# Kōura abundance and distribution in Lake Rotorua and potential effects of hypolimnetic dosing and sediment capping

**REPORT PREPARED FOR BAY OF PLENTY REGIONAL COUNCIL**

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Cover photo: Joe Butterworth and Joe Bidois collecting kōura out of the korapa, from a tau kōura set in Lake Rotorua, 3 December 2011.

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# 1 EXECUTIVE SUMMARY


Lake Rotorua is a polymictic lake which stratifies intermittently during the summer/autumn period. During these events nutrients (nitrogen and phosphorous) are released from the sediments and this release of phosphorous is a key driver of late summer/autumn algal blooms. The Bay of Plenty Regional Council (BOPRC) has a number of proposals to improve water quality including two in-lake treatments, hypolimnetic dosing and sediment capping.

One of the main concerns to Te Arawa is the potential effects of these treatments on kōura (freshwater crayfish, *Paranephrops planifrons*). Kōura are an important mahinga kai species in Lake Rotorua where large quantities are known to be present (Kusabs, unpublished PhD data). The aims of this study were to determine the abundance and distribution of kōura in Lake Rotorua and to discuss the potential effects of sediment capping and hypolimnetic dosing on Lake Rotorua kōura.

Kōura were found to be abundant in Lake Rotorua with a total of 2626 kōura captured in the 2 surveys (December 2010 and December 2011). Koura were present in depths from 5 to 21 m with kōura most numerous from 10 to 17 m deep. Kōura distribution was influenced by thermal stratification and hypolimnetic deoxygenation. When Lake Rotorua was mixed (December 2011) kōura were present at depths down to 21 m, however, when the lake was stratified (December 2010) kōura were forced to move into the oxygenated epilimnetic waters above 19 m.

Although the risk of hypolimnetic dosing and sediment capping to kōura populations is small, it may be prudent to carry out these treatments when the lake is stratified and kōura have moved out of the hypolimnion. Confining the hypolimnetic dosing and sediment capping treatments to the deoxygenated hypolimnion will further decrease the risk of these treatments on the Lake Rotorua kōura population.

# 2 INTRODUCTION

The Bay of Plenty Regional Council (BOPRC) is leading the restoration and protection programme for the Rotorua lakes. Lake Rotorua is a eutrophic lake that exceeds its specified trophic level index (TLI) as specified in the Regional Water and Land Plan. Moreover, in recent years a pattern of late summer autumn algal blooms has occurred in Lake Rotorua which has caused problems in the Okere Arm of Lake Rotoiti and in the Kaituna River.

Lake Rotorua is a polymictic lake which stratifies intermittently during the summer/autumn period during these events nutrients (nitrogen and phosphorous) are released from the sediments. This release of phosphorous is a key driver of the late summer to autumn algal blooms. The BOPRC has a number of proposals to improve water quality including hypolimnetic dosing and sediment capping.

**Hypolimnetic dosing**

Hypolimnetic dosing, or hypo dosing, is aimed at locking up free available phosphorous in the water column which is released from the sediments when the lake stratifies and the bottom waters become anoxic. It is envisaged that reducing the amount of phosphorous in the water column will cut the supply of phosphorous that supports the late summer/autumn algae blooms. It is proposed that alum will be applied directly to the hypolimnion (deeper waters) of the lake to lock up phosphorous, with dosing carried out when the Lake Rotorua monitoring buoy indicates low oxygen levels in the bottom waters.

**Sediment capping**

Sediment capping is the application of a thin (1 – 2 mm thick) layer of material on the lake sediments to prevent the release of phosphorous from the deep water lake sediments. Sediment capping works by locking up phosphorous with either Alum or Lanthanum so that it remains locked in the sediments. Three sediment capping agents have been tested in the Rotorua lakes in recent years these are; Phoslock (a commercial product from Australia), Aqual-P (a modified zeolite product developed by SCION) and Allophane (a natural volcanic clay mineral quarried near Rotorua). Laboratory tests show that all three products have the potential to lock phosphorous in lake sediments. In addition, Alum and Aqual-P have been trialled successfully in the small, sheltered Lake Okaro. However, it is unclear whether sediment capping will work in a large, exposed lake such as Lake Rotorua. The Bay of Plenty Regional Council is proposing to trial these capping agents in mesocosms on 30m x 30m patches on the bed of Lake Rotorua.

One of the main concerns to Te Arawa is the potential effects on koura. Koura are an important mahinga kai species in Lake Rotorua where large quantities are present. As part of a PhD study of 7 Rotorua lakes by the author, the highest abundance of koura was found in Lake Rotorua 50 to 200m off Mokoia Island (Kusabs, unpublished PhD data).

The aims of this study were to determine the abundance and distribution of kōura in Lake Rotorua and to discuss the potential effects of sediment capping and hypo dosing on Lake Rotorua kōura.

# 3 METHODS

## *3.1 Tau kōura construction and use – hypolimnetic dosing*

The Lake Rotorua kōura population was sampled using the tau kōura (Fig. 1), a traditional Māori method of harvesting kōura in the Te Arawa and Taupō lakes (Hiroa 1921, Kusabs & Quinn 2009).

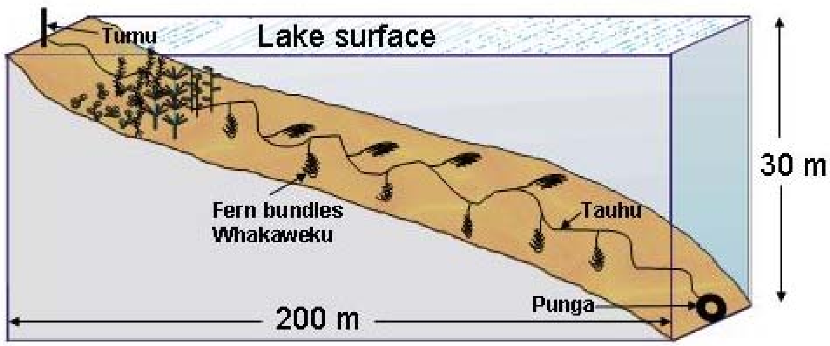


**Figure 1** Schematic diagram of the tau kōura. The depth and length of tau are indicative and can be varied depending on lake bathymetry.

Two tau kōura were set in Lake Rotorua, both located on the western side of Mokoia Island (Fig. 2, Table 1). Each tau kōura was comprised of 20 dried bracken fern (*Pteridium esculentum*) bundles each with c. 10 dried fronds per bundle. The fronds were bound together using 250 or 300 mm length industrial strength cable ties and were attached using hay baling twine (approximately 2.5 m long) to a 450 m length of sinking anchor rope and set. One end of the bottom line was attached to a large boulder on the shoreline of Mokoia Island while the lake end was anchored to the lake bottom using a car tyre filled with concrete. Both tau kōura were set in water depths ranging from 5 to 21 m.

The tau kōura were left for at least one month to allow kōura to colonise the ferns. Fern bundles were deployed on 29 October 2010 and retrieved on 8 December 2010, replaced with new fern bundles on 2 September 2011 and retrieved again on 3 December 2011.

Table 1 Sampling site, number of fern bundles, location, grid reference (NZTM = New Zealand Transverse Mercator Projection) and direction of transect for kōura monitoring sites located in Lake Rotorua.

| Sampling site | Grid reference (NZTM) | Number of fern bundles |
|---|---|---|
| 1. Rotorua1 | E 1887695.98 N 5780484.232 | 20 |
| 2. Rotorua 2 | E 1887307.30 N5780547.97 | 20 |
| 3. Sediment capping site | E 1887428.50 N 5782201.10 | 15 ( 3 x5) |


**Figure 2** Kōura monitoring sites, Lake Rotorua, December 2010 - 2011. Numbers in black boxes (1 = tau kōura 1, 2 = tau kōura 2, and 3 = tau kōura 3) show the approximate locations and extent of the kōura monitoring sites.

### *3.2 Kōura collection and measurement*

Harvesting was achieved by lifting the shore end of the rope and successively raising each fern bundle while moving along the tauhu (bottom line) in a boat. A korapa (large net) was placed beneath the fern bundle before it was lifted out of the water. The fern bundle was then shaken to dislodge all kōura from the fern into the korapa. The fern bundle was then returned to the water.

The kōura were then collected and placed into labelled (2 litre) plastic containers covered by lids to keep kōura shaded and calm before analysis. The analysis consisted of counting all captured kōura and estimating biovolume (litres of kōura per whakaweku or bundle). In addition, total wet weight of the catch from each tau (i.e. all 20 whakaweku) was measured using a Salter spring balance accurate to 10 g. Subsamples of the population, typically involving measuring all kōura captured on every third whakaweku (e.g. 1, 3, 6, 9 etc.) or at least 200 individuals, were assessed for sex, reproductive state (presence of eggs or young) and shell softness (soft or hard). Each kōura in the subsamples was measured for orbit-carapace length (OCL), from the back of the eye to the back of the carapace, using callipers (electronic digital accurate to 1 mm). After processing, all kōura were returned live to the water in close proximity to the tau. Total sample handling time for two people to retrieve and process the samples from each tau was typically 3 hours.

### *3.3 Tau kōura location - sediment capping*

A modified version of tau kōura method was used at site 3 at the sediment capping trial site located approximately 2 km north of Mokoia Island (Fig. 2, Table 1). Three long lines made of 100 m lengths of sinking anchor rope were deployed at a water depth of about 20 m, each with 5 fern bundles (as described in 3.1) attached. We tied each end of the rope to small anchor weights and attached a buoy using 23 m of thick cord on to the retrieval end. Harvesting was achieved by lifting the retrieval end of the rope and successively raising the fern bundles while moving along the boat. The fern bundles were harvested using a korapa placed beneath them before the bundle was lifted out of the water and shaken.

## 4 RESULTS

### *4.1 Kōura distribution, abundance and yield*

Kōura were abundant on the western side of Mokoia Island with a total of 2626 kōura captured in the two surveys in December 2010 and December 2011. In contrast, no live kōura were captured (although 6 dead kōura were present) at site 3 located approximately 2 km north-west of Mokoia Island (Fig. 2), in December 2010.

Kōura abundance and yield (biovolume and weight) was similar at the two sites, and were highest in December 2011 (Table 2). The highest CPUE was recorded at Rotorua 2 in December 2011 with a CPUE of 42 kōura per whakaweku, whereas the highest biovolume and wet weight was recorded at Rotorua 1 in December 2011 (Table 2).

Table 2 Mean CPUE, biovolume (l), wet weight (kg) and maximum depth limit for kōura captured in 2 tau kōura (comprised of 20 whakaweku) set on the western side of Mokoia Island, Lake Rotorua, 8 December 2010 and 2 December 2011.

| | CPUE (n) | | Biovolume (L) | | Weight of catch (kg) | | Max depth of kōura (m) | |
|---|---|---|---|---|---|---|---|---|
| Date | Rotorua 1 | Rotorua 2 | Rotorua 1 | Rotorua 2 | Rotorua 1 | Rotorua 2 | Rotorua 1 | Rotorua 2 |
| Dec 2010 | 28.5 | 25.3 | 15.2 | 15.7 | 6.2 | 5.5 | 18.8 | 19.5 |
| Dec 2011 | 35.7 | 42 | 19.3 | 17.7 | 9.5 | 9 | >21 | >21 |

The distribution of kōura differed between the two sampling events. In December 2010, no kōura were captured below 18.8 and 19.5 m at sites Rotorua 1 and Rotorua 2, respectively. However, in December 2011, kōura were captured below 21 m at both sites 1 and 2 (Table 3). Moreover, in the December 2011, 25 % of the total catch (n = 6 bundles) was captured below 19.5 m on the Rotorua 1 tau kōura and 6 % of the catch (n = 3 bundles) was captured below 19.5 m on the Rotorua 2 tau kōura (Table 3). Kōura were most numerous on the 2 Rotorua tau kōura from 11 to 17 m in December 2010 and from 10 to 16 m in December 2011 (Table 3) with the highest catches recorded between 13 and 15 m.

Table 3 Depth (m) of fern bundle, mean CPUE, and number of fern bundles (n) for 2 tau kōura (comprised of 20 whakaweku) set on the western side of Mokoia Island, Lake Rotorua, December 2010 and December 2011. Figures highlighted in bold show the bundles with the highest CPUE's.

| | CPUE (n) | |
|---|---|---|
| Depth (m) | December 2010 | December 2011 |
| 5.1 - 6 | 2 (1) | - |
| 6.1 - 7 | - | 3 (1) |
| 7.1 - 8 | 5 (1) | - |
| 8.1 - 9 | 3 (1) | 25.5 (2) |
| 9.1 -10 | 3 (1) | 21 (2) |
| 10.1 - 11 | 27 (1) | **62.5 (2)** |
| 11.1 - 12 | **40.7 (3)** | **53 (2)** |
| 12.1 - 13 | **56 (1)** | **56.5 (2)** |
| 13.1 - 14 | **161 (1)** | **75.7 (3)** |
| 14.1 - 15 | **24.3 (4)** | **81 (4)** |
| 15.1 - 16 | **54 (6)** | **67 (1)** |
| 16.1 - 17 | **45 (2)** | 23.3 (3) |
| 17.1 - 18 | 22 (2) | 27 (5) |
| 18.1 - 19 | 4 (2) | 19 (2) |
| 19.1 - 20 | 0 (6) | 22 (7) |
| 20.1 - 21 | 0 (3) | 22.7 (3) |
| 21+ | 0 (1) | 29 (1) |

## *4.2* Size

In general, kōura size was similar between years and between sites. The highest mean size of kōura, 24 mm Orbital Carapace Length (OCL), was recorded at Rotorua 1 in December 2011 and the lowest, 20.9 mm, at Rotorua 2 in December 2010 (Table 4). The smallest and largest kōura measured were 11 and 50 mm OCL, respectively (Table 4).

Table 4 Mean size and range (OCL) mm of kōura captured from the two tau kōura sites set on the western side of Mokoia Island, Lake Rotorua, December 2010 and December 2011.

| | Mean size (OCL) mm | | Size range (OCL) mm | |
|---|---|---|---|---|
| Date | Rotorua 1 | Rotorua 2 | Rotorua 1 | Rotorua 2 |
| Dec 2010 | 22.2 (7.01) | 20.9 (6.44) | 11 - 49 | 11.5 - 37 |
| Dec 2011 | 23.95 (8.13) | 22.6 (7.49) | 11 - 50 | 11 - 47 |

## *4.3 Percentage females, breeding size with eggs and soft shells*

Female kōura comprised approximately 50% of the population with the percentage of females in subsamples ranging from 45.7 to 50.2 % (Table 5). The percentage of breeding sized females with eggs or hatchlings was relatively low and ranged from 2 to 6.9 % (Table 5). However, the proportion of kōura with soft shells was consistently high at the two survey sites and on both sampling occasions (Table 5). The percentage of kōura with soft shells ranged from 16.3 to 21.9 % (Table 5).

Table 5 Sampling site, sampling date, number of kōura sampled, mean percentage of females, mean percentage of breeding size females with eggs or young (defined as >23 mm OCL) and mean percentage of kōura with soft shells, in subsamples taken from 2 tau kōura (comprised of 20 fern bundles each) set in Lake Rotorua on the western side of Mokoia Island.

| Site | Date | Number of kōura sampled | % Female | % Breeding size females with eggs | % Soft shells |
|---|---|---|---|---|---|
| Rotorua 1 | 8 Dec 2010 | 311 | 50.2 | 2.4 | 21.9 |
| | 2 Dec 2011 | 301 | 47.5 | 2.9 | 16.3 |
| Rotorua 2 | 8 Dec 2010 | 245 | 45.7 | 2.0 | 18 |
| | 2 Dec 2011 | 253 | 47 | 6.9 | 15 |

# 5 DISCUSSION

## *5.1 Kōura abundance and distribution*

As in previous surveys kōura were abundant in Lake Rotorua off the western side of Mokoia Island. The mean CPUE's recorded in this study (for both sites) were comparable to that recorded in a kōura survey carried out in Lake Rotorua in April 2009 and higher than those recorded in lakes Ōkaro, Ōkāreka, Tarawera and Rotokākāhi (Table 5; Kusabs unpublished PhD data). Only Lake Rotoma had a higher mean CPUE than the Lake Rotorua surveys (Table 6).

Table 6 Mean CPUE of kōura captured in this study compared to those recorded in April 2009 from 7 Rotorua lakes (2 tau comprised of 10 fern bundles) (Kusabs unpublished PhD data).

| December 2010 & 2011 | | | | | April 2009 | | | |
|---|---|---|---|---|---|---|---|---|
| Rotorua 1 | Rotorua 2 | Rotorua | Rotoiti | Tarawera | Rotoma | Okareka | Rotokakahi | Okaro |
| 32.1 | 33.7 | 37.9 | 21.8 | 3.4 | 41.8 | 7.1 | 3.5 | 0 |

Kōura were more abundant in December 2011 than in December 2010, with a mean CPUE of 38.9 and 26.9, respectively. The difference in kōura abundance may be due to two reasons, (1) duration of fern bundle deployment before sampling and (2) the effects of thermal stratification.

In the 2010 survey, fern bundles were deployed on 29 October 2010 and retrieved on 8 December 2010, whereas, in the 2011 survey fern bundles were deployed on 2 September 2011 and retrieved on 3 December 2011. Therefore, kōura in the 2011 survey had an additional 2 months to colonise the fern bundles which may have resulted in greater catches.

In the 2010 survey, no kōura were captured below 18.8 m and 19.5 m at sites Rotorua 1 and Rotorua 2, respectively. This was almost certainly due to thermal stratification in Lake Rotorua resulting in deoxygenation of the hypolimnion (Figure 3). Moreover, no kōura were captured at the proposed sediment capping trial site located approximately 2 km north-west of Mokoia Island although dead kōura were present, suggesting that either low dissolved oxygen (DO) or some other toxic event killed them before they were able to leave. Hypolimnetic deoxygenation has been shown to affect kōura distribution in lakes Rotoiti, Okareka, Rotokakahi (Kusabs unpublished PhD study) where kōura are forced to move into the oxygenated epilimnetic waters. Hypolimnetic deoxygenation resulted in 9 fern bundles with zero catches and another 5 bundles with reduced catches, thereby reducing CPUE.

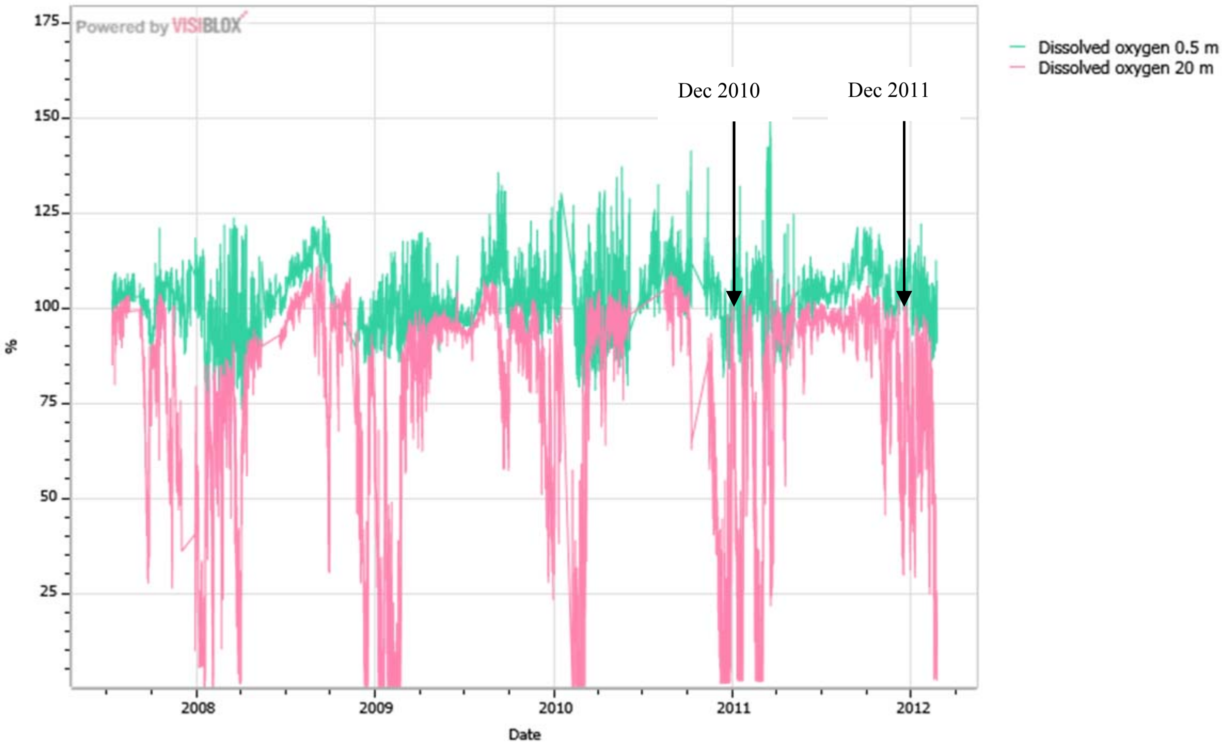


**Figure 3** Surface and bottom water dissolved oxygen levels in Lake Rotorua, 2007 to 2012. Note the extended period of low dissolved oxygen levels in November – December 2010. Figure courtesy of D. Hamilton, University of Waikato.

## *5.2 Potential effects of hypo dosing and sediment capping on kōura*

Aluminium is the active ingredient of both modified zeolite and alum floc and overseas studies have shown that it can be toxic to aquatic organisms (Soucek 2006). In a recent study carried out in Lake Okaro, Parkyn et al. (2010) found that applications of 350 g $m^{-2}$ modified zeolite did not impact the survival of kōura or produce any significant sub-lethal effects on kōura mobility or physiology. Furthermore, laboratory sediment tests, kōura did not show any consistent effect from short-term (10 days) exposure to modified zeolite (at concentrations of 350, 700 or 2,100 g $m^{-2}$) or to alum. They concluded that there was strong evidence that applications of 350 g $m^{-2}$ modified zeolite will have no short-term effect on adult kōura. However, they did state that longer-term chronic exposures, especially if multiple applications are required, may affect individual kōura responses (e.g. growth and reproduction) and population responses (through bioaccumulation of Al, or food web interactions, such as smothering or toxic effects on prey communities).

The results of this study show that stratification, and hypolimnetic deoxygenation, markedly influence kōura distribution in Lake Rotorua. When the lake was mixed kōura were present at depths down to 21 m, however, when the lake stratified kōura moved into the oxygenated epilimnetic waters above 19 m. Kōura were most numerous in the 11 to 17 m depth when the lake was stratified and from 10 to 16 m when the lake was mixed. Although the risk of hypo dosing and sediment capping to kōura populations is small, it may be prudent to carry out hypolimnetic dosing and sediment capping when the lake is stratified and kōura have moved out of the hypolimnion. Confining the hypo dosing and sediment capping treatments to the deoxygenated hypolimnion will further decrease the risk of these treatments on the kōura population.

## 6 SUMMARY

Kōura were found to be abundant in Lake Rotorua with a total of 2626 kōura captured in the 2 surveys with a mean CPUE of ~ 33 kōura per fern bundle. Kōura were present in depths from 5 to 21 m with kōura most abundant between 10 to 17 m. Kōura distribution was influenced by thermal stratification and hypolimnetic deoxygenation. When the lake was mixed (December 2011) kōura were present at depths down to 21 m, however, when the lake was stratified (December 2010) kōura moved into the oxygenated epilimnetic waters above 19 m. In addition, no live kōura were captured in the tau kōura set 2 km north of Mokoia Island (at the 20 m water depth) when the lake was stratified in December 2010. It is recommended that hypo dosing and sediment capping treatments be carried out when Lake Rotorua is stratified and the hypolimnion is deoxygenated.

# 7 ACKNOWLEDGEMENTS

Thanks to Roger Bawden from Wildland Consultants provided the map of Lake Rotorua.

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