OHAU CHANNEL DIVERSION WALL

Monitoring of kōura and kakahi populations in the Okere Arm and Lake Rotoiti

REPORT NUMBER 4 PREPARED FOR BAY OF PLENTY REGIONAL COUNCIL

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August 2010

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Cover photo: Willie and Wiremu Emery retrieving tau kōura, Lake Rotoiti. Note the korapa (catch net) under the whakaweku (fern bundle).

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1 INTRODUCTION

Kōura (*Paranephrops planifrons*) and kakahi (*Hyridella menzeisi*) support important customary fisheries in Lake Rotoiti where significant quantities are still harvested. As part of the efforts to improve water quality in Lake Rotoiti, Bay of Plenty Regional Council has built a wall that diverts nutrient rich water from Lake Rotorua down the Kaituna River. The wall has separated Lake Rotoiti into two ecologically separate waterways, an eastern basin (no Lake Rotorua influence) and a very small western basin (Lake Rotorua influence). Wall construction was completed in July 2008.

Ngati Pikiao is the kaitiaki of Lake Rotoiti and are actively involved in kaitiakitanga, the sustainable protection of natural resources. Kaitiakitanga ensures conservation, protection and maintenance of resources through responsible actions, behaviour, conduct and practices. Two of the main concerns to Ngati Pikiao are the potential impacts of the Ohau channel diversion wall on kōura and kakahi in Lake Rotoiti and the Okere Arm.

Baseline monitoring of kōura and kakahi populations in the Okere Arm and Lake Rotoiti was carried out, from December 2005 to September 2007 (Kusabs et al. 2006, 2008, & 2009). This monitoring showed that kōura and kakahi were present in high numbers in both the Okere Arm and Lake Rotoiti. The objective of this study was to carry out the fourth assessment (and second since the diversion wall became operational) of kōura and kakahi populations in the Okere Arm and Lake Rotoiti.

2 METHODS

2.1 Tau location and lay out

The Lake Rotoiti kōura population was sampled using the tau kōura, a traditional Maori method of harvesting kōura in the Te Arawa and Taupō lakes (Kusabs & Quinn 2009). Three tau kōura were set in Lake Rotoiti, one was located in the Okere Arm (Okere) at NZMG E 2803800 N 6348162, off Te Akau Point (Te Akau) at E 2803747 N 6346463, and near Manupirua Hotpools (Hotpools) at E 2806500 N 6345700 (Fig. 1). Fieldwork was carried out on an approximate 3 monthly basis from July 2009 to July 2010.

Figure 1 Kōura and kakahi monitoring sites, Lake Rotoiti, 2009-10. Numbers in red boxes show the approximate location of the kōura monitoring sites and numbers in black circles kakahi sites.

The tau kōura were comprised of 10 whakaweku, dried rarauhe or bracken fern (*Pteridium esculentum*) bundles, each with c. 10-14 dried fronds per bundle, were attached to a bottom line (a 200m length of sinking anchor rope) and set. One end of the bottom line was attached discreetly to the base of a tree on the shoreline while the lake end was anchored to the lake bottom using a heavy weight (a car tyre filled with concrete). The Okere Arm tau was set in an area relatively free of large aquatic macrophytes in a water depth of approximately 4 to 7m. The Te Akau tau (fern bundles) was set in water depths ranging from 7m to 17m. In March 2009(as part of the primary author's PhD study) an additional tau kōura was set near Manupirua Hotpools in depths ranging from 11m to 27m.

The tau kōura were left for 1 month to allow kōura to colonise the fern and was retrieved on 13 July 2009, 8 November 2009, 17 March 2010 and 17 July 2010. Owing to decomposition whakaweku (bracken fern bundles) were replaced on 9 November 2009.

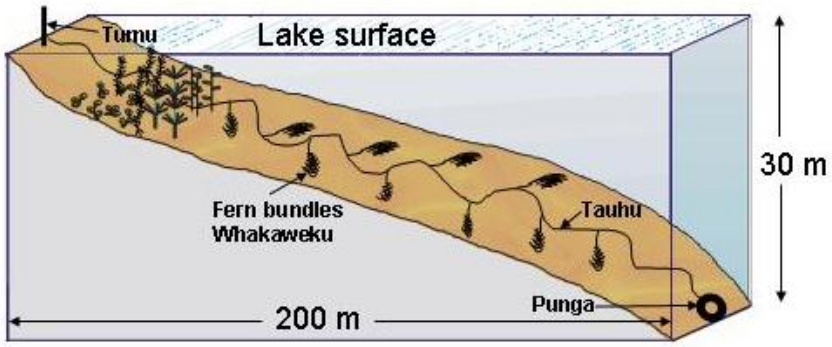

Figure 2 Schematic diagram of the tau kōura. The depth and length of tau are indicative and can be varied depending on lake bathymetry.

2.2 Kōura harvesting

Harvesting was achieved by lifting one end of the rope and successively raising each whakaweku while moving along the bottom line in a boat. A korapa (a large net designed especially for this purpose) was placed beneath the whakaweku before it was lifted out of the water (cover photo). The whakaweku were then shaken to dislodge all kōura from the fern into the korapa. The whakaweku was then returned to the water. The kōura were then collected and sorted into labelled plastic boxes with lids above them to keep them shaded and calm before being measured and weighed. All kōura were counted and the volume of the total kōura catch measured.

2.3 Kōura measurement

Subsamples of the population were measured, typically this comprised all kōura captured on whakaweku 3, 5 and 7, or at least 100 individuals, to assess size class distribution. All kōura in the subsamples were measured for OCL (orbit-carapace length) to the nearest 1mm using callipers, and shell softness, sex and reproductive state (presence of eggs or young) recorded. After processing, all kōura were returned live to the water in close proximity to the tau.

2.4 Kakahi monitoring

Kakahi transects were located at each of 3 sites along the area between Ohau channel and the Rotoiti delta and at 3 reference sites in Lake Rotoiti that were outside the diversion wall area. Grid references for the 6 sampling sites and locations are shown in Table 1 and Fig. 1, respectively. At each site 40m transects, 0.5 m wide, and perpendicular to the shore, were inspected out into the lake from standard points to a depth where the water was regularly

wadeable. All kakahi within 0.5m up current from a weighted survey line, observed with an underwater viewer, were counted with the counts summed for each 1 m interval.

Table 1 Sampling site, number, location, grid reference and direction of transect for 6 kakahi monitoring sites located in Okere Arm and Lake Rotoiti.

Sampling site	Location	Grid reference (NZ Geodatum)	Compass bearing
1. Boat Ramp	Okere Arm	E 2802931 N 6346315	70^{o}
2. Rest area	Okere Arm	E 2803075 N6346554	110^{o}
3. Ditch	Okere Arm	E 2803237 N 6346621	90^{o}
4. Okawa Bay	Lake Rotoiti	E 2802903 N 6345642	75^{o}
5. Tumoana Point	Lake Rotoiti	E 2805639 N 6345842	350^{o}
6. Ruato Bay	Lake Rotoiti	E 2811245 N 6343779	290^{o}

An 'L' shaped measuring device constructed of 25mm PVC pipe (1.2m high x 0.5m wide) was used to measure water depth (to the nearest 1cm) and to maintain the 0.5m distance from the survey line. Sediment type is an important determinant of mussel density (James 1985) and was visually assessed along the transect lines as mud, mud-sand, clean sand, gravely sand, sandy gravel etc. Surveys were carried out, where possible, when weather conditions and water clarity allowed good visual observations to be made of kakahi in Lake Rotoiti and the Okere Arm.

2.5 Data Analysis

A detailed statistical comparison of the survey results pre and post wall completion was not attempted as it was decided that it would be more useful to conduct such an analysis after the completion of the 5 year study.

3 RESULTS

3.1 Kōura

3.1.1 Abundance and yield

Large accumulations of hornwort (*Ceratophyllum demersum*) were present on the Te Akau and Hotpools tau kōura when it was retrieved on 17 July 2010. These accumulations of hornwort smothered the whakaweku (fern bundles) causing rapid decomposition and reducing their efficacy.

A total of 1997 kōura were captured in the Okere Arm tau in the 5 surveys from 17 April 2009 to 17 July 2010, while 868 and 1176 kōura were captured at Te Akau and Hotpools, over the same period, respectively (Table 2). The mean CPUE at Okere ranged from 20.1 to 62.7 kōura per whakaweku, 4.2 to 32.4 kōura per whakaweku at Te Akau and 5.9 to 44.9

kōura per whakaweku at the Hotpools (Table 2 & Fig. 3). The highest and lowest catches of kōura in the Okere Arm were recorded in April 2009 and November 2009, respectively. Whereas at Te Akau the highest kōura catch was recorded in April 2009 and the lowest in July 2010 (Table 2). At the Hotpools the highest mean CPUE's were recorded in July 2009 and lowest in July 2010.

In general, at the Te Akau and Hotpools sites, biovolume and wet weight reflected mean CPUE e.g. the highest mean CPUE (44.9 kōura whakaweku^{-1}), biovolume (22.2 l) and wet weight (8.2 kg) were recorded at the Hotpools in July 2009 (Table 2). However, in the Okere Arm, where large differences in mean size of kōura occurred, there was no such pattern e.g. in March 2010, mean CPUE was moderate (23.6 kōura whakaweku^{-1}) but wet weight (0.2 kg) and biovolume (2 l) were low (Tables 2). This was due to the small mean size of kōura captured (9.6 mm OCL) (Table 3).

Table 2 Mean CPUE (Catch Per Unit Effort), biovolume (l), wet weight (kg) of kōura captured in a tau kōura (comprised of 10 whakaweku or fern bundles) set in the Okere Arm (Okere), Te Akau (T Akau) and Hotpools (Hot) sampling sites 17 April 2009 to 17 July 2010.

Sampling date	Mean CPUE			Biovolume (l)			Wet weight (kg)		
	Okere	T Akau	Hot	Okere	T Akau	Hot	Okere	T Akau	Hot
17 April 2009	62.7	32.4	12.5	11.7	19.9	5.9	3.0	7.0	2.0
13 July 2009	52.7	21.9	44.9	9.1	15.0	22.2	2.5	5.0	8.2
8 November 2009	20.1	10.9	35.5	3.2	8.9	16.5	1.4	3.0	5.2
17 March 2010	23.6	17.4	18.8	2.0	14.4	11.5	0.2	4.8	3.6
17 July 2010	40.6	4.2	5.9	5.3	5.3	4.2	1.4	1.0	1.0

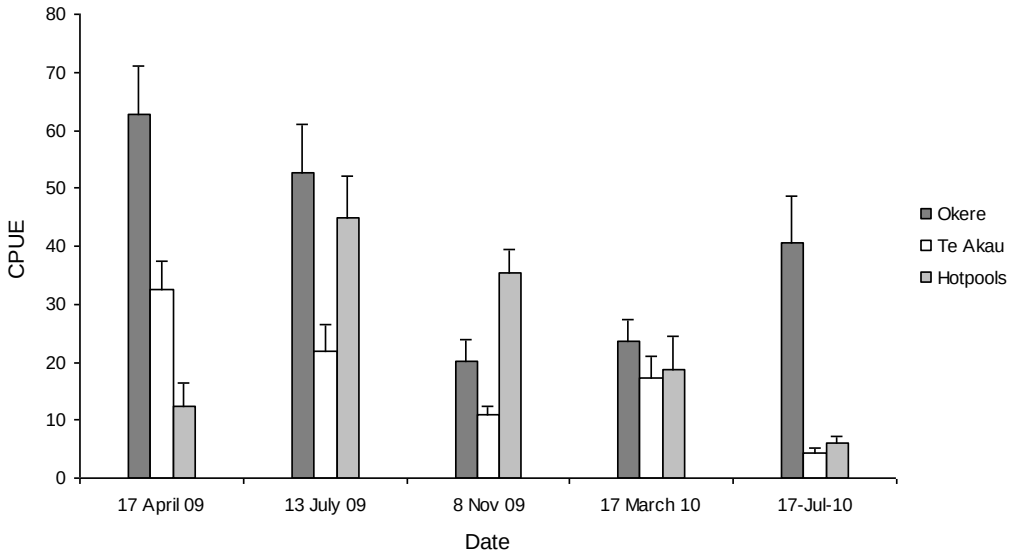

Figure 3 Mean catch per unit effort (CPUE) of kōura (±SE; n=10) for kōura captured in the Okere Arm and Te Akau and Hotpools tau kōura , Lake Rotoiti, 17 April 2009 to 17 July 2010.

3.1.2 Size

The highest mean size of kōura, 34.4 mm OCL, was recorded at Te Akau in July 2010 and the lowest 9.6 mm at Okere Arm in March 2010 (Table 3). Kōura ranged in size from 6 to 38 mm at Okere, 16 to 50 mm at Te Akau, and 6 to 45 mm at the Hotpools (Table 3). Length frequency distributions of the 5 samples of Okere and Te Akau kōura are shown in Figs. 4 & 5. These distributions show that the kōura population was comprised mainly of small (OCL < 18 mm) and medium (OCL 19 – 27 mm) sized kōura in the Okere Arm (Fig. 4), whereas the Hotpools population was comprised of small, medium and large sized kōura (Fig. 5) and the Te Akau population of medium and large sized koura (Fig. 5).

Table 3 Mean (± SD) OCL and OCL range of kōura captured in a tau kōura (comprised of 10 whakaweku or fern bundles) set in the Okere Arm, Te Akau and Hotpools sampling sites 17 April 2009 to 17 July 2010.

Sampling date	Mean OCL (mm + SD)			OCL range (mm)		
	Okere Arm	Te Akau	Hotpools	Okere Arm	Te Akau	Hotpools
17 April 2009	17.6 (6.0)	29.9 (4.8)	26.7 (6.2)	8 - 38	16 - 45	8 - 38
13 July 2009	16.9 (5.7)	31.5 (4.7)	28.1 (5.7)	9 - 34	21 - 50	12 – 44
8 November 2009	18.0 (5.0)	31.7 (4.2)	27.8 (5.9)	9 – 35	21 – 43	11 – 43
17 March 2010	9.6 (3.3)	33.1 (5.4)	27.9 (7.2)	6 – 32	16 - 48	6 - 45
17 July 2010	15.1 (4.8)	34.4 (4.4)	25.2 (7.5)	8 - 34	24 - 43	11 - 38

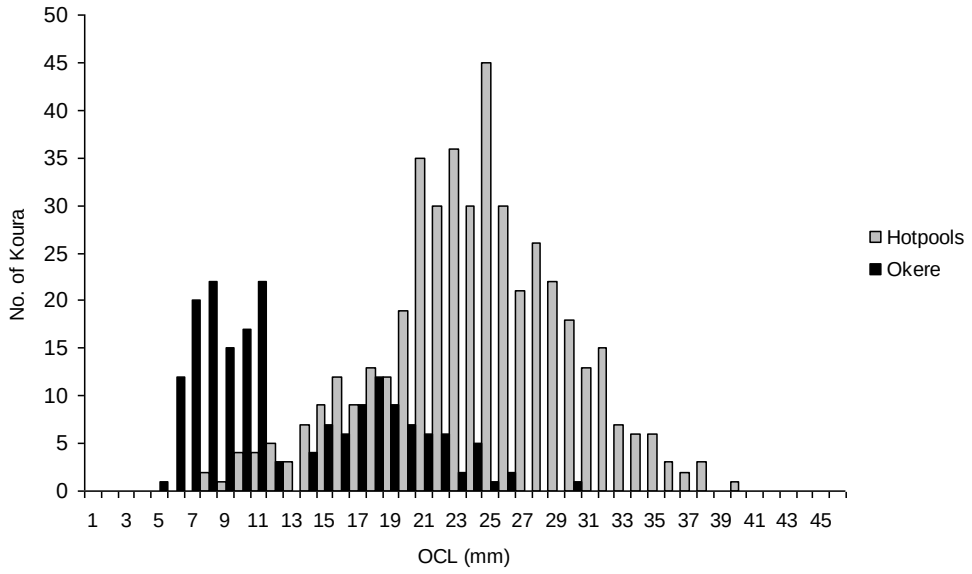

Figure 4 Length (OCL) frequency distributions of kōura captured from tau kōura at Hotpools and Okere Arm, 13 July 2009.

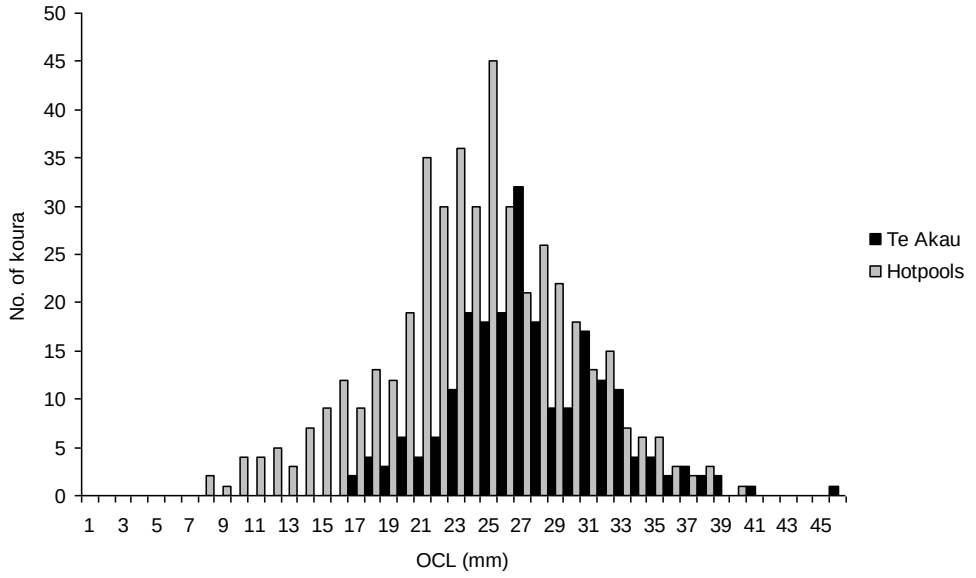

Figure 5 Length (OCL) frequency distributions of kōura captured from tau kōura at Hotpools and Te Akau, 13 July 2009.

3.1.3 Breeding

The percentage of females in subsamples from Okere Arm, Te Akau and Hotpools ranged from 53.9% to 59.8%; 46.6% to 69%, and 42.4% to 63.7%, respectively for the 2009/10 sampling period (Table 4). The proportion of "breeding size" females with eggs or young was highest at all sites in July (2009 & 2010) and November 2009 and lowest in March 2010 (Table 4).

The proportion of kōura with soft shells ranged from 7.3% to 16.7% at Te Akau and 5.6% to 19.1% Hotpools over the April 2009 to July 2010 sampling period (Table 4). The highest proportion of kōura with soft shells 34.3% was recorded in the Okere Arm in November 2009 and lowest proportion 1.7% also in the Okere Arm in July 2009 (Table 4).

Table 4 Percentage of females, percentage of breeding size females with eggs or young (defined as >23 mm OCL) and percentage of kōura with soft shells, in subsamples taken from tau kōura (comprised of 10 fern bundles) set in the Okere Arm (Ok), Te Akau (TA), and Hotpools (Hot) sampling sites, Lake Rotoiti, 17 April 2009 to 17 July 2010. n = number of females with eggs or young.

Date	Number of kōura sexed			% of females in sample			% of breeding size females with eggs (n)			% of sample with soft shells		
	Ok	TA	Hot	Ok	TA	Hot	Ok	TA	Hot	Ok	TA	Hot
17 April 09	193	209	124	53.9	66	63.7	16(4)	16(21)	24(14)	6.2	13.4	5.6
13 July 09	175	219	449	54.3	58.4	45.9	63(12)	87(109)	66(130)	1.7	7.3	9.4
8 Nov 09	200	109	355	56	62.4	55.8	22(5)	82(55)	62(105)	34.3	14.7	14.6
17 March 10	78	174	187	56.4	46.6	48.1	0(0)	3.8(3)	2.7(2)	4.2	14.9	19.1
17 July 10	244	42	59	59.8	69	42.4	42(5)	90(26)	77(13)	7.7	16.7	15.3

3.2 Kakahi

3.2.1 Abundance

Field work was carried out on 14 September 2009, 2 December 2009, 12 March 2010, and 9 June 2010. Prolific algae blooms in Lake Rotorua and the Okere Arm meant that kakahi counts in the Okere Arm (especially the reserve and ditch sites) were adversely affected by poor underwater visibility with no counts possible in March 2010 and June 2010. A total of 2235 kakahi were counted in the 4 (2009/10) surveys at the 6 sampling sites. The highest densities of kakahi were recorded at the Okawa Bay site (a control site) (Table 5).

Kakahi numbers varied markedly amongst sampling events, for example at the 'Okawa Bay' site, kakahi numbers ranged from 274 to 608 transect (or per $20m^2$). The lowest numbers of kakahi were present at the 'Tumoana' site which had a mean count of 2 kakahi transect $^{-1}$ (Table 5 and Fig. 6).

Table 5 Number of kakahi counted, totals, mean and standard errors for 0.5m wide x 40m long transects at the six sampling sites situated in Lake Rotoiti, September 2009 to June 2010. NC = no count possible owing to poor underwater visibility. * = count affected by poor underwater visibility.

	Boat ramp Okere Arm	Rest area Okere Arm	Ditch Okere Arm	Okawa Bay Control	Tumoana Bay Control	Ruato Bay Control
September 09	54	91	157	396	7	53
December 09	51	60	57*	274	0	44
March 10	21	NC	NC	265	1	10
June 10	53	NC	NC	608	0	33
Mean ± SE	44.8 ± 7.9	75.5± 15.5	107 ± 50	385.8 ± 79.9	2 ± 1.7	35 ± 9.3

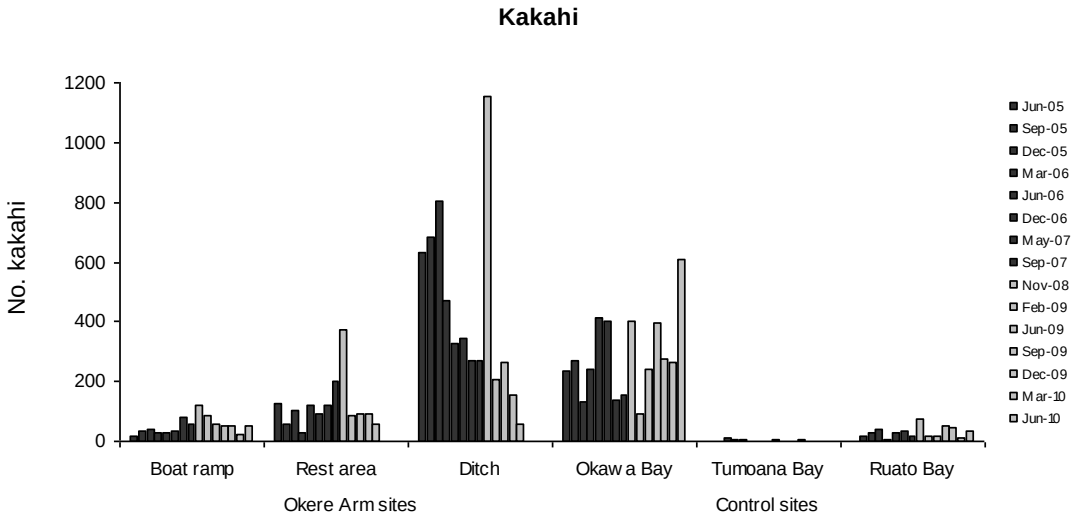

Figure 6 The mean number of kakahi recorded at 6 sites (0.5m x 40m transects) situated in Lake Rotoiti, June 2005 to July 2010. Dark shaded bars represent those surveys carried out prior to the operation of the Ohau Channel diversion wall and light shaded bars those surveys carried out following completion of the wall.

4 DISCUSSION

4.1 Kōura

The Okere Arm and Te Akau study sites continue to support abundant kōura populations. The mean CPUE's at all 3 sites (Okere, Te Akau and Hotpools) were highly variable, for example, at the Hotpools site the highest mean CPUE (44.9) was recorded in July 2009 and the lowest (5.9) in July 2010. The low catch in July 2010 at Te Akau and the Hotpools is most probably due to the inundation of the whakaweku (fern bundles) with large amounts of dislodged hornwort resulting in the rapid decomposition of the fern and a reduction in its efficacy.

Hornwort is a brittle, poorly attached plant (anchorage is by buried, modified, leaves) and is prone to dislodgement by water currents and wave action and other disturbance factors. Because it is easily dislodged hornwort can smother the tau kōura particularly the whakaweku (fern bundles). The easiest way to ensure that whakaweku are not smothered is to retrieve the tau kōura on a regular 1- 2 month basis or replace whakaweku 1-2 months prior to monitoring.

Nevertheless, kōura abundance at Okere and Te Akau during this study period (2009/2010) seem to be lower than that recorded in previous surveys (2005 – 2007) (Fig. 7). Note: it is planned to conduct a detailed statistical comparison of the survey results pre and post wall completion after the completion of the 5 year study next year (August 2011).

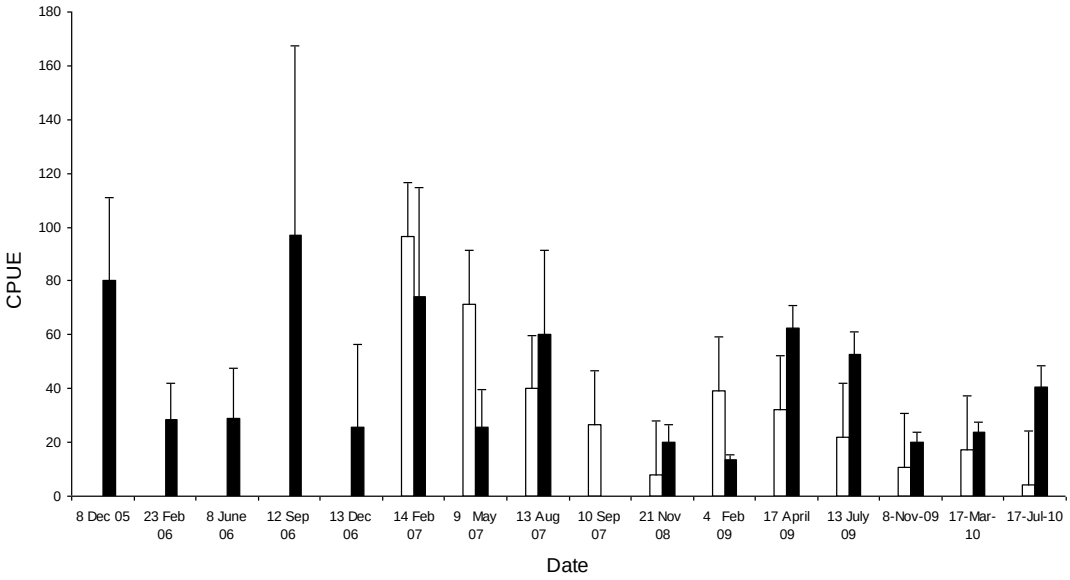

Figure 7 Mean catch per unit effort (CPUE) of kōura (±SE; n=10) for kōura captured in the Okere Arm (shaded bars) and Te Akau tau kōura (unshaded bars), Lake Rotoiti, for all sampling occasions, December 2005 to July 2010.

The tau kōura is a new method and its use as a monitoring tool is still being researched. This study shows that efficacy can be adversely affected by inundation with aquatic macrophytes and sediments which results in the decomposition of the whakaweku. In addition, warm nutrient rich water (as occurs in the Okere Arm in summer) can also lead to rapid decay of whakaweku. These site specific effects and other aspects of the methodology (such as optimum saturation time) are being investigated as part of a PhD study by the primary author.

Comparison with other Rotorua lakes

In a recent survey (using the tau kōura method) in seven Rotorua Lakes CPUE of kōura at Okere, Te Akau and Hot pools, were comparable to those recorded at; lakes Rotoma and Rotorua and higher than those from lakes Okaro, Okareka, Tarawera and Rotokakahi (Table 5) (Kusabs unpublished PhD data). The CPUE of 62.7 recorded at Okere was the second highest recorded during a survey of kōura populations in 7 Rotorua lakes (Table 6).

Table 6 Mean CPUE of kōura captured in tau kōura (comprised of 10 whakaweku or fern bundles) set in 7 Rotorua lakes on 3 to 6 March 2009 and retrieved on 14 - 17 April 2009, 9 - 14 July 2009, and 5 – 9 November 2009. Note: the mean CPUE's for lakes Okaro, Okareka, Rotokakahi, Rotoma, Rotorua and Tarawera, were obtained from 2 tau kōura (Kusabs in press).

Mean CPUE	**Okere**	**Te Akau**	**Hot pools**	Tarawera	Rotoma	Okareka	Rotokakah	Rotorua	Okaro
April 2009	62.7	32.4	11.1	3.4	41.8	7.1	3.5	37.9	0
July 2009	52.7	21.9	44.9	9.4	30.0	3.6	12	56.5	0
Nov 2009	20.1	10.9	35.5	42	261.5	18.5	85	94.7	0

Size

As in previous samplings kōura were larger at Te Akau (and Hotpools) than at Okere, where the smaller size range was similar to that of stream populations (Parkyn et al. 2002b). This confirms the findings of Devcich (1979) who found that juvenile kōura are released by their mothers into the productive littoral zone in Lake Rotoiti where there is more food and warmer temperatures, whereas, adult kōura assemble into high-density bands above the 30 m depth contour during the day.

In addition, there appears to be a difference in the size structure of the kōura populations at Te Akau and the Hotpools sites, with the Te Akau kōura population comprised mainly of large kōura with very few small kōura recorded. In comparison, at the Hotpools site a greater proportion of the population was comprised of kōura less than 20mm OCL. The reason for this is unknown as small kōura (6 mm OCL) have been recorded at Te Akau in previous surveys (Kusabs et al 2009). It will be interesting to see if this trend continues next season.

Egg Bearing

Kōura breeding appears to be continuous in Lake Rotoiti, although the least likely time to find females with eggs is in February. The percentage of "breeding" size females with eggs in the current study was highest in July and November at Te Akau and the Hotpools and in July in the Okere Arm. This is similar to previous surveys where the proportion of "breeding" size females peaked in the winter and spring months.

Kakahi

Kakahi counts were compromised by algae blooms that resulted in poor water clarity in the March and June 2010 surveys. The occurrence of algae blooms (*Microcystis wesenbergii*) in Lake Rotorua in winter is a relatively new phenomenon and makes accurate counts in the Okere Arm rest area and Ditch sites difficult, hence, kakahi counts at these sites were far lower than in previous surveys (Table 7). Nevertheless, there was a noticeable accumulation of silt in the Okere Arm monitoring sites (within the diversion wall) which is probably due to a reduction in easterly wave action and/or an eddying affect. Sediment type is an important determinant of mussel density (James 1985) and future surveys will help to determine what affect silt accumulation has on kakahi health and abundance in the Okere Arm. Interestingly, kakahi abundance at the Boat Ramp site (in the Okere Arm) which is shallower and clearer, were similar to that recorded in previous surveys.

Table 7 Number of kakahi counted, totals, mean and standard errors for 0.5m wide x 40m long transects at the six sampling sites situated in Lake Rotoiti, June 2005 to July 2010. Shaded area indicates this report's sampling period. NI = not included in monitoring programme until September 2005. NC = no count possible due to poor water clarity.

Date	Boat ramp Okere Arm	Rest area Okere Arm	Ditch Okere Arm	Okawa Bay Control	Tumoana Control	Ruato Bay Control	Total
Jun-05	20	125	633	236	NI	NI-	1014
Sep-05	33	57	686	269	0	19	1064
Dec-05	40	106	803	131	9	29	1118
Mar-06	28	28	471	240	4	42	813
Jun-06	28	119	329	413	3	7	899
Dec 06	37	89	343	402	0	29	900
May 07	81	119	269	140	0	33	642
Sep 07	59	201	272	155	2	19	708
Nov 08	118	374	1156	401	4	74	2127
Feb 09	85	85	205	94	2	16	487
June 09	59	92	266	240	1	17	675
Sep 09	54	91	157	396	7	53	758
Dec 09	51	60	57	274	0	44	486
Mar10	21	NC	NC	265	1	10	297
June 10	53	NC	NC	608	0	33	694
Mean $\pm$ SE	51 $\pm$ 7	119 $\pm$ 24	434 $\pm$ 85	284 $\pm$ 37	2 $\pm$ 0.8	30 $\pm$ 5	845

In contrast, to the reduced numbers of kakahi observed in the Okere Arm, the highest kakahi counts since surveys began in 2005, were recorded at Okawa Bay (n = 608) in June 2010 and Ruato Bay (n = 53) in September 2009 (Table 7). As in previous years, kakahi are present at low numbers in Tumoana Bay (Table 7).

Kakahi samples were collected in September 2009 for comparison (analysis is being carried out by NIWA) with pre-wall samples to compare health and condition relationships. A detailed statistical comparison of the kōura and kakahi monitoring results pre and post wall will be carried out following the completion of next seasons (2010 to 2011) sampling.

5 SUMMARY

Lake Rotoiti and the Okere Arm continue to support abundant kōura populations with CPUE's comparable to those recorded at, Rotoma and Rotorua and higher than those in lakes Okaro, Okareka, Tarawera and Rotokakahi (Kusabs unpublished PhD data). Kōura CPUE was more variable than in previous years with very low catches recorded in July 2010. This is almost certainly due to the inundation and smothering of the whakaweku (fern bundles) with large amounts of dislodged hornwort. It is planned to retrieve tau kōura more frequently to avoid the accumulation of hornwort and smothering of the whakaweku.

Kakahi remain abundant in the Okere Arm and Lake Rotoiti, although algae blooms in Lake Rotorua made accurate counts impossible at two sites in the Okere Arm in March and June 2010. The highest kakahi counts since surveys began in 2005 were recorded at Okawa Bay in July 2010 and Ruato Bay in September 2009. There was a noticeable accumulation of fine silt at the Okere Arm monitoring sites which may affect kakahi health and abundance in the Okere Arm.

6 ACKNOWLEDGEMENTS

Thanks to John Quinn and Chris Hickey from NIWA for their on-going assistance with the monitoring programme (supported by the FRST funded Aquatic Restoration Programme 0010305). Roger Bawden from Wildland Consultants provided the map of Lake Rotoiti.

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