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Taharoa data deficient shallow lakes survey May 2014

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Table of contents

List of figures

List of tables

Executive summary

Eighteen out of 71 shallow lakes in the Waikato region have been defined as ‘data deficient’, meaning that there is insufficient information known about them to enable an effective classification for prioritising management efforts and interventions. In this multiagency (Waikato Regional Council, Department of Conservation and the National Institute of Water and Atmospheric research) study baseline physico-chemical, submerged plant and ecological information was collected for four of these lakes (Numiti, Rotoroa, Piopio, Rototapu) located on the west coast near Taharoa. Physico-chemical information included the collection of dissolved oxygen/temperature and depth profiles from each lake and standardised collection of information for lake clarity and nutrient concentrations. Biological information included fyke and minnow trapping for fish, observations and call recordings for birds, marginal terrestrial and aquatic plant assessments (Lake SPI) and littoral sweeps and water column hauls for aquatic invertebrates. Results for each lake are discussed including potential priorities for future management of these relatively remote dune lakes.

Introduction

There are 71 shallow lakes (less than 10m deep) recognised within the Waikato region. Of these 18 have been defined as 'data deficient', meaning that there is insufficient information known about them to enable an effective classification for prioritising management efforts and interventions (Wildlands 2011). Obtaining general physical, chemical and biological information about these lakes is a priority for assessing and ranking them against other lakes, and for identifying potential management actions. Waikato Regional Council's (WRC) 'Shallow Lakes Investigations & Monitoring project' collects water quality, macrophyte and zooplankton information on actively managed lakes to assess the performance of management actions. An additional objective of this project is to collect baseline water quality and ecological information from any shallow lakes where such information is deficient or unknown. To help meet this objective an investigation was undertaken to fill some existing knowledge gaps for a cluster of data deficient shallow dune lakes located on the mid west coast of the Waikato Region. A range of physico-chemical and ecological parameters were investigated. Physico-chemical information included the collection of dissolved oxygen and temperature depth profiles from each lake and standardised collection of information for lake clarity and nutrient concentrations. Biological information included assessments of fish and bird species and communities, marginal terrestrial and aquatic plant (Lake SPI) assessments, and littoral and pelagic aquatic invertebrates.

Methodology

Four data deficient lakes were investigated in this survey, Lakes Numiti, Rotoroa, Piopio and Rototapu (Figure 1). All information from these lakes was collected from the 14th – 16th May 2014. The following section outlines the specific methodologies employed to collect these data.

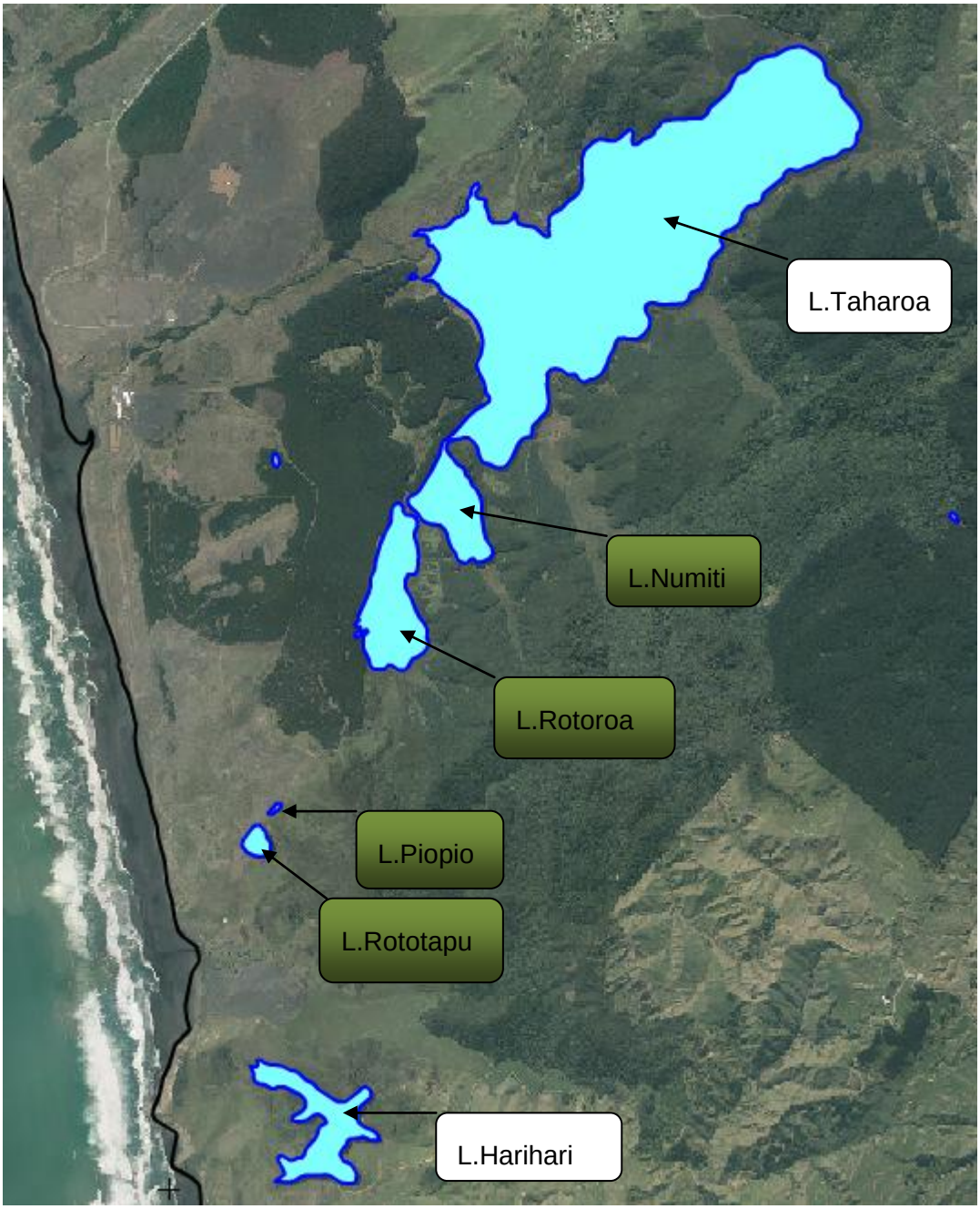


Figure 1. Location of Taharoa Lakes on the west coast of the Waikato Region. Lakes Numiti, Rotoroa, Piopio and Rototapu (shaded green) were the data deficient lakes sampled during this investigation

Birds

Birds were surveyed by two observers from the Department of Conservation (DoC). Observers listened and looked for bird species whilst walking around the accessible edges of each lake. At intervals, spotless crake (and sometimes marsh crake) calls were played to increase the probability of detecting this species which responds to playback. Five acoustic recorders were placed alongside raupo/swamp millet areas on the edges of Lakes Rotoroa and Numiti for one night, set to record for 30 minutes before sunset to 1 hour after sunset and 1 hour 30 minutes before dawn, with the aim of detecting the nationally endangered bittern. A list of locations where bird species were heard or observed can be found in Appendix 2 and the specific locations of where playback recorders were deployed can be found in Appendix 9.

Fish

Fish were sampled by WRC staff in each lake using standardised fyke nets and minnow traps. Net dimensions, type and mesh size are described in Joy et al. (2013).

A fleet of 24 fyke nets (with exclusion chambers built in) and 48 fine mesh Gee's minnow traps were deployed with the number of nets set per lake determined by lake size. Two minnow traps were set with each fyke net (one within 5m on either side of the fyke) and each fyke net was set perpendicular from the lake edge. A bamboo pole was used to fix each fyke leader to the lake shore and a single weight was clipped to the cod end to keep the net aligned and submerged on the lake bed. Nets were generally set by boat and left overnight and retrieved the following day. Upon retrieval fyke nets and minnow traps were transferred to a shore based crew who processed all captured fish. Fish were identified, measured for total length and then released. Except for eels, the first 50 individuals of each fish species were measured, followed by an additional 10 individuals per net after that. For eels, all individuals from every net were anaesthetized using AquiS® to enable accurate identification and measurement. Size frequency distributions were generated for those species where sufficient numbers were captured. In total 48 fyke nets and 96 minnow traps were set and retrieved across the four lakes in this survey. A full list of specific net locations by lake can be found in Appendix 5.

Aquatic plants

Staff from the National Institute of Water and Atmospheric research (NIWA) assessed aquatic plant communities using standardised Lake SPI protocols (Clayton and Edwards 2006 a,b,c) in each of the data deficient lakes surveyed during this investigation. Briefly, at selected baseline sites (typically three transects/lake), scuba divers swam from the lake shore to the deepest extent of the vegetation. Depth extent (±0.1 m using a dive computer) was defined as the cut-off for 10% plant cover, with ≥75% cover defining charophyte 'meadows'. The presence and depth extent of key native plant communities were noted, and their combined proportional contribution to the vegetation was estimated. The presence of any of 10 invasive weeds was also noted, together with their depth extent, the nature of weed cover, height, and overall proportional contribution to the vegetation.

Given the relative remoteness of this area, the opportunity to update Lake SPI scores for other better known dune lakes in this area (specifically Taharoa and Harihari, see Figure 1. for location) was also undertaken. For the purpose of this report, only results from lakes Numiti, Rotoroa, Rototapu and Piopio will be discussed. In the case of Piopio and Rototapu, these lakes were assessed but were deemed unsuitable for LakeSPI assessment as they provided no, or limited potential habitat for submerged plants. More information on Lake SPI from this survey can be found in Appendix 3

Terrestrial plants

Staff from the Department of Conservation undertook an assessment of terrestrial plants for each lake by walking the perimeter and slopes around each sampled waterbody. A species list was compiled for each lake and is discussed in each lake's relevant section with full data lists appended at the end of this report (see Appendix 8). Specimens of threatened species were taken for later confirmation and lodged at the Waikato herbarium.

Littoral aquatic invertebrates

Littoral invertebrates were collected by WRC staff and combined into one composite sample from each lake. A hand held sweep net (500 μm mesh) was used to sample the marginal aquatic plants (from water surface to a maximum depth of 1 m) at four locations (North, South, East and West) on each lake. Sampling effort was standardised to 30 seconds at each location resulting in a semi-quantitative sample representing a total of two-minute effort at each lake (see Suren et al. 2010). Invertebrate samples were preserved immediately in 70% isopropyl alcohol and then transferred to EOS Ecology for identification and enumeration. The sorting method was to count the first 200 individuals found in each sample, and then scan the rest of the sample for rare taxa. At Lake Rototapu, freshwater mussels were also collected from the littoral margins, these were identified to a species level and a subsample sent to Te Papa museum in Wellington. A full species list of littoral invertebrates by lake can be found in Appendix 7.

Zooplankton

Zooplankton samples were collected from each lake by WRC staff. Three vertical hauls (haul speed 1 ms^{-1}) were taken from the deepest location within each lake. These samples were immediately fixed in isopropyl alcohol according to the methods of Duggan et al. (2001) and sent to The University of Waikato for taxonomic identification. A preliminary Rotifer Trophic level Index (TLI) was calculated for each lake. This index is based on a study by Duggan (2001) that indicated that lake trophic state was a major determinant controlling rotifer species distribution among North Island lakes. Based on the response of rotifers a quantitative bioindicator rotifer index was developed. In the laboratory rotifer samples were enumerated where possible until a total of at least 100 individuals of "indicator species" were recorded; i.e., species that have an assigned TLI optima and tolerance score given by Duggan et al. (2001). Based on the resulting lists, the bioindicator method of Duggan et al. (2001a) was used to determine lake trophic state. All identifications were made to species level wherever possible. A full species list of identified zooplankton by lake can be found in Appendix 1.

Water chemistry

Dissolved oxygen and temperature profiles of the lakes were evaluated using standardised WRC protocols (see Appendix 4). Water samples were collected from each lake by WRC staff and placed immediately on ice. Samples were sent to Hill laboratories in Hamilton for nutrient analyses. A range of water quality parameters were assessed (See Table 1 & Appendix 6). Total nitrogen, total phosphorus and chlorophyll *a* concentrations from water quality results (all (mg/m^3), along with secchi depth (m), were then used to determine a preliminary Trophic Level Index (Burns et al. 2000) for each lake. It is important to note that a one-off water sample is unlikely to provide other than a very preliminary assessment of nutrient status for a lake.

The following equations were used to calculate each individual trophic value for Chlorophyll *a* (TLc), Secchi depth (TLs), total nitrogen (TLn) and total phosphorus (TLp):

- $TLc = 2.22 + 2.54\log(Chla)$
- $TLs = 5.56 + 2.60\log(1/SD - 1/40)$
- $TLp = 0.218 + 2.92\log(TP)$
- $TLn = -3.61 + 3.01\log(TN)$

The average trophic level index (TLI) for each lake was calculated by:

- $TLI = \Sigma\ (TLc + TLs + TLp + TLn)/4$

Table 1: Thresholds for determining a lake's trophic state (adapted from Burns et al. 2000).

Nutrient enrichment category	Trophic state	Trophic level	Chla (mg/m^3)	Secchi depth (m)	TP (mg/m^3)	TN (mg/m^3)
Low	Oligotrophic	2-3	< 2	> 7	< 10	< 200
Medium	Mesotrophic	3-4	2–5	3-7	10–20	200–300
High	Eutrophic	4-5	5–15	1–3	20–50	300–500
Very high	Supertrophic	5-6	15-30	0.5–1	50–100	500–1500
Extremely high	Hypertrophic	6-7	> 30	< 0.5	> 100	> 1500

Biosecurity procedures

To prevent the inadvertent spread of invasive species, all aquatic equipment used was sterilised between different waterbodies using standard tested solutions (70g salt/litre for nets traps etc and trigene/sterigene at 5-7% solution for boat hulls, waders; see Dugdale & Wells 2002, Matheson et al. 2007).

Results and discussion

Fish general

Shortfin eels (*Anguilla australis*) were the only fish species detected across all four surveyed lakes during this survey (Table 2). Another anguillid, the endemic longfin eel (*Anguilla dieffenbachii*), was also detected in two of the lakes. This species is currently listed as 'declining' under the most recent New Zealand threat classification rankings (Goodman et al. 2014), and was detected in very low numbers in this survey. Common bullies (*Gobiomorphus cotidianus*) were detected in three of the four lakes surveyed and were the most numerically abundant species in each of those lakes. Their numerical dominance most likely reflects their general habitat flexibility and ability to reproduce locally without the requirement for direct access to sea. Similarly, common smelt were also located in three out of four lakes and the presence of this species particularly in the small disconnected Lake Rototapu suggests that this species is also capable of limited local recruitment within this lake without requiring access to the sea.

Inanga (*Galaxias maculatus*) were detected in the two largest lakes surveyed (Numiti and Rotoroa). It is likely that these fish have used the fish pass at the Lake Taharoa outlet to access these two connected lakes as there are no known landlocked inanga populations in New Zealand south of Kaitaia in Northland. All inanga captured were relatively large fish (73-113 mm) and although not aged were likely to be at least 1+ yrs of age.

During net setting and retrieval a small school of grey mullet was regularly seen in a shallow weedy bay along the eastern shoreline in Lake Rotoroa. Since there are no known records of landlocked recruiting grey mullet in New Zealand, it is likely that these fish have also accessed this connected lake via the Taharoa fish pass at some stage and swam through both Lake Taharoa and Numiti to get to Lake Rotoroa.

In addition to the summary of fish numbers captured during this data-deficient lake survey in Table 2, more detailed descriptions for fish including size frequency information (for any species where 10 or more fish were captured and measured) are provided for each lake under its relevant heading below.

Table 2: Numbers of fish and koura captured using fyke nets and minnow traps set overnight in lakes Numiti, Rotoroa, Rototapu and Piopio in May 2014

Lake	SFE	LFE	Common bulies	Smelt	Inanga	Koura
Numiti	201	4	2016	78	9	0
Rotoroa	242	4	3332	1	9	1
Rototapu	38	0	132	2	0	1
Piopio	1	0	0	0	0	0
Totals	482	8	5480	81	18	2

Physico-chemical general

On the basis of one off physic-chemical measurements, Lake Rototapu appeared to be the lake in best condition having both the lowest Burns TLI and Rotifer TLI score of the four lakes sampled (Table 3). Both values suggest that the lake was mesotrophic at the time of sampling. This lake was also the clearest of the lakes sampled and almost

twice as clear as the other three lakes. All other lakes exhibited Burns and Rotifer TLI values ranging from eutrophic to supertrophic.

Table 3: Summary of lake physico-chemical parameters

Parameter	Numiti	Rotoroa	Rototapu	Piopio
Maximum depth (m)	10.6	14.7	9	3.4
Size (ha)	15.8	22.4	2	0.2
Turbidity (NTU)	7.3	7.4	1.58	11.5
Secchi (m)	0.86	1.48	2.15	0.6
pH (pH units)	7.7	7.7	7.1	6.8
Electrical conductivity (mS/m)	26.2	29.7	21	47.3
Volatile suspended solids (g/m^3)	5	5	<2	2
Total suspended solids (g/m^3)	7	6	<2	5
Total ammoniacal N (g/m^3)	0.3	0.21	<0.010	0.022
Nitrate-N + Nitrite-N (g/m^3)	0.063	0.033	0.009	0.057
Total Kjeldahl Nitrogen (g/m^3)	0.71	0.71	0.16	0.22
Dissolved Reactive Phosphorous (g/m^3)	<0.004	0.007	0.004	<0.004
Total Phosphorous (g/m^3)	0.030	0.043	0.007	0.029
Chlorophyll a (g/m^3)	0.029	0.021	0.008	0.006
TLI (Burns)	5.17	5.05	3.63	4.43
TLI (Rotifer)	5.19	5.77	3.04	4.65

Individual lake results

Figure 2: Lake Piopio (0.2 ha)

Birds

A single spotless crake and a single fernbird were the only wetland birds recorded from Lake Piopio, and both were 'observed' from bird calls. Paradise shelducks and black shags were two species of waterbirds observed flying overhead at the lake. Other birds heard or observed at Lake Piopio were skylark, welcome swallow, goldfinch, magpie, chaffinch, fantail, grey warbler, blackbird, spur-winged plover, yellowhammer, song thrush and kingfisher.

Fish

This small degraded waterbody was the smallest of the lakes sampled and evidence of livestock access and disturbance on the western shoreline was noticeable (Figure 2). It is disconnected from the ocean and at the time of sampling appeared to be clearly isolated from Lake Rototapu. Only one individual sub-adult shortfin eel (524 mm TL) was captured from the three fyke nets and six minnow traps which were set here (Figure 3).

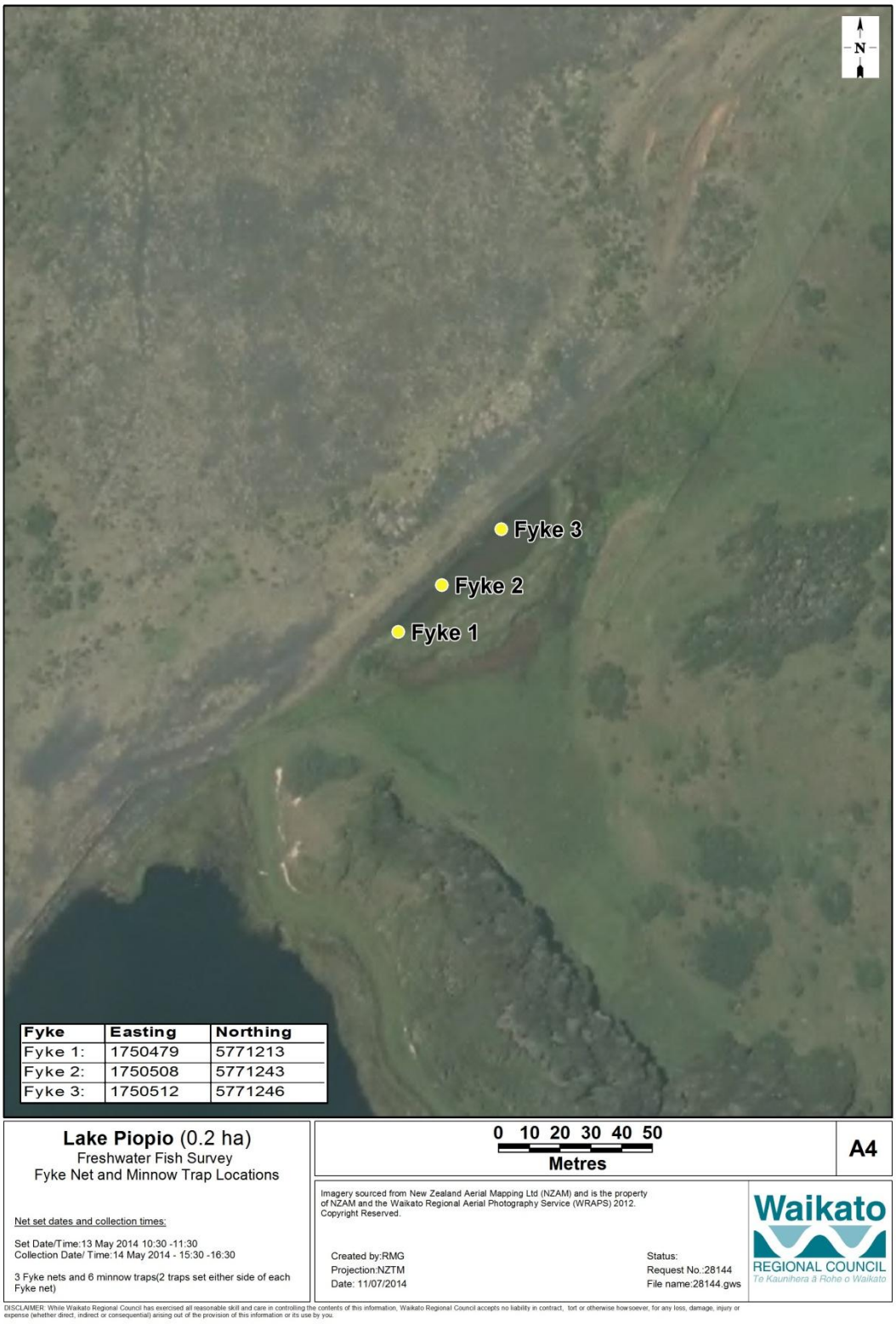


Figure 3: Lake Piopio fyke net and minnow trap locations

Lake Piopio (0.2 ha)

Aquatic plants

Lake Piopio was not suitable for a LakeSPI survey. The waterbody consists of a small ponded area between a steep dune face and rāupo wetland (*Typha orientalis*). Much of the dune face and lake bottom was bare sandy substrate, there was evidence of cattle

access and water clarity was low, but patches of a milfoil, pondweed and charophyte species were recorded to c. 1.5 m depth.

Terrestrial plants

Lake Piopio is surrounded by pasture and is open to grazing from all sides. The western edge of the lake consists of a sand bank, which is dominated by introduced plants such as sheep's sorrel (*Rumex acetosella*) and grasses such as kikuyu (*Pennisetum clandestinum*). On the eastern margin closest to the water's edge the dominant vegetation is a mix of *Machaerina articulata* and *Typha orientalis*, interspersed with swamp millet (*Isachne globosa*). This vegetation type is 5 to 10m wide along this edge. The margin closest to the pasture is a mixture of *Carex* spp. and introduced grasses. The northern end of the lake supports a community dominated by flax (*Phormium tenax*). The vegetation surrounding this lake is degraded and has been opened up by trampling and grazing from stock (Figure 2). There is no functional fencing around this lake.

Littoral invertebrates

This small waterbody was dominated by *Paroxyethira hendersoni* (29%) an algal piercing caddisfly. This lake had the highest %EPT (Ephemeroptera, Plecoptera, Trichoptera) 29% of all the sites due to the presence of this species (next highest was 6%). There were also large numbers of Cladocera, Copepods and Sphaeriidae, a small freshwater clam. Lake Piopio was the only site of the four where Sphaeriidae, Collembola, the aquatic beetle Antiporus, the bug Sigara and nematodes were found. No mayflies or stoneflies were found in the lake and there was a general lack of amphipods with <1% of the sample consisting of these as opposed to 20-46% in the other lakes.

Zooplankton

Rotifers, principally *Synchaeta pectinata* and *Trichocerca similis* and the copepods *Calamoecia lucasi* and *Mesocyclops leuckarti* dominated the zooplankton assemblage in this lake. A preliminary Rotifer TLI value of 5.77 was produced for this lake (Table 3). The rotifer inferred TLI score indicated a lake that was potentially supertrophic at the time of assessment (very nutrient enriched), although it is important to recognize that no definitive assessment of nutrient status can be made on the basis of a single rotifer sample. For a full list detailing species presence, see Appendix 1 - 'Zooplankton composition and trophic state assessment of rotifer assemblages'.

Physico-chemical parameters

Piopio was the shallowest (3.4 m deep), smallest (0.2 Ha) and most turbid (suspended turbidity 11.5 ntu, secchi disk 0.6 m) of the four lakes sampled. It also had the highest conductivity (47.3 ms/m) of the four lakes. Using the Burn's TLI parameters for lake water quality resulted in a Burn's TLI value of 4.43, meaning that, at the time of survey, the lake was likely to be eutrophic (high nutrient enrichment).

Lake Rotoroa (22.4 ha)

Birds

A relatively diverse wetland bird fauna was recorded at Lake Rotoroa. Spotless crakes were heard responding to playback from five places while a bittern was also flushed from the surrounding vegetation (see Appendix 2). In addition seven fernbird calls were heard and pukeko and morepork calls were also identified during recorder playback. Other birds seen in the vegetation around this lake included Harrier, fantail, chaffinch, grey warbler, kingfisher, tui, silvereye, eastern rosella, spur wing plover, welcome swallow and bellbird.

Numerous waterbird species were also observed on the lake and included 11 dabchicks including two juveniles, seven scaup, nine black swans, eight feral geese and black shags

Fish

A variety of fish species was captured in this lake, and the catch comprised of smelt, inanga, common bullies, and short and longfin eels (Table 4). A small school of adult grey mullet (individuals c. 350-400 mm long) was visually recorded on numerous occasions midway along the eastern shoreline. This was the only observation of this species within this lake or any of the other lakes during the survey. The grey mullet appeared to be grazing diatoms from the top of a narrowly defined macrophyte bed that had established in the only shallow embayment in this lake. In addition to fish, a single koura was also captured in one of the fyke nets at this lake (Figure 3). The locations of where fyke nets and minnow traps were deployed are shown in Figure 5.

Table 4: Summary of fish captured from 21 fykes and 41 minnow traps (one minnow half lost during deployment) set overnight in Lake Rotoroa in May 2014.

Parameter	Bullies	SFE	LFE	Smelt	Inanga
Total measured in all nets and traps	130	238	4	1	9
Average size (mm)	39	531	505	48	89
Shortest (mm)	24	235	411	48	73
Largest (mm)	59	777	716	48	113
Total captured in 21 fyke nets	2252	240	4	1	7
Total captured in 41 minnow traps	1080	2	0	0	2
Average # per fyke - counts included	107	11	0.1	0.04	0.3
Average # per minnow - counts included	26	0.05	0	0	0.05

Size frequency distributions of the most numerically dominant fish indicated that a reasonably healthy population of common bullies was present represented by a range of size classes from juvenile to adults. Similarly the shortfin eel population in this lake was represented by a range of size classes. It is notable however that no eels less than 235 mm were captured in this lake (Table 4). While it is possible that the lack of detection of small eels may indicate recruitment issues to the lake it also suggests that these smaller size classes may be using different habitats within the lakes that made them less susceptible to the capture methods used in this study (Chisnall 1996). Certainly large eels are known to be cannibalistic if the opportunity arises and subsequently small eels tend to limit the risk of predation by remaining within complex stable cover until they are large enough to fend for themselves (Chisnall 1996). Evidence from fish pass monitoring at the Taharoa fish pass by Tonkin & Taylor as part of the New Zealand Steel mine consent suggests elvers are frequently negotiating the pass and entering lake Taharoa during each migration season. Since connectivity between Taharoa, Numiti and Rotoroa is available, potential for recruitment to all these waterbodies presently exists.

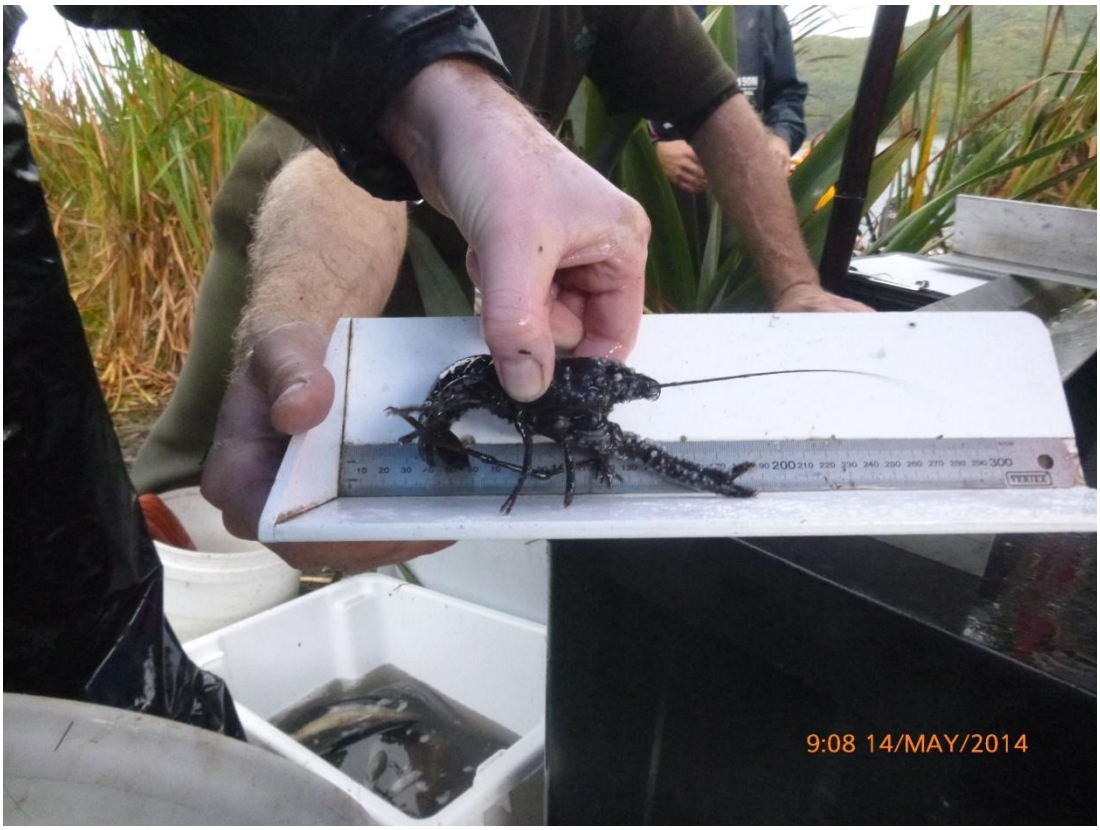


Figure 4: **Freshwater crayfish (koura) captured in one of the fyke nets set on Lake Rotoroa. Only two koura were captured during the entire survey, the other being in Lake Rototapu.**

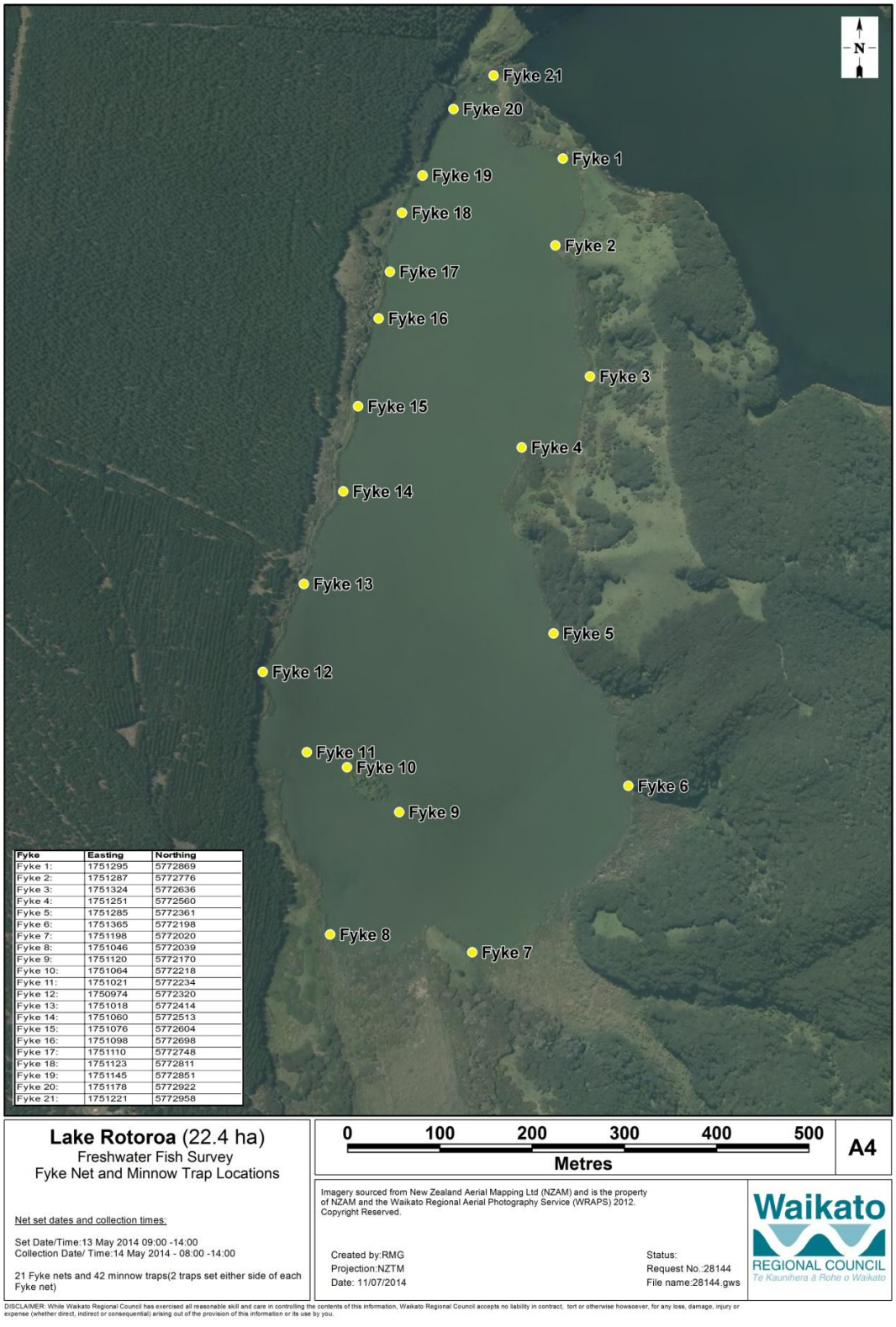


Figure 5: Lake Rotoroa fyke net and minnow trap locations.

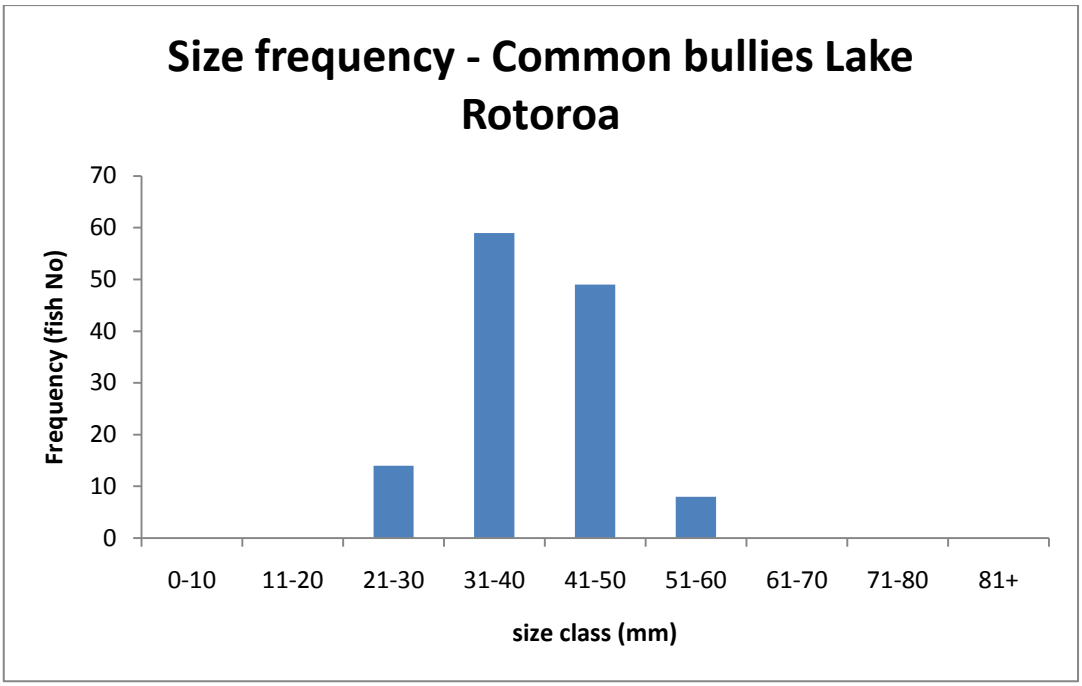


Figure 6: Size frequency distribution of common bullies captured in Lake Rotoroa

Visual comparisons of length frequency distributions were made against those collected for Lake Numiti by Chisnall & Ruru (2008). There appears to be no noticeable change in population structure of shortfin eels between the two studies, with the population dominated by fish between about 450 and 650 mm (Figure 6). It is stressed that caution is required when comparing these data sets as different nets and mesh sizes were used.

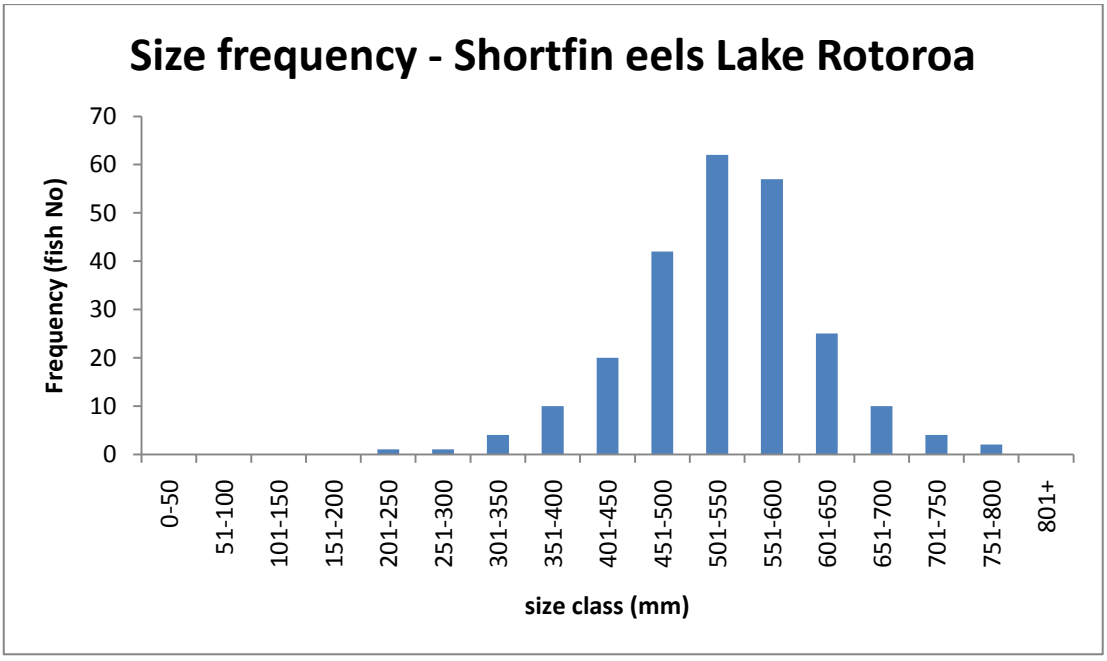


Figure 7: Size frequency distribution of Shortfin eels captured in Lake Rotoroa

Aquatic plants

The following excerpt from the NIWA Lake SPI report (2014) summarises the aquatic plant community in Lake Rotoroa:

"*A LakeSPI Index of 27% in 2014 categorises Lake Rotoroa as having a Moderate condition. This score resulted from a strong invasive weed influence from Elodea canadensis, limited native plant diversity and a restricted vegetated extent at between 3 and 4 m depth. Elodea frequently formed high cover beds, but native pondweeds*

were also locally abundant. Another weed, Potamogeton crispus was common, however Lagarosiphon major was not seen, although it is assumed to be present due to the open connection of this lake with Lake Numiti. Plant observations from 1983 (NIWA unpublished records) were limited to a snorkel depth of 2 m. Nevertheless, native milfoils and charophyte meadows were recorded (these species were absent in 2014) as well as native pondweed, while elodea was 'not as abundant' as in Lakes Taharoa and Numiti. This indicates the lake would have scored a higher LakeSPI index than it does in 2014, but there are insufficient data to generate an indicative historical score."

Please refer to Appendix 3: Table 3-60: LakeSPI results for Lake Rotoroa.

Terrestrial plants

The surrounding vegetation on the eastern side was predominantly regenerating kanuka (*Kunzea ericoides*) forest with remnant puriri (*Vitex lucens*), kohekohe (*Dysoxylum spectabile*), rimu (*Dacrydium cupressinum*) and karaka (*Corynocarpus laevigatus*). The understory has been heavily browsed and *Coprosma rhamnoides* now dominates the understory. The western side is dominated by a production forest of *Pinus radiata*. On the western edge of the lake iron sand supports a vegetation type dominated mostly by adventive species such as *Lupinus arborea*, and *Cortaderia jubata*. Some native species typical of this type of habitat are present such as *Ozothamnus leptophyllus* and *Ficinia nodosa*. The lake margin supports a thin strip of raupo (*Typha orientalis*).

Patches of raupo dominated wetland have formed in the shallow bays around the lake margins. The two largest of these wetlands are at the southern end of the lake. Grey willow (*Salix cinerea*) has invaded these wetlands and is the dominant species in half of the wetland. Other species interspersed amongst the raupo include *Coprosma tenuicaulis* and *Leptospermum scoparium*. As the wetlands progress further inland the stature of the vegetation gets lower and tends to be dominated by *Machaerina rubiginosa* and *Isolepis prolifera*.

The invasive weed, royal fern (*Osmunda regalis*) was noted in several locations on the edge of the raupo wetlands.

Towards the southern end of the lake is an island measuring roughly 1500 m^2 in size. This island supported several browse susceptible species not found in the surrounding forest including *Melicope ternata*, and *Litsea calicaris*. An ornamental cherry *Prunus serrulata* was also found on the island and appears to be spreading.

Of note is the discovery of the swamp buttercup (*Ranunculus macropus*) ranked as data deficient in the latest revision of the New Zealand threatened and uncommon plant list 2012. The swamp buttercup was found growing in a wetland amongst raupo and swamp millet at the southern end of the lake. The site had been opened up by stock and the ranunculus was thriving in the tracking created. The swamp buttercup was scattered over an area of about 3000sqm.

Littoral invertebrates

The littoral aquatic invertebrate fauna of this lake was dominated by Acari (mites) (32%), Platyhelminthes (flatworms) (26%) and Amphipods (21%). This lake had the lowest %EPT of the four lakes with 3.5%. The algal piercing caddisfly *Oxyethira albiceps* was only found at this lake as were Daphnia (water flea) and the snails Gyraulus and Lymnaea which are generally considered to be data deficient or not threatened in NZ. The lake had a low proportion of insects (8%) and Oligochaetes (worms) (<1%).

Zooplankton

Rotifers, principally *Hexarthra intermedia* and *Pompholyx complanata*, the cladoceran *Daphnia galeata* and copepods *Calamoecia lucasi* and *Mesocyclops leuckarti* dominated the zooplankton assemblage in this lake. A preliminary Rotifer TLI value of 5.77 (super-trophic) was produced for this lake (Table 3). For a full list detailing species

presence see Appendix 1 ‘Zooplankton composition and trophic state assessment of rotifer assemblages’.

Physico-chemical parameters

Lake Rotoroa was the largest (27.4 ha) and deepest (14.7m) of the lakes sampled (Table 3). It was the second clearest (secchi 1.48m) but had the highest total phosphorus (TP 0.043g/m^3). Using the more traditional Burn’s TLI parameters for lake water quality a Burn’s TLI of 5.05 was calculated. This means that, at the time of survey, the lake was likely to super-trophic (very high nutrient enrichment), a value and nutrient enrichment category comparable to that inferred by the rotifer community.

Lake Numiti (15.8 ha)

Birds

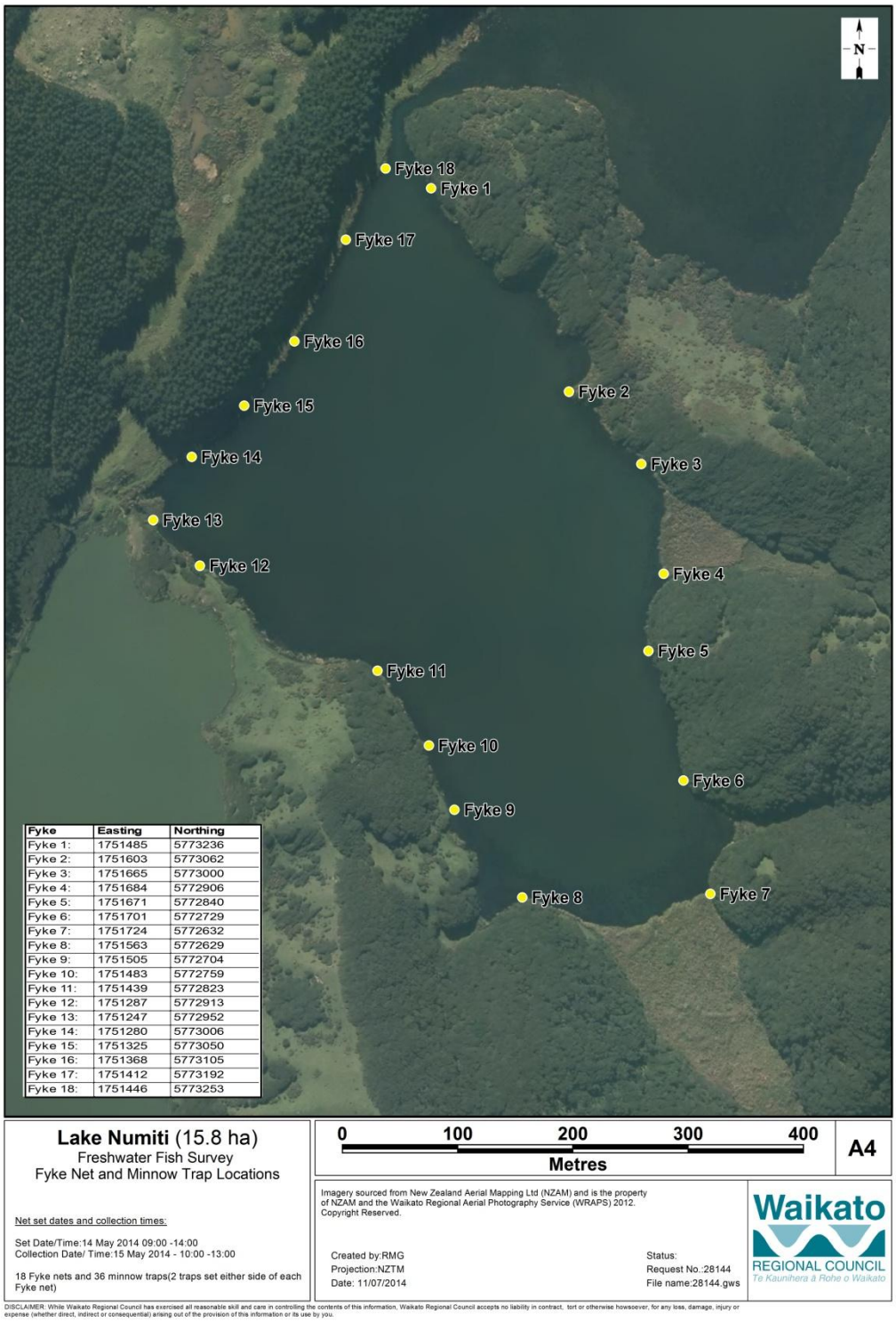
At Lake Numiti Department of conservation staff heard spotless crakes responding to playback at one location (see Appendix 2). Pukeko were also heard on the recorders. Additionally one fermbird was also heard during the day. A variety of waterbirds were noted on the lake surface from the 13th-14th May and these included black swans (n=6 on the 13th and n=9 on the 14th), mallards, dabchicks (n=5), feral geese (n=5), 1 black shag and Waikato Regional Council staff also saw Canada geese (n=5).

Other birds noted by DoC staff at this site included fantail, grey warbler, harrier, kingfisher, pheasant, magpie, blackbird, chaffinch, silvereye, eastern rosella, tui, bellbird, welcome swallow, spurwing plover and morepork (heard on recorders)

Fish

Eighteen fyke nets and 36 minnow traps were deployed in Lake Numiti (see Figure 9 for locations). A total of five fish species were captured by these gears and all were native species. Numerically, common bullies were the most abundant fish species recorded followed by shortfin eels

Figure 8: Drying fyke nets and minnow traps post retrieval from Lake Numiti (background)



Fyke	Easting	Northing
Fyke 1:	1751485	5773236
Fyke 2:	1751603	5773062
Fyke 3:	1751665	5773000
Fyke 4:	1751684	5772906
Fyke 5:	1751671	5772840
Fyke 6:	1751701	5772729
Fyke 7:	1751724	5772632
Fyke 8:	1751563	5772629
Fyke 9:	1751505	5772704
Fyke 10:	1751483	5772759
Fyke 11:	1751439	5772823
Fyke 12:	1751287	5772913
Fyke 13:	1751247	5772952
Fyke 14:	1751280	5773006
Fyke 15:	1751325	5773050
Fyke 16:	1751368	5773105
Fyke 17:	1751412	5773192
Fyke 18:	1751446	5773253

Figure 9: Lake Numiti fyke net and minnow trap locations

Table 5: Summary of fish captured from 18 fykes and 36 minnow traps set overnight in Lake Numiti in May 2014.

	Bullies	SFE	LFE	Smelt	Inanga
total measured in all nets and traps	223	200	4	73	8
average size	36	535	393	56	84
shortest	14	233	334	42	74
largest	97	830	535	79	92
Total captured in 18 fyke nets	1489	199	4	78	8
Total captured in 36 minnow traps	527	2	0	0	0
Average # per fyke - counts included	83	11	0.2	4	0.4
Average # per minnow - counts included	15	0.06	0	0	0

Visual comparisons of length frequency distributions for eels from the current survey in this lake were also made against those collected in the same lake by Chisnall & Ruru (2008). As for Lake Rotoroa, caution is required as different nets and mesh sizes were used. Nevertheless, the data suggest there has been a sizeable reduction in the proportion of the shortfin eels between about 400 and 500 mm in length that make up the Lake Numiti population. Overall a greater size range of shortfin eels were collected during the 2014 survey (233 – 830 mm, Fig. 10) compared with the 2007 survey (390 – 755 mm). The capture of smaller eels in 2014 is likely to be attributable to the finer meshed fyke nets and possibly also the exclusion grills incorporated into the nets used in the present survey, which are designed to reduce predation. It is also worth noting that the population structure of shortfin eels in this lake is different from that in Lake Rotoroa, even though the two are connected some of the time.

Longfin eels remain a very small component of the eel population in this lake and insufficient longfin eels were caught in either of the 2007 or 2014 studies to allow population structure to be assessed. Earlier surveys of Numiti found a much greater proportion of longfin eels in this lake. In a survey carried out sometime between 1990 and 1993 approximately 25% of the eels caught in Numiti were longfin eels (Chisnall & Ruru 2008). In the 2007 and 2014 surveys longfin eels made up 2.6 and less than 2 % of the eel population respectively. As with lake Rotoroa, large numbers of common bullies spanning a range of sizes were captured in nets and minnows (Figure 11,Table 5). Interestingly, significant numbers of smelt (n=78, Table 5) were captured in numerous fyke nets within this lake ranging from 42-79 mm (Figure 12) but only one smelt was captured from the adjoining Lake Rotoroa. It is unclear why more smelt were captured in Numiti than Rotoroa.

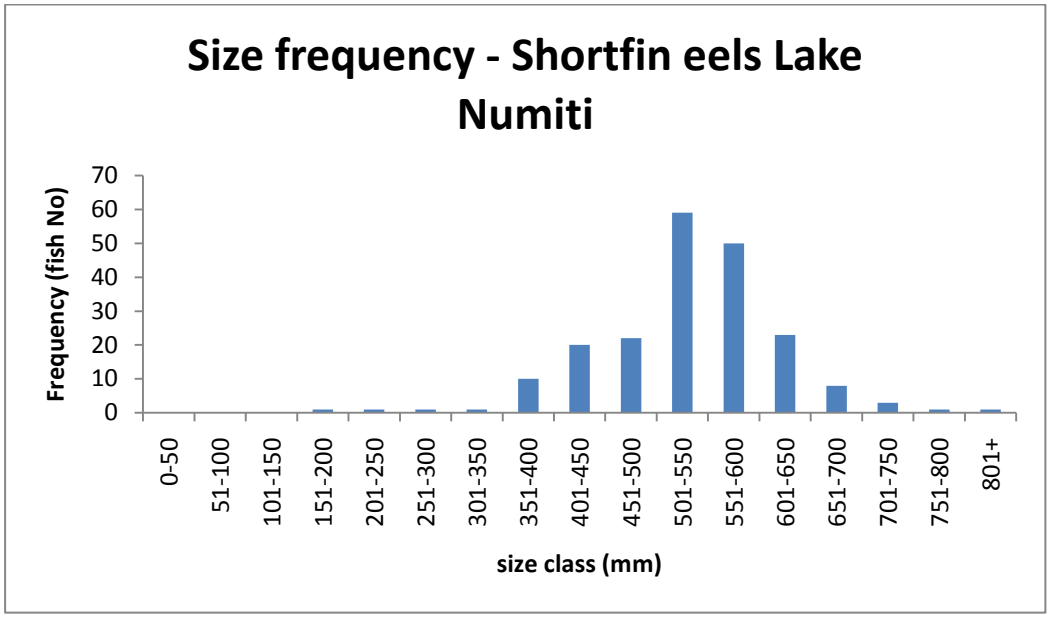


Figure 10: Size frequency distribution of Shortfin eels captured in Lake Numiti

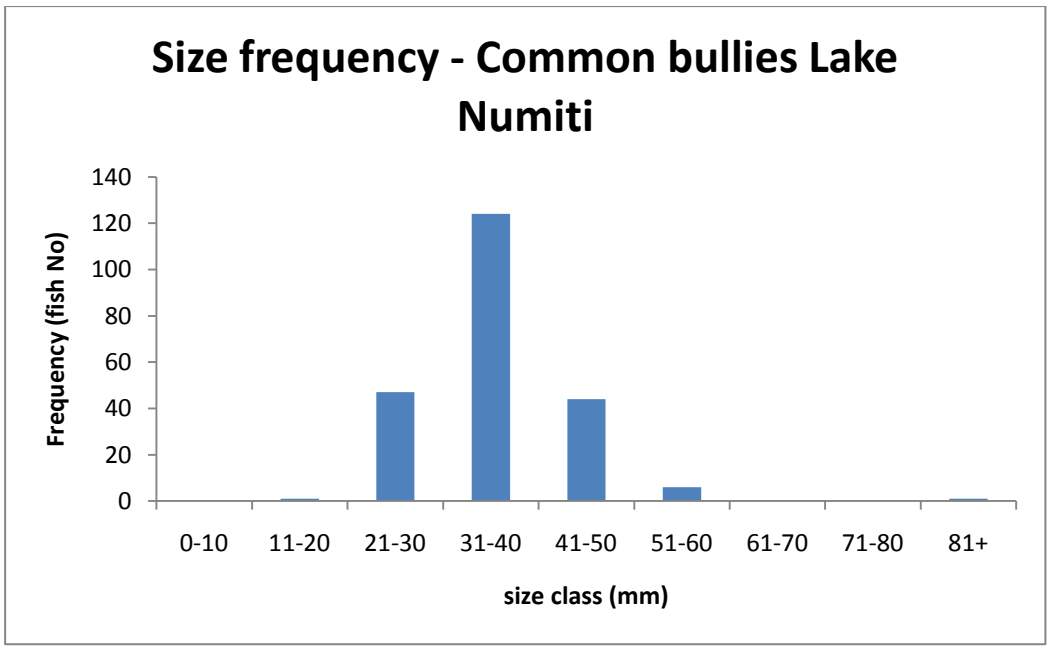


Figure 11: Size frequency distribution of Common bullies captured in Lake Numiti

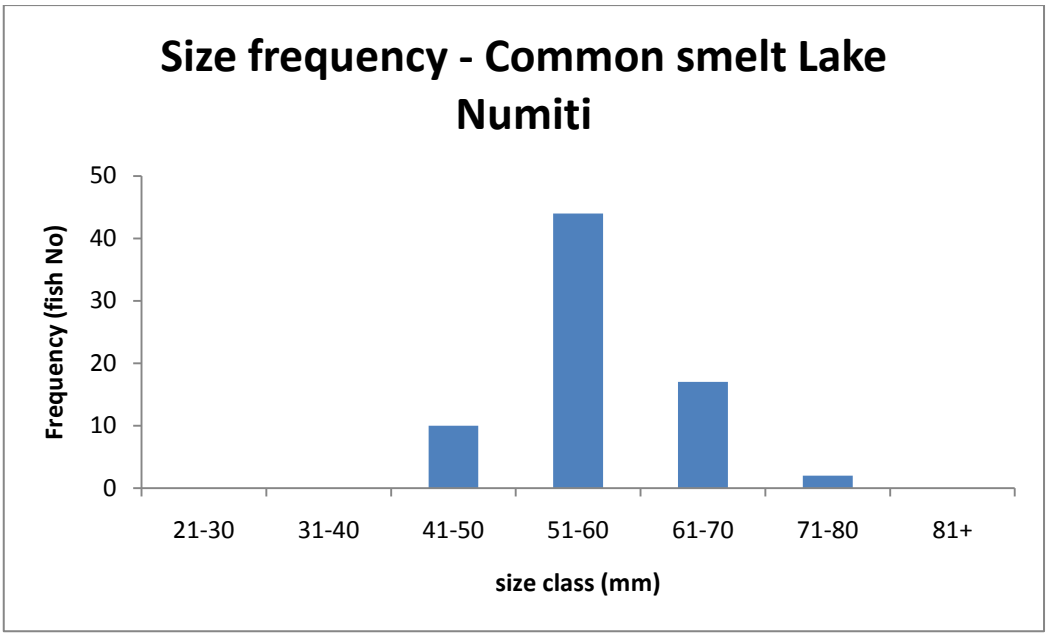


Figure 12: Size frequency distribution of Common smelt captured in Lake Numiti

Aquatic plants

Excerpt copied from 2014 NIWA LakeSPI report

Currently Lake Numiti is in a Moderate condition with a LakeSPI Index of 39%. Native pondweeds, a milfoil and shallow charophyte meadows were present to a restricted depth of 2.8 m. Aquatic weeds, particularly Elodea canadensis, but also including Lagarosiphon major and Potamogeton crispus, contributed to the Invasive Impact Index of 56%. However, these weeds had an open canopy growth that enabled native plants to co-exist and to dominate in places. In 1983 divers recorded submerged vegetation to a depth of 6 m at one of the later LakeSPI survey sites. Elodea was dominant at this time, but charophytes were observed to form a high cover meadow over a 5 to 6 m depth range. Since this time, vegetation depth limits have retracted by over 3 m depth. The likely cause of these changes are decreases in water clarity via nutrient enrichment and subsequent algal blooms, such as was evident during the 2014 survey. In 1983 L. major was not recorded in the lake, but was observed in the connecting channel between Lakes Numiti and Taharoa. Potamogeton crispus was not recorded in 1983, but is spread widely via seed by waterfowl and has been previously recorded in the connected Lake Taharoa. Please refer to Appendix 3: for Table 3-58: LakeSPI results for Lake Numiti.

Terrestrial plants

The vegetation description for Lake Numiti is the same as that for Lake Rotoroa. There is a peninsula that separates the two lakes, which was dominated by kikuyu grassland and regenerating kanuka. The raupo wetland associated with Lake Numiti had the largest and most significant infestation of royal fern of the lakes visited.

Littoral invertebrates

This invertebrate sample from this lake was dominated by Amphipods (46%) and Acari (mites) (37%), approximately three times as many as found in the other three lakes. The lake correspondingly had a low %EPT of 4%. Ferrissia, a freshwater limpet considered not threatened was only found at this lake, as was the non-biting midge *Chironomus* which was present in low numbers. The sample also had a low proportion of insects (6%) and Oligochaeta (worms; <1 %).

Zooplankton

Rotifers, principally *Pompholyx complanata* and *Trichocerca similis* and copepods *Calamoecia lucasi* and *Mesocyclops leuckarti* dominated the zooplankton assemblage in this lake. The Rotifer TLI score for this lake was calculated to be 5.19 (super-trophic, Table 3) and was very similar to the Burns TLI score (5.17) thus placing it in the same

category for nutrient enrichment. For a full list detailing species presence see Appendix 1 ‘Zooplankton composition and trophic state assessment of rotifer assemblages’.

Water chemistry

Numiti was the second deepest (10.6 m) and largest lake (15.8 ha) sampled. The lake had a mean Secchi depth of 0.86 m. It also exhibited the highest reading for Total Ammoniacal N (0.3 g/m^3), Nitrate/Nitrite (0.063 g/m^3), TKN (0.71 g/m^3 equal highest with Lake Rotoroa) and Chl *a* (0.029 g/m^3). The Burn’s TLI assessment for lake water quality resulted in a TLI of 5.17 for this lake (Table 3). This means that, as with Lake Rotoroa, that this lake was likely to be super-trophic (very high nutrient enrichment) at the time of survey (Table 3).

Lake Rototapu (2 ha)

Birds

One spotless crake was heard around the margin at Lake Rototapu while on the lake scaup (n=4) and black swans (n=2) were seen. Paradise shelducks and black shags were not seen on the lake itself but were seen flying overhead at this locality. A range of other marginal birds were also recorded by DoC staff proximal to lake Rototapu and these included; skylark, welcome swallow, goldfinch, magpie, chaffinch, fantail, grey warbler, blackbird, spurwinged plover, yellowhammer, song thrush and kingfisher.

Fish

Shortfin eels, common bullies and low numbers of common smelt were captured in this lake (Table 6) from the 6 fykes and 12 minnows set here (Figure 15). Although a lake outlet appeared to exist, there was no flow exiting the lake at the time of the survey. It is possible that during periods of heavy rainfall limited opportunities for eels to make their way up into this waterbody from the sea may exist although an apparent steep waterfall between the lake outlet and the ocean would limit access to most fish species. When compared to Lakes Numiti and Rotoroa, the lack of any small eels being captured in this lake (smallest was 408 mm; Table 6, Figure 16) supports a lack of consistent access for migratory fish to this waterbody.

Figure 13: Releasing shortfin eels back to Rototapu following measuring – population here dominated by adults with no evidence of recruitment within this waterbody.

The detection and presence of smelt in this waterbody was unexpected. The morphology of these fish including a large mouth and eye diameter relative to body length (Figure 14) suggests that a local non diadromous (non-migratory) population occurs here.

Figure 14: Common smelt from Rototapu – note large eyes and mouth relative to body - tell-tale signs of a lake locked population.

The presence of common bullies also possibly suggests that this lake once had better connection to the ocean (via the other lakes in this chain), alternatively this species could have arrived through either deliberate or accidental translocations of fish into this waterbody. Common bullies, like smelt, are not obligatorily diadromous and can form landlocked populations, as is apparent for this species in Rototapu (Figure 17).

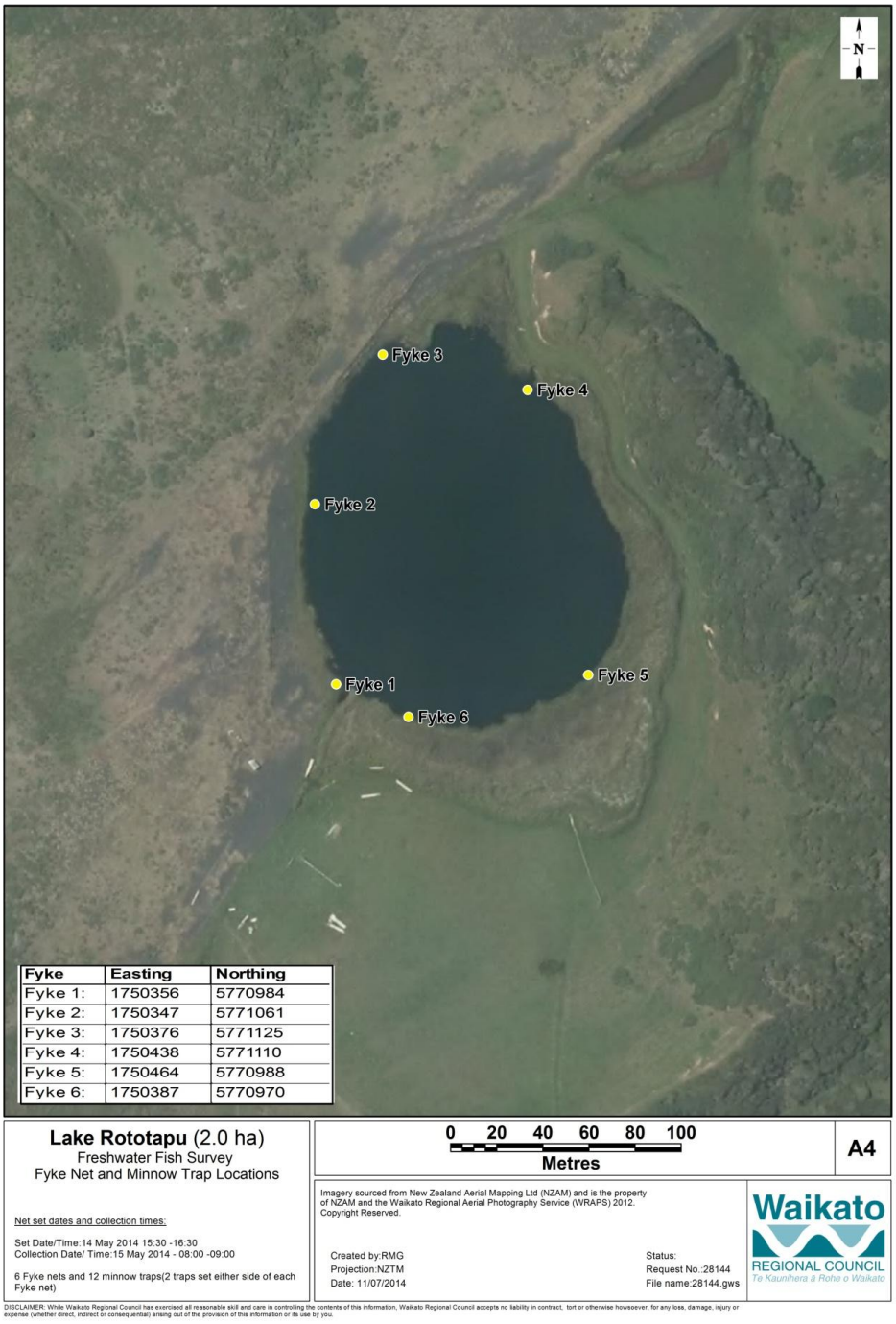


Figure 15: Lake Rototapu fyke net and minnow trap locations

Table 6: Summary of fish captured from 6 fykes and 12 minnow traps set overnight in Lake Rototapu in May 2014

Parameter	Bullies	SFE	Smelt
total measured in all nets and traps	132	38	2
average size (mm)	40	553	65
Shortest (mm)	22	408	58
Largest (mm)	65	743	71
Total captured in 6 fyke nets	80	38	2
Total captured in 12 minnow traps	52	0	0
Average # per fyke - counts included	13	6	0.3
Average # per minnow - counts included	4	0	0

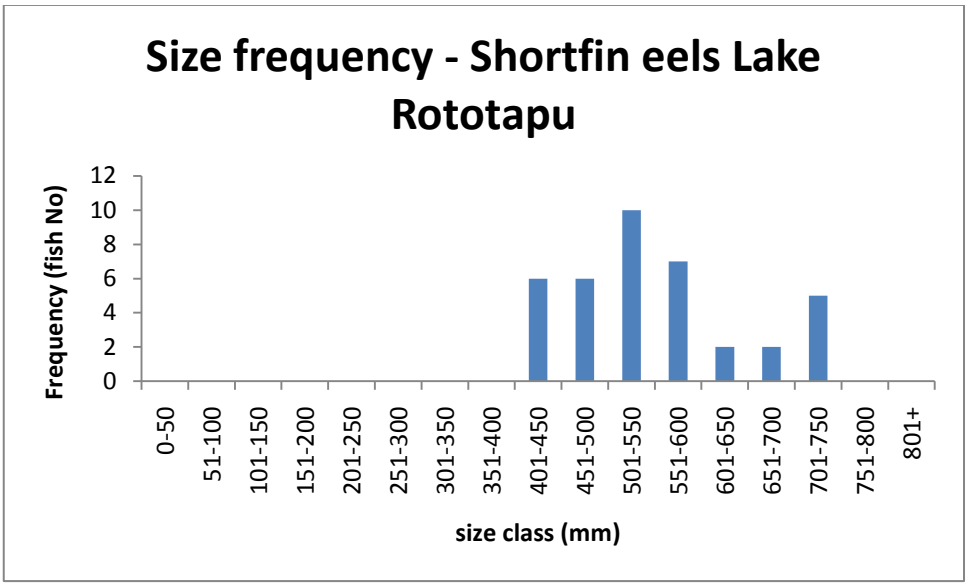


Figure 16: Size frequency distribution of Shortfin eels captured in Lake Rototapu (note absence of eels less than 400mm)

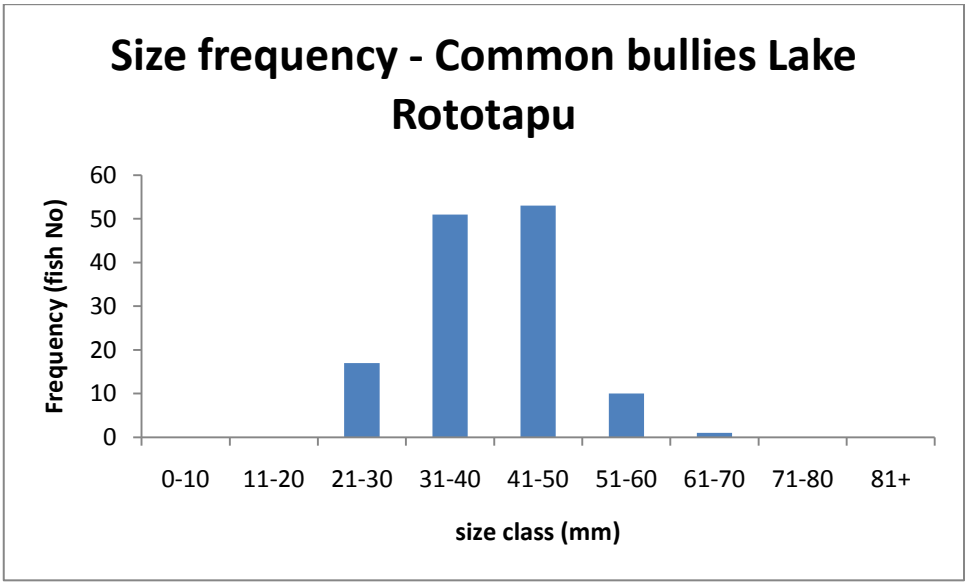


Figure 17: Size frequency distribution of Common bullies captured in Lake Rototapu

Aquatic plants

NIWA - Excerpt copied from 2014 NIWA LakeSPI report

Lake Rototapu scores a Moderate LakeSPI Index of 41% (Table 3-56). Although the alien weeds, elodea (Elodea canadensis) and water buttercup (Ranunculus trichophyllus), were recorded, these co-existed with native pondweed, shallower milfoils and sparse growths of a charophyte. The main depth of vegetation development of 4-5 m was apparently constrained by the water clarity, although some individual pondweed plants were encountered at 7 m, which might suggest a deeper vegetation limit in the recent past. Water buttercup spreads from seed and is transported by waterfowl. Although Lake Rototapu was the only Kawhia lake where water buttercup was recorded in 2014, this weed has been recorded in Lake Taharoa previously. This lake is small (c. 2 ha) but proportionately deep (9.8 m) with sandy, sloping margins. Along the steeper eastern margin, a floating sudd of emergent species (Eleocharis sphacelata, Machaerina articulata, Typha orientalis, Phormium tenax) grows out over 2m depth, which would otherwise be habitat for shallow submerged vegetation. Please refer to Appendix 3: Table 3-56: LakeSPI results for Lake Rototapu.

Terrestrial plants

Lake Rototapu is also surrounded by pasture but due to its larger size the marginal vegetation is more intact than Lake Piopio. The western edge of the lake is sand and supports a turf community which includes species such as *Lilaeopsis novae-zelandiae*, *Gratiola sexdentata* and *Myriophyllum propinquum*. The fence on this edge is slightly effective, but stock are still free to wander. Weed species such as *Ludwigia palustris* and *Persicaria hydropiper* are common in this turf.

There is no fence surrounding the rest of the lake and stock are free to graze right up to the margin of the wetland vegetation. The dominant vegetation around the rest of the lake is a *Typha/Macherina/Isachne* mix with scattered *Phormium* throughout which forms a band 10 – 20 m wide to the edge of the water. In the south eastern corner in the middle of this vegetation type there is a band of vegetation dominated by *Juncus, Blechnum* and *Isachne*.

Littoral invertebrates

Aquatic invertebrates from this lake were dominated by Amphipods (32%) and the aquatic beetle Enochrus (28%). The lake had the highest proportion of insects in any of the four lakes (45%), largely due to the relative abundance of beetles. The non-biting midge larvae of the subfamily Chironominae and the moth larvae *Hygraula nitens* were found in low numbers and only at this lake. The lake had a %EPT of 6% and the highest proportion of Oligochaeta (worms; 4%).

The freshwater mussel (kakahi; *Echyridella menziesii*), which is considered ‘At Risk’ in the latest New Zealand threat classification (Grainger et al. 2014), was very numerous around the lake margin. A small sample of kakahi specimens were sent to Te papa museum for preservation in their collection. Kakahi rely on fish as they have a life stage that parasitises fish, so a healthy fish population will positively benefit the kakahi population.

Zooplankton

Rotifers, principally *Polyarthra dolichoptera* and *Trichocerca similis*, the cladoceran *Daphnia galeata* and the copepod *Calamoecia lucasi* dominated the zooplankton assemblage in this lake. The Rotifer TLI score for this lake was calculated to be 3.04 (Meso-trophic, Table 3) and was again very similar to the Burns TLI score for this lake (3.63.) thus placing it in the same category for nutrient enrichment. For a full list detailing species presence see Appendix 1 ‘Zooplankton composition and trophic state assessment of rotifer assemblages’.

Water chemistry

Lake Rototapu was easily the clearest of the lakes investigated (secchi 2.15 m, turbidity 1.48 ntu). It also exhibited the lowest conductivity (21 mS/m), TKN (0.16 g/m^3), TAN and TP (below detection). Using the Burn's TLI parameters for lake water quality a TLI of 3.63 was calculated for this lake. This means that at the time of survey Lake Rototapu was likely to be meso-trophic (medium nutrient enrichment).

General issues and recommendations for future lake management

This document is intended to provide a current snapshot of information detailing the physical chemical and biological attributes of these four previously data deficient Taharoa dune lakes. Although some basic management actions have been provided below, the information in this report may be used by the Lake Taharoa Trustees to develop a more comprehensive and more strategic management plan for each of these lakes and to address some of the terrestrial (e.g royal fern) and aquatic issues (e.g. nutrient enrichment) that have been identified. In the interim the following identifies some of the issues that could be considered.

Lake Rototapu has high values in terms of freshwater mussels and the presence of a spotless crake. The lake could easily be surrounded with a stock proof fence. This would reduce the input of sediment and faecal bacteria entering the lake. It would enable plants to grow and supply food resources to the lake.

Nutrient enrichment

It is not possible from a one-off sampling survey to establish the primary cause(s) of nutrient enrichment to these lakes but blue-green algal blooms were evident on both Rotoroa and Numiti. It is not known at the time of sampling whether these blooms were generating toxins that could impact human health in a recreational context (e.g. swimming) but the presence of these blue-green algae species does raise this possibility. Long term catchment protection and re-vegetation should reduce the transmission of nutrients to these waterbodies and reduce the likelihood of blue green algal blooms.

Figure 18: Blue green algal bloom on Lake Rotoroa during sampling

Invertebrates

The invertebrate communities at the connected lakes Numiti and Rotoroa were more similar to each other with respect to community composition than they were to the other two lakes. Likewise the invertebrate communities at lakes Rototapu and Piopio were more similar to each other than to the other two lakes. This likely reflects the close proximity of the lakes to each other and possibly their size. Maintenance and ideally improvement of water quality in these lakes over time should enable diverse invertebrate communities to be supported. Protection and improvement in water quality and riparian margins (i.e. through fencing) is essential for building long term resilience into the lake food webs (including littoral areas) to support higher trophic species such as eels (tuna).

Fish

The fish communities were similar between the three larger lakes sampled and were dominated numerically by shortfin eels and common bullies. Only one eel was captured in Lake Piopio, which is likely to be due to a combination of limited fish habitat and having poor connectivity to Rototapu and the sea. Longfin eels and inanga were the two "At Risk" fish species collected from Lakes Numiti and Rotoroa. No "At Risk" species were collected from Rototapu or Piopio.

The size structure of shortfin eel populations was slightly different in each of the three larger lakes. The differences between Numiti and Rotoroa were large enough to suggest that movement between the two connected lakes is either restricted and/or each lake is subject to a different harvest pressure for eels. Interestingly smelt were much more commonly encountered in Numiti than Rotoroa, which may also suggest that while a hydrological connection exists between those lakes, the lakes may nevertheless be functioning differently from each other.

Longfin eels represent a minor component of the sampled eel populations. What proportion of these eel populations should be comprised of longfin eels under natural conditions is not known, however for Lake Numiti at least, there appears to have been a significant decrease in the proportion of longfin eels when the data are compared with captures recorded in the early 1990's. It is highly recommended that any harvesting of eels considers the return of any longfin eels from the catch (from all lakes) to re-establish the abundance of this species locally.

Birds

Numerous bird species were recorded within the Taharoa dune lake system during the survey. These included the nationally endangered Australasian bittern (*Botaurus poiciloptilus*), nationally vulnerable dabchick (*Poliocephalus rufopectus*), relictual spotless crake (*Porzana tabuensis*), declining fernbird (*Bowdleria punctata*) and naturally uncommon black shag (*Phalacrocorax carbo*). The bittern, spotless crakes and fernbirds were all within raupo/swamp millet vegetation, which provides essential habitat for them. Bittern were not heard calling when data on recorders were reviewed, but May is not a time when this species is likely to be calling frequently.

More sophisticated surveys in spring (breeding season) would be required to estimate abundance for species of interest, however the information gained during this survey shows presence of spotless crakes and fernbirds in most areas of raupo/swamp millet at all lakes and presence of bittern at the larger lake system.

Terrestrial Plants

Lake Piopio and Rototapu are highest priorities for fencing. Their small size leaves them more vulnerable to impacts from stock. However the removal of stock may have a negative impact on the turf community at Lake Piopio allowing adventive species to smother the turf species so careful informed and adaptive management is likely to be required here.

The tracking created by stock at the *Ranunculus macropus* site appears to be of benefit at current levels but if farming activities were to increase the impact may be too much and fencing might need to be considered.

Royal fern is the most serious weed present around the lakes. An eradication program for royal fern should be put in place as soon as possible before the effort required becomes too great. Regular monitoring will be required at all the lakes to ensure it does not infest Piopio and Rototapu, which are currently free of this weed.

Grey willow has the potential to modify the wetlands significantly and at its current density would not be difficult to eradicate using “drill & drench” or “cut & paste” methods. The cherry tree on Rotoroa Island is also an easy target for eradication.

Pampas has the potential to be a serious problem; smothering natives and preventing regeneration. At the moment, the few scattered pampas plants around Lake Numiti and Rotoroa could be easily eradicated with herbicide.

Ideally, stock should be prevented from gaining access to any of the wetlands and the surrounding forest as this will allow an understory to regenerate and help control sediment run-off into the lakes, improving water quality.

Acknowledgements

We would like to thank the Taharoa Lakes Trustees and New Zealand Steel mine staff for allowing us access to their rohe and conducting this survey.

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Appendices

Appendix 1: Zooplankton Composition and a Trophic State Assessment of Rotifer Assemblages

	Numiti	Piopio	Rototapu	Rotoroa
	13/05/2014	14/05/2014	13/05/2014	13/05/2014
ROTIFERA				
Anuraeopsis fissa				3
Ascomorpha ovalis			1	
Brachionus caudatus	1			
Collotheca sp.			1	2
Filinia terminalis	1			
Gastropus hyptopus		1	1	
Hexarthra intermedia	1			52
Hexarthra mira			10	
Keratella cochlearis	6		1	3
Keratella procurva				2
Monommata sp.		1		
Polyarthra dolichoptera		13	104	
Pompholyx complanata	76	13		31
Synchaeta oblonga	3		7	
Synchaeta pectinata	2	34	2	
Trichocerca pusilla			1	
Trichocerca similis	20	65	25	7
ARTHROPODA				
Cladoceans				
Bosmina meridionalis	3	2	1	3
Daphnia galeata				92

Copepods				
Calamoecia lucasi	35	26	25	75
Mesocyclops leuckarti	13	36		21
nauplii	46	94	2	62
Total rotifers	110	127	153	100
Total Cladocera	3	2	1	95
Total Copepods	94	156	27	158
Total Crustacea	97	158	28	253
TLI	**5.186485758**	**4.646018353**	**3.037808288**	**5.767589683**

Appendix 2: Information about playback used to detect the presence of spotless crakes at the Taharoa lake complex

Date	Time	Location	Grid ref	No. crakes	Notes
13/05/2014	0905	L. Rototapu	E2660579 N6332638	0	
13/05/2014	0926	L. Rototapu	E2660670 N6332781	1	
13/05/2014	0940	L. Piopio	E2660698 N6332904	1	
13/05/2014	0950	L. Piopio	E2660744 N6332950	0	
13/05/2014	1000	L. Rototapu	E2660593 N6332851	1	Same bird as one heard at 0926
13/05/2014	1137	L. Rotoroa	E2661217 N6333434	1	Bittern here also
13/05/2014	1151	L. Rotoroa	E2661295 N6333508	1	
13/05/2014	1240	L. Rotoroa	E2661449 N6333666	2-3	
13/05/2014	1400	L. Numiti	E2661988 N6334190	1	
14/05/2014		L. Numiti	E2661995 N6334188	2	Likely includes bird from yesterday.
14/05/2014	1019	L. Harihari	E1750350 N5769649	1	
14/05/2014	1112	L. Harihari	E1750996 N5769110	1	

Appendix 3: Assessment of lakes in the Waikato Region using LakeSPI - NIWA

NIWA Client Report No: HAM2014-062

Report date: June 2014

NIWA Project: EVW14209

Relevant tables for 3 of the 4 Data Deficient assessed lakes – Lakes Rotoroa, Numiti and Rototapu (Lake Piopio excluded)

Table 3-60: LakeSPI results for Lake Rotoroa.

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Impact Index (%)
Pristine	1800s	93	88	0
Present day	2014	27	22	69

Table 3-58: LakeSPI results for Lake Numiti.

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Impact Index (%)
Pristine	1800s	93	87	0
Historical	1983	37	48	67
Present day	2014	39	37	56

Table 3-56: LakeSPI results for Lake Rototapu.

State	Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Impact Index (%)
Pristine	1800s	**93**	**89**	0
Present day	2014	41	44	54

Appendix 4: Lake dissolved oxygen and water temperature profile data

Name-Date-Time	**Lake Piopio - 14/5/14 @ 15.30**		
GPS (NZTM)	**E1750505/N5771229N**		
Located Number	**3110_1**		
DEPTH	**DO**	**PCDO**	**TEMP**
0.00	4.74	47.1	15.2
0.50	4.46	44.4	15.2
1.00	3.9	38.6	15.1
1.50	3.66	36.2	15.1
2.00	3.32	32.9	15.1
2.50	3.25	32.2	15
3.00	0.15	1.4	15.1

Name-Date-Time	**Lake Rotoroa - 13/5/14 @ 09.30**		
GPS (NZTM)	**E1751162/N5772308**		
Located Number	**3109_1**		
DEPTH	**DO**	**PCDO**	**TEMP**
0.00	6.7	68.2	16.8
0.50	6.75	68.8	16.8
1.00	6.54	66.6	16.8
1.50	6.49	66.2	16.8
2.00	6.38	65	16.8
2.50	6.35	64.7	16.8
3.00	6.35	64.7	16.8
3.50	6.34	64.7	16.8
4.00	6.33	64.5	16.8
4.50	6.33	64.5	16.8
5.00	6.36	64.8	16.8
5.50	6.37	65	16.8
6.00	6.38	65	16.8
6.50	6.38	65	16.8
7.00	6.37	64.9	16.8
7.50	6.36	64.8	16.8

8.00	6.36	64.8	16.7
8.50	6.35	64.7	16.7
9.00	6.35	64.7	16.7
9.50	6.37	64.8	16.7
10.00	6.36	64.7	16.7
10.50	6.26	63.7	16.7
11.00	6.25	63.6	16.7
11.50	6.19	63	16.7
12.00	6.2	63.1	16.7
12.50	6.18	63	16.7
13.00	6.17	62.9	16.7
13.50	6.16	62.7	16.7
14.00	6.16	62.5	16.7
14.50	6.02	61.2	16.7

Name-Date-Time	**Lake Rototapu - 13/5/14 @ 15.30**		
GPS (NZTM)	**E1750403/N5771042**		
Located Number	**3111_1**		
DEPTH	**DO**	**PCDO**	**TEMP**
0.00	9.06	91.9	16.4
0.50	9.08	92.2	16.5
1.00	9.07	92.2	16.5
1.50	9.06	92.1	16.5
2.00	9.03	91.6	16.4
2.50	8.73	88.4	16.3
3.00	8.63	87.2	16.2
3.50	8.53	86.2	16.2
4.00	8.52	86	16.2
4.50	8.48	85.7	16.2
5.00	8.47	85.5	16.2
5.50	8.47	85.5	16.2
6.00	8.44	85.2	16.2
6.50	8.4	84.8	16.2
7.00	8.4	84.8	16.2
7.50	8.39	84.6	16.2
8.00	8.36	84.4	16.2

8.50	8.31	83.9	16.2

Name-Date-Time	**Lake Numiti - 13/5/14 @ 11.00**		
GPS (NZTM)	**E1751536/N5772974**		
Located Number	**3108_1**		
DEPTH	**DO**	**PCDO**	**TEMP**
0.00	8.7	88.2	16.7
0.50	8.34	84.3	16.5
1.00	8.18	82.7	16.4
1.50	8.14	82.3	16.4
2.00	8.12	82	16.4
2.50	8.11	81.9	16.4
3.00	8.1	81.8	16.4
3.50	8.08	81.7	16.4
4.00	8.08	81.7	16.4
4.50	8.07	81.6	16.4
5.00	8.08	81.7	16.4
5.50	8.05	81.4	16.4
6.00	8.06	81.5	16.4
6.50	8.06	81.5	16.4
7.00	8.05	81.4	16.4
7.50	8.04	81.3	16.4
8.00	8	80.9	16.4
8.50	7.97	80.6	16.4
9.00	7.98	80.7	16.4
9.50	7.94	80.3	16.4
10.00	8.04	81.3	16.4
10.50	6.79	68.7	16.5

Appendix 5: GPS locations and physical dimensions of nets set in each lake during May 2014 survey

FISH COLLECTION FORM (TRAPPING)

Site:	**Lake Rotoroa 3109_1**		**Date:**	13/05/2014
	Easting	**Northing**		
Fyke 1:	1751295	5772869	**Crew:**	Callum B
Fyke 2:	1751287	5772776		Patrick W
Fyke 3:	1751324	5772636		Mike L
Fyke 4:	1751251	5772560		Mark H
Fyke 5:	1751285	5772361		Bruno D
Fyke 6:	1751365	5772198		Adrian J
Fyke 7:	1751198	5772020		Steve S
Fyke 8:	1751046	5772039		
Fyke 9:	1751120	5772170	net/traps set on eastern side of island	
Fyke 10:	1751064	5772218	net/traps set on western side of island	
Fyke 11:	1751021	5772234		
Fyke 12:	1750974	5772320		
Fyke 13:	1751018	5772414		
Fyke 14:	1751060	5772513		
Fyke 15:	1751076	5772604		
Fyke 16:	1751098	5772698		
Fyke 17:	1751110	5772748		
Fyke 18:	1751123	5772811		
Fyke 19:	1751145	5772851		
Fyke 20:	1751178	5772922		
Fyke 21:	1751221	5772958		

Set time:	09.00-14.00	**Collection time:**	08.00 -

			14.00

Mesh size (mm)			**Fyke dimensions**	
Fyke Leader:	4		Leader height (cm):	60
Fyke Trap:	4		Fyke mouth diameter (cm):	70
Minnow trap:	4		Fyke exclusion grid size (mm):	25
			No. Of funnels (baffles):	3

FISH COLLECTION FORM (TRAPPING)

Site:	**Lake Piopio 3110_1**		**Date:**	13/05/2014
	Easting	**Northing**		
Fyke 1:	1750479	5771213	**Crew:**	Callum B
Fyke 2:	1750508	5771243		Patrick W
Fyke 3:	1750512	5771246		Steve S
				Bruno D
				Mike L
				Adrian J
				Mark H
Set time:	10.30a.m.		**Collection time:**	15.30pm

Mesh size (mm)			**Fyke dimensions**	
Fyke Leader:	4		Leader height (cm):	60
Fyke Trap:	4		Fyke mouth diameter (cm):	70
Minnow trap:	4		Fyke exclusion grid size (mm):	25
			No. Of funnels (baffles):	3

FISH COLLECTION FORM (TRAPPING)

Site:	**Lake**	**Rototapu**	**Date:**	14/05/2014

3111_1

	Easting	**Northing**		
Fyke 1:	1750356	5770984	**Crew:**	Callum B
Fyke 2:	1750347	5771061		Patrick W
Fyke 3:	1750376	5771125		Steve S
Fyke 4:	1750438	5771110		Bruno D
Fyke 5:	1750464	5770988		Mike L
Fyke 6:	1750387	5770970		Adrian J
				Mark H

Set time:	15.30-16.30	**Collection time:**	8:30:00 a.m. - 9:30

Mesh size (mm)

Fyke Leader:	4
Fyke Trap:	4
Minnow trap:	4

Fyke dimensions

Leader height (cm):	60
Fyke mouth diameter (cm):	70
Fyke exclusion grid size (mm):	25
No. Of funnels (baffles):	3

FISH COLLECTION FORM (TRAPPING)

Site:	**Lake Numiti 3108_1**		**Date:**	14/05/2014
	Easting	**Northing**		
Fyke 1:	1751485	5773236	**Crew:**	Callum B
Fyke 2:	1751603	5773062		Patrick W
Fyke 3:	1751665	5773000		Steve S
Fyke 4:	1751684	5772906		Mark H
Fyke 5:	1751671	5772840		Adrian J
Fyke 6:	1751701	5772729		Mike L
Fyke 7:	1751724	5772632		Bruno D
Fyke 8:	1751563	5772629		
Fyke 9:	1751505	5772704		
Fyke 10:	1751483	5772759		
Fyke 11:	1751439	5772823		
Fyke 12:	1751287	5772913		
Fyke 13:	1751247	5772952		
Fyke 14:	1751280	5773006		
Fyke 15:	1751325	5773050		
Fyke 16:	1751368	5773105		
Fyke 17:	1751412	5773192		
Fyke 18:	1751446	5773253		
Set time:	09.00-14.00		**Collection time:**	10.00 -13.00

Mesh size (mm)		**Fyke dimensions**	
Fyke Leader:	4	Leader height (cm):	60
Fyke Trap:	4	Fyke mouth diameter (cm):	70
Minnow trap:	4	Fyke exclusion grid size (mm):	25
		No. Of funnels (baffles):	3

Appendix 6: Hill Laboratories water quality results for one off sample during May 2014 survey

Sample Type: Aqueous						
Sample Name:		3109_1 Lake Rotoroa 13-May-2014 10:00 am	3108_1 Lake Numiti 13-May-2014 11:00 am	3110_1 Lake Pio Pio 13-May-2014 3:30 pm	3111_1 Lake Rototapu 13-May-2014 3:30 pm	
Lab Number:		1276311.1	1276311.2	1276311.3	1276311.4	
Turbidity	NTU	7.4	7.3	11.5	1.58	-
pH	pH Units	7.7	7.7	6.8	7.1	-
Electrical Conductivity (EC)	mS/m	29.7	26.2	47.3	21.0	-
Volatile Suspended Solids*	g/m³	5	5	2	< 2	-
Total Suspended Solids	g/m³	6	7	5	< 2	-
Total Ammoniacal-N	g/m³	0.21	0.30	0.022	< 0.010	-
Nitrate-N + Nitrite-N	g/m³	0.033	0.063	0.057	0.009	-
Total Kjeldahl Nitrogen (TKN)	g/m³	0.71	0.71	0.22	0.16	-
Dissolved Reactive Phosphorus	g/m³	0.007	< 0.004	< 0.004	0.004	-
Total Phosphorus	g/m³	0.043	0.030	0.029	0.007	-
Chlorophyll a	g/m³	0.021	0.029	0.006	0.008	-

Appendix 7: Aquatic macroinvertebrate taxa list

Site Number	3108_1	3109_1	3110_1	3111_1
Taxa name	Lake Numiti	Lake Rotoroa	Lake Piopio	Lake Rototapu
Acari	98	81	7	4
Aeshna brevistyla		1	P	3
Anisops		P	P	
Antiporus			1	
Chironominae				1
Chironomus	P			
Collembola			1	
Cyclopoida	7	9	52	20
Daphnia/Simocephalus		2	51	6
Diaprepocoris	P	P	P	3
Enochrus	P	P	P	81
Ferrissia	2			
Gyraulus		P		
Hemicordulia australiae	P		P	
Hirudinea	P		1	
Hydra		10	5	3
Hygraula nitens				1
Lymnaea		P		
Microvelia macgregori				1
Nematoda			1	
Oligochaeta	1	2	11	12
Orthocladiinae	1	3	12	7
Ostracoda		1	4	
Oxyethira albiceps		3		
Amphipoda - Paracalliope	121	53		94
Paroxyethira hendersoni	11	6	98	18
Physa	1	6		7
Platyhelminthes		66	17	
Potamopyrgus antipodarum	16	5	30	15
Amphipoda - Talitridae	P	P	P	
Sphaeriidae			32	
Tanytarsini	1	3	2	5
Xanthocnemis	2	1	4	11

Note: Sorting method was to count the first 200 individuals in each sample then scan the rest of the sample for rare taxa. P means present in scan for rare taxa.

Appendix 8: Vascular Plant species lists for Taharoa Lakes. Surveyed 13-14th May 2014

Lake Rotoroa Island

Shrubs, Trees & Lianes

Alectryon excelsus subsp. excelsus	titoki
Brachyglottis repanda	rangiora
Coprosma rhamnoides	
Coprosma robusta	karamu
Corynocarpus laevigatus	karaka
Litsea calicaris	mangeo
Melicope ternata	wharangi
Melicytus ramiflorus	mahoe
Myrsine australis	mapou
Piper excelsum subsp. excelsum	kawakawa
Prunus serrulata*	

Ferns & Fern Allies

Asplenium flaccidum	hanging spleenwort
Asplenium oblongifolium	shining spleenwort
Microsorum pustulatum subsp. pustulatum	hound's tongue fern
Pyrrosia eleagnifolia	leather leaf fern

Herbs

Cirsium vulgare*	scotch thistle
Conyza sumatrensis*	fleabane
Geranium molle*	
Haloragis erecta subsp. erecta	shrubby toatoa
Lotus pedunculatus*	lotus
Physalis peruviana*	cape gooseberry
Phytolacca octandra*	inkweed
Solanum nigrum*	black nightshade

Grasses & Grass like plants

Bolboschoenus fluviatilis	kopungawha
Carex flagellifera	trip me up
Carex secta	purei
Cordyline australis	ti kouka
Cortaderia jubata*	pampas
Gahnia lacera	cutty grass
Oplismenus hirtellus subsp. imbecillis	bush oat grass
Phormium tenax	harakeke
Rhopalostylis sapida	nikau

Lake Rotoroa & Numiti

Shrubs, Trees & Lianes

Coprosma robusta x propinqua	
Coprosma rhamnoides	
Coprosma robusta	karamu
Coprosma tenuicaulis	swamp coprosma
Corynocarpus laevigatus	karaka
Dacrycarpus dacrydioides	kahikatea
Dacrydium cupressinum	rimu
Dysoxylum spectabile	kohekohe
Geniostoma ligustrifolium var. ligustrifolium	hangehange
Hypericum androsaemum*	tutsan
Knightea excels	rewarewa
Kunzea ericoides var. ericoides	kanuka
Leptospermum scoparium	manuka
Leucopogon fasciculatus	mingimingi
Lupinus arboreus*	lupin
Melicytus ramiflorus	mahoe
Metrosideros perforata	rata
Myrsine australis	mapou
Ozothamnus leptophyllus	tauhinu
Parsonsia heterophylla	new zealand jasmine
Piper excelsum subsp. excelsum	kawakawa
Pseudopanax crassifolius	horoeka
Rhabdothamnus solandri	taurepo
Rubus fruiticosus agg.*	blackberry
Salix cinerea*	grey willow
Ulex europaeus*	gorse
Vitex lucens	puriri

Ferns & Fern Allies

Adiantum cunninghamii	common maidenhair
Asplenium flaccidum	hanging spleenwort
Blechnum filiforme	thread fern
Blechnum fluviatile	kiwikiwi
Blechnum minus	swamp kiokio
Cyathea dealbata	ponga
Cyathea medullaris	mamaku
Deparia petersenii subsp. congrua	
Dicksonia squarrosa	wheki
Diplazium australe	
Doodia australis	rasp fern
Histiopteris incisa	water fern
Microsorum pustulatum	hound’s tongue fern
Osmunda regalis*	royal fern
Paesia scaberula	pig fern
Pneumatopteris pennigera	piupiu
Pteridium esculentum	bracken
Pteris macilenta	sweet fern
Pyrrosia eleagnifolia	leather leaf fern

Herbs

Calystegia sepium subsp. roseata	pink bindweed
Centella uniflora	
Cirsium vulgare*	scotch thistle
Conyza sumatrensis*	fleabane
Dichondra repens	mercury bay weed
Digitalis purpurea*	foxglove
Epilobium pallidiflorum	willowherb
Galium propinquum	
Gamochaeta coarctata	purple cudweed
Hydrocotyle moschata var. moschata	
Hydrocotyle pterocarpa	
Hypochaeris radicata*	catsear
Jacobaea vulgaris*	ragwort
Lobelia anceps	new zealand lobelia
Lotus pedunculatus*	lotus
Myosotis laxa subsp. caespitosa*	water forget-me-not
Myriophyllum propinquum	common water milfoil
Nasturtium officinale*	water cress
Persicaria decipiens	
Persicaria hydropiper*	water pepper
Plantago australis*	swamp plantain
Plantago lanceolata*	narrow leaved plantain
Prunella vulgaris*	selfheal
Ranunculus macropus	
Ranunculus repens*	buttercup
Senecio bipinnatisectus*	Australian fireweed
Sonchus oleraceus*	sow thistle

Grasses & Grass like plants

Ammophila arenaria*	marram
Carex dissita	forest sedge
Carex geminata	rautahi
Carex maorica	maori sedge
Carex secta	purei
Carex virgata	pukio
Collospermum hastatum	
Cordyline australis	ti kouka
Cordyline banksii	ti ngahere
Cortaderia jubata*	pampas
Cyperus eragrostis*	umbrella sedge
Cyperus ustulatus	giant umbrella sedge
Eleocharis acuta	sharp spike sedge
Ficinia nodosa	wiwi
Isachne globosa	swamp millet
Isolepis prolifera	
Juncus articulatus*	jointed rush
Juncus effusus var. effusus*	soft rush
Juncus prismatocarpus	
Juncus sarophorus	fan flowered rush
Kyllinga brevifolia*	

Machaerina rubiginosa	
Microlaena avenacea	bush rice grass
Microlaena stipoides	meadow rice grass
Oplismenus hirtellus subsp. imbecillis	bush oat grass
Pennisetum clandestinum*	kikuyu
Phormium tenax	harakeke
Poa anceps	broad leaved poa
Rhopalostylis sapida	nikau
Rytidosperma gracile	dainty bristle grass
Schoenoplectus tabernaemontani	kuawa
Schoenus maschalinus	dwarf bog rush
Sparganium subglobosum	bur reed
Typha orientalis	raupo

Lake Rototapu

Ferns & Fern Allies

Azolla pinnata*	ferny azolla
Blechnum minus	swamp kiokio

Herbs

Calystegia sepium subsp. roseata	pink bindweed
Centella uniflora	
Cotula coronopifolia	bachelor’s button
Galium propinquum	
Gratiola sexdentata	
Hydrocotyle pterocarpa	
Hypochaeris radicata*	catsear
Lemna disperma	common duckweed
Lotus pedunculatus*	
Ludwigia palustris*	water purslane
Myriophyllum propinquum	common water milfoil
Persicaria hydropiper*	water pepper
Senecio minimus	fireweed

Grasses & Grass like plants

Ammophila arenaria*	marram
Carex maorica	maori sedge
Carex secta	purei
Eleocharis acuta	kuta
Eleocharis sphacelata	sharp spike sedge
Hierochloe redolens	karetu
Holcus lanatus*	Yorkshire fog
Isachne globosa	swamp millet
Isolepis prolifera	
Juncus prismatocarpus	
Lilaeopsis novae-zelandiae	
Machaerina articulata	jointed twig rush
Machaerina rubiginosa	
Pennisetum clandestinum*	kikuyu
Phormium tenax	harakeke

Sparganium subglobosum	bur reed
Typha orientalis	raupo

Lake Piopio

Ferns & Fern Allies

Azolla pinnata*	ferny azolla

Herbs

Calystegia sepium subsp. roseata	pink bindweed
Cotula coronopifolia	bachelor’s button
Lemna minor	common duckweed
Persicaria hydropiper*	water pepper
Rumex acetosella*	sheep’s sorrel

Grasses & Grass like plants

Carex geminata	rautahi
Carex maorica	maori sedge
Carex virgata	pukio
Cyperus ustulatus	giant umbrella sedge
Juncus effusus var. effusus*	soft rush
Juncus prismatocarpus	
Isachne globosa	swamp millet
Machaerina articulata	jointed twig rush
Pennisetum clandestinum*	kikuyu
Phormium tenax	harakeke
Typha orientalis	raupo

Appendix 9: Locations of acoustic recorders used to detect the presence of bitterns and other bird species at Taharoa lake complex

Number	Location
1	E2661210 N6333729
2	E2661295 N6333508
3	E2661523 N6333773
4	E2661924 N6334330
5	E2661895 N6334606