35.3	unmarked	4.87	3.56	127
22-Feb-17	Fyke net	Fyke net	Recapture	21	3	Longfin eel	1	850	1764	unmarked	6.75	7.48	128
21-Feb-17	Gill net	Count	NA	2	18	Perch	1	165	68.4	unmarked	5.11	4.23	128
22-Feb-17	Fyke net	Fyke net	Recapture	21	3	Longfin eel	1	800	1858	marked	6.68	7.53	129

21-Feb-17	Gill net	Count	NA	2	18	Perch	1	155	56.2	unmarked	5.04	4.03	129
22-Feb-17	Fyke net	Fyke net	Recapture	21	3	Longfin eel	1	830	1876	unmarked	6.72	7.54	130
21-Feb-17	Gill net	Count	NA	2	18	Perch	1	155	61.5	unmarked	5.04	4.12	130
22-Feb-17	Fyke net	Fyke net	Recapture	21	3	Longfin eel	1	780	1598	unmarked	6.66	7.38	131
21-Feb-17	Gill net	Count	NA	2	18	Perch	1	147	48.1	unmarked	4.99	3.87	131
22-Feb-17	Fyke net	Fyke net	Recapture	21	3	Longfin eel	1	730	1484	unmarked	6.59	7.30	132
21-Feb-17	Gill net	Count	NA	2	18	Perch	1	164	64.5	unmarked	5.10	4.17	132
21-Feb-17	Gill net	Count	NA	3	18	Perch	1	160	61	unmarked	5.08	4.11	133
22-Feb-17	Fyke net	Fyke net	Recapture	21	3	Shortfin eel	1	480	275	unmarked	6.17	5.62	133
21-Feb-17	Gill net	Count	NA	3	18	Perch	1	150	53.2	unmarked	5.01	3.97	134
22-Feb-17	Fyke net	Fyke net	Recapture	21	3	Shortfin eel	1	660	598	unmarked	6.49	6.39	134
21-Feb-17	Gill net	Count	NA	3	18	Perch	1	170	73.2	unmarked	5.14	4.29	135
22-Feb-17	Fyke net	Fyke net	Recapture	21	3	Shortfin eel	1	680	809	unmarked	6.52	6.70	135
21-Feb-17	Gill net	Count	NA	3	18	Perch	1	148	49.2	unmarked	5.00	3.90	136
22-Feb-17	Fyke net	Fyke net	Recapture	21	3	Shortfin eel	1	575	462	unmarked	6.35	6.14	136
21-Feb-17	Gill net	Count	NA	3	18	Perch	1	150	54.3	unmarked	5.01	3.99	137
22-Feb-17	Fyke net	Fyke net	Recapture	21	3	Shortfin eel	1	640	616	unmarked	6.46	6.42	137
22-Feb-17	Fyke net	Fyke net	Recapture	21	3	Longfin eel	1	585	530	unmarked	6.37	6.27	138
21-Feb-17	Gill net	Count	NA	3	18	Perch	1	155	61.6	unmarked	5.04	4.12	138
22-Feb-17	Fyke net	Fyke net	Recapture	21	3	Longfin eel	1	510	406	unmarked	6.23	6.01	139
21-Feb-17	Gill net	Count	NA	3	18	Perch	1	145	43.8	unmarked	4.98	3.78	139
22-Feb-17	Fyke net	Fyke net	Recapture	21	3	Longfin eel	1	595	618	unmarked	6.39	6.43	140
21-Feb-17	Gill net	Count	NA	3	18	Perch	1	149	48.8	unmarked	5.00	3.89	140
21-Feb-17	Gill net	Count	NA	3	18	Perch	1	160	60.9	unmarked	5.08	4.11	141
22-Feb-17	Fyke net	Fyke net	Recapture	21	3	Shortfin eel	1	805	1101	unmarked	6.69	7.00	141
21-Feb-17	Gill net	Count	NA	3	18	Perch	1	150	54.5	unmarked	5.01	4.00	142

22-Feb-17	Fyke net	Fyke net	Recapture	21	3	Shortfin eel	1	640	529	unmarked	6.46	6.27	142
22-Feb-17	Fyke net	Fyke net	Recapture	21	3	Longfin eel	1	610	776	unmarked	6.41	6.65	143
21-Feb-17	Gill net	Count	NA	3	18	Perch	1	172	80.4	unmarked	5.15	4.39	143
22-Feb-17	Fyke net	Fyke net	Recapture	21	3	Longfin eel	1	550	518	unmarked	6.31	6.25	144
21-Feb-17	Gill net	Count	NA	3	18	Perch	1	168	79.5	unmarked	5.12	4.38	144
22-Feb-17	Fyke net	Fyke net	Recapture	21	3	Longfin eel	1	480	339	unmarked	6.17	5.83	145
21-Feb-17	Gill net	Count	NA	3	18	Perch	1	155	57.4	unmarked	5.04	4.05	145
21-Feb-17	Gill net	Count	NA	3	18	Perch	1	145	46.8	unmarked	4.98	3.85	146
22-Feb-17	Fyke net	Fyke net	Recapture	21	3	Shortfin eel	1	535	306	unmarked	6.28	5.72	146
22-Feb-17	Fyke net	Fyke net	Recapture	21	3	Longfin eel	1	415	165	unmarked	6.03	5.11	147
21-Feb-17	Gill net	Count	NA	3	18	Perch	1	168	70.1	unmarked	5.12	4.25	147
21-Feb-17	Gill net	Count	NA	3	18	Perch	1	162	64.7	unmarked	5.09	4.17	148
22-Feb-17	Fyke net	Fyke net	Recapture	21	3	Shortfin eel	1	440	171.65	unmarked	6.09	5.15	148
22-Feb-17	Fyke net	Fyke net	Recapture	21	3	Perch	13			unmarked			149
21-Feb-17	Gill net	Count	NA	3	18	Perch	1	150	52.7	unmarked	5.01	3.96	149
21-Feb-17	Gill net	Count	NA	3	18	Perch	1	172	82.2	unmarked	5.15	4.41	150
22-Feb-17	Fyke net	Fyke net	Recapture	22	3	Shortfin eel	1	850	1403	unmarked	6.75	7.25	150
22-Feb-17	Fyke net	Fyke net	Recapture	23	3	Longfin eel	1	770	1458	marked	6.65	7.28	151
21-Feb-17	Gill net	Count	NA	3	18	Perch	1	180	82.8	unmarked	5.19	4.42	151
22-Feb-17	Fyke net	Fyke net	Recapture	23	3	Longfin eel	1	970	2744	marked	6.88	7.92	152
21-Feb-17	Gill net	Count	NA	3	18	Perch	1	165	69	unmarked	5.11	4.23	152
22-Feb-17	Fyke net	Fyke net	Recapture	23	3	Longfin eel	1	915	2692	unmarked	6.82	7.90	153
21-Feb-17	Gill net	Count	NA	3	18	Perch	1	165	68	unmarked	5.11	4.22	153
22-Feb-17	Fyke net	Fyke net	Recapture	23	3	Longfin eel	1	845	1870	marked	6.74	7.53	154
21-Feb-17	Gill net	Count	NA	3	18	Perch	1	157	58.5	unmarked	5.06	4.07	154
21-Feb-17	Gill net	Count	NA	3	18	Perch	1	155	55.3	unmarked	5.04	4.01	155

22-Feb-17	Fyke net	Fyke net	Recapture	23	3	Shortfin eel	1	706	751	unmarked	6.56	6.62	155
21-Feb-17	Gill net	Count	NA	3	18	Perch	1	165	63.9	unmarked	5.11	4.16	156
22-Feb-17	Fyke net	Fyke net	Recapture	23	3	Shortfin eel	1	584	460	unmarked	6.37	6.13	156
22-Feb-17	Fyke net	Fyke net	Recapture	23	3	Longfin eel	1	900	2204	marked	6.80	7.70	157
21-Feb-17	Gill net	Count	NA	3	18	Perch	1	140	49.4	unmarked	4.94	3.90	157
22-Feb-17	Fyke net	Fyke net	Recapture	23	3	Longfin eel	1	600	614	marked	6.40	6.42	158
21-Feb-17	Gill net	Count	NA	3	18	Perch	1	150	60.1	unmarked	5.01	4.10	158
22-Feb-17	Fyke net	Fyke net	Recapture	23	3	Longfin eel	1	790	1610	marked	6.67	7.38	159
21-Feb-17	Gill net	Count	NA	3	18	Perch	1	148	48.8	unmarked	5.00	3.89	159
21-Feb-17	Gill net	Count	NA	3	18	Perch	1	154	55.8	unmarked	5.04	4.02	160
22-Feb-17	Fyke net	Fyke net	Recapture	23	3	Shortfin eel	1	726	996	unmarked	6.59	6.90	160
22-Feb-17	Fyke net	Fyke net	Recapture	23	3	Longfin eel	1	562	595	unmarked	6.33	6.39	161
21-Feb-17	Gill net	Count	NA	4	25	Perch	1	180	83.8	unmarked	5.19	4.43	161
23-Feb-17	Fyke net	Fyke net	Recapture	1	3	Longfin eel	1	970	3179.7	marked	6.88	8.06	162
21-Feb-17	Gill net	Count	NA	4	25	Perch	1	170	69.1	unmarked	5.14	4.24	162
23-Feb-17	Fyke net	Fyke net	Recapture	1	3	Longfin eel	1	880	2301.8	marked	6.78	7.74	163
21-Feb-17	Gill net	Count	NA	4	25	Perch	1	185	85	unmarked	5.22	4.44	163
23-Feb-17	Fyke net	Fyke net	Recapture	1	3	Longfin eel	1	580	577.2	unmarked	6.36	6.36	164
21-Feb-17	Gill net	Count	NA	4	25	Perch	1	160	60.2	unmarked	5.08	4.10	164
21-Feb-17	Gill net	Count	NA	4	25	Perch	1	155	56.3	unmarked	5.04	4.03	165
23-Feb-17	Fyke net	Fyke net	Recapture	1	3	Shortfin eel	1	490	242.04	unmarked	6.19	5.49	165
23-Feb-17	Fyke net	Fyke net	Recapture	1	3	Longfin eel	1	744	1318.7	unmarked	6.61	7.18	166
21-Feb-17	Gill net	Count	NA	4	25	Perch	1	165	68	unmarked	5.11	4.22	166
23-Feb-17	Fyke net	Fyke net	Recapture	1	3	Perch	6			unmarked			167
21-Feb-17	Gill net	Count	NA	4	25	Perch	1	168	67.8	unmarked	5.12	4.22	167
21-Feb-17	Gill net	Count	NA	4	25	Perch	1	175	78.8	unmarked	5.16	4.37	168

23-Feb-17	Fyke net	Fyke net	Recapture	2	3	Shortfin eel	1	720	827.07	unmarked	6.58	6.72	168
23-Feb-17	Fyke net	Fyke net	Recapture	2	3	Longfin eel	1	820	1821.0	unmarked	6.71	7.51	169
21-Feb-17	Gill net	Count	NA	4	25	Perch	1	165	74.1	unmarked	5.11	4.31	169
23-Feb-17	Fyke net	Fyke net	Recapture	3	3	Longfin eel	1	890	2389.8	unmarked	6.79	7.78	170
21-Feb-17	Gill net	Count	NA	4	25	Perch	1	168	66.8	unmarked	5.12	4.20	170
23-Feb-17	Fyke net	Fyke net	Recapture	5	3	Perch	1			unmarked			171
21-Feb-17	Gill net	Count	NA	5	25	Perch	1	155	53.1	unmarked	5.04	3.97	171
21-Feb-17	Gill net	Count	NA	5	25	Perch	1	160	59.2	unmarked	5.08	4.08	172
23-Feb-17	Fyke net	Fyke net	Recapture	5	3	Shortfin eel	1	795	1134.88	unmarked	6.68	7.03	172
23-Feb-17	Fyke net	Fyke net	Recapture	6	3	Longfin eel	1	680	978.4	unmarked	6.52	6.89	173
21-Feb-17	Gill net	Count	NA	5	25	Perch	1	180	79.5	unmarked	5.19	4.38	173
23-Feb-17	Fyke net	Fyke net	Recapture	6	3	Longfin eel	1	730	1238.16	unmarked	6.59	7.12	174
21-Feb-17	Gill net	Count	NA	5	25	Perch	1	170	75.5	unmarked	5.14	4.32	174
21-Feb-17	Gill net	Count	NA	5	25	Perch	1	175	71	unmarked	5.16	4.26	175
23-Feb-17	Fyke net	Fyke net	Recapture	6	3	Shortfin eel	1	455	191.04	unmarked	6.12	5.25	175
21-Feb-17	Gill net	Count	NA	5	25	Perch	1	177	65.4	unmarked	5.18	4.18	176
23-Feb-17	Fyke net	Fyke net	Recapture	6	3	Shortfin eel	1	690	721.98	unmarked	6.54	6.58	176
23-Feb-17	Fyke net	Fyke net	Recapture	6	3	Perch	6			unmarked			177
21-Feb-17	Gill net	Count	NA	5	25	Perch	1	160	63.4	unmarked	5.08	4.15	177
21-Feb-17	Gill net	Count	NA	5	25	Perch	1	187	92.3	unmarked	5.23	4.53	178
23-Feb-17	Fyke net	Fyke net	Recapture	7	3	Shortfin eel	1	600	462.09	unmarked	6.40	6.14	178
23-Feb-17	Fyke net	Fyke net	Recapture	7	3	Longfin eel	1	950	2967.4	unmarked	6.86	8.00	179
21-Feb-17	Gill net	Count	NA	5	25	Perch	1	166	60.2	unmarked	5.11	4.10	179
23-Feb-17	Fyke net	Fyke net	Recapture	7	3	Perch	4			unmarked			180
23-Feb-17	Fyke net	Fyke net	Recapture	9	3	Perch	2	205		unmarked			180
21-Feb-17	Gill net	Count	NA	5	25	Perch	1	175	70.3	unmarked	5.16	4.25	180

21-Feb-17	Gill net	Count	NA	5	25	Perch	1	180	77.9	unmarked	5.19	4.36	181
23-Feb-17	Fyke net	Fyke net	Recapture	8	3	Shortfin eel	1	604	472.00	unmarked	6.40	6.16	181
21-Feb-17	Gill net	Count	NA	5	25	Perch	1	170	73.4	unmarked	5.14	4.30	182
23-Feb-17	Fyke net	Fyke net	Recapture	8	3	Shortfin eel	1	670	657.26	unmarked	6.51	6.49	182
23-Feb-17	Fyke net	Fyke net	Recapture	8	3	Longfin eel	1	328	87.1	unmarked	5.79	4.47	183
21-Feb-17	Gill net	Count	NA	5	25	Perch	1	180	77.9	unmarked	5.19	4.36	183
21-Feb-17	Gill net	Count	NA	5	25	Perch	1	155	55.7	unmarked	5.04	4.02	184
23-Feb-17	Fyke net	Fyke net	Recapture	9	3	Shortfin eel	1	725	845.55	unmarked	6.59	6.74	184
21-Feb-17	Gill net	Count	NA	5	25	Perch	1	175	81.3	unmarked	5.16	4.40	185
23-Feb-17	Fyke net	Fyke net	Recapture	9	3	Shortfin eel	1	526	303.53	unmarked	6.27	5.72	185
21-Feb-17	Gill net	Count	NA	5	25	Perch	1	158	52.8	unmarked	5.06	3.97	186
23-Feb-17	Fyke net	Fyke net	Recapture	9	3	Shortfin eel	1	591	440.32	unmarked	6.38	6.09	186
21-Feb-17	Gill net	Count	NA	5	25	Perch	1	177	81.6	unmarked	5.18	4.40	187
23-Feb-17	Fyke net	Fyke net	Recapture	9	3	Shortfin eel	1	748	934.21	unmarked	6.62	6.84	187
21-Feb-17	Gill net	Count	NA	5	25	Perch	1	154	53.2	unmarked	5.04	3.97	188
23-Feb-17	Fyke net	Fyke net	Recapture	9	3	Shortfin eel	1	670	657.26	unmarked	6.51	6.49	188
21-Feb-17	Gill net	Count	NA	5	25	Perch	1	165	64.4	unmarked	5.11	4.17	189
23-Feb-17	Fyke net	Fyke net	Recapture	9	3	Shortfin eel	1	725	845.55	unmarked	6.59	6.74	189
21-Feb-17	Gill net	Count	NA	5	25	Perch	1	158	55.8	unmarked	5.06	4.02	190
23-Feb-17	Fyke net	Fyke net	Recapture	9	3	Shortfin eel	1	621	515.74	unmarked	6.43	6.25	190
21-Feb-17	Gill net	Count	NA	5	25	Perch	1	162	59.5	unmarked	5.09	4.09	191
23-Feb-17	Fyke net	Fyke net	Recapture	9	3	Shortfin eel	1	560	370.73	unmarked	6.33	5.92	191
21-Feb-17	Gill net	Count	NA	5	25	Perch	1	181	90.6	unmarked	5.20	4.51	192
23-Feb-17	Fyke net	Fyke net	Recapture	9	3	Shortfin eel	1	681	692.34	unmarked	6.52	6.54	192
21-Feb-17	Gill net	Count	NA	5	25	Perch	1	160	59.5	unmarked	5.08	4.09	193
23-Feb-17	Fyke net	Fyke net	Recapture	9	3	Shortfin eel	1	639	565.00	unmarked	6.46	6.34	193

23-Feb-17	Fyke net	Fyke net	Recapture	10	3	Longfin eel	1	990	3402.5	unmarked	6.90	8.13	194
21-Feb-17	Gill net	Count	NA	5	25	Perch	1	160	58.7	unmarked	5.08	4.07	194
23-Feb-17	Fyke net	Fyke net	Recapture	10	3	Longfin eel	1	527	420.0	unmarked	6.27	6.04	195
21-Feb-17	Gill net	Count	NA	5	25	Perch	1	178	77.2	unmarked	5.18	4.35	195
23-Feb-17	Fyke net	Fyke net	Recapture	10	3	Longfin eel	1	578	570.6	unmarked	6.36	6.35	196
21-Feb-17	Gill net	Count	NA	5	25	Perch	1	150	57.2	unmarked	5.01	4.05	196
21-Feb-17	Gill net	Count	NA	5	25	Perch	1	158	55.6	unmarked	5.06	4.02	197
23-Feb-17	Fyke net	Fyke net	Recapture	10	3	Shortfin eel	1	575	403.38	unmarked	6.35	6.00	197
21-Feb-17	Gill net	Count	NA	5	25	Perch	1	145	50.8	unmarked	4.98	3.93	198
23-Feb-17	Fyke net	Fyke net	Recapture	10	3	Shortfin eel	1	595	449.91	unmarked	6.39	6.11	198
23-Feb-17	Fyke net	Fyke net	Recapture	10	3	Longfin eel	1	480	308.0	marked	6.17	5.73	199
21-Feb-17	Gill net	Count	NA	5	25	Perch	1	170	70.4	unmarked	5.14	4.25	199
21-Feb-17	Gill net	Count	NA	5	25	Perch	1	165	68.2	unmarked	5.11	4.22	200
23-Feb-17	Fyke net	Fyke net	Recapture	10	3	Shortfin eel	1	675	673.05	unmarked	6.51	6.51	200
21-Feb-17	Gill net	Count	NA	5	25	Perch	1	180	86.5	unmarked	5.19	4.46	201
23-Feb-17	Fyke net	Fyke net	Recapture	10	3	Shortfin eel	1	570	392.28	unmarked	6.35	5.97	201
23-Feb-17	Fyke net	Fyke net	Recapture	10	3	Longfin eel	1	780	1542.6	unmarked	6.66	7.34	202
21-Feb-17	Gill net	Count	NA	5	25	Perch	1	160	58.3	unmarked	5.08	4.07	202
21-Feb-17	Gill net	Count	NA	5	25	Perch	1	172	72	unmarked	5.15	4.28	203
23-Feb-17	Fyke net	Fyke net	Recapture	10	3	Shortfin eel	1	575	403.38	unmarked	6.35	6.00	203
23-Feb-17	Fyke net	Fyke net	Recapture	10	3	Longfin eel	1	480	308.0	unmarked	6.17	5.73	204
21-Feb-17	Gill net	Count	NA	5	25	Perch	1	150	55.8	unmarked	5.01	4.02	204
23-Feb-17	Fyke net	Fyke net	Recapture	10	3	Longfin eel	1	375	135.8	unmarked	5.93	4.91	205
21-Feb-17	Gill net	Count	NA	5	25	Perch	1	198	106.4	unmarked	5.29	4.67	205
21-Feb-17	Gill net	Count	NA	5	25	Perch	1	155	57.6	unmarked	5.04	4.05	206
23-Feb-17	Fyke net	Fyke net	Recapture	11	3	Shortfin eel	1	825	1277.36	unmarked	6.72	7.15	206

21-Feb-17	Gill net	Count	NA	5	25	Perch	1	162	66.8	unmarked	5.09	4.20	207
23-Feb-17	Fyke net	Fyke net	Recapture	11	3	Shortfin eel	1	460	197.83	unmarked	6.13	5.29	207
21-Feb-17	Gill net	Count	NA	5	25	Perch	1	170	71.5	unmarked	5.14	4.27	208
23-Feb-17	Fyke net	Fyke net	Recapture	13	3	Shortfin eel	1	995	2323.35	unmarked	6.90	7.75	208
21-Feb-17	Gill net	Count	NA	5	18	Perch	1	155	56.5	unmarked	5.04	4.03	209
23-Feb-17	Fyke net	Fyke net	Recapture	13	3	Shortfin eel	1	800	1157.82	unmarked	6.68	7.05	209
23-Feb-17	Fyke net	Fyke net	Recapture	13	3	Perch	1	200		unmarked	5.30		210
21-Feb-17	Gill net	Count	NA	5	18	Perch	1	160	60.4	unmarked	5.08	4.10	210
21-Feb-17	Electrofishing	Count	NA	1	NA	Perch	100			unmarked			211
23-Feb-17	Fyke net	Fyke net	Recapture	14	3	Shortfin eel	1	940	1937.61	unmarked	6.85	7.57	211
21-Feb-17	Electrofishing	Count	NA	2	NA	Perch	96			unmarked			212
23-Feb-17	Fyke net	Fyke net	Recapture	14	3	Shortfin eel	1	625	526.42	unmarked	6.44	6.27	212
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	90	12.3	unmarked	4.50	2.51	213
23-Feb-17	Fyke net	Fyke net	Recapture	14	3	Shortfin eel	1	605	474.50	unmarked	6.41	6.16	213
23-Feb-17	Fyke net	Fyke net	Recapture	14	3	Longfin eel	1	1060	4268.3	unmarked	6.97	8.36	214
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	90	11.4	unmarked	4.50	2.43	214
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	140	39.4	unmarked	4.94	3.67	215
23-Feb-17	Fyke net	Fyke net	Recapture	14	3	Shortfin eel	1	612	492.25	marked	6.42	6.20	215
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	86	10.2	unmarked	4.45	2.32	216
23-Feb-17	Fyke net	Fyke net	Recapture	16	3	Shortfin eel	1	580	414.68	unmarked	6.36	6.03	216
23-Feb-17	Fyke net	Fyke net	Recapture	16	3	Longfin eel	1	605	663.9	unmarked	6.41	6.50	217
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	95	17.7	unmarked	4.55	2.87	217
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	105	17.8	unmarked	4.65	2.88	218
23-Feb-17	Fyke net	Fyke net	Recapture	16	3	Shortfin eel	1	560	370.73	unmarked	6.33	5.92	218
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	145	47.5	unmarked	4.98	3.86	219
23-Feb-17	Fyke net	Fyke net	Recapture	16	3	Perch	1	225		unmarked	5.42		219

21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	138	44.3	unmarked	4.93	3.79	220
23-Feb-17	Fyke net	Fyke net	Recapture	16	3	Perch	1	160		unmarked	5.08		220
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	82	8.8	unmarked	4.41	2.17	221
23-Feb-17	Fyke net	Fyke net	Recapture	16	3	Perch	1	190		unmarked	5.25		221
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	85	9.4	unmarked	4.44	2.24	222
23-Feb-17	Fyke net	Fyke net	Recapture	16	3	Perch	1	95		unmarked	4.55		222
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	157	55.1	unmarked	5.06	4.01	223
23-Feb-17	Fyke net	Fyke net	Recapture	18	3	Perch	1	160		unmarked	5.08		223
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	170	78.8	unmarked	5.14	4.37	224
23-Feb-17	Fyke net	Fyke net	Recapture	20	3	Shortfin eel	1	730	864.31	unmarked	6.59	6.76	224
23-Feb-17	Fyke net	Fyke net	Recapture	20	3	Longfin eel	1	835	1933.9	unmarked	6.73	7.57	225
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	90	11.2	unmarked	4.50	2.42	225
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	85	9	unmarked	4.44	2.20	226
23-Feb-17	Fyke net	Fyke net	Recapture	20	3	Shortfin eel	1	795	1134.88	unmarked	6.68	7.03	226
23-Feb-17	Fyke net	Fyke net	Recapture	20	3	Longfin eel	1	630	759.4	unmarked	6.45	6.63	227
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	88	11.4	unmarked	4.48	2.43	227
23-Feb-17	Fyke net	Fyke net	Recapture	20	3	Longfin eel	1	480	308.0	unmarked	6.17	5.73	228
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	97	14.7	unmarked	4.57	2.69	228
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	168	74.4	unmarked	5.12	4.31	229
23-Feb-17	Fyke net	Fyke net	Recapture	20	3	Shortfin eel	1	215	17.44	unmarked	5.37	2.86	229
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	219	151.8	unmarked	5.39	5.02	230
23-Feb-17	Fyke net	Fyke net	Recapture	22	3	Shortfin eel	1	591	440.32	unmarked	6.38	6.09	230
23-Feb-17	Fyke net	Fyke net	Recapture	22	3	Longfin eel	1	585	593.9	unmarked	6.37	6.39	231
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	130	36.3	unmarked	4.87	3.59	231
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	160	62.4	unmarked	5.08	4.13	232
23-Feb-17	Fyke net	Fyke net	Recapture	22	3	Shortfin eel	1	590	437.94	unmarked	6.38	6.08	232

21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	95	13.5	unmarked	4.55	2.60	233
23-Feb-17	Fyke net	Fyke net	Recapture	22	3	Shortfin eel	1	630	539.98	unmarked	6.45	6.29	233
23-Feb-17	Fyke net	Fyke net	Recapture	22	3	Longfin eel	1	500	352.7	unmarked	6.21461	5.87	234
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	95	11.8	unmarked	4.55	2.47	234
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	99	14.3	unmarked	4.60	2.66	235
23-Feb-17	Fyke net	Fyke net	Recapture	22	3	Shortfin eel	1	605	474.50	unmarked	6.40523	6.16	235
23-Feb-17	Fyke net	Fyke net	Recapture	23	3	Longfin eel	1	1200	6441.9	unmarked	7.09008	8.77	236
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	80	7.8	unmarked	4.38	2.05	236
23-Feb-17	Fyke net	Fyke net	Recapture	23	3	Longfin eel	1	1150	5593.5	unmarked	7.04752	8.63	237
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	80	8.4	unmarked	4.38	2.13	237
23-Feb-17	Fyke net	Fyke net	Recapture	23	3	Longfin eel	1	765	1446.3	unmarked	6.63988	7.28	238
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	85	10.3	unmarked	4.44	2.33	238
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	80	7.3	unmarked	4.38	1.99	239
23-Feb-17	Fyke net	Fyke net	Recapture	23	3	Shortfin eel	1	814	1223.77	unmarked	6.70196	7.11	239
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	78	7.3	unmarked	4.36	1.99	240
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	181	91.4	unmarked	5.20	4.52	241
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	149	49.1	unmarked	5.00	3.89	242
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	150	56.1	unmarked	5.01	4.03	243
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	155	68.5	unmarked	5.04	4.23	244
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	160	60.9	unmarked	5.08	4.11	245
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	165	68.8	unmarked	5.11	4.23	246
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	157	49	unmarked	5.06	3.89	247
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	77	9.5	unmarked	4.34	2.25	248
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	83	8.9	unmarked	4.42	2.19	249
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	90	11.8	unmarked	4.50	2.47	250
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	84	9	unmarked	4.43	2.20	251

21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	94	12.2	unmarked	4.54	2.50	252
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	90	13.4	unmarked	4.50	2.60	253
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	95	13.1	unmarked	4.55	2.57	254
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	97	14.8	unmarked	4.57	2.69	255
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	77	8.4	unmarked	4.34	2.13	256
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	87	11	unmarked	4.47	2.40	257
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	85	10	unmarked	4.44	2.30	258
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	85	9.8	unmarked	4.44	2.28	259
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	91	11.5	unmarked	4.51	2.44	260
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	139	40	unmarked	4.93	3.69	261
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	100	14.5	unmarked	4.61	2.67	262
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	86	10.5	unmarked	4.45	2.35	263
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	91	11.7	unmarked	4.51	2.46	264
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	94	11.2	unmarked	4.54	2.42	265
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	74	6.6	unmarked	4.30	1.89	266
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	93	13	unmarked	4.53	2.56	267
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	75	7.8	unmarked	4.32	2.05	268
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	78	6.8	unmarked	4.36	1.92	269
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	86	9.4	unmarked	4.45	2.24	270
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	86	8.9	unmarked	4.45	2.19	271
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	85	8.2	unmarked	4.44	2.10	272
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	80	5.4	unmarked	4.38	1.69	273
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	98	15.6	unmarked	4.58	2.75	274
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	69	5.2	unmarked	4.23	1.65	275
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	83	8.7	unmarked	4.42	2.16	276
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	92	14.7	unmarked	4.52	2.69	277

21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	95	11.3	unmarked	4.55	2.42	278
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	83	8.6	unmarked	4.42	2.15	279
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	84	8.6	unmarked	4.43	2.15	280
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	91	11.5	unmarked	4.51	2.44	281
21-Feb-17	Electrofishing	Count	NA	3	NA	Perch	1	72	6.3	unmarked	4.28	1.84	282
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	140	41.2	unmarked	4.94	3.72	283
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	165	67.9	unmarked	5.11	4.22	284
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	95	11.9	unmarked	4.55	2.48	285
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	150	52.9	unmarked	5.01	3.97	286
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	146	46.2	unmarked	4.98	3.83	287
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	88	9.6	unmarked	4.48	2.26	288
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	148	51.3	unmarked	5.00	3.94	289
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	155	47.3	unmarked	5.04	3.86	290
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	89	9.5	unmarked	4.49	2.25	291
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	92	10.6	unmarked	4.52	2.36	292
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	148	51.3	unmarked	5.00	3.94	293
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	89	10	unmarked	4.49	2.30	294
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	151	58.7	unmarked	5.02	4.07	295
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	140	42.3	unmarked	4.94	3.74	296
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	88	10.4	unmarked	4.48	2.34	297
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	88	9.4	unmarked	4.48	2.24	298
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	155	63.9	unmarked	5.04	4.16	299
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	81	9.4	unmarked	4.39	2.24	300
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	86	9.3	unmarked	4.45	2.23	301
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	98	13.1	unmarked	4.58	2.57	302
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	90	9.9	unmarked	4.50	2.29	303

21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	83	8.3	unmarked	4.42	2.12	304
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	150	48.1	unmarked	5.01	3.87	305
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	155	60.3	unmarked	5.04	4.10	306
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	95	11.1	unmarked	4.55	2.41	307
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	150	46.5	unmarked	5.01	3.84	308
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	79	7.8	unmarked	4.37	2.05	309
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	98	14.7	unmarked	4.58	2.69	310
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	91	11.7	unmarked	4.51	2.46	311
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	95	12.3	unmarked	4.55	2.51	312
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	86	8.5	unmarked	4.45	2.14	313
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	82	8.4	unmarked	4.41	2.13	314
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	145	41.4	unmarked	4.98	3.72	315
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	150	56.9	unmarked	5.01	4.04	316
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	95	12	unmarked	4.55	2.48	317
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	95	10.4	unmarked	4.55	2.34	318
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	94	12.7	unmarked	4.54	2.54	319
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	97	14.7	unmarked	4.57	2.69	320
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	78	6.8	unmarked	4.36	1.92	321
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	85	8.5	unmarked	4.44	2.14	322
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	95	13.2	unmarked	4.55	2.58	323
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	90	12	unmarked	4.50	2.48	324
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	88	11.1	unmarked	4.48	2.41	325
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	142	45.2	unmarked	4.96	3.81	326
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	156	61.5	unmarked	5.05	4.12	327
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	91	12.5	unmarked	4.51	2.53	328
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	89	10.5	unmarked	4.49	2.35	329

21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	144	44.4	unmarked	4.97	3.79	330
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	135	40.2	unmarked	4.91	3.69	331
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	155	62.5	unmarked	5.04	4.14	332
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	146	48.1	unmarked	4.98	3.87	333
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	144	43.8	unmarked	4.97	3.78	334
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	104	17.6	unmarked	4.64	2.87	335
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	83	8.7	unmarked	4.42	2.16	336
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	85	10.3	unmarked	4.44	2.33	337
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	87	9.4	unmarked	4.47	2.24	338
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	93	12.6	unmarked	4.53	2.53	339
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	140	41.2	unmarked	4.94	3.72	340
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	168	68.8	unmarked	5.12	4.23	341
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	85	8.9	unmarked	4.44	2.19	342
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	150	54.4	unmarked	5.01	4.00	343
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	83	7.8	unmarked	4.42	2.05	344
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	187	100.7	unmarked	5.23	4.61	345
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	87	10.6	unmarked	4.47	2.36	346
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	185	89	unmarked	5.22	4.49	347
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	142	45.2	unmarked	4.96	3.81	348
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	91	11.5	unmarked	4.51	2.44	349
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	94	13.8	unmarked	4.54	2.62	350
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	85	8.5	unmarked	4.44	2.14	351
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	75	6.2	unmarked	4.32	1.82	352
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	194	96.8	unmarked	5.27	4.57	353
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	98	15.2	unmarked	4.58	2.72	354
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	82	7.8	unmarked	4.41	2.05	355

21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	78	7.4	unmarked	4.36	2.00	356
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	90	11.6	unmarked	4.50	2.45	357
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	89	10.5	unmarked	4.49	2.35	358
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	86	9.1	unmarked	4.45	2.21	359
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	95	12.7	unmarked	4.55	2.54	360
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	88	10.4	unmarked	4.48	2.34	361
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	82	8.3	unmarked	4.41	2.12	362
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	89	10.7	unmarked	4.49	2.37	363
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	155	57.2	unmarked	5.04	4.05	364
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	160	63.9	unmarked	5.08	4.16	365
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	150	49.8	unmarked	5.01	3.91	366
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	145	43	unmarked	4.98	3.76	367
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	138	40	unmarked	4.93	3.69	368
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	138	42.4	unmarked	4.93	3.75	369
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	158	59.5	unmarked	5.06	4.09	370
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	145	48.2	unmarked	4.98	3.88	371
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	139	43.3	unmarked	4.93	3.77	372
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	130	32	unmarked	4.87	3.47	373
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	146	48.2	unmarked	4.98	3.88	374
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	82	10.5	unmarked	4.41	2.35	375
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	85	9.7	unmarked	4.44	2.27	376
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	105	17.8	unmarked	4.65	2.88	377
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	90	11.5	unmarked	4.50	2.44	378
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	81	7.5	unmarked	4.39	2.01	379
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	87	10.3	unmarked	4.47	2.33	380
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	96	14.3	unmarked	4.56	2.66	381

21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	81	7.5	unmarked	4.39	2.01	382
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	87	10.3	unmarked	4.47	2.33	383
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	96	14.9	unmarked	4.56	2.70	384
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	81	9	unmarked	4.39	2.20	385
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	66	4	unmarked	4.19	1.39	386
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	92	12.3	unmarked	4.52	2.51	387
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	98	16	unmarked	4.58	2.77	388
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	89	12	unmarked	4.49	2.48	389
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	79	8.8	unmarked	4.37	2.17	390
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	78	5.8	unmarked	4.36	1.76	391
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	87	9.9	unmarked	4.47	2.29	392
21-Feb-17	Electrofishing	Count	NA	4	NA	Perch	1	84	9	unmarked	4.43	2.20	393
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	169	76.7	unmarked	5.13	4.34	394
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	149	62.4	unmarked	5.00	4.13	395
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	106	17.1	unmarked	4.66	2.84	396
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	91	12	unmarked	4.51	2.48	397
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	86	9.1	unmarked	4.45	2.21	398
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	92	12.6	unmarked	4.52	2.53	399
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	86	9.6	unmarked	4.45	2.26	400
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	79	7.2	unmarked	4.37	1.97	401
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	95	12.5	unmarked	4.55	2.53	402
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	90	11.5	unmarked	4.50	2.44	403
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	93	11.6	unmarked	4.53	2.45	404
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	84	9.1	unmarked	4.43	2.21	405
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	78	7.1	unmarked	4.36	1.96	406
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	89	9.1	unmarked	4.49	2.21	407

21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	92	9	unmarked	4.52	2.20	408
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	75	6.7	unmarked	4.32	1.90	409
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	96	13.8	unmarked	4.56	2.62	410
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	88	11.8	unmarked	4.48	2.47	411
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	158	59.7	unmarked	5.06	4.09	412
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	158	61	unmarked	5.06	4.11	413
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	85	10	unmarked	4.44	2.30	414
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	89	11.8	unmarked	4.49	2.47	415
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	86	10.2	unmarked	4.45	2.32	416
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	90	11.4	unmarked	4.50	2.43	417
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	81	8.1	unmarked	4.39	2.09	418
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	90	9.8	unmarked	4.50	2.28	419
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	89	10.8	unmarked	4.49	2.38	420
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	87	10.2	unmarked	4.47	2.32	421
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	82	8.5	unmarked	4.41	2.14	422
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	96	13.9	unmarked	4.56	2.63	423
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	82	8.5	unmarked	4.41	2.14	424
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	96	13.9	unmarked	4.56	2.63	425
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	82	8.1	unmarked	4.41	2.09	426
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	90	11	unmarked	4.50	2.40	427
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	84	9.9	unmarked	4.43	2.29	428
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	80	7.5	unmarked	4.38	2.01	429
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	83	7.6	unmarked	4.42	2.03	430
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	94	12.6	unmarked	4.54	2.53	431
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	133	34.2	unmarked	4.89	3.53	432
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	88	8.4	unmarked	4.48	2.13	433

21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	86	9.6	unmarked	4.45	2.26	434
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	82	8.3	unmarked	4.41	2.12	435
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	82	8.4	unmarked	4.41	2.13	436
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	92	12.1	unmarked	4.52	2.49	437
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	95	13.8	unmarked	4.55	2.62	438
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	89	10.2	unmarked	4.49	2.32	439
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	82	8.4	unmarked	4.41	2.13	440
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	100	17.8	unmarked	4.61	2.88	441
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	91	10.9	unmarked	4.51	2.39	442
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	89	10.9	unmarked	4.49	2.39	443
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	91	10.8	unmarked	4.51	2.38	444
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	81	7.2	unmarked	4.39	1.97	445
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	90	10	unmarked	4.50	2.30	446
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	96	12.7	unmarked	4.56	2.54	447
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	83	8.8	unmarked	4.42	2.17	448
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	86	9.4	unmarked	4.45	2.24	449
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	91	10.5	unmarked	4.51	2.35	450
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	85	9.2	unmarked	4.44	2.22	451
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	91	11	unmarked	4.51	2.40	452
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	90	11	unmarked	4.50	2.40	453
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	79	7.5	unmarked	4.37	2.01	454
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	85	10.4	unmarked	4.44	2.34	455
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	89	9.6	unmarked	4.49	2.26	456
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	79	8.3	unmarked	4.37	2.12	457
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	79	6.4	unmarked	4.37	1.86	458
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	90	10.8	unmarked	4.50	2.38	459

21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	83	8.3	unmarked	4.42	2.12	460
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	86	10.8	unmarked	4.45	2.38	461
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	82	8.4	unmarked	4.41	2.13	462
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	90	10.5	unmarked	4.50	2.35	463
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	82	8.7	unmarked	4.41	2.16	464
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	85	9.4	unmarked	4.44	2.24	465
21-Feb-17	Electrofishing	Count	NA	5	NA	Perch	1	94	12.5	unmarked	4.54	2.53	466
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	161	65.3	unmarked	5.08	4.18	467
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	170	68.6	unmarked	5.14	4.23	468
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	159	63.1	unmarked	5.07	4.14	469
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	154	55.2	unmarked	5.04	4.01	470
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	172	71.4	unmarked	5.15	4.27	471
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	163	64.3	unmarked	5.09	4.16	472
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	152	52.2	unmarked	5.02	3.96	473
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	155	53.3	unmarked	5.04	3.98	474
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	164	60.3	unmarked	5.10	4.10	475
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	156	49.5	unmarked	5.05	3.90	476
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	156	60.8	unmarked	5.05	4.11	477
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	144	46.1	unmarked	4.97	3.83	478
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	154	56.5	unmarked	5.04	4.03	479
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	146	45	unmarked	4.98	3.81	480
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	150	54.5	unmarked	5.01	4.00	481
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	155	56.3	unmarked	5.04	4.03	482
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	148	47.3	unmarked	5.00	3.86	483
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	157	53.6	unmarked	5.06	3.98	484
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	141	40.6	unmarked	4.95	3.70	485

22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	156	56.5	unmarked	5.05	4.03	486
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	152	54.3	unmarked	5.02	3.99	487
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	180	82	unmarked	5.19	4.41	488
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	134	35.2	unmarked	4.90	3.56	489
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	95	12.3	unmarked	4.55	2.51	490
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	143	42.2	unmarked	4.96	3.74	491
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	135	32.1	unmarked	4.91	3.47	492
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	106	16.4	unmarked	4.66	2.80	493
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	94	12.4	unmarked	4.54	2.52	494
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	93	12	unmarked	4.53	2.48	495
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	98	12.8	unmarked	4.58	2.55	496
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	89	9.9	unmarked	4.49	2.29	497
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	99	12.9	unmarked	4.60	2.56	498
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	79	6	unmarked	4.37	1.79	499
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	84	7.6	unmarked	4.43	2.03	500
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	98	13.8	unmarked	4.58	2.62	501
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	95	12.4	unmarked	4.55	2.52	502
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	89	8.3	unmarked	4.49	2.12	503
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	80	6	unmarked	4.38	1.79	504
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	101	15	unmarked	4.62	2.71	505
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	100	16.5	unmarked	4.61	2.80	506
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	92	11.3	unmarked	4.52	2.42	507
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	102	16.2	unmarked	4.62	2.79	508
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	103	16.4	unmarked	4.63	2.80	509
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	99	14.2	unmarked	4.60	2.65	510
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	91	10.6	unmarked	4.51	2.36	511

22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	95	11.1	unmarked	4.55	2.41	512
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	105	15.1	unmarked	4.65	2.71	513
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	94	11.8	unmarked	4.54	2.47	514
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	104	16.9	unmarked	4.64	2.83	515
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	80	6.2	unmarked	4.38	1.82	516
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	89	10.3	unmarked	4.49	2.33	517
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	88	11.4	unmarked	4.48	2.43	518
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	82	6.3	unmarked	4.41	1.84	519
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	91	8.7	unmarked	4.51	2.16	520
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	78	5.9	unmarked	4.36	1.77	521
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	89	9	unmarked	4.49	2.20	522
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	86	8.7	unmarked	4.45	2.16	523
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	83	7.5	unmarked	4.42	2.01	524
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	81	7.8	unmarked	4.39	2.05	525
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	93	11.4	unmarked	4.53	2.43	526
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	80	6.5	unmarked	4.38	1.87	527
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	90	9.2	unmarked	4.50	2.22	528
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	82	7.4	unmarked	4.41	2.00	529
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	84	7	unmarked	4.43	1.95	530
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	85	8.1	unmarked	4.44	2.09	531
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	89	9.2	unmarked	4.49	2.22	532
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	91	9.7	unmarked	4.51	2.27	533
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	89	9.9	unmarked	4.49	2.29	534
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	86	7.5	unmarked	4.45	2.01	535
22-Feb-17	Electrofishing	Count	NA	6	NA	Perch	1	84	6.4	unmarked	4.43	1.86	536
22-Feb-17	Electrofishing	Count	NA	6	NA	Longfin eel	1	900	2480	unmarked	6.80	7.82	537

22-Feb-17	Electrofishing	Count	NA	6	NA	Longfin eel	1	900	2480	unmarked	6.80	7.82	538
22-Feb-17	Electrofishing	Count	NA	6	NA	Longfin eel	1	900	2480	unmarked	6.80	7.82	539
22-Feb-17	Electrofishing	Count	NA	6	NA	Longfin eel	1	900	2480	unmarked	6.80	7.82	540
22-Feb-17	Electrofishing	Count	NA	6	NA	Longfin eel	1	900	2480	unmarked	6.80	7.82	541
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	90	10.9	unmarked	4.50	2.39	542
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	190	101.2	unmarked	5.25	4.62	543
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	190	96.3	unmarked	5.25	4.57	544
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	168	70.2	unmarked	5.12	4.25	545
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	107	18	unmarked	4.67	2.89	546
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	95	11.1	unmarked	4.55	2.41	547
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	95	12	unmarked	4.55	2.48	548
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	94	11.7	unmarked	4.54	2.46	549
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	100	15.2	unmarked	4.61	2.72	550
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	81	7.2	unmarked	4.39	1.97	551
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	91	10.5	unmarked	4.51	2.35	552
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	88	9.4	unmarked	4.48	2.24	553
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	96	15.1	unmarked	4.56	2.71	554
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	89	10	unmarked	4.49	2.30	555
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	96	13.4	unmarked	4.56	2.60	556
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	88	9.2	unmarked	4.48	2.22	557
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	98	13.3	unmarked	4.58	2.59	558
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	84	8.6	unmarked	4.43	2.15	559
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	88	8.7	unmarked	4.48	2.16	560
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	90	9.8	unmarked	4.50	2.28	561
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	77	6.5	unmarked	4.34	1.87	562
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	91	9.6	unmarked	4.51	2.26	563

22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	96	12.4	unmarked	4.56	2.52	564
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	92	10.3	unmarked	4.52	2.33	565
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	79	7.6	unmarked	4.37	2.03	566
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	89	7.9	unmarked	4.49	2.07	567
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	94	11.3	unmarked	4.54	2.42	568
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	88	9.7	unmarked	4.48	2.27	569
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	96	14.2	unmarked	4.56	2.65	570
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	92	12.5	unmarked	4.52	2.53	571
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	105	16.5	unmarked	4.65	2.80	572
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	88	10.1	unmarked	4.48	2.31	573
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	84	8.8	unmarked	4.43	2.17	574
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	100	13.3	unmarked	4.61	2.59	575
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	85	7.8	unmarked	4.44	2.05	576
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	90	10.2	unmarked	4.50	2.32	577
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	86	9.4	unmarked	4.45	2.24	578
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	93	11.5	unmarked	4.53	2.44	579
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	94	12.5	unmarked	4.54	2.53	580
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	94	12.3	unmarked	4.54	2.51	581
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	83	8	unmarked	4.42	2.08	582
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	101	12.7	unmarked	4.62	2.54	583
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	70	4.3	unmarked	4.25	1.46	584
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	85	9.6	unmarked	4.44	2.26	585
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	83	8.5	unmarked	4.42	2.14	586
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	91	12.1	unmarked	4.51	2.49	587
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	85	7.8	unmarked	4.44	2.05	588
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	100	13.9	unmarked	4.61	2.63	589

22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	90	9.1	unmarked	4.50	2.21	590
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	90	9.7	unmarked	4.50	2.27	591
22-Feb-17	Electrofishing	Count	NA	7	NA	Perch	1	80	7.3	unmarked	4.38	1.99	592
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	157	55.4	unmarked	5.06	4.01	593
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	88	9.2	unmarked	4.48	2.22	594
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	90	10.4	unmarked	4.50	2.34	595
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	155	58.5	unmarked	5.04	4.07	596
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	155	62.4	unmarked	5.04	4.13	597
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	182	93.2	unmarked	5.20	4.53	598
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	151	52.8	unmarked	5.02	3.97	599
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	92	11.2	unmarked	4.52	2.42	600
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	103	15.4	unmarked	4.63	2.73	601
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	87	8.8	unmarked	4.47	2.17	602
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	85	9.2	unmarked	4.44	2.22	603
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	98	14.2	unmarked	4.58	2.65	604
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	84	7.9	unmarked	4.43	2.07	605
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	83	8.1	unmarked	4.42	2.09	606
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	72	4.5	unmarked	4.28	1.50	607
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	82	7.3	unmarked	4.41	1.99	608
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	89	10.8	unmarked	4.49	2.38	609
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	94	10.7	unmarked	4.54	2.37	610
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	94	12.5	unmarked	4.54	2.53	611
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	90	10.4	unmarked	4.50	2.34	612
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	79	6.9	unmarked	4.37	1.93	613
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	91	10.2	unmarked	4.51	2.32	614
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	92	10.5	unmarked	4.52	2.35	615

22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	84	7.9	unmarked	4.43	2.07	616
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	93	10.2	unmarked	4.53	2.32	617
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	86	9.4	unmarked	4.45	2.24	618
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	88	9.1	unmarked	4.48	2.21	619
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	102	14	unmarked	4.62	2.64	620
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	95	11.8	unmarked	4.55	2.47	621
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	98	11.7	unmarked	4.58	2.46	622
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	91	11.3	unmarked	4.51	2.42	623
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	79	7.6	unmarked	4.37	2.03	624
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	88	9.2	unmarked	4.48	2.22	625
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	99	14.4	unmarked	4.60	2.67	626
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	90	9.5	unmarked	4.50	2.25	627
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	91	12.7	unmarked	4.51	2.54	628
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	93	11.5	unmarked	4.53	2.44	629
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	89	10.4	unmarked	4.49	2.34	630
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	91	12.7	unmarked	4.51	2.54	631
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	93	11.5	unmarked	4.53	2.44	632
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	89	10.4	unmarked	4.49	2.34	633
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	91	11.8	unmarked	4.51	2.47	634
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	171	77.5	unmarked	5.14	4.35	635
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	173	77.4	unmarked	5.15	4.35	636
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	89	10.6	unmarked	4.49	2.36	637
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	99	14.4	unmarked	4.60	2.67	638
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	98	14.1	unmarked	4.58	2.65	639
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	91	11.8	unmarked	4.51	2.47	640
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	79	6.5	unmarked	4.37	1.87	641

22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	90	11.4	unmarked	4.50	2.43	642
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	95	12.1	unmarked	4.55	2.49	643
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	84	8.4	unmarked	4.43	2.13	644
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	87	11.2	unmarked	4.47	2.42	645
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	86	10.1	unmarked	4.45	2.31	646
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	91	9.9	unmarked	4.51	2.29	647
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	95	14.1	unmarked	4.55	2.65	648
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	90	10.6	unmarked	4.50	2.36	649
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	103	13.4	unmarked	4.63	2.60	650
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	95	11.3	unmarked	4.55	2.42	651
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	89	10.3	unmarked	4.49	2.33	652
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	76	5.8	unmarked	4.33	1.76	653
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	103	14.9	unmarked	4.63	2.70	654
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	89	9.7	unmarked	4.49	2.27	655
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	85	8.3	unmarked	4.44	2.12	656
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	89	10.7	unmarked	4.49	2.37	657
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	94	12.2	unmarked	4.54	2.50	658
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	91	10.9	unmarked	4.51	2.39	659
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	85	9	unmarked	4.44	2.20	660
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	80	8.2	unmarked	4.38	2.10	661
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	87	9.8	unmarked	4.47	2.28	662
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	91	10.4	unmarked	4.51	2.34	663
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	82	7.8	unmarked	4.41	2.05	664
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	86	9	unmarked	4.45	2.20	665
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	89	10.2	unmarked	4.49	2.32	666
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	91	11.4	unmarked	4.51	2.43	667

22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	96	12.8	unmarked	4.56	2.55	668
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	86	9.9	unmarked	4.45	2.29	669
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	85	8.9	unmarked	4.44	2.19	670
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	82	7.4	unmarked	4.41	2.00	671
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	91	11.5	unmarked	4.51	2.44	672
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	90	9.4	unmarked	4.50	2.24	673
22-Feb-17	Electrofishing	Count	NA	8	NA	Perch	1	91	10.3	unmarked	4.51	2.33	674
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	176	82.4	unmarked	5.17	4.41	675
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	172	78	unmarked	5.15	4.36	676
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	195	112.5	unmarked	5.27	4.72	677
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	143	42.9	unmarked	4.96	3.76	678
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	151	51	unmarked	5.02	3.93	679
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	158	56	unmarked	5.06	4.03	680
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	101	17.9	unmarked	4.62	2.88	681
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	84	8.2	unmarked	4.43	2.10	682
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	84	7.3	unmarked	4.43	1.99	683
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	90	9.1	unmarked	4.50	2.21	684
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	90	9.3	unmarked	4.50	2.23	685
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	99	12.6	unmarked	4.60	2.53	686
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	83	9	unmarked	4.42	2.20	687
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	76	5.8	unmarked	4.33	1.76	688
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	90	10.8	unmarked	4.50	2.38	689
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	92	10.8	unmarked	4.52	2.38	690
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	75	6.4	unmarked	4.32	1.86	691
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	93	11.1	unmarked	4.53	2.41	692
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	89	9.8	unmarked	4.49	2.28	693

22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	148	49.3	unmarked	5.00	3.90	694
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	93	11.7	unmarked	4.53	2.46	695
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	91	10.8	unmarked	4.51	2.38	696
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	105	15.1	unmarked	4.65	2.71	697
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	90	10.6	unmarked	4.50	2.36	698
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	80	7	unmarked	4.38	1.95	699
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	80	7.4	unmarked	4.38	2.00	700
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	83	7.9	unmarked	4.42	2.07	701
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	84	9.4	unmarked	4.43	2.24	702
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	84	7.8	unmarked	4.43	2.05	703
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	86	10.5	unmarked	4.45	2.35	704
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	94	10.4	unmarked	4.54	2.34	705
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	86	9.2	unmarked	4.45	2.22	706
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	85	9.5	unmarked	4.44	2.25	707
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	85	8.7	unmarked	4.44	2.16	708
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	91	10.7	unmarked	4.51	2.37	709
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	101	13.4	unmarked	4.62	2.60	710
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	84	9.9	unmarked	4.43	2.29	711
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	90	11.1	unmarked	4.50	2.41	712
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	87	5.7	unmarked	4.47	1.74	713
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	83	7.3	unmarked	4.42	1.99	714
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	106	16.3	unmarked	4.66	2.79	715
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	81	6.8	unmarked	4.39	1.92	716
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	94	11.1	unmarked	4.54	2.41	717
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	85	8.9	unmarked	4.44	2.19	718
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	102	16.5	unmarked	4.62	2.80	719

22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	85	7.6	unmarked	4.44	2.03	720
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	158	64.3	unmarked	5.06	4.16	721
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	156	49.1	unmarked	5.05	3.89	722
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	180	76.1	unmarked	5.19	4.33	723
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	155	59	unmarked	5.04	4.08	724
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	181	84.1	unmarked	5.20	4.43	725
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	158	59.5	unmarked	5.06	4.09	726
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	141	41	unmarked	4.95	3.71	727
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	153	52.3	unmarked	5.03	3.96	728
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	148	51.8	unmarked	5.00	3.95	729
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	101	11.6	unmarked	4.62	2.45	730
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	99	13.2	unmarked	4.60	2.58	731
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	94	11.9	unmarked	4.54	2.48	732
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	86	6.9	unmarked	4.45	1.93	733
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	98	11.7	unmarked	4.58	2.46	734
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	104	14.8	unmarked	4.64	2.69	735
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	78	5.8	unmarked	4.36	1.76	736
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	80	6.9	unmarked	4.38	1.93	737
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	95	11.8	unmarked	4.55	2.47	738
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	104	15.4	unmarked	4.64	2.73	739
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	86	8	unmarked	4.45	2.08	740
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	97	13.2	unmarked	4.57	2.58	741
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	78	7.2	unmarked	4.36	1.97	742
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	90	9.7	unmarked	4.50	2.27	743
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	86	8.8	unmarked	4.45	2.17	744
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	74	5.8	unmarked	4.30	1.76	745

22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	91	10.2	unmarked	4.51	2.32	746
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	90	11.2	unmarked	4.50	2.42	747
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	87	8.7	unmarked	4.47	2.16	748
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	78	7.2	unmarked	4.36	1.97	749
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	85	8.3	unmarked	4.44	2.12	750
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	85	7.8	unmarked	4.44	2.05	751
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	87	9.9	unmarked	4.47	2.29	752
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	83	8.2	unmarked	4.42	2.10	753
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	96	12.5	unmarked	4.56	2.53	754
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	86	8.3	unmarked	4.45	2.12	755
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	85	7.3	unmarked	4.44	1.99	756
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	93	10.8	unmarked	4.53	2.38	757
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	96	9.8	unmarked	4.56	2.28	758
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	82	8.1	unmarked	4.41	2.09	759
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	85	7.7	unmarked	4.44	2.04	760
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	72	5.2	unmarked	4.28	1.65	761
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	75	6.2	unmarked	4.32	1.82	762
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	74	6.1	unmarked	4.30	1.81	763
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	94	10.6	unmarked	4.54	2.36	764
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	95	10.8	unmarked	4.55	2.38	765
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	90	8.6	unmarked	4.50	2.15	766
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	82	7.1	unmarked	4.41	1.96	767
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	98	11.1	unmarked	4.58	2.41	768
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	103	17.5	unmarked	4.63	2.86	769
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	90	10.1	unmarked	4.50	2.31	770
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	95	11.8	unmarked	4.55	2.47	771

22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	92	9.2	unmarked	4.52	2.22	772
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	92	10.5	unmarked	4.52	2.35	773
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	94	10.6	unmarked	4.54	2.36	774
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	81	7	unmarked	4.39	1.95	775
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	84	8.1	unmarked	4.43	2.09	776
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	100	14.5	unmarked	4.61	2.67	777
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	100	13	unmarked	4.61	2.56	778
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	84	8.6	unmarked	4.43	2.15	779
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	91	10	unmarked	4.51	2.30	780
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	99	13.1	unmarked	4.60	2.57	781
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	82	7.6	unmarked	4.41	2.03	782
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	77	6.6	unmarked	4.34	1.89	783
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	97	11.6	unmarked	4.57	2.45	784
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	92	9.7	unmarked	4.52	2.27	785
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	101	14.5	unmarked	4.62	2.67	786
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	165	60.2	unmarked	5.11	4.10	787
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	160	62.3	unmarked	5.08	4.13	788
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	85	7.8	unmarked	4.44	2.05	789
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	83	7.3	unmarked	4.42	1.99	790
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	72	4.4	unmarked	4.28	1.48	791
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	131	37.6	unmarked	4.88	3.63	792
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	136	36.5	unmarked	4.91	3.60	793
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	97	13.6	unmarked	4.57	2.61	794
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	104	14.9	unmarked	4.64	2.70	795
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	78	7.8	unmarked	4.36	2.05	796
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	88	10.3	unmarked	4.48	2.33	797

22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	84	7.5	unmarked	4.43	2.01	798
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	80	7.2	unmarked	4.38	1.97	799
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	81	8	unmarked	4.39	2.08	800
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	87	9.8	unmarked	4.47	2.28	801
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	90	9.9	unmarked	4.50	2.29	802
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	85	9.4	unmarked	4.44	2.24	803
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	100	13.2	unmarked	4.61	2.58	804
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	95	11.7	unmarked	4.55	2.46	805
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	87	9.1	unmarked	4.47	2.21	806
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	96	12	unmarked	4.56	2.48	807
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	88	9	unmarked	4.48	2.20	808
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	83	7.1	unmarked	4.42	1.96	809
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	79	7.2	unmarked	4.37	1.97	810
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	89	9.6	unmarked	4.49	2.26	811
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	84	8.2	unmarked	4.43	2.10	812
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	90	10.4	unmarked	4.50	2.34	813
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	93	11.9	unmarked	4.53	2.48	814
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	95	11.8	unmarked	4.55	2.47	815
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	86	9.3	unmarked	4.45	2.23	816
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	94	11.8	unmarked	4.54	2.47	817
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	85	7.7	unmarked	4.44	2.04	818
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	73	5	unmarked	4.29	1.61	819
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	86	9.2	unmarked	4.45	2.22	820
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	81	7.1	unmarked	4.39	1.96	821
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	79	7.1	unmarked	4.37	1.96	822
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	98	11.6	unmarked	4.58	2.45	823

22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	91	9.6	unmarked	4.51	2.26	824
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	85	8.9	unmarked	4.44	2.19	825
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	89	10.1	unmarked	4.49	2.31	826
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	90	13.8	unmarked	4.50	2.62	827
22-Feb-17	Electrofishing	Count	NA	9	NA	Perch	1	80	6.5	unmarked	4.38	1.87	828
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	169	72.9	unmarked	5.13	4.29	829
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	162	59.8	unmarked	5.09	4.09	830
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	159	62.4	unmarked	5.07	4.13	831
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	148	44.6	unmarked	5.00	3.80	832
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	149	48.3	unmarked	5.00	3.88	833
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	166	67.4	unmarked	5.11	4.21	834
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	88	10.6	unmarked	4.48	2.36	835
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	99	12.4	unmarked	4.60	2.52	836
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	91	9.7	unmarked	4.51	2.27	837
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	86	9.5	unmarked	4.45	2.25	838
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	76	7.2	unmarked	4.33	1.97	839
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	160	58.9	unmarked	5.08	4.08	840
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	155	56.3	unmarked	5.04	4.03	841
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	162	63.1	unmarked	5.09	4.14	842
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	91	12.8	unmarked	4.51	2.55	843
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	81	7	unmarked	4.39	1.95	844
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	96	13.1	unmarked	4.56	2.57	845
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	78	7	unmarked	4.36	1.95	846
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	82	7.4	unmarked	4.41	2.00	847
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	147	48.3	unmarked	4.99	3.88	848
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	109	16.6	unmarked	4.69	2.81	849

22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	86	9.6	unmarked	4.45	2.26	850
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	90	8.8	unmarked	4.50	2.17	851
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	79	6.4	unmarked	4.37	1.86	852
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	100	13	unmarked	4.61	2.56	853
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	95	10.4	unmarked	4.55	2.34	854
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	91	9.7	unmarked	4.51	2.27	855
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	93	11.6	unmarked	4.53	2.45	856
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	91	11.8	unmarked	4.51	2.47	857
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	95	11	unmarked	4.55	2.40	858
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	90	9.2	unmarked	4.50	2.22	859
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	88	9.1	unmarked	4.48	2.21	860
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	92	11.7	unmarked	4.52	2.46	861
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	92	9.2	unmarked	4.52	2.22	862
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	93	10.6	unmarked	4.53	2.36	863
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	100	12.9	unmarked	4.61	2.56	864
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	90	10.8	unmarked	4.50	2.38	865
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	84	8.4	unmarked	4.43	2.13	866
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	79	8.2	unmarked	4.37	2.10	867
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	90	10.8	unmarked	4.50	2.38	868
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	84	8.4	unmarked	4.43	2.13	869
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	79	8.2	unmarked	4.37	2.10	870
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	90	9.5	unmarked	4.50	2.25	871
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	88	7.8	unmarked	4.48	2.05	872
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	85	9.9	unmarked	4.44	2.29	873
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	90	10.4	unmarked	4.50	2.34	874
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	89	8.2	unmarked	4.49	2.10	875

22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	84	6.8	unmarked	4.43	1.92	876
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	74	5.2	unmarked	4.30	1.65	877
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	79	6.8	unmarked	4.37	1.92	878
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	90	8.3	unmarked	4.50	2.12	879
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	84	7.6	unmarked	4.43	2.03	880
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	85	8.4	unmarked	4.44	2.13	881
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	87	8.8	unmarked	4.47	2.17	882
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	160	67.2	unmarked	5.08	4.21	883
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	155	49.3	unmarked	5.04	3.90	884
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	151	52.6	unmarked	5.02	3.96	885
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	153	47.7	unmarked	5.03	3.86	886
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	164	62.9	unmarked	5.10	4.14	887
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	145	45.9	unmarked	4.98	3.83	888
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	157	57.8	unmarked	5.06	4.06	889
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	154	53.2	unmarked	5.04	3.97	890
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	151	48.1	unmarked	5.02	3.87	891
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	163	60.5	unmarked	5.09	4.10	892
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	138	39.3	unmarked	4.93	3.67	893
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	145	46.8	unmarked	4.98	3.85	894
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	86	8.3	unmarked	4.45	2.12	895
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	79	7.4	unmarked	4.37	2.00	896
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	110	19	unmarked	4.70	2.94	897
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	87	8	unmarked	4.47	2.08	898
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	81	6.9	unmarked	4.39	1.93	899
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	104	14.5	unmarked	4.64	2.67	900
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	93	10	unmarked	4.53	2.30	901

22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	87	6.9	unmarked	4.47	1.93	902
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	100	13.7	unmarked	4.61	2.62	903
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	75	5.7	unmarked	4.32	1.74	904
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	80	7.2	unmarked	4.38	1.97	905
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	88	9.7	unmarked	4.48	2.27	906
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	79	6.8	unmarked	4.37	1.92	907
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	78	7.2	unmarked	4.36	1.97	908
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	78	7.2	unmarked	4.36	1.97	909
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	90	9.8	unmarked	4.50	2.28	910
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	86	9.8	unmarked	4.45	2.28	911
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	77	5.6	unmarked	4.34	1.72	912
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	85	8.3	unmarked	4.44	2.12	913
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	83	7.6	unmarked	4.42	2.03	914
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	88	10.8	unmarked	4.48	2.38	915
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	83	8.7	unmarked	4.42	2.16	916
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	84	8	unmarked	4.43	2.08	917
22-Feb-17	Electrofishing	Count	NA	10	NA	Perch	1	84	7.8	unmarked	4.43	2.05	918
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	224	163.9	unmarked	5.41	5.10	919
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	200	133	unmarked	5.30	4.89	920
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	165	61.3	unmarked	5.11	4.12	921
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	165	64.5	unmarked	5.11	4.17	922
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	136	35	unmarked	4.91	3.56	923
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	153	52.3	unmarked	5.03	3.96	924
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	95	10	unmarked	4.55	2.30	925
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	90	10.4	unmarked	4.50	2.34	926
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	95	13.1	unmarked	4.55	2.57	927

22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	89	11.3	unmarked	4.49	2.42	928
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	86	8.3	unmarked	4.45	2.12	929
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	100	12.7	unmarked	4.61	2.54	930
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	95	11.1	unmarked	4.55	2.41	931
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	89	8.6	unmarked	4.49	2.15	932
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	81	7.4	unmarked	4.39	2.00	933
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	92	9.2	unmarked	4.52	2.22	934
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	87	9.8	unmarked	4.47	2.28	935
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	90	9.3	unmarked	4.50	2.23	936
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	80	7.1	unmarked	4.38	1.96	937
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	91	10.8	unmarked	4.51	2.38	938
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	76	5.4	unmarked	4.33	1.69	939
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	190	109.4	unmarked	5.25	4.70	940
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	150	55.4	unmarked	5.01	4.01	941
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	150	49.4	unmarked	5.01	3.90	942
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	168	73.6	unmarked	5.12	4.30	943
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	84	9.1	unmarked	4.43	2.21	944
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	91	9.8	unmarked	4.51	2.28	945
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	87	9.9	unmarked	4.47	2.29	946
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	80	5.7	unmarked	4.38	1.74	947
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	90	10.4	unmarked	4.50	2.34	948
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	98	13.9	unmarked	4.58	2.63	949
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	94	11.2	unmarked	4.54	2.42	950
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	81	7.5	unmarked	4.39	2.01	951
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	89	10	unmarked	4.49	2.30	952
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	88	11	unmarked	4.48	2.40	953

22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	97	11.8	unmarked	4.57	2.47	954
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	90	10	unmarked	4.50	2.30	955
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	93	9.2	unmarked	4.53	2.22	956
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	89	9.8	unmarked	4.49	2.28	957
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	95	12	unmarked	4.55	2.48	958
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	82	8.2	unmarked	4.41	2.10	959
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	95	10.8	unmarked	4.55	2.38	960
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	93	8.1	unmarked	4.53	2.09	961
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	89	9.4	unmarked	4.49	2.24	962
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	86	9.2	unmarked	4.45	2.22	963
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	96	12.6	unmarked	4.56	2.53	964
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	81	6.8	unmarked	4.39	1.92	965
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	91	10.4	unmarked	4.51	2.34	966
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	94	10.3	unmarked	4.54	2.33	967
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	88	9.2	unmarked	4.48	2.22	968
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	89	9.1	unmarked	4.49	2.21	969
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	86	8.5	unmarked	4.45	2.14	970
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	220	163	unmarked	5.39	5.09	971
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	200	123	unmarked	5.30	4.81	972
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	179	86	unmarked	5.19	4.45	973
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	153	58.2	unmarked	5.03	4.06	974
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	154	52.8	unmarked	5.04	3.97	975
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	152	53	unmarked	5.02	3.97	976
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	135	38.4	unmarked	4.91	3.65	977
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	94	12	unmarked	4.54	2.48	978
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1	81	7.4	unmarked	4.39	2.00	979

22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1			unmarked			980
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1			unmarked			981
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1			unmarked			982
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1			unmarked			983
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1			unmarked			984
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1			unmarked			985
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1			unmarked			986
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1			unmarked			987
22-Feb-17	Fyke netting	Count	NA	Fyke leftover	3	Perch	1			unmarked			988
22-Feb-17	Electrofishing	Count	NA	6	NA	Shortfin eel	1	280	40.5	unmarked	5.63	3.70	989
22-Feb-17	Electrofishing	Count	NA	6	NA	Shortfin eel	1	250	25.9	unmarked	5.52	3.25	990
22-Feb-17	Electrofishing	Count	NA	8	NA	Shortfin eel	1	341	59.1	unmarked	5.83	4.08	991
22-Feb-17	Electrofishing	Count	NA	8	NA	Shortfin eel	1	166	6.5	unmarked	5.11	1.87	992
22-Feb-17	Electrofishing	Count	NA	8	NA	Shortfin eel	1	146	4.5	unmarked	4.98	1.50	993
22-Feb-17	Electrofishing	Count	NA	8	NA	Shortfin eel	1	116	2.5	unmarked	4.75	0.92	994
22-Feb-17	Electrofishing	Count	NA	8	NA	Shortfin eel	1	235	19.1	unmarked	5.46	2.95	995
22-Feb-17	Electrofishing	Count	NA	9	NA	Shortfin eel	1	105	1.8	unmarked	4.65	0.59	996
22-Feb-17	Electrofishing	Count	NA	9	NA	Shortfin eel	1	115	1.8	unmarked	4.74	0.59	997
22-Feb-17	Electrofishing	Count	NA	9	NA	Shortfin eel	1	150	5.5	unmarked	5.01	1.70	998
22-Feb-17	Electrofishing	Count	NA	9	NA	Shortfin eel	1	216	14.6	unmarked	5.38	2.68	999
22-Feb-17	Electrofishing	Count	NA	9	NA	Shortfin eel	1	215	15	unmarked	5.37	2.71	1000
22-Feb-17	Electrofishing	Count	NA	10	NA	Shortfin eel	1	200	12.6	unmarked	5.30	2.53	1001
22-Feb-17	Electrofishing	Count	NA	4	NA	Banded kokopu	1	53	1.1	unmarked	3.97	0.10	1002
22-Feb-17	Electrofishing	Count	NA	9	NA	Banded kokopu	1	47	0.9	unmarked	3.85	-0.11	1003
22-Feb-17	Electrofishing	Count	NA	9	NA	Banded kokopu	1	46	0.6	unmarked	3.83	-0.51	1004
22-Feb-17	Electrofishing	Count	NA	9	NA	Banded kokopu	1	50	1.1	unmarked	3.91	0.10	1005

Appendix 1: Results from the fish sampling in Lake Rotokare on 8-9 June 2017.

Date	Fishing_type	Fishing_type_mesh	Net_number	Net_mesh_mm	Species	Count_of_fish	Length_mm	weight_g	ln_len	ln_weight	order
7/06/2017	Gill_net	Gill_net	1	18	Perch	1	173	74	5.15	4.30	1
7/06/2017	Gill_net	Gill_net	1	18	Perch	1	174	71	5.16	4.26	2
7/06/2017	Gill_net	Gill_net	1	18	Perch	1	171	74	5.14	4.30	3
7/06/2017	Gill_net	Gill_net	1	18	Perch	1	179	86	5.19	4.45	4
7/06/2017	Gill_net	Gill_net	1	18	Perch	1	173	77	5.15	4.34	5
7/06/2017	Gill_net	Gill_net	1	18	Perch	1	158	55	5.06	4.01	6
7/06/2017	Gill_net	Gill_net	1	18	Perch	1	184	94	5.21	4.54	7
7/06/2017	Gill_net	Gill_net	1	18	Perch	1	161	67	5.08	4.20	8
7/06/2017	Gill_net	Gill_net	1	18	Perch	1	167	64	5.12	4.16	9
7/06/2017	Gill_net	Gill_net	1	18	Perch	1	170	72	5.14	4.28	10
7/06/2017	Gill_net	Gill_net	1	18	Perch	1	174	62	5.16	4.13	11
7/06/2017	Gill_net	Gill_net	1	18	Perch	1	166	57	5.11	4.04	12
7/06/2017	Gill_net	Gill_net	1	18	Perch	1	154	55	5.04	4.01	13
7/06/2017	Gill_net	Gill_net	1	18	Perch	1	175	81	5.16	4.39	14
7/06/2017	Gill_net	Gill_net	1	18	Perch	1	162	65	5.09	4.17	15
7/06/2017	Gill_net	Gill_net	1	18	Perch	1	168	70	5.12	4.25	16
7/06/2017	Gill_net	Gill_net	1	18	Perch	1	157	59	5.06	4.08	17
7/06/2017	Gill_net	Gill_net	1	18	Perch	1	154	53	5.04	3.97	18
7/06/2017	Gill_net	Gill_net	1	18	Perch	1	158	60	5.06	4.09	19
7/06/2017	Gill_net	Gill_net	1	18	Perch	1	153	56	5.03	4.03	20
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	433	1658	6.07	7.41	21
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	230	210	5.44	5.35	22
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	177	74	5.18	4.30	23
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	168	74	5.12	4.30	24

7/06/2017	Gill_net	Gill_net	2	18	Perch	1	164	56	5.10	4.03	25
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	165	68	5.11	4.22	26
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	177	85	5.18	4.44	27
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	189	104	5.24	4.64	28
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	182	91	5.20	4.51	29
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	180	84	5.19	4.43	30
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	168	73	5.12	4.29	31
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	210	136	5.35	4.91	32
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	212	131	5.36	4.88	33
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	177	83	5.18	4.42	34
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	178	88	5.18	4.48	35
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	180	87	5.19	4.47	36
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	174	79	5.16	4.37	37
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	176	85	5.17	4.44	38
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	158	62	5.06	4.13	39
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	148	49	5.00	3.89	40
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	162	62	5.09	4.13	41
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	122	26	4.80	3.26	42
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	173	80	5.15	4.38	43
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	157	53	5.06	3.97	44
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	186	96	5.23	4.56	45
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	172	79	5.15	4.37	46
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	151	51	5.02	3.93	47
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	151	50	5.02	3.91	48
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	114	23	4.74	3.14	49
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	119	24	4.78	3.18	50

7/06/2017	Gill_net	Gill_net	2	18	Perch	1	133	33	4.89	3.50	51
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	124	27	4.82	3.30	52
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	133	21	4.89	3.04	53
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	149	51	5.00	3.93	54
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	117	25	4.76	3.22	55
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	116	25	4.75	3.22	56
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	122	25	4.80	3.22	57
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	119	22	4.78	3.09	58
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	125	26	4.83	3.26	59
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	128	30	4.85	3.40	60
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	118	24	4.77	3.18	61
7/06/2017	Gill_net	Gill_net	2	18	Perch	1	116	23	4.75	3.14	62
7/06/2017	Gill_net	Gill_net	3	18	Perch	1	187	104	5.23	4.64	63
7/06/2017	Gill_net	Gill_net	3	18	Perch	1	178	85	5.18	4.44	64
7/06/2017	Gill_net	Gill_net	3	18	Perch	1	114	22	4.74	3.09	65
7/06/2017	Gill_net	Gill_net	3	18	Perch	1	117	23	4.76	3.14	66
7/06/2017	Gill_net	Gill_net	3	18	Perch	1	126	25	4.84	3.22	67
7/06/2017	Gill_net	Gill_net	4	18	Perch	1	169	72	5.13	4.28	68
7/06/2017	Gill_net	Gill_net	4	18	Perch	1	164	70	5.10	4.25	69
7/06/2017	Gill_net	Gill_net	4	18	Perch	1	159	60	5.07	4.09	70
7/06/2017	Gill_net	Gill_net	4	18	Perch	1	203	117	5.31	4.76	71
7/06/2017	Gill_net	Gill_net	4	18	Perch	1	182	87	5.20	4.47	72
7/06/2017	Gill_net	Gill_net	4	18	Perch	1	153	53	5.03	3.97	73
7/06/2017	Gill_net	Gill_net	4	18	Perch	1	123	27	4.81	3.30	74
7/06/2017	Gill_net	Gill_net	4	18	Perch	1	121	24	4.80	3.18	75
7/06/2017	Gill_net	Gill_net	4	18	Perch	1	149	52	5.00	3.95	76

7/06/2017	Gill_net	Gill_net	4	18	Perch	1	151	48	5.02	3.87	77
7/06/2017	Gill_net	Gill_net	4	18	Perch	1	131	28	4.88	3.33	78
7/06/2017	Gill_net	Gill_net	4	18	Perch	1	122	26	4.80	3.26	79
7/06/2017	Gill_net	Gill_net	4	18	Perch	1	116	23	4.75	3.14	80
7/06/2017	Gill_net	Gill_net	4	18	Perch	1	118	24	4.77	3.18	81
7/06/2017	Gill_net	Gill_net	4	18	Perch	1	126	29	4.84	3.37	82
7/06/2017	Gill_net	Gill_net	4	18	Perch	1	116	23	4.75	3.14	83
7/06/2017	Gill_net	Gill_net	4	18	Perch	1	128	26	4.85	3.26	84
7/06/2017	Gill_net	Gill_net	4	18	Perch	1	122	26	4.80	3.26	85
7/06/2017	Gill_net	Gill_net	4	18	Perch	1	114	21	4.74	3.04	86
7/06/2017	Gill_net	Gill_net	4	18	Perch	1	123	25	4.81	3.22	87
7/06/2017	Gill_net	Gill_net	4	18	Perch	1	116	22	4.75	3.09	88
7/06/2017	Gill_net	Gill_net	4	18	Perch	1	122	25	4.80	3.22	89
7/06/2017	Gill_net	Gill_net	4	18	Perch	1	108	18	4.68	2.89	90
7/06/2017	Gill_net	Gill_net	4	18	Perch	1	118	25	4.77	3.22	91
7/06/2017	Gill_net	Gill_net	4	18	Perch	1	119	24	4.78	3.18	92
7/06/2017	Gill_net	Gill_net	4	18	Perch	1	124	26	4.82	3.26	93
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	174	82	5.16	4.41	94
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	164	61	5.10	4.11	95
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	182	84	5.20	4.43	96
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	174	72	5.16	4.28	97
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	162	56	5.09	4.03	98
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	181	89	5.20	4.49	99
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	189	104	5.24	4.64	100
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	171	65	5.14	4.17	101
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	170	67	5.14	4.20	102

7/06/2017	Gill_net	Gill_net	5	25	Perch	1	165	65	5.11	4.17	103
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	163	64	5.09	4.16	104
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	188	93	5.24	4.53	105
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	176	79	5.17	4.37	106
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	156	55	5.05	4.01	107
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	164	59	5.10	4.08	108
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	179	91	5.19	4.51	109
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	157	54	5.06	3.99	110
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	183	92	5.21	4.52	111
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	165	67	5.11	4.20	112
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	167	77	5.12	4.34	113
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	168	66	5.12	4.19	114
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	157	57	5.06	4.04	115
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	164	67	5.10	4.20	116
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	183	83	5.21	4.42	117
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	170	74	5.14	4.30	118
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	156	57	5.05	4.04	119
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	178	85	5.18	4.44	120
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	172	71	5.15	4.26	121
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	177	78	5.18	4.36	122
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	214	149	5.37	5.00	123
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	207	118	5.33	4.77	124
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	179	84	5.19	4.43	125
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	170	71	5.14	4.26	126
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	162	58	5.09	4.06	127
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	169	85	5.13	4.44	128

7/06/2017	Gill_net	Gill_net	5	25	Perch	1	178	81	5.18	4.39	129
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	196	106	5.28	4.66	130
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	174	81	5.16	4.39	131
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	199	112	5.29	4.72	132
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	168	74	5.12	4.30	133
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	159	60	5.07	4.09	134
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	192	105	5.26	4.65	135
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	181	79	5.20	4.37	136
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	178	74	5.18	4.30	137
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	205	111	5.32	4.71	138
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	184	105	5.21	4.65	139
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	157	54	5.06	3.99	140
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	158	56	5.06	4.03	141
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	177	81	5.18	4.39	142
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	169	59	5.13	4.08	143
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	173	80	5.15	4.38	144
7/06/2017	Gill_net	Gill_net	5	25	Perch	1	163	66	5.09	4.19	145
7/06/2017	Gill_net	Gill_net	6	25	Perch	1	156	57	5.05	4.04	146
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	327	773	5.79	6.65	147
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	260	298	5.56	5.70	148
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	171	69	5.14	4.23	149
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	203	120	5.31	4.79	150
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	167	75	5.12	4.32	151
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	178	87	5.18	4.47	152
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	168	70	5.12	4.25	153
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	179	91	5.19	4.51	154

7/06/2017	Gill_net	Gill_net	7	25	Perch	1	194	106	5.27	4.66	155
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	153	52	5.03	3.95	156
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	155	55	5.04	4.01	157
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	155	61	5.04	4.11	158
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	174	81	5.16	4.39	159
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	169	68	5.13	4.22	160
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	184	97	5.21	4.57	161
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	196	126	5.28	4.84	162
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	255	282	5.54	5.64	163
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	183	94	5.21	4.54	164
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	168	74	5.12	4.30	165
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	178	80	5.18	4.38	166
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	159	65	5.07	4.17	167
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	182	84	5.20	4.43	168
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	157	63	5.06	4.14	169
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	193	97	5.26	4.57	170
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	185	105	5.22	4.65	171
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	178	83	5.18	4.42	172
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	158	59	5.06	4.08	173
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	168	70	5.12	4.25	174
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	174	83	5.16	4.42	175
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	185	104	5.22	4.64	176
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	166	77	5.11	4.34	177
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	173	72	5.15	4.28	178
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	159	65	5.07	4.17	179
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	173	89	5.15	4.49	180

7/06/2017	Gill_net	Gill_net	7	25	Perch	1	190	106	5.25	4.66	181
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	192	101	5.26	4.62	182
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	187	99	5.23	4.60	183
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	160	64	5.08	4.16	184
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	175	77	5.16	4.34	185
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	169	72	5.13	4.28	186
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	164	68	5.10	4.22	187
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	118	25	4.77	3.22	188
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	117	23	4.76	3.14	189
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	183	88	5.21	4.48	190
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	158	57	5.06	4.04	191
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	161	63	5.08	4.14	192
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	175	73	5.16	4.29	193
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	165	71	5.11	4.26	194
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	174	85	5.16	4.44	195
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	160	64	5.08	4.16	196
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	149	52	5.00	3.95	197
7/06/2017	Gill_net	Gill_net	7	25	Perch	1	156	61	5.05	4.11	198
7/06/2017	Gill_net	Gill_net	8	25	Perch	1	168	70	5.12	4.25	199
7/06/2017	Gill_net	Gill_net	8	25	Perch	1	195	110	5.27	4.70	200
7/06/2017	Gill_net	Gill_net	8	25	Perch	1	166	69	5.11	4.23	201
7/06/2017	Gill_net	Gill_net	8	25	Perch	1	183	84	5.21	4.43	202
7/06/2017	Gill_net	Gill_net	8	25	Perch	1	175	77	5.16	4.34	203
7/06/2017	Gill_net	Gill_net	8	25	Perch	1	215	136	5.37	4.91	204
7/06/2017	Gill_net	Gill_net	8	25	Perch	1	174	72	5.16	4.28	205
7/06/2017	Gill_net	Gill_net	8	25	Perch	1	160	60	5.08	4.09	206

7/06/2017	Gill_net	Gill_net	8	25	Perch	1	196	108	5.28	4.68	207
7/06/2017	Gill_net	Gill_net	8	25	Perch	1	205	124	5.32	4.82	208
7/06/2017	Gill_net	Gill_net	8	25	Perch	1	206	118	5.33	4.77	209
7/06/2017	Gill_net	Gill_net	8	25	Perch	1	160	62	5.08	4.13	210
7/06/2017	Gill_net	Gill_net	8	25	Perch	1	184	92	5.21	4.52	211
7/06/2017	Gill_net	Gill_net	8	25	Perch	1	173	72	5.15	4.28	212
7/06/2017	Gill_net	Gill_net	8	25	Perch	1	180	81	5.19	4.39	213
7/06/2017	Gill_net	Gill_net	8	25	Perch	1	185	93	5.22	4.53	214
7/06/2017	Gill_net	Gill_net	8	25	Perch	1	182	95	5.20	4.55	215
7/06/2017	Gill_net	Gill_net	8	25	Perch	1	179	89	5.19	4.49	216
7/06/2017	Gill_net	Gill_net	8	25	Perch	1	190	102	5.25	4.62	217
7/06/2017	Gill_net	Gill_net	8	25	Perch	1	155	61	5.04	4.11	218
7/06/2017	Gill_net	Gill_net	8	25	Perch	1	185	103	5.22	4.63	219
7/06/2017	Gill_net	Gill_net	8	25	Perch	1	180	89	5.19	4.49	220
7/06/2017	Gill_net	Gill_net	8	25	Perch	1	177	81	5.18	4.39	221
7/06/2017	Gill_net	Gill_net	8	25	Perch	1	190	100	5.25	4.61	222
7/06/2017	Gill_net	Gill_net	8	25	Perch	1	188	89	5.24	4.49	223
7/06/2017	Gill_net	Gill_net	8	25	Perch	1	184	90	5.21	4.50	224
7/06/2017	Gill_net	Gill_net	8	25	Perch	1	180	89	5.19	4.49	225
7/06/2017	Gill_net	Gill_net	8	25	Perch	1	195	101	5.27	4.62	226
7/06/2017	Gill_net	Gill_net	8	25	Perch	1	171	80	5.14	4.38	227
7/06/2017	Gill_net	Gill_net	8	25	Perch	1	190	95	5.25	4.55	228
7/06/2017	Gill_net	Gill_net	8	25	Perch	1	185	96	5.22	4.56	229
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	186	101	5.23	4.62	230
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	151	52	5.02	3.95	231
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	160	58	5.08	4.06	232

7/06/2017	Gill_net	Gill_net	9	18	Perch	1	183	95	5.21	4.55	233
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	178	88	5.18	4.48	234
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	158	57	5.06	4.04	235
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	165	70	5.11	4.25	236
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	178	81	5.18	4.39	237
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	190	94	5.25	4.54	238
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	179	89	5.19	4.49	239
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	178	82	5.18	4.41	240
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	169	75	5.13	4.32	241
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	124	25	4.82	3.22	242
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	120	24	4.79	3.18	243
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	161	57	5.08	4.04	244
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	165	63	5.11	4.14	245
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	147	49	4.99	3.89	246
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	149	49	5.00	3.89	247
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	170	71	5.14	4.26	248
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	127	31	4.84	3.43	249
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	154	55	5.04	4.01	250
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	178	77	5.18	4.34	251
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	165	68	5.11	4.22	252
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	152	50	5.02	3.91	253
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	157	57	5.06	4.04	254
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	159	58	5.07	4.06	255
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	122	26	4.80	3.26	256
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	123	26	4.81	3.26	257
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	194	107	5.27	4.67	258

7/06/2017	Gill_net	Gill_net	9	18	Perch	1	178	82	5.18	4.41	259
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	150	54	5.01	3.99	260
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	123	26	4.81	3.26	261
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	194	107	5.27	4.67	262
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	178	82	5.18	4.41	263
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	150	54	5.01	3.99	264
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	123	26	4.81	3.26	265
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	165	67	5.11	4.20	266
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	120	23	4.79	3.14	267
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	185	91	5.22	4.51	268
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	158	59	5.06	4.08	269
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	156	56	5.05	4.03	270
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	155	58	5.04	4.06	271
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	156	60	5.05	4.09	272
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	146	49	4.98	3.89	273
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	157	55	5.06	4.01	274
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	153	48	5.03	3.87	275
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	174	77	5.16	4.34	276
7/06/2017	Gill_net	Gill_net	9	18	Perch	1	112	21	4.72	3.04	277
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	174	82	5.16	4.41	278
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	170	72	5.14	4.28	279
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	183	88	5.21	4.48	280
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	170	77	5.14	4.34	281
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	170	71	5.14	4.26	282
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	157	54	5.06	3.99	283
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	188	97	5.24	4.57	284

7/06/2017	Gill_net	Gill_net	10	25	Perch	1	179	84	5.19	4.43	285
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	180	88	5.19	4.48	286
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	168	65	5.12	4.17	287
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	185	88	5.22	4.48	288
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	175	80	5.16	4.38	289
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	176	83	5.17	4.42	290
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	176	65	5.17	4.17	291
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	178	97	5.18	4.57	292
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	176	86	5.17	4.45	293
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	187	98	5.23	4.58	294
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	169	72	5.13	4.28	295
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	156	57	5.05	4.04	296
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	167	65	5.12	4.17	297
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	175	75	5.16	4.32	298
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	163	60	5.09	4.09	299
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	186	90	5.23	4.50	300
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	164	64	5.10	4.16	301
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	174	78	5.16	4.36	302
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	161	58	5.08	4.06	303
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	164	64	5.10	4.16	304
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	170	69	5.14	4.23	305
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	174	72	5.16	4.28	306
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	171	79	5.14	4.37	307
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	158	55	5.06	4.01	308
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	178	81	5.18	4.39	309
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	182	86	5.20	4.45	310

7/06/2017	Gill_net	Gill_net	10	25	Perch	1	176	79	5.17	4.37	311
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	159	54	5.07	3.99	312
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	160	54	5.08	3.99	313
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	173	76	5.15	4.33	314
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	185	96	5.22	4.56	315
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	181	88	5.20	4.48	316
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	175	75	5.16	4.32	317
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	160	61	5.08	4.11	318
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	179	79	5.19	4.37	319
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	197	113	5.28	4.73	320
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	171	68	5.14	4.22	321
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	151	51	5.02	3.93	322
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	172	76	5.15	4.33	323
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	183	90	5.21	4.50	324
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	155	58	5.04	4.06	325
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	185	94	5.22	4.54	326
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	192	103	5.26	4.63	327
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	177	83	5.18	4.42	328
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	160	60	5.08	4.09	329
7/06/2017	Gill_net	Gill_net	10	25	Perch	1	160	57	5.08	4.04	330
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	230	213	5.44	5.36	331
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	170	74	5.14	4.30	332
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	189	103	5.24	4.63	333
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	174	83	5.16	4.42	334
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	183	90	5.21	4.50	335
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	161	63	5.08	4.14	336

8/06/2017	Gill_net	Gill_net	1	18	Perch	1	154	53	5.04	3.97	337
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	163	59	5.09	4.08	338
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	154	50	5.04	3.91	339
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	167	66	5.12	4.19	340
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	168	65	5.12	4.17	341
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	152	52	5.02	3.95	342
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	155	57	5.04	4.04	343
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	153	55	5.03	4.01	344
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	148	44	5.00	3.78	345
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	148	48	5.00	3.87	346
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	154	53	5.04	3.97	347
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	154	51	5.04	3.93	348
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	120	24	4.79	3.18	349
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	124	26	4.82	3.26	350
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	148	46	5.00	3.83	351
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	150	49	5.01	3.89	352
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	116	24	4.75	3.18	353
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	155	55	5.04	4.01	354
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	156	52	5.05	3.95	355
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	157	57	5.06	4.04	356
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	120	29	4.79	3.37	357
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	133	35	4.89	3.56	358
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	125	28	4.83	3.33	359
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	128	31	4.85	3.43	360
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	127	29	4.84	3.37	361
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	129	29	4.86	3.37	362

8/06/2017	Gill_net	Gill_net	1	18	Perch	1	126	25	4.84	3.22	363
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	128	32	4.85	3.47	364
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	124	25	4.82	3.22	365
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	126	27	4.84	3.30	366
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	128	27	4.85	3.30	367
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	114	20	4.74	3.00	368
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	117	22	4.76	3.09	369
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	117	22	4.76	3.09	370
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	122	23	4.80	3.14	371
8/06/2017	Gill_net	Gill_net	1	18	Perch	1	117	24	4.76	3.18	372
8/06/2017	Gill_net	Gill_net	1	25	Perch	2	298	504	5.70	6.22	373
8/06/2017	Gill_net	Gill_net	1	25	Perch	2	170	73	5.14	4.29	374
8/06/2017	Gill_net	Gill_net	1	25	Perch	2	185	103	5.22	4.63	375
8/06/2017	Gill_net	Gill_net	1	25	Perch	2	188	91	5.24	4.51	376
8/06/2017	Gill_net	Gill_net	1	25	Perch	2	185	95	5.22	4.55	377
8/06/2017	Gill_net	Gill_net	1	25	Perch	2	160	63	5.08	4.14	378
8/06/2017	Gill_net	Gill_net	1	25	Perch	2	180	78	5.19	4.36	379
8/06/2017	Gill_net	Gill_net	1	25	Perch	2	175	76	5.16	4.33	380
8/06/2017	Gill_net	Gill_net	1	25	Perch	2	203	113	5.31	4.73	381
8/06/2017	Gill_net	Gill_net	1	25	Perch	2	187	97	5.23	4.57	382
8/06/2017	Gill_net	Gill_net	1	25	Perch	2	167	72	5.12	4.28	383
8/06/2017	Gill_net	Gill_net	1	25	Perch	2	149	58	5.00	4.06	384
8/06/2017	Gill_net	Gill_net	1	25	Perch	2	169	62	5.13	4.13	385
8/06/2017	Gill_net	Gill_net	1	25	Perch	2	190	106	5.25	4.66	386
8/06/2017	Gill_net	Gill_net	1	25	Perch	2	173	75	5.15	4.32	387
8/06/2017	Gill_net	Gill_net	1	25	Perch	2	166	65	5.11	4.17	388

8/06/2017	Gill_net	Gill_net	1	25	Perch	2	149	59	5.00	4.08	389
8/06/2017	Gill_net	Gill_net	1	25	Perch	2	168	67	5.12	4.20	390
8/06/2017	Gill_net	Gill_net	1	25	Perch	2	188	92	5.24	4.52	391
8/06/2017	Gill_net	Gill_net	1	25	Perch	2	162	65	5.09	4.17	392
8/06/2017	Gill_net	Gill_net	1	25	Perch	2	166	68	5.11	4.22	393
8/06/2017	Gill_net	Gill_net	1	25	Perch	2	184	91	5.21	4.51	394
8/06/2017	Gill_net	Gill_net	1	25	Perch	2	179	86	5.19	4.45	395
8/06/2017	Gill_net	Gill_net	1	25	Perch	2	170	68	5.14	4.22	396
8/06/2017	Gill_net	Gill_net	1	25	Perch	2	154	51	5.04	3.93	397
8/06/2017	Gill_net	Gill_net	1	25	Perch	2	159	59	5.07	4.08	398
8/06/2017	Gill_net	Gill_net	1	25	Perch	2	158	56	5.06	4.03	399
8/06/2017	Gill_net	Gill_net	1	25	Perch	2	168	69	5.12	4.23	400
8/06/2017	Gill_net	Gill_net	1	25	Perch	2	161	60	5.08	4.09	401
8/06/2017	Gill_net	Gill_net	1	25	Perch	2	164	61	5.10	4.11	402
8/06/2017	Gill_net	Gill_net	1	25	Perch	2	156	56	5.05	4.03	403
8/06/2017	Gill_net	Gill_net	1	25	Perch	2	164	66	5.10	4.19	404
8/06/2017	Gill_net	Gill_net	1	25	Perch	3	250	240	5.52	5.48	405
8/06/2017	Gill_net	Gill_net	1	25	Perch	3	190	96	5.25	4.56	406
8/06/2017	Gill_net	Gill_net	1	25	Perch	3	176	81	5.17	4.39	407
8/06/2017	Gill_net	Gill_net	1	25	Perch	3	188	98	5.24	4.58	408
8/06/2017	Gill_net	Gill_net	1	25	Perch	3	176	76	5.17	4.33	409
8/06/2017	Gill_net	Gill_net	1	25	Perch	3	159	56	5.07	4.03	410
8/06/2017	Gill_net	Gill_net	1	25	Perch	3	154	53	5.04	3.97	411
8/06/2017	Gill_net	Gill_net	1	25	Perch	3	128	30	4.85	3.40	412
8/06/2017	Gill_net	Gill_net	1	25	Perch	3	129	27	4.86	3.30	413
8/06/2017	Gill_net	Gill_net	1	25	Perch	3	113	18	4.73	2.89	414

8/06/2017	Gill_net	Gill_net	1	25	Perch	3	124	26	4.82	3.26	415
8/06/2017	Gill_net	Gill_net	1	25	Perch	3	118	22	4.77	3.09	416
8/06/2017	Gill_net	Gill_net	1	25	Perch	3	116	22	4.75	3.09	417
8/06/2017	Gill_net	Gill_net	1	25	Perch	3	123	22	4.81	3.09	418
8/06/2017	Gill_net	Gill_net	1	25	Perch	3	117	21	4.76	3.04	419
8/06/2017	Gill_net	Gill_net	1	25	Perch	3	113	22	4.73	3.09	420
8/06/2017	Gill_net	Gill_net	1	25	Perch	3	118	24	4.77	3.18	421
8/06/2017	Gill_net	Gill_net	1	25	Perch	3	121	23	4.80	3.14	422
8/06/2017	Gill_net	Gill_net	1	25	Perch	3	116	21	4.75	3.04	423
8/06/2017	Gill_net	Gill_net	1	25	Perch	3	114	19	4.74	2.94	424
8/06/2017	Gill_net	Gill_net	1	25	Perch	3	118	21	4.77	3.04	425
8/06/2017	Gill_net	Gill_net	1	25	Perch	4	313	600	5.75	6.40	426
8/06/2017	Gill_net	Gill_net	1	25	Perch	5	150	51	5.01	3.93	427
8/06/2017	Gill_net	Gill_net	1	25	Perch	5	278	426	5.63	6.05	428
8/06/2017	Gill_net	Gill_net	1	25	Perch	5	297	446	5.69	6.10	429
8/06/2017	Gill_net	Gill_net	1	25	Perch	5	187	101	5.23	4.62	430
8/06/2017	Gill_net	Gill_net	1	25	Perch	5	150	51	5.01	3.93	431
8/06/2017	Gill_net	Gill_net	1	25	Perch	5	156	53	5.05	3.97	432
8/06/2017	Gill_net	Gill_net	1	25	Perch	5	158	61	5.06	4.11	433
8/06/2017	Gill_net	Gill_net	1	25	Perch	5	126	26	4.84	3.26	434
8/06/2017	Gill_net	Gill_net	1	25	Perch	5	121	27	4.80	3.30	435
8/06/2017	Gill_net	Gill_net	1	25	Perch	5	124	26	4.82	3.26	436
8/06/2017	Gill_net	Gill_net	1	25	Perch	5	132	37	4.88	3.61	437
8/06/2017	Gill_net	Gill_net	1	25	Perch	5	151	51	5.02	3.93	438
8/06/2017	Gill_net	Gill_net	1	25	Perch	5	126	28	4.84	3.33	439
8/06/2017	Gill_net	Gill_net	1	25	Perch	5	131	34	4.88	3.53	440

8/06/2017	Gill_net	Gill_net	1	25	Perch	5	134	35	4.90	3.56	441
8/06/2017	Gill_net	Gill_net	1	25	Perch	5	125	31	4.83	3.43	442
8/06/2017	Gill_net	Gill_net	1	25	Perch	5	119	22	4.78	3.09	443
8/06/2017	Gill_net	Gill_net	1	25	Perch	5	110	22	4.70	3.09	444
8/06/2017	Gill_net	Gill_net	1	25	Perch	5	121	26	4.80	3.26	445
8/06/2017	Gill_net	Gill_net	1	25	Perch	5	128	32	4.85	3.47	446
8/06/2017	Gill_net	Gill_net	1	25	Perch	5	112	24	4.72	3.18	447
8/06/2017	Gill_net	Gill_net	1	25	Perch	5	119	24	4.78	3.18	448
8/06/2017	Gill_net	Gill_net	1	25	Perch	5	116	23	4.75	3.14	449
8/06/2017	Gill_net	Gill_net	1	25	Perch	5	123	26	4.81	3.26	450
8/06/2017	Gill_net	Gill_net	1	25	Perch	5	115	21	4.74	3.04	451
8/06/2017	Gill_net	Gill_net	1	25	Perch	5	115	20	4.74	3.00	452
8/06/2017	Gill_net	Gill_net	1	25	Perch	5	121	26	4.80	3.26	453
8/06/2017	Gill_net	Gill_net	1	25	Perch	5	116	23	4.75	3.14	454
8/06/2017	Gill_net	Gill_net	1	25	Perch	6	282	410	5.64	6.02	455
8/06/2017	Gill_net	Gill_net	1	25	Perch	6	165	66	5.11	4.19	456
8/06/2017	Gill_net	Gill_net	1	25	Perch	6	203	125	5.31	4.83	457
8/06/2017	Gill_net	Gill_net	1	25	Perch	6	204	122	5.32	4.80	458
8/06/2017	Gill_net	Gill_net	1	25	Perch	6	181	96	5.20	4.56	459
8/06/2017	Gill_net	Gill_net	1	25	Perch	6	199	118	5.29	4.77	460
8/06/2017	Gill_net	Gill_net	1	25	Perch	6	189	93	5.24	4.53	461
8/06/2017	Gill_net	Gill_net	1	25	Perch	6	178	79	5.18	4.37	462
8/06/2017	Gill_net	Gill_net	1	25	Perch	6	187	90	5.23	4.50	463
8/06/2017	Gill_net	Gill_net	1	25	Perch	6	169	76	5.13	4.33	464
8/06/2017	Gill_net	Gill_net	1	25	Perch	6	168	72	5.12	4.28	465
8/06/2017	Gill_net	Gill_net	1	25	Perch	6	182	83	5.20	4.42	466

8/06/2017	Gill_net	Gill_net	1	25	Perch	6	185	87	5.22	4.47	467
8/06/2017	Gill_net	Gill_net	1	25	Perch	6	179	81	5.19	4.39	468
8/06/2017	Gill_net	Gill_net	1	25	Perch	6	204	119	5.32	4.78	469
8/06/2017	Gill_net	Gill_net	1	25	Perch	6	178	79	5.18	4.37	470
8/06/2017	Gill_net	Gill_net	1	25	Perch	6	175	80	5.16	4.38	471
8/06/2017	Gill_net	Gill_net	1	25	Perch	6	165	65	5.11	4.17	472
8/06/2017	Gill_net	Gill_net	1	25	Perch	6	162	61	5.09	4.11	473
8/06/2017	Gill_net	Gill_net	1	25	Perch	6	160	58	5.08	4.06	474
8/06/2017	Gill_net	Gill_net	1	25	Perch	6	165	59	5.11	4.08	475
8/06/2017	Gill_net	Gill_net	1	25	Perch	6	165	63	5.11	4.14	476
8/06/2017	Gill_net	Gill_net	1	25	Perch	6	162	58	5.09	4.06	477
8/06/2017	Gill_net	Gill_net	1	25	Perch	6	159	60	5.07	4.09	478
8/06/2017	Gill_net	Gill_net	1	25	Perch	6	161	60	5.08	4.09	479
8/06/2017	Gill_net	Gill_net	1	25	Perch	6	174	78	5.16	4.36	480
8/06/2017	Gill_net	Gill_net	1	25	Perch	6	165	64	5.11	4.16	481
8/06/2017	Gill_net	Gill_net	1	25	Perch	6	160	56	5.08	4.03	482
8/06/2017	Gill_net	Gill_net	1	25	Perch	6	151	55	5.02	4.01	483
8/06/2017	Gill_net	Gill_net	1	25	Perch	7	324	628	5.78	6.44	484
8/06/2017	Gill_net	Gill_net	1	25	Perch	7	269	361	5.59	5.89	485
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	307	605	5.73	6.41	486
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	180	87	5.19	4.47	487
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	174	82	5.16	4.41	488
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	172	81	5.15	4.39	489
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	124	27	4.82	3.30	490
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	195	120	5.27	4.79	491
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	171	84	5.14	4.43	492

8/06/2017	Gill_net	Gill_net	1	25	Perch	8	160	58	5.08	4.06	493
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	153	57	5.03	4.04	494
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	155	52	5.04	3.95	495
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	153	54	5.03	3.99	496
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	122	28	4.80	3.33	497
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	122	25	4.80	3.22	498
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	123	25	4.81	3.22	499
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	134	33	4.90	3.50	500
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	132	33	4.88	3.50	501
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	119	23	4.78	3.14	502
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	120	24	4.79	3.18	503
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	123	25	4.81	3.22	504
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	134	33	4.90	3.50	505
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	132	33	4.88	3.50	506
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	119	23	4.78	3.14	507
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	120	24	4.79	3.18	508
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	128	26	4.85	3.26	509
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	123	27	4.81	3.30	510
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	117	23	4.76	3.14	511
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	120	25	4.79	3.22	512
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	118	24	4.77	3.18	513
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	122	24	4.80	3.18	514
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	113	22	4.73	3.09	515
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	125	26	4.83	3.26	516
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	123	25	4.81	3.22	517
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	111	21	4.71	3.04	518

8/06/2017	Gill_net	Gill_net	1	25	Perch	8	115	24	4.74	3.18	519
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	116	22	4.75	3.09	520
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	115	22	4.74	3.09	521
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	118	23	4.77	3.14	522
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	121	26	4.80	3.26	523
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	117	25	4.76	3.22	524
8/06/2017	Gill_net	Gill_net	1	25	Perch	8	117	23	4.76	3.14	525

Appendix 2:

Site	Length class (mm)	*N* total	Number empty	Mean stomach fullness (1-5)	Mean stomach fullness (%)	Percent of volume of food items																	
						Chironimids		Zooplankton		Detritus		Odonata		Unidentified insect		Macrophyte		Algae		Snail - Physa		Diptera	
						N	Mean	*N*	Mean	*N*	Mean	*N*	Mean	*N*	Mean	*N*	Mean	*N*	Mean	*N*	Mean	*N*	Mean
3	72-110	9	0	4.4	89	1	1	9	99	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	11-180	9	0	3.8	76	5	16	8	69	0	0	2	12	1	2	0	0	1	1	0	0	0	0
	180-249	2	0	4.0	80	2	53	1	40	0	0	0	0	1	7	0	0	0	0	0	0	0	0
4	72-110	9	0	4.0	80	2	2	9	92	0	0	0	0	3	5	0	0	0	0	1	1	0	0
	111-180	8	1	4.5	90	7	45	4	47	4	8	0	0	0	0	0	0	0	0	0	0	0	0
	180-249	3	0	4.7	93	2	32	1	27	1	8	0	0	0	0	0	0	0	0	0	0	1	33
5	72-110	10	0	4.2	84	4	1	10	99	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	111-180	5	0	3.6	72	1	37	3	55	2	7	0	0	0	0	1	1	0	0	0	0	0	0
6	72-110																						
	111-180	10	0	3.8	76	9	66	4	30	5	4	0	0	0	0	0	0	0	0	0	0	0	0
7	72-110	14	0	4.0	80	2	4	14	96	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	111-180	3	1	3.3	67	1	45	1	20	2	10	0	0	1	25	0	0	0	0	0	0	0	0
	180-249	2	1	2.0	40	1	90	0	0	1	10	0	0	0	0	0	0	0	0	0	0	0	0
8	72-110	13	0	3.8	75	2	6	13	92	0	0	0	0	2	2	0	0	0	0	0	0	0	0
	111-180	6	0	3.2	63	2	18	5	67	1	3	2	9	1	3	0	0	0	0	0	0	0	0
	180-249	1	0	4.0	80	1	90	0	0	1	10	0	0	0	0	0	0	0	0	0	0	0	0
9	72-110	8	0	4.3	85	2	6	7	81	0	0	0	0	1	13	0	0	0	0	0	0	0	0
	111-180	12	0	4.4	88	5	30	6	25	3	10	1	4	5	31	0	0	0	0	0	0	0	0
10	72-110	10	0	4.6	92	3	3	7	87	0	0	0	0	1	9	1	1	0	0	0	0	0	0
	111-180	10	0	3.7	74	5	35	6	55	4	7	0	0	1	1	1	1	2	1	0	0	0	0
Total	72-110	73	0	4.2	84	16	3	69	93	0	0	0	0	7	4	1	0	0	0	1	0	0	0
	111-180	63	2	3.8	76	35	36	37	47	21	6	5	3	9	8	2	0	3	0	0	0	0	0
	180-249	8	1	3.7	73	6	55	2	23	3	6	0	0	1	2	0	0	0	0	0	0	1	14

Appendix 2; Table 1: Volumetric tomach contents of 144 perch sampled by boat electrofishing in Lake Rotokare on 21-22 Feb 2017.

	Length class	*N*	Number	Mean stomach	Mean stomach	Chironimids		Zooplankton		Detritus		Odonata		Unidentified insect		Macrophyte		Algae		Snail - Physa		Diptera	
Site	(mm)	total	empty	fullness (1-5)	fullness (%)	*N*	Mean	*N*	Mean	*N*	Mean	*N*	Mean	*N*	Mean	*N*	Mean	*N*	Mean	*N*	Mean	*N*	Mean
1	111-180	3	0	4.3	86	2	50	3	39	2	8	0	0	1	3	0	0	0	0	0	0	0	0
	180-249	7	1	3.1	62	4	58	2	29	4	8	0	0	1	5	0	0	0	0	0	0	0	0
2	111-180	8	0	3.0	60	4	31	7	61	3	8	0	0	0	0	0	0	0	0	0	0	0	0
	180-249	2	0	5.0	100	2	88	0	0	2	12	0	0	0	0	0	0	0	0	0	0	0	0
3	111-180	10	0	4.3	86	4	3	10	96	0	0	0	0	1	1	0	0	0	0	0	0	0	0
	180-249	0	0	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	111-180	8	0	3.6	72	1	6	8	94	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	180-249	2	0	3.5	70	0	0	2	95	0	0	0	0	1	5	0	0	0	0	0	0	0	0
5	111-180	9	1	3.7	74	1	1	8	96	0	0	1	3	0	0	0	0	0	0	0	0	0	0
	180-249	1	0	4.0	80	0	0	1	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	111-180	38	1	3.8	76	12	18	36	77	5	3	1	1	2	1	0	0	0	0	0	0	0	0
	180-249	12	1	3.9	78	6	36	5	56	6	5	0	0	2	3	0	0	0	0	0	0	0	0

Appendix 2; Table 2: Volumetric stomach contents of 50 perch sampled by gill netting on 21 Feb 2017.

						Percent of volume of food items																	
	Length class	*N*	Number	Mean stomach	Mean stomach	Chironimids		Zooplankton		Detritus		Odonata		Unidentified insect		Macrophyte		Algae		Snail - Physa		Diptera	
Site	(mm)	total	empty	fullness (1-5)	fullness (%)	*N*	Mean	*N*	Mean	*N*	Mean	*N*	Mean	*N*	Mean	*N*	Mean	*N*	Mean	*N*	Mean	*N*	Mean
Total	72-110	73	0	4.3	85	16	3	41	93	0	0	1	0	4	4	0	0	0	0	0	0	0	0
	111-180	101	3	3.7	74	47	27	73	61	26	5	6	2	11	5	2	0	3	0	0	0	0	0
	180-249	20	2	3.6	72	12	50	7	34	9	7	0	0	3	3	0	0	0	0	0	0	1	6

Appendix 2; Table 3: Volumetric stomach contents of 194 perch caught by both boat electrofishing and gill netting on 21-22 Feb 2017.

Appendix 2: Stable isotope results from June and December 2017.

code	Species	weight_g	length_mm	Percent_C	Percent_N	delta13C	delta15N	Order
JBK001	Banded Kokopu	53	1.1	46.39	13.80	-31.13	6.68	107
JBK002	Banded Kokopu	46	0.6	47.18	14.12	-29.30	7.04	108
JBK003	Banded Kokopu	47	0.9	45.00	13.51	-27.53	8.30	109
JBK004	Banded Kokopu	50	1.1	47.35	14.07	-30.78	7.21	110
CHA001	Charophyte sp.	-	-	37.12	3.34	-25.79	-5.02	91
CHA002	Charophyte sp.	-	-	37.36	3.51	-25.34	-4.40	92
CHIRNMIV	Chironomid larvae	-	-	38.39	8.27	-25.13	2.89	148
CHIRNMW	Chironomid larvae	-	-	43.22	9.26	-28.47	2.14	149
CHL001	Chironomid larvae	-	-	45.03	10.11	-31.78	2.63	85
CHL002	Chironomid larvae	-	-	33.68	6.77	-27.08	3.94	86
DFL001	Dragonfly nymph	1.5	16.5	42.18	10.05	-31.01	8.50	96
DFL002	Dragonfly nymph	1.7	18	43.68	10.82	-32.02	3.84	97
DFL003	Dragonfly nymph	1.8	18	47.41	9.73	-30.71	3.40	98
DFL004	Dragonfly nymph	1.6	17	42.83	10.42	-31.87	3.78	99
DFL005	Dragonfly nymph	1.4	16	44.06	10.49	-32.29	2.86	100
DFL006	Dragonfly nymph	1.5	17	44.06	10.31	-29.14	6.73	101
LSM001	Lagarosiphon. M	-	-	37.47	3.77	-29.67	-1.29	87
LSM002	Lagarosiphon. M	-	-	36.20	3.15	-27.64	-3.23	88
EELFU05	Longfin eel	725	1363	41.90	10.82	-27.15	8.65	38
EELFU09	Longfin eel	872	2484	42.49	10.65	-26.66	9.18	42
EELFU12	Longfin eel	707	1141	44.86	11.25	-26.63	8.95	45
EELFU14	Longfin eel	594	660	41.41	10.89	-27.45	8.39	47
EELFU16	Longfin eel	702	1199	43.83	11.59	-27.17	8.82	49
EELFU17	Longfin eel	500	396	43.16	11.04	-25.69	8.89	50

EELFU18	Longfin eel	474	343	43.07	11.81	-25.79	8.01	51
EELFU19	Longfin eel	623	975	43.64	11.39	-27.39	8.81	52
LFE002	Longfin eel	1448	750	43.91	11.40	-27.24	8.65	2
LFE004	Longfin eel	6690	1120	43.47	10.50	-27.22	8.50	4
LFE005	Longfin eel	352	520	46.43	12.22	-27.12	8.96	5
LFE006	Longfin eel	1764	850	45.95	11.13	-27.36	9.00	6
LFE007	Longfin eel	1380	760	45.82	10.86	-27.65	9.44	7
LFE009	Longfin eel	2458	916	48.95	11.25	-27.95	9.15	9
LFE010	Longfin eel	4663	1140	44.07	11.24	-27.48	8.97	10
LFE011	Longfin eel	1760	764	45.91	11.49	-27.16	8.84	11
LFE012	Longfin eel	2897	925	49.56	11.42	-27.33	9.21	12
LFE013	Longfin eel	1002	665	44.51	12.44	-26.82	9.05	13
LFE014	Longfin eel	2387	854	44.69	11.92	-27.35	8.88	14
LFE015	Longfin eel	675	610	45.74	12.25	-27.37	8.13	15
LFE016	Longfin eel	1092	628	43.72	11.90	-26.91	8.42	16
LFE017	Longfin eel	5192	1110	42.87	11.73	-26.85	9.44	17
LFE001	Longfin eel	3920	1060	43.01	10.49	-27.39	9.11	1
LFE003	Longfin eel	3330	994	49.13	10.65	-28.05	9.95	3
LFE008	Longfin eel	3234	970	44.81	11.80	-26.99	9.31	8
PER001	Perch	5.4	80	47.21	13.68	-25.47	6.78	111
PER002	Perch	10.2	90	46.39	13.62	-25.52	6.97	112
PER003	Perch	9.4	85	46.96	13.53	-25.62	7.01	113
PER004	Perch	12	91	45.98	13.48	-25.23	6.96	114
PER005	Perch	18.6	110	47.50	14.07	-25.35	6.79	115
PER006	Perch	66.1	159	47.30	14.21	-27.30	7.93	116
PER007	Perch	8.1	84	48.09	14.16	-25.03	7.29	117

PER008	Perch	76.5	174	46.77	14.09	-27.35	6.80	118
PER009	Perch	9.1	87	47.03	13.83	-25.33	7.29	119
PER010	Perch	55	154	47.48	14.33	-26.82	6.92	120
PER011	Perch	17.6	100	48.36	14.21	-25.49	6.95	121
PER012	Perch	8.4	80	48.62	14.21	-25.54	7.25	122
PER013	Perch	59.2	158	46.54	13.96	-27.08	7.03	123
PER014	Perch	59.9	160	47.33	14.08	-27.02	7.19	124
PER015	Perch	14.4	95	48.37	14.34	-25.40	6.92	125
PER016	Perch	39.2	137	47.92	14.42	-27.16	7.37	126
PER017	Perch	63.9	165	47.09	14.21	-27.28	7.17	127
PER018	Perch	8.1	85	48.37	14.27	-25.57	7.33	128
PER019	Perch	147.3	204	48.05	14.59	-27.83	7.63	129
PER020	Perch	96	198	47.38	14.26	-28.60	6.86	130
PER021	Perch	10.5	89	47.65	14.09	-25.48	7.06	131
PER022	Perch	96.8	194	46.82	14.10	-27.18	7.44	132
PER023	Perch	43.8	143	46.94	14.03	-26.54	7.23	133
PER024	Perch	10.3	87	47.27	14.01	-25.42	7.18	134
PER025	Perch	151.5	210	46.69	14.20	-25.50	8.63	135
PER026	Perch	407	285	45.71	13.88	-28.29	7.32	136
PER027	Perch	193.7	235	47.30	13.79	-27.98	7.81	137
PER028	Perch	1658	433	47.55	14.30	-26.45	9.15	138
PER029	Perch	24	119	46.79	14.07	-31.24	6.67	139
PER030	Perch	87	182	45.93	13.87	-28.86	7.24	140
PER031	Perch	21	112	46.68	13.85	-30.76	6.87	141
PER032	Perch	210	230	46.18	13.86	-27.47	8.3	142
PER033	Perch	78	174	46.05	13.79	-29.25	7.03	143

PER034	Perch	24	120	46.79	13.82	-31.07	6.83	144
PER035	Perch	66	167	46.25	13.81	-29.80	6.91	145
PER036	Perch	240	250	45.41	13.83	-27.24	8.02	146
PER037	Perch	27	124	45.10	13.51	-28.10	6.82	147
LZP001	Zooplankton	-	-	33.18	4.95	-37.41	3.85	102
LZP002	Zooplankton	-	-	29.17	3.33	-35.43	2.32	103
PHYTO 1	phytoplankton			33.22	4.71	-28.94	1.44	152
PHYTO2	Phytoplankton			33.15	4.35	-28.62	2.99	153
PGO001	Potamogeton. O	-	-	36.95	4.47	-42.17	-2.39	89
PGO002	Potamogeton. O	-	-	36.37	4.35	-42.12	-2.44	90
SED N	Sediment			6.63	0.50	-28.12	2.03	150
SEDW	Sediment			43.23	2.69	-28.98	1.67	151
EELFU01	Shortfin eel	516	333	41.98	11.63	-28.70	6.44	35
EELFU02	Shortfin eel	819	1323	45.81	11.02	-27.28	8.72	36
EELFU03	Shortfin eel	560	494	41.93	11.91	-28.87	6.93	37
EELFU06	Shortfin eel	610	522	42.95	11.81	-26.75	7.07	39
EELFU07	Shortfin eel	871	1650	44.73	10.85	-28.08	9.11	40
EELFU08	Shortfin eel	624	614	40.14	11.69	-28.74	6.91	41
EELFU10	Shortfin eel	623	607	42.64	10.73	-27.45	8.37	43
EELFU11	Shortfin eel	838	1428	44.93	11.01	-28.04	8.73	44
EELFU13	Shortfin eel	524	338	41.48	11.39	-29.83	7.13	46
EELFU15	Shortfin eel	621	610	44.49	11.51	-25.69	8.03	48
EELFU20	Shortfin eel	620	657	43.31	9.51	-29.32	7.12	53
EELFU21	Shortfin eel	500	287	40.97	11.80	-26.50	6.80	54
EELFU22	Shortfin eel	590	423	42.83	11.54	-26.18	8.13	55
EELFU23	Shortfin eel	554	435	38.90	10.87	-26.29	7.18	56

EELFU24	Shortfin eel	636	584	35.39	9.98	-26.16	8.47	57
EELFU25	Shortfin eel	475	248	42.57	11.94	-26.60	6.87	58
EELFU26	Shortfin eel	530	413	43.08	11.53	-28.82	6.97	59
SFE001	Shortfin eel	465	615	44.08	11.84	-27.89	8.80	18
SFE002	Shortfin eel	497	625	45.78	11.73	-28.22	8.71	19
SFE003	Shortfin eel	804	700	39.70	10.74	-27.86	8.51	20
SFE004	Shortfin eel	1054	760	43.45	11.03	-28.02	8.61	21
SFE005	Shortfin eel	1490	845	48.31	10.80	-29.20	8.95	22
SFE006	Shortfin eel	2001	930	45.87	11.24	-28.41	8.53	23
SFE007	Shortfin eel	1189	785	42.52	11.43	-28.03	8.97	24
SFE008	Shortfin eel	674	692	41.48	11.50	-28.10	7.84	25
SFE009	Shortfin eel	313	525	43.02	11.95	-27.26	7.54	26
SFE010	Shortfin eel	468	608	44.61	11.78	-28.76	7.75	27
SFE011	Shortfin eel	470	578	43.25	11.63	-27.17	7.66	28
SFE012	Shortfin eel	588	616	41.89	11.86	-27.80	7.34	29
SFE013	Shortfin eel	580	640	43.45	11.52	-27.93	8.04	30
SFE014	Shortfin eel	640	643	43.64	10.57	-29.37	7.40	31
SFE015	Shortfin eel	517	650	41.59	10.63	-27.99	8.59	32
SFE016	Shortfin eel	875	628	43.64	12.00	-26.73	8.50	33
SFE017	Shortfin eel	456	615	40.07	11.66	-26.95	8.15	34
SNA001	Snail: physa&lymnaea	-	-	32.80	6.13	-28.90	6.69	93
SNA002	Snail: physa&lymnaea	-	-	34.36	6.48	-29.15	6.94	94
SNA003	Snail: physa&lymnaea	-	-	31.57	5.71	-28.34	6.75	95
WPP001	Winter phytoplankton	-	-	31.37	4.93	-38.21	-0.61	106
DZP001	Zooplankton	-	-	46.33	5.54	-42.97	6.87	104
DZP002	Zooplankton	-	-	43.30	4.75	-41.42	4.99	105

ZOO 1	Zooplankton	29.39	5.53	-26.89	4.56	154
ZOO 2	Zooplankton	29.67	4.30	-28.36	5.64	155

Appendix 2: Stable isotope results from 19 December 2017 for untreated eel muscle and fin tissue.

codea	Code	lipid_treatment	species	tissue_type	length_mm	weight_g	ln_length	ln_weight	weight_mg	percent_N	d15N	percent_C	d13C	C:N ratio
EELMT01	EEL001	Treated	Shortfin eel	Muscle	516	333	6.25	5.81	2.230	13.26	8.16	44.03	-32.05	3.32
EELMT02	EEL002	Treated	Shortfin eel	Muscle	819	1323	6.71	7.19	2.227	13.52	9.25	44.98	-29.42	3.33
EELMT04	EEL004	Treated	Shortfin eel	Muscle	450	192	6.11	5.26	2.226	13.76	6.88	45.38	-31.38	3.30
EELMT05	EEL005	Treated	Longfin eel	Muscle	725	1363	6.59	7.22	2.260	13.81	9.36	45.21	-27.21	3.27
EELMT06	EEL006	Treated	Shortfin eel	Muscle	610	522	6.41	6.26	2.211	13.37	8.81	45.76	-28.87	3.42
EELMT08	EEL008	Treated	Shortfin eel	Muscle	624	614	6.44	6.42	2.249	13.73	7.59	46.58	-31.80	3.39
EELMT09	EEL009	Treated	Longfin eel	Muscle	872	2484	6.77	7.82	2.222	12.68	9.36	47.59	-29.35	3.75
EELMT10	EEL010	Treated	Shortfin eel	Muscle	623	607	6.43	6.41	2.230	13.80	8.79	45.89	-28.91	3.33
EELMT11	EEL011	Treated	Shortfin eel	Muscle	838	1428	6.73	7.26	2.224	13.35	8.48	46.93	-30.23	3.52
EELMT12	EEL012	Treated	Longfin eel	Muscle	707	1141	6.56	7.04	2.224	13.25	8.95	45.29	-26.67	3.42
EELMT13	EEL013	Treated	Shortfin eel	Muscle	524	338	6.26	5.82	2.262	13.76	7.55	45.41	-30.15	3.30
EELMT14	EEL014	Treated	Longfin eel	Muscle	594	660	6.39	6.49	2.232	13.85	8.69	45.93	-27.23	3.32
EELMT15	EEL015	Treated	Shortfin eel	Muscle	621	610	6.43	6.41	2.238	13.32	8.48	46.45	-26.32	3.49
EELMT16	EEL016	Treated	Longfin eel	Muscle	702	1199	6.55	7.09	2.234	12.79	7.58	47.95	-28.33	3.75
EELMT17	EEL017	Treated	Longfin eel	Muscle	500	396	6.21	5.98	2.245	13.58	8.51	45.27	-26.53	3.33
EELMT18	EEL018	Treated	Longfin eel	Muscle	474	343	6.16	5.84	2.269	12.96	8.40	42.80	-27.14	3.30
EELMT19	EEL019	Treated	Longfin eel	Muscle	623	975	6.43	6.88	2.286	13.46	8.86	46.03	-27.06	3.42
EELMT20	EEL020	Treated	Shortfin eel	Muscle	620	657	6.43	6.49	2.240	13.09	7.71	46.63	-29.68	3.56
EELMT22	EEL022	Treated	Shortfin eel	Muscle	590	423	6.38	6.05	2.226	13.26	8.57	43.86	-26.70	3.31
EELMT23	EEL023	Treated	Shortfin eel	Muscle	554	435	6.32	6.08	2.245	13.49	8.09	44.61	-27.50	3.31
EELMT24	EEL024	Treated	Shortfin eel	Muscle	636	584	6.46	6.37	2.211	13.44	8.28	45.00	-27.35	3.35
EELMT25	EEL025	Treated	Shortfin eel	Muscle	475	248	6.16	5.51	2.252	13.69	7.36	45.04	-27.13	3.29
EELMT26	EEL026	Treated	Shortfin eel	Muscle	530	413	6.27	6.02	2.269	13.12	7.50	44.01	-28.13	3.35

EELMU01	EEL001	Untreated	Shortfin eel	Muscle	516	333	6.25	5.81	2.208	13.74	7.12	45.65	-27.75	3.32
EELMU02	EEL002	Untreated	Shortfin eel	Muscle	819	1323	6.71	7.19	2.209	13.02	8.87	47.14	-28.41	3.62
EELMU03	EEL003	Untreated	Shortfin eel	Muscle	560	494	6.33	6.20	2.278	13.35	6.93	45.98	-31.25	3.44
EELMU04	EEL004	Untreated	Shortfin eel	Muscle	450	192	6.11	5.26	2.275	13.64	8.14	45.77	-31.02	3.36
EELMU05	EEL005	Untreated	Longfin eel	Muscle	725	1363	6.59	7.22	2.208	12.77	8.74	48.73	-28.87	3.82
EELMU06	EEL006	Untreated	Shortfin eel	Muscle	610	522	6.41	6.26	2.219	10.91	7.15	52.17	-30.60	4.78
EELMU07	EEL007	Untreated	Shortfin eel	Muscle	871	1650	6.77	7.41	2.219	12.10	8.59	50.12	-31.01	4.14
EELMU08	EEL008	Untreated	Shortfin eel	Muscle	624	614	6.44	6.42	2.245	13.10	7.12	50.05	-32.46	3.82
EELMU09	EEL009	Untreated	Longfin eel	Muscle	872	2484	6.77	7.82	2.269	12.66	9.21	49.73	-29.28	3.93
EELMU10	EEL010	Untreated	Shortfin eel	Muscle	623	607	6.43	6.41	2.268	13.18	8.78	45.68	-29.11	3.47
EELMU11	EEL011	Untreated	Shortfin eel	Muscle	838	1428	6.73	7.26	2.257	11.54	8.35	46.85	-30.64	4.06
EELMU12	EEL012	Untreated	Longfin eel	Muscle	707	1141	6.56	7.04	2.229	12.79	8.99	44.30	-28.52	3.46
EELMU13	EEL013	Untreated	Shortfin eel	Muscle	524	338	6.26	5.82	2.226	10.52	7.21	35.77	-33.00	3.40
EELMU14	EEL014	Untreated	Longfin eel	Muscle	594	660	6.39	6.49	2.259	13.60	8.68	45.34	-28.81	3.33
EELMU15	EEL015	Untreated	Shortfin eel	Muscle	621	610	6.43	6.41	2.263	12.60	8.68	47.37	-27.91	3.76
EELMU16	EEL016	Untreated	Longfin eel	Muscle	702	1199	6.55	7.09	2.205	13.15	8.77	47.43	-29.39	3.61
EELMU17	EEL017	Untreated	Longfin eel	Muscle	500	396	6.21	5.98	2.214	13.79	9.11	45.63	-27.19	3.31
EELMU18	EEL018	Untreated	Longfin eel	Muscle	474	343	6.16	5.84	2.226	13.54	8.36	45.02	-28.24	3.32
EELMU19	EEL019	Untreated	Longfin eel	Muscle	623	975	6.43	6.88	2.267	13.32	8.73	46.53	-28.87	3.49
EELMU20	EEL020	Untreated	Shortfin eel	Muscle	620	657	6.43	6.49	2.271	12.58	7.67	49.22	-31.54	3.91
EELMU21	EEL021	Untreated	Shortfin eel	Muscle	500	287	6.21	5.66	2.228	13.57	6.77	45.52	-31.42	3.35

EELMU22	EEL022	Untreated	Shortfin eel	Muscle	590	423	6.38	6.05	2.244	13.58	8.54	45.90	-28.58	3.38
EELMU23	EEL023	Untreated	Shortfin eel	Muscle	554	435	6.32	6.08	2.260	14.13	7.99	46.66	-28.91	3.30
EELMU24	EEL024	Untreated	Shortfin eel	Muscle	636	584	6.46	6.37	2.211	13.40	8.34	44.80	-29.12	3.34
EELMU26	EEL026	Untreated	Shortfin eel	Muscle	530	413	6.27	6.02	2.251	14.05	7.85	46.66	-29.79	3.32
EELFT01	EEL001	Treated	Shortfin eel	Fin	516	333	6.25	5.81	2.217	11.94	6.30	40.81	-28.86	3.42
EELFT02	EEL002	Treated	Shortfin eel	Fin	819	1323	6.71	7.19	2.208	10.48	8.72	41.05	-26.91	3.92
EELFT03	EEL003	Treated	Shortfin eel	Fin	560	494	6.33	6.20	2.254	11.59	6.97	39.26	-28.59	3.39
EELFT04	EEL004	Treated	Shortfin eel	Fin	450	192	6.11	5.26	2.241	12.07	8.22	42.50	-30.01	3.52
EELFT05	EEL005	Treated	Longfin eel	Fin	725	1363	6.59	7.22	2.258	12.31	7.20	41.64	-26.23	3.38
EELFT06	EEL006	Treated	Shortfin eel	Fin	610	522	6.41	6.26	2.205	11.78	8.80	44.70	-27.13	3.79
EELFT07	EEL007	Treated	Shortfin eel	Fin	871	1650	6.77	7.41	2.224	12.66	9.35	43.96	-26.90	3.47
EELFT08	EEL008	Treated	Shortfin eel	Fin	624	614	6.44	6.42	2.258	12.55	7.23	43.40	-28.92	3.46
EELFT09	EEL009	Treated	Longfin eel	Fin	872	2484	6.77	7.82	2.248	11.54	9.34	42.17	-25.80	3.65
EELFT10	EEL010	Treated	Shortfin eel	Fin	623	607	6.43	6.41	2.209	12.22	8.55	41.80	-26.07	3.42
EELFT11	EEL011	Treated	Shortfin eel	Fin	838	1428	6.73	7.26	2.272	10.53	8.85	41.40	-27.41	3.93
EELFT12	EEL012	Treated	Longfin eel	Fin	707	1141	6.56	7.04	2.263	10.49	8.86	41.13	-26.26	3.92
EELFT13	EEL013	Treated	Shortfin eel	Fin	524	338	6.26	5.82	2.280	12.42	7.16	42.78	-29.16	3.44
EELFT15	EEL015	Treated	Shortfin eel	Fin	621	610	6.43	6.41	2.220	11.70	7.95	43.76	-25.37	3.74
EELFT16	EEL016	Treated	Longfin eel	Fin	702	1199	6.55	7.09	2.217	12.43	8.87	43.70	-26.50	3.52
EELFT17	EEL017	Treated	Longfin eel	Fin	500	396	6.21	5.98	2.263	11.54	8.88	41.30	-24.97	3.58
EELFT19	EEL019	Treated	Longfin eel	Fin	623	975	6.43	6.88	2.272	11.06	8.89	41.70	-26.68	3.77
EELFT20	EEL020	Treated	Shortfin eel	Fin	620	657	6.43	6.49	2.248	12.22	7.06	40.95	-27.80	3.35
EELFT21	EEL021	Treated	Shortfin eel	Fin	500	287	6.21	5.66	2.223	12.58	6.74	40.68	-26.09	3.23
EELFT23	EEL023	Treated	Shortfin eel	Fin	554	435	6.32	6.08	2.259	12.33	7.40	40.11	-25.66	3.25
EELFT24	EEL024	Treated	Shortfin eel	Fin	636	584	6.46	6.37	2.211	11.64	8.63	39.32	-25.60	3.38

EELFU01	EEL001	Untreated	Shortfin eel	Fin	516	333	6.25	5.81	2.230	11.63	6.44	41.98	-28.70	3.61
EELFU02	EEL002	Untreated	Shortfin eel	Fin	819	1323	6.71	7.19	2.250	11.02	8.72	45.81	-27.28	4.16
EELFU03	EEL003	Untreated	Shortfin eel	Fin	560	494	6.33	6.20	2.237	11.91	6.93	41.93	-28.87	3.52
EELFU05	EEL005	Untreated	Longfin eel	Fin	725	1363	6.59	7.22	2.214	10.82	8.65	41.90	-27.15	3.87
EELFU06	EEL006	Untreated	Shortfin eel	Fin	610	522	6.41	6.26	2.233	11.81	7.07	42.95	-26.75	3.64
EELFU07	EEL007	Untreated	Shortfin eel	Fin	871	1650	6.77	7.41	2.279	10.85	9.11	44.73	-28.08	4.12
EELFU08	EEL008	Untreated	Shortfin eel	Fin	624	614	6.44	6.42	2.219	11.69	6.91	40.14	-28.74	3.43
EELFU09	EEL009	Untreated	Longfin eel	Fin	872	2484	6.77	7.82	2.210	10.65	9.18	42.49	-26.66	3.99
EELFU10	EEL010	Untreated	Shortfin eel	Fin	623	607	6.43	6.41	2.230	10.73	8.37	42.64	-27.45	3.97
EELFU11	EEL011	Untreated	Shortfin eel	Fin	838	1428	6.73	7.26	2.259	11.01	8.73	44.93	-28.04	4.08
EELFU12	EEL012	Untreated	Longfin eel	Fin	707	1141	6.56	7.04	2.199	11.25	8.95	44.86	-26.63	3.99
EELFU13	EEL013	Untreated	Shortfin eel	Fin	524	338	6.26	5.82	2.212	11.39	7.13	41.48	-29.83	3.64
EELFU14	EEL014	Untreated	Longfin eel	Fin	594	660	6.39	6.49	2.259	10.89	8.39	41.41	-27.45	3.80
EELFU15	EEL015	Untreated	Shortfin eel	Fin	621	610	6.43	6.41	2.242	11.51	8.03	44.49	-25.69	3.87
EELFU16	EEL016	Untreated	Longfin eel	Fin	702	1199	6.55	7.09	2.267	11.59	8.82	43.83	-27.17	3.78
EELFU17	EEL017	Untreated	Longfin eel	Fin	500	396	6.21	5.98	2.264	11.04	8.89	43.16	-25.69	3.91
EELFU18	EEL018	Untreated	Longfin eel	Fin	474	343	6.16	5.84	2.221	11.81	8.01	43.07	-25.79	3.65
EELFU19	EEL019	Untreated	Longfin eel	Fin	623	975	6.43	6.88	2.267	11.39	8.81	43.64	-27.39	3.83
EELFU20	EEL020	Untreated	Shortfin eel	Fin	620	657	6.43	6.49	2.281	9.51	7.12	43.31	-29.32	4.55
EELFU21	EEL021	Untreated	Shortfin eel	Fin	500	287	6.21	5.66	2.214	11.80	6.80	40.97	-26.50	3.47
EELFU22	EEL022	Untreated	Shortfin eel	Fin	590	423	6.38	6.05	2.275	11.54	8.13	42.83	-26.18	3.71
EELFU23	EEL023	Untreated	Shortfin eel	Fin	554	435	6.32	6.08	2.285	10.87	7.18	38.90	-26.29	3.58
EELFU24	EEL024	Untreated	Shortfin eel	Fin	636	584	6.46	6.37	2.243	9.98	8.47	35.39	-26.16	3.55
EELFU25	EEL025	Untreated	Shortfin eel	Fin	475	248	6.16	5.51	2.281	11.94	6.87	42.57	-26.60	3.57
EELFU26	EEL026	Untreated	Shortfin eel	Fin	530	413	6.27	6.02	2.277	11.53	6.97	43.08	-28.82	3.74