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Lakes Ngāpouri, Ngāhewa and Tutaeinanga

Monitoring of kōura and common bully using the tau kōura

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Prepared by:
Ian Kusabs
Ian Kusabs and Associates Limited

For:
Waikato Regional Council
Private Bag 3038
Waikato Mail Centre
HAMILTON 3240

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Deniz Ozkundakci Date March 2017

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Dominique Noiton Date March 2017

LAKES NGĀPOURI, NGĀHEWA AND TUTAEINANGA

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REPORT PREPARED FOR WAIKATO REGIONAL COUNCIL

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Cover photo: Ian Kusabs setting whakaweku (fern bundles) in Lake Tutaeinanga, October 2016.

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1 INTRODUCTION

Lakes Ngāpouri (Opouri), Ngāhewa and Tutaeinanga are found in the geothermal area around Maungakakaramea (Rainbow Mountain) and Waiotapu. The beds of these three lakes are under ownership by Te Arawa Lakes Trust and were part of the Te Arawa Lakes Settlement Act 2006. They are the only lakes of this settlement which fall within the Waikato Regional Council district.

Lakes Ngāpouri, Ngāhewa and Tutaeinanga (hereby referred to as the Waiotapu lakes) are highly eutrophic and frequently experience nuisance cyanobacteria blooms driven by high nitrogen (N) and phosphorus (P) inputs from the catchment and a high internal P load released from the sediments during summer stratification.

Kōura (*Paranephrops planifrons*) are an important component of lake food webs and support important customary fisheries in the Te Arawa lakes where they are harvested for human consumption by local Māori (Hiroa 1921; Kusabs *et al.* 2015a; Kusabs *et al.* 2015b). Although, kōura are relatively well studied in many of the Te Arawa lakes, little is known about kōura populations in the Waiotapu lakes.

The aim of this study was to provide baseline information on the kōura populations in the Waiotapu lakes to underpin a restoration plan for the three lakes.

2 METHODS

2.1 Tau kōura location and lay out

The tau kōura, a traditional Māori method of harvesting kōura in the Te Arawa and Taupō lakes (Kusabs and Quinn 2009) was used to sample kōura populations in the three lakes. Tau kōura were deployed in Lake Ngāpouri at WGS84 - 38.33928 176.33229, Lake Ngāhewa at - 38.315770 176.372833, and in Lake Tutaeinanga at - 38.332615 176.321802 (Fig. 1).

Each tau kōura was comprised of 10 whakaweku (dried bracken fern; *Pteridium esculentum*, bundles), with c. 10-14 dried fronds per bundle, which were attached to a bottom line (a 200 m length of sinking anchor rope) and set in depths ranging from 4.5 to 15.5 m in Lake Ngāpouri, 2.0 to 4.5 m in Lake Ngāhewa and 0.5 to 8.2 m in Lake Tutaeinanga (Fig. 2).

The tau kōura were set in lakes Ngāpouri and Ngāhewa on 22 October 2016, and Lake Tutaeinanga on 24 October 2016. The whakaweku were left for approximately two months to allow kōura to colonise the fern before being retrieved on 28 December 2016. Tau kōura were returned to the water following retrieval.

2.2 Fish measurement

Total length (TL, mm) of each fish was measured using vernier calipers (± 0.5 mm). After processing, all fish were returned to the water near the tau kōura. Catch Per Unit Effort (CPUE) was defined as the number of fish per whakaweku.

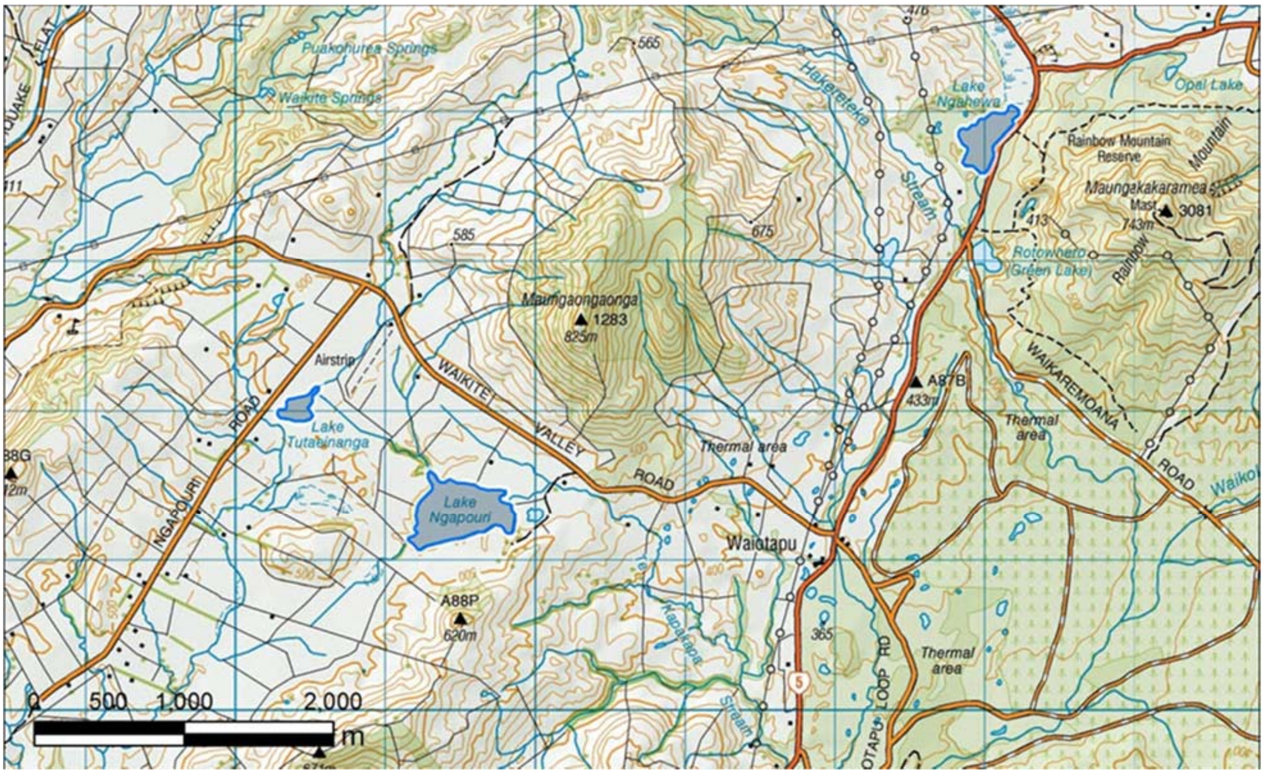


Figure 1 Map showing the location of lakes Ngāpouri, Ngāhewa and Tutaeinanga.

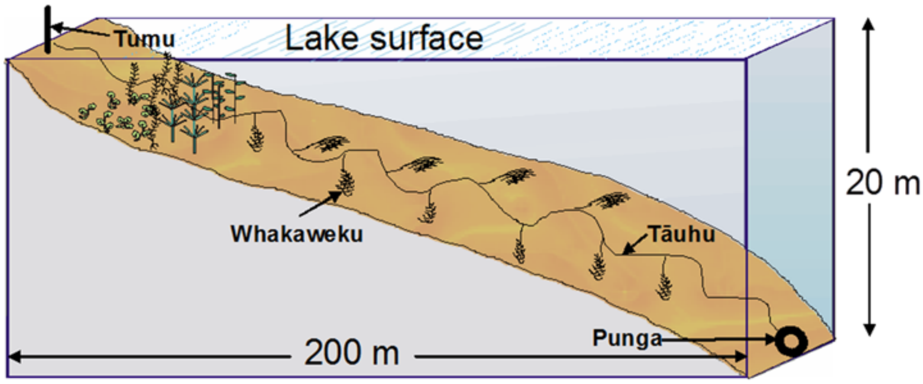


Figure 2 Schematic diagram of a tau kōura. The depth and length of tau are indicative and can be varied depending on lake bathymetry.

3 RESULTS

3.1 Sampling Conditions

Tau kōura were retrieved in sunny, calm, conditions on 28 December 2016. At the time of the survey the Waiotapu lakes were stratified and the bottom waters more than likely deoxygenated[1]. Sampling details are summarised in Table 1 below.

Table 1 Tau kōura location (map reference), lake area, whakaweku depth (the depth which whakaweku were deployed), surface water temperature (°C) and Secchi disc depth (m) in lakes Ngāpouri, Ngāhewa and Tutaeinanga, 28 December 2016.

Lake	Map reference WGS84[2]	Lake area (ha)	Whakaweku depth (m)	Water temperature (°C)	Secchi depth (m)
Ngāpouri	- 38.33928 176.33229	19	4.5 – 15.5	20.0	3.5
Ngāhewa	- 38.315770 176.372833	8.4	2.5 – 4.5	19.5	1.75
Tutaeinanga	- 38.332615 176.321802	3.1	0.5 – 8.5	22.0	1.5

3.2 Kōura and fish species present

Common bully (*Gobiomorphus cotidianus*) was the only species captured in the survey. In addition, a large (TL = 280 mm), dead goldfish (*Carassius auratus*) was found floating in Lake Ngāhewa. No kōura were captured in the Waiotapu lakes.

3.3 Common bully

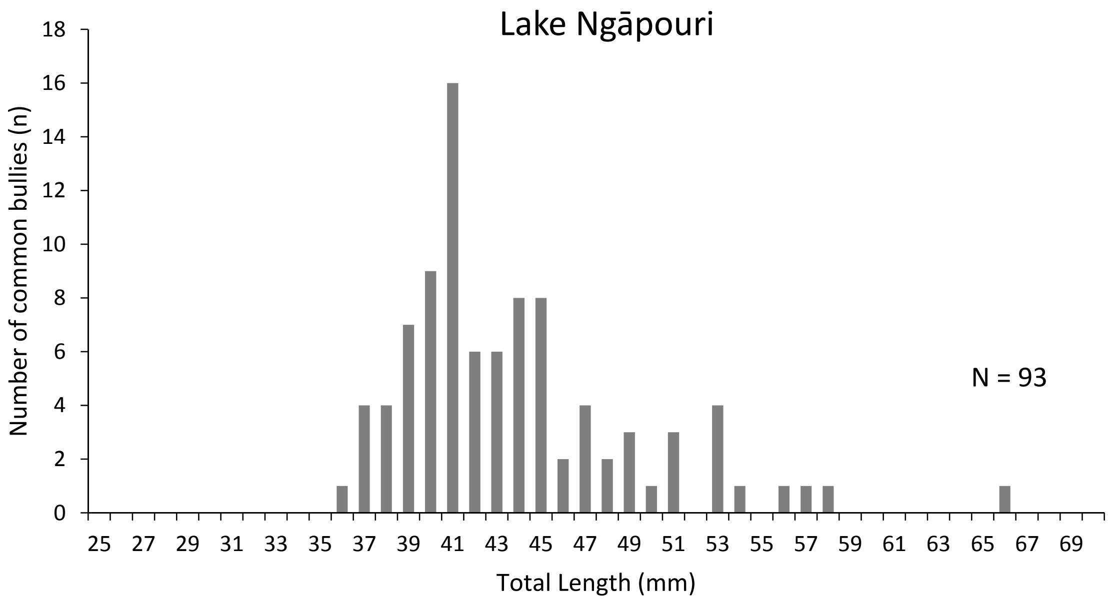
A total of 145 common bullies were captured in lakes Ngāpouri (mean CPUE 9.3) and Ngāhewa (mean CPUE 5.2), but none were captured in Lake Tutaeinanga. Common bully were only captured on whakaweku (n = 2) set at water depths less than 5 m in Lake Ngāpouri and on whakaweku (n = 3) set at depths ranging from 2.5 to 3.5 m in Lake Ngāhewa. No common bully were captured on whakaweku set at depths from 6.5 to 15.5 m in Lake Ngāpouri and 4.1 to 4.5 m in Lake Ngāhewa.

The mean size of bullies captured in lakes Ngāpouri and Ngāhewa was 43.8 mm and 49.7 mm, respectively (Table 2, Fig. 3). Common bully ranged in size from 36 to 66 mm in Lake Ngāpouri and 29 to 70 mm in Lake Ngāhewa (Table 3, Fig. 3).

[1] Anoxic conditions are most probably present in the Waiotapu Lakes from November to June. A further survey is planned for winter 2017 when the lakes are fully mixed.
[2] Decimal degrees

Table 2 Mean CPUE (± SD) of common bully collected from tau kōura set in lakes Ngāpouri, Ngāhewa and Tutaeinanga, October to December 2016. Mean CPUE – mean catch per unit effort. Mean, minimum, maximum lengths - total lengths in mm. SD – standard deviation.

Lake	Mean CPUE (n ± SD)	Mean length (mm ± SD)	Minimum length (mm)	Maximum length (mm)
Ngāpouri	9.3 (20.2)	43.8 (5.4)	36	66
Ngāhewa	5.2 (10.9)	49.7 (6.8)	29	70
Tutaeinanga	0.0	-	-	-



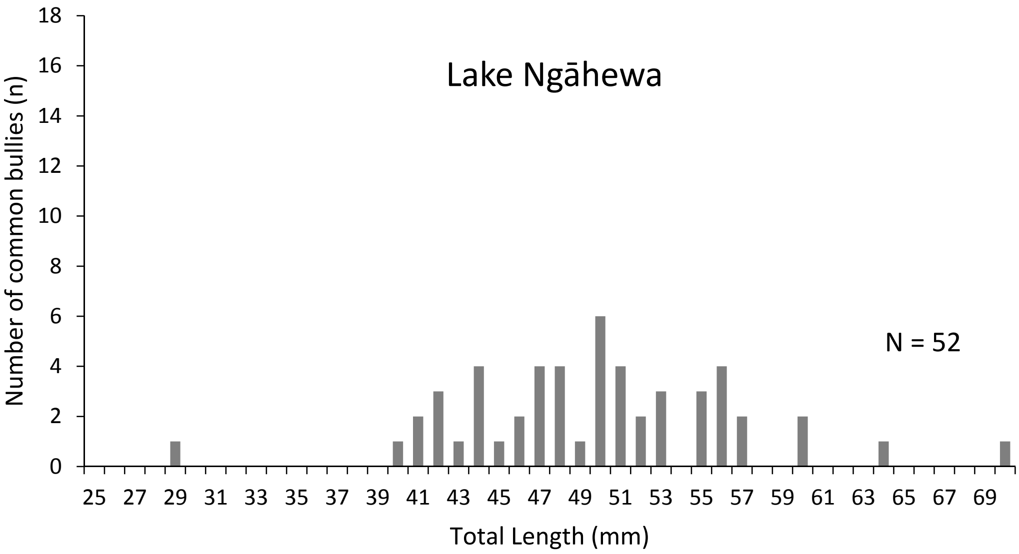


Figure 3 Length (TL) frequency graph for common bully captured from lakes Ngāpouri and Ngāhewa. Tau kōura were set in lakes Ngāpouri and Ngāhewa on 22 October 2016, and Lake Tutaeinanga on 24 October 2016 and retrieved on 28 December 2016.

Figure 4 Retrieving tau kōura set in Lake Ngāpouri, 28 December 2016.

Figure 5 A large (TL = 280 mm), dead goldfish found floating in Lake Ngāhewa, 28 December 2016.

4 DISCUSSION

4.1 Kōura

No kōura were captured in this survey of the Waiotapu lakes. However, prior to catchment development in the late 1950's, Lake Ngāpouri was known to be 'full of kōura' and neighbouring Lake Ōkaro (where kōura are now absent) was known to contain 'exceptionally big freshwater crayfish' (Gee 1960). Moreover, while no kōura were found in this study, they have been recorded in previous resource inventory reports of Lake Ngāpouri and Ngāhewa (Boswell *et al.* 1985; Kelly 2010). In addition, kōura are common in the small unnamed stream that flows into Lake Ngāhewa (Kusabs 2004) and it is possible that kōura may also be present in tributaries and springs flowing into lakes Ngāpouri and Tutaeinanga.

Unfortunately, the methods used to sample kōura were not described in detail by Boswell et al. (1985) who reported that kōura had been recorded in Lake Ngāhewa and that they were also present in Lake Ngāpouri. Kelly (2010) carried out small scale trap surveys, using baited minnow traps, set overnight, in the inflowing tributary and outlet of Lake Ngāhewa in November 2009 and found "healthy populations of common bullies, kōura and rainbow trout". Minnow traps are commonly used for sampling kōura in lentic waters and can yield reliable kōura abundance estimates. However, population parameters, such as size structure, sex ratios, age, and maturity status, may be different in traps than the general population. Female crayfish are generally less active than males, resulting in unequal sex ratios. The tau kōura is a microhabitat trap that provides cover as a form of attractant instead of food and does not have these biases. Kusabs (2015) compared tau kōura and trapping studies in Lake Rotoiti and found that the tau kōura not only had a higher mean CPUE but also did not have the sex and size biases inherent in baited traps. It therefore seems unlikely that the absence of kōura was due to methodology, but it could be due to the different habitats sampled. In this study, whakaweku were set in Lake Ngāhewa at depths ranging from 2 m to 4 m whereas Kelly, (2010) surveyed the shallow water tributary and outlet stream, where dissolved oxygen levels would have been more suitable for kōura.

Although the causes of kōura extirpation in the Waiotapu lakes are unknown, a range of stressors associated with eutrophication will have contributed to their decline. Summer anoxia has reduced available habitat and food sources and the seasonal over-turn may cause elevated ammoniacal-N concentrations and release of hydrogen sulphide. In addition, degradation of benthic habitat quality, predation from trout or cormorants when kōura were constrained to the littoral zone during summer anoxia, and ingestion of toxic cyanobacteria may all have affected kōura abundance.

Hypolimnetic deoxygenation is most likely the main cause of kōura decline. Kusabs et al. (2015) found that eutrophication in conjunction with lake morphology appeared to indirectly affect kōura distribution in the sheltered, steep-sided lakes, through hypolimnetic deoxygenation. Kōura were excluded from the deoxygenated hypolimnion of Lakes Ōkāreka, Rotokakahi, and Rotoiti in April when the lakes were stratified and concentrations of dissolved oxygen <5 mg L^{-1}. Periodic stratification events also cause intermittent hypolimnetic deoxygenation in Lake Rotorua (Burger *et al.* 2008; Trolle *et al.* 2011) which leads to the movement of kōura into shallower water (Kusabs and Butterworth 2011).

In lakes Ngāhewa and Tutaeinanga dissolved oxygen concentrations regularly fall below 5 mg L^{-1} at depths of 2.5 m and 1.5 m, respectively (WRC records, 2007 to 2010). Lake Ngāpouri is considerably deeper than Ngāhewa and Tutaeinanga with a maximum depth of 24.5 m (*cf.* to 5 and 11 m, respectively). Prior to catchment development (in the late 1950's), the hypolimnion of Lake Ngāpouri remained oxygenated throughout the year but by 1966 the hypolimnion had become anoxic (Fish 1970) and by 2007/08 it was anoxic for eight months of the year (November to June), with a high nutrient content and cyanobacteria biomass (Pearson 2012). Moreover, Lake Ngāpouri has also been affected by at least one lake-wide fish kill incident which occurred following a summer 'turn-over' event in the early 1990's, with hundreds of rainbow trout (*Oncorhynchus mykiss*), common smelt (*Retropinna retropinna*) and kōura washed up on the northern side of the lake (I. Kusabs, pers. obs.).

4.2 Fish

Common bullies were abundant in lakes Ngāpouri and Ngāhewa but were not present in Tutaeinanga. Common bullies have not been reported previously in Ngāpouri. There is no mention of bullies by Boswell et al. (1985) or on the New Zealand Freshwater Fish Database (accessed 31 July 2017). It is unknown how, and when, this fish became established in Lake Ngāpouri.

The age structure of common bully in lakes Ngāpouri and Ngāhewa are consistent with the findings of Stephens (1982) who found that common bully tend to be short-lived in lakes, with few reaching age three; they were 35-40 mm long at age one, and 50-60 mm at two in Lake Waahi. Common bully are known to spawn throughout the year (Stephens 1982) and the 29 mm total length (TL) fish captured in Lake Ngāhewa indicates that bullies may spawn at least twice in this lake.

This is the first record of goldfish in Lake Ngāhewa; this is surprising given that this lake flows into the Waiotapu Stream where goldfish are abundant. Introduced to New Zealand in the 1860s, goldfish are widespread and well established in the North Island and are known as 'morihana' by local Māori. Goldfish have been associated with adverse impacts on water quality through resuspension of sediment and nutrients during feeding and are likely to compete with native fish for food and other resources (Collier and Grainger 2015).

No common smelt were captured in this survey as the tau kōura method does not target this shoaling species, which swim in schools near the water surface rather than resting or hiding on the substrate.

4.3 Lake Restoration

Freshwater crayfish increasingly feature as indicator species because of the important role they play in aquatic ecosystems and their iconic and heritage values (Reynolds and Souty-Grosset 2012). Moreover, crayfish have been shown to be excellent water quality indicators (Fureder and Reynolds 2003; Reynolds and Souty-Grosset 2012). In New Zealand, kōura are denizens of good-quality water and their re-establishment in the Waiotapu lakes would be an excellent bioindicator of lake restoration success. Therefore, kōura re-establishment should be a key long-term goal of the Waiotapu lakes restoration programme.

Lake restoration needs to take account of the whole lake ecosystem and needs to incorporate management measures for the range of stressors and factors which adversely affect lake-dwelling kōura populations. Periodic deoxygenation of bottom waters in the Waiotapu lakes is a major factor which will impede the successful reintroduction of kōura. It is recommended that a range of lake restoration methods be implemented to improve water quality so that kōura populations can reestablish in the Waiotapu lakes. Until water quality conditions improve there is little that can be done to restore kōura in the lakes themselves. In the meantime, the status of kōura in the inflowing tributaries should be determined and if necessary measures implemented to protect them and their habitat. These stream populations will provide a source of kōura for the recolonisation of the lakes when water quality is suitable.

5 SUMMARY AND RECOMMENDATIONS

No kōura were captured in this survey of lakes Ngāpouri, Ngāhewa and Tutaeinanga. It is probable that multiple stressors associated with the eutrophication process, particularly rapid and prolonged hypolimnetic deoxygenation, have led to kōura extirpation in the Waiotapu lakes. Major improvements in lake water quality are required before kōura populations can be re-established in the lakes, until this occurs there is little point in reintroducing kōura. The successful re-establishment of kōura should be a key long-term goal of the Waiotapu lakes restoration programme. It is envisaged that kōura in the inflowing tributaries will provide a source of recruitment for the lakes when water quality conditions improve.

6 ACKNOWLEDGEMENTS

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