OHAU CHANNEL DIVERSION WALL

Monitoring of kōura and kākahi populations in the Ōkere Arm and Lake Rotoiti

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Cover photo: The Emery's retrieving a tau kōura at Lake Rotoiti. Note the accumulation of hornwort on the whakaweku (fern bundle).

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1 INTRODUCTION

Kōura (*Paranephrops planifrons*) and kākahi (*Hyridella menzeisi*) support important customary fisheries in Lake Rotoiti where large 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, preventing it from entering Lake Rotoiti. 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.

Baseline monitoring of kōura and kākahi populations in the Ōkere Arm and Lake Rotoiti was carried out from December 2005 to September 2007 (Kusabs *et al.* 2006, 2008). This monitoring showed that kōura and kākahi were present in high numbers in both the Ōkere Arm and Lake Rotoiti. The objective of this study was to determine if there have been any changes in the kōura and kākahi populations in the Ōkere Arm and Lake Rotoiti since the installation of the Ohau Channel diversion wall.

2 METHODS

2.1 Tau kōura location and lay out

The Lake Rotoiti kōura population was sampled using the tau kōura, a traditional Māori method of harvesting kōura in the Te Arawa and Taupō lakes (Kusabs & Quinn 2009). Three tau kōura were set in Lake Rotoiti, located in the Ōkere Arm (Ōkere), Te Ākau Point (Te Ākau) and near Manupirua hot pools (Hotpools; Fig. 1, see Kusabs *et al.* 2010 for NZMG grid references). Fieldwork was carried out on an approximate 3 monthly basis from July 2010 to November 2011.

The methods used in this study are described in previous reports (see Kusabs *et al.* 2010). Each tau kōura was comprised of 10 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 (Fig. 2). The Ōkere Arm, Te Ākau and Hotpools tau kōura were in water depths ranging from 4 to 7 m, 7 m to 17 m and 11 m to 27 m, respectively.

The tau kōura were left for 1 month to allow kōura to colonise the fern and retrieved every 3 months. The tau kōura were replaced back into the water once kōura had been monitored. Owing to decomposition, whakaweku (or fern bundles) were replaced every 6 months in the Ōkere Arm (and every 9- 12 months at Te Ākau and Hotpools.

Figure 1 Kōura and kākahi monitoring sites, Lake Rotoiti, 2005-11. Numbers in red boxes show the approximate locations of the kōura monitoring sites and numbers in black circles indicate kākahi sites.

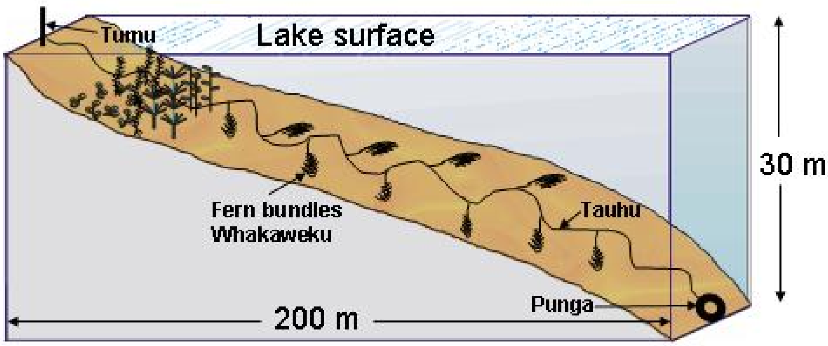

Figure 2 Schematic diagram of the tau kōura. The depth and length of tau are indicative and can be varied depending on lake bathymetry.

2.4 *Kākahi monitoring*

Kākahi transects were located at 6 sampling sites in Lake Rotoiti (Table 1 and Fig. 1). At each site 40 m 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 kākahi in an area of 0.5 m wide running parallel to and up-current from a weighted survey line were counted using an underwater viewer. Counts were summed for each 1 m interval. Where possible, surveys were carried out when weather conditions and water clarity allowed good visual observations to be made of kākahi in Lake Rotoiti and the Ōkere Arm.

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

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

3.4 Kākahi condition

Thirty kākahi (> 50 mm length) were randomly collected from Ōkere (site 3) and Ōkawa Bay (site 4) on 25 May 2007 and again on 14 September 2009 for condition comparisons. Condition index was defined as: dry flesh weight (mg) / shell weight (g).

2.5 Data Analysis

Analysis of variance (ANOVA) was used to compare mean CPUE of kōura and kākahi abundance before and after the completion of the Ohau Channel diversion wall. In addition, time series analyses were performed for kākahi abundance at the 6 sampling sites and kōura at 2 sites (Ōkere and Te Ākau) over the sampling period (2005 to 2011). ANOVA was also used to compare kākahi condition in Ōkawa Bay and the Ōkere Arm prior (May 2007) and post (September 2009) wall completion. Where necessary, data were $\log_{10}$ transformed before ANOVA to approximate a normal distribution.

3 RESULTS

3.1 Kōura

3.1.1 Abundance

A total of 8067 kōura were captured at Ōkere (n = 19 surveys) from 8 December 2005 to 2 November 2011, while 3971 were captured at Te Ākau (n = 14 surveys) from 14 February 2007 to 2 November 2011, and 2057 kōura at Manupirua Hotpools (n = 9 surveys) from 17 April 2009 to 2 November 2011 (Fig. 3 and Table 5, appendix 1).

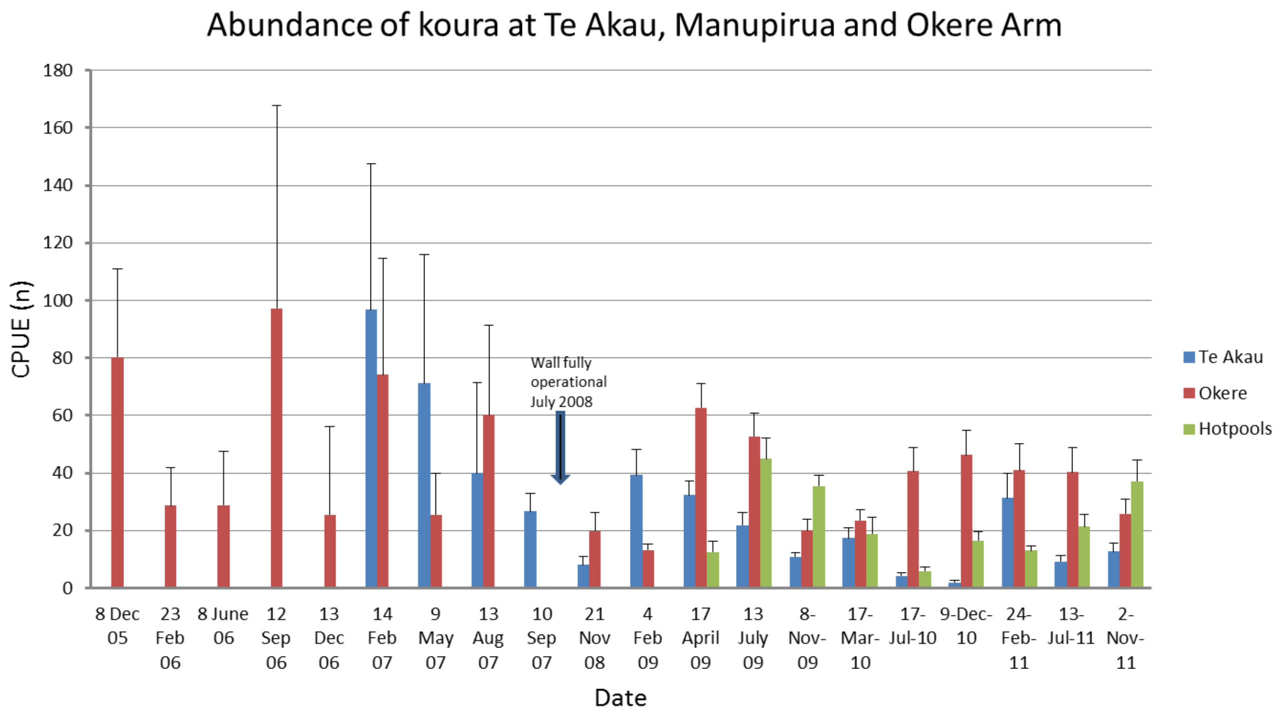

Figure 3 Mean catch per unit effort (CPUE) of kōura (± SE; n = 10) captured in tau kōura set in Ōkere Arm, Te Ākau and Manupirua hot pools, Lake Rotoiti, 8 December 2005 to 2 November 2011.

Mean CPUE at Ōkere ranged from 13.3 to 97.2 kōura per whakaweku, at Te Ākau 1.9 to 96.7 kōura per whakaweku, and at Manupirua Hotpools 5.9 to 44.9 kōura per whakaweku (Fig. 3, Table 5, appendix 1). There was a negative linear relationship between kōura CPUE and time although this was not significant (P = 0.18).

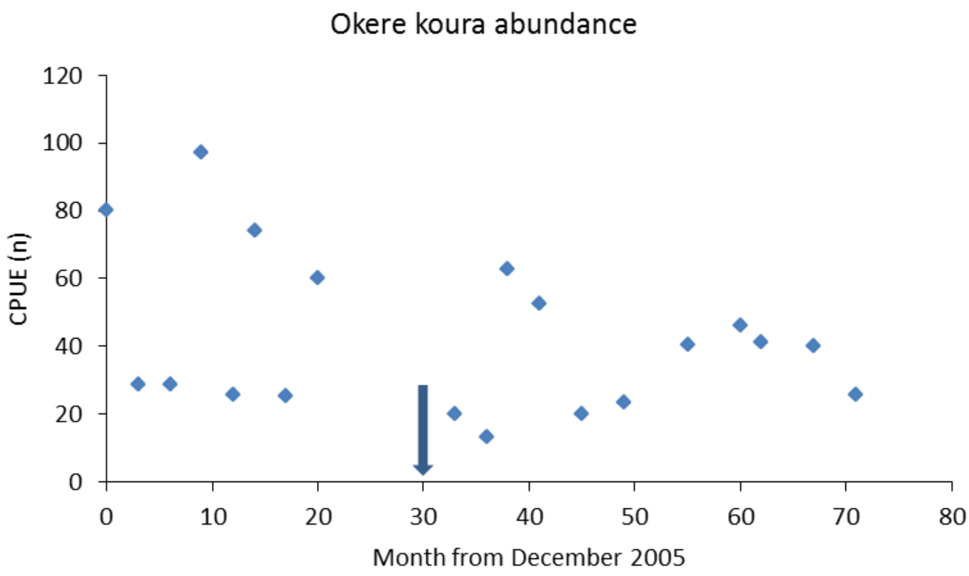

Figure 4 Relationship between Ōkere kōura abundance (mean CPUE) and time. The arrow indicates when the diversion wall was completed at month 30 (July 2008).

At the control site located at Te Ākau, there was a significant decline in kōura CPUE (R^2 = 0.56, P = 0.0023) over the sampling period (Fig. 4). Some of this decline can be attributed to 2 unusually low catches were recorded in July and December 2010 (Figure 2, Table 5 appendix 1) when the whakaweku (fern bundles) were smothered with large accumulations of hornwort (*Ceratophyllum demersum*; see cover photo).

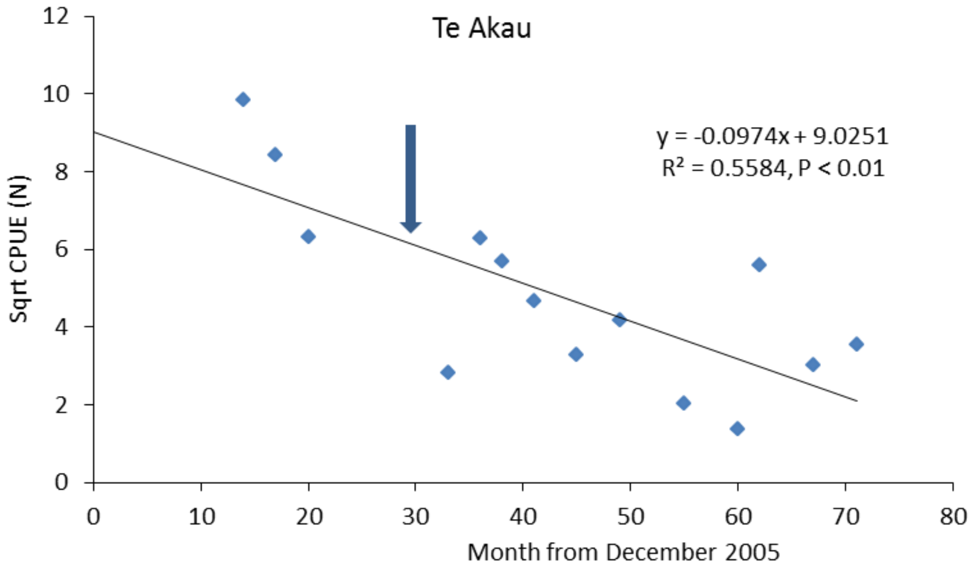

Figure 5 Relationship between Ōkere kōura abundance (mean CPUE) and time (beginning December 2005). The arrow indicates when the diversion wall was completed at month 30 (July 2008).

3.1.2 *Yield*

Yield was determined by biovolume of the catch. Biovolume ranged from 2 l to 17.4 l at Ōkere and 2.7 l to 44 l at Te Ākau (Table 5, appendix 1). There was no significant (R^2 = 0.1605, P = 0.0892) relationship between kōura biovolume at Ōkere over the sampling period (Fig. 6). There was a weakly significant difference in kōura biovolume at Te Ākau (R^2 = 0.28, P = 0.0566; Fig. 7).

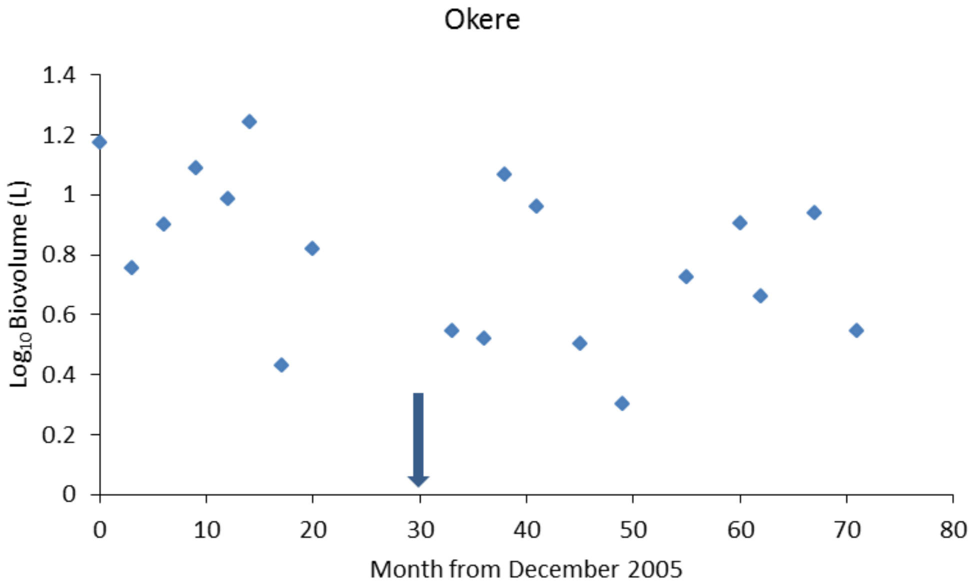

Figure 6 Relationship between Ōkere kōura biovolume (l) and time (sampling period beginning December 2005). The arrow indicates when the diversion wall was completed at month 30 (July 2008).

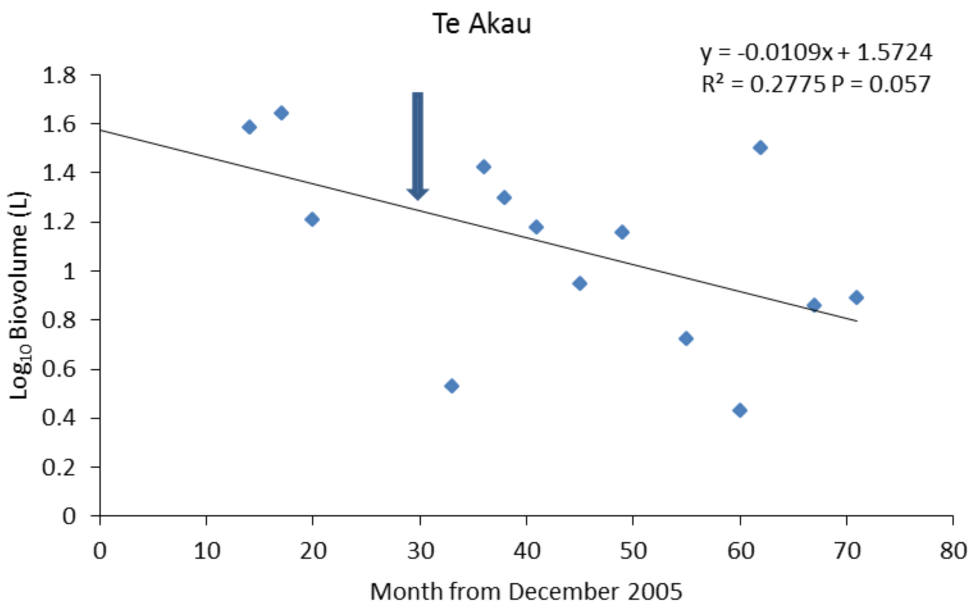

Figure 7 Relationship between Te Ākau kōura biovolume (l) and time (sampling period beginning February 2007). The arrow indicates when the diversion wall was completed at month 30 (July 2008).

3.1.3 Size

The highest mean size of kōura, 34.4 mm Orbital Carapace Length (OCL), was recorded at Te Ākau in July 2010 and the lowest, 9.6 mm, at Ōkere Arm in March 2010 (Table 6, appendix 1). In general, Ōkere kōura were mainly small (OCL < 18 mm) and medium (OCL 19 – 27 mm) sized (Fig. 4), whereas the Te Ākau and Hotpools kōura populations were comprised mainly of medium and large sized kōura (Figs. 8 & 9). Kōura ranged in size from 6 to 40 mm at Ōkere, 6 to 51 mm at Te Ākau and 6 – 47 mm at Manupirua Hotpools (Table 6, appendix 1).

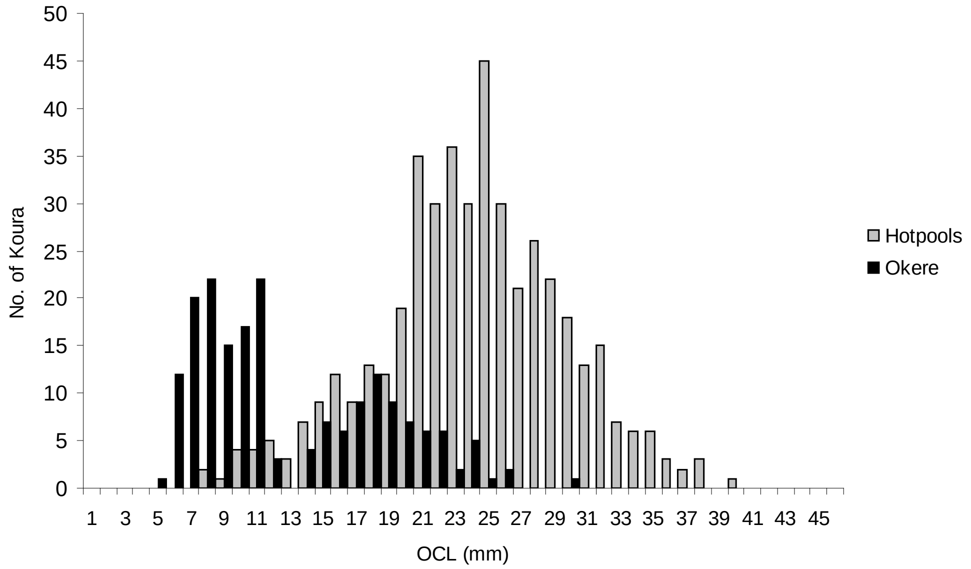

Figure 8 Length (Orbital carapace length) frequency distributions of kōura captured from tau kōura at Manupirua hot pools and Ōkere Arm, 13 July 2009.

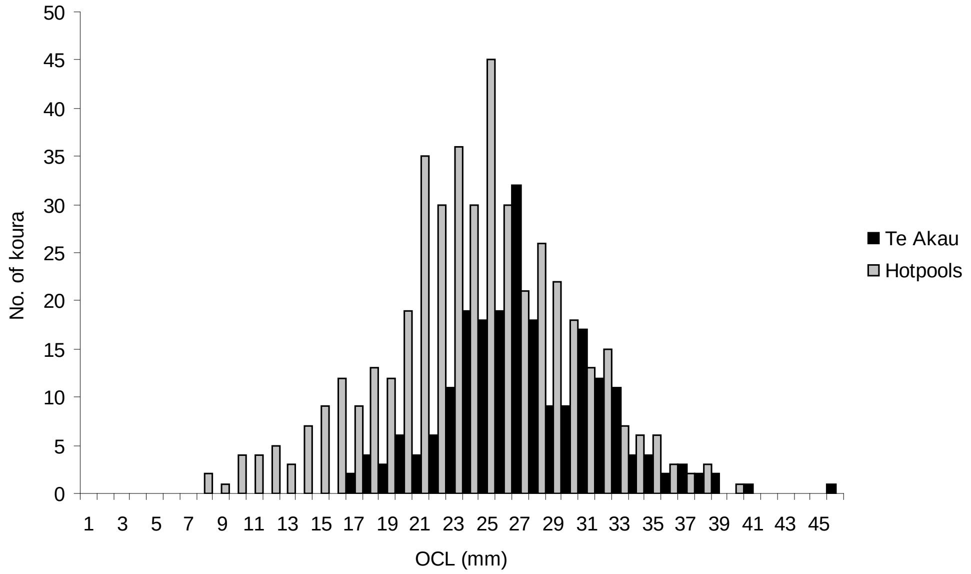

Figure 9 Length (OCL) frequency distributions of kōura captured from tau kōura at Hotpools and Te Ākau, 13 July 2009.

There was a significant decline in the mean size (OCL) of Ōkere kōura (treatment site) over the sampling period (R^2 = 0.22, P = 0.042; Fig. 10), whereas there was a significant increase (R^2 = 0.49, P = 0.002) in the size of Te Ākau kōura (control site) over the same period (Fig. 11).

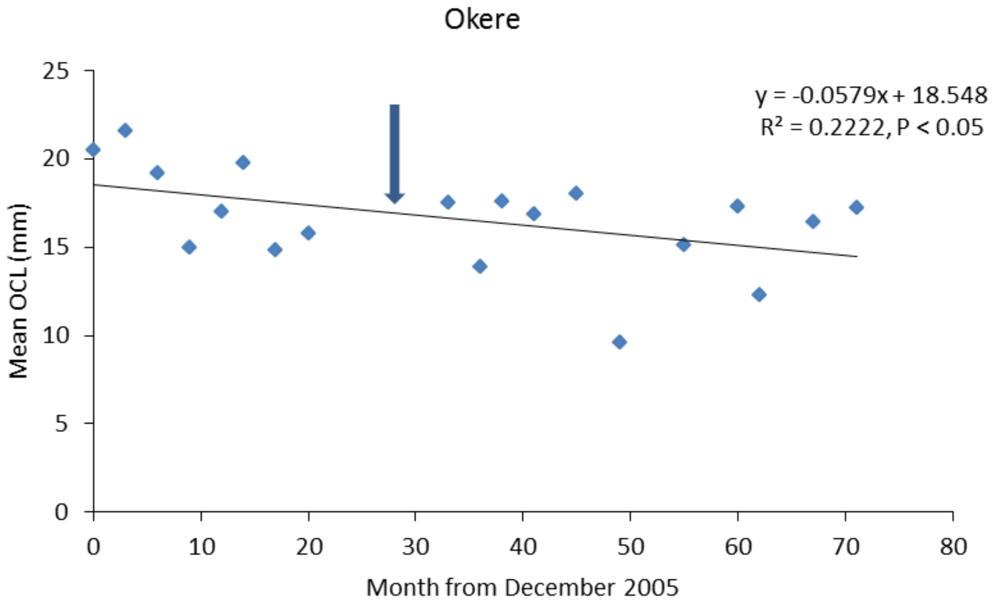

Figure 10 Relationship between mean size (OCL) of Ōkere kōura and time (sampling period beginning December 2005). The arrow indicates when the diversion wall was completed at month 30 (July 2008).

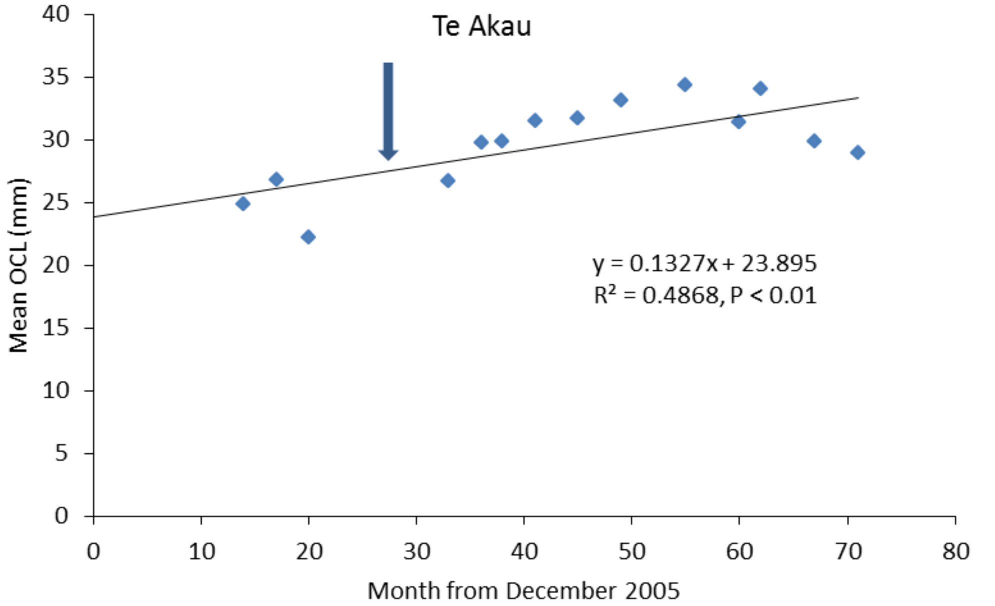

Figure 11 Relationship between mean size (OCL) of Te Ākau kōura and time (sampling period beginning February 2007). The arrow indicates when the diversion wall was completed at month 30 (July 2008).

3.1.4 Percentage females, breeding size with eggs and soft shells

The mean percentage of females in subsamples from Ōkere Arm, Te Ākau and Hotpools were 52%, 52.1% and 48.4%, respectively (Table 2 & Table 7, appendix 1). The percentage of females ranged from 42.1 to 59.8 % at Ōkere, 35.5 to 69.7 % at Te Ākau and 42.4 to 63.7 % at Manupirua Hotpools (Table 7, appendix 1).

Females with eggs or young were present throughout the year, except in February and March. The percentage of breeding sized females with eggs or hatchlings was highest at all sites in winter (mean % of females with eggs at Te Ākau for 4 winters from 2007 to 2011 was 82%) (Table 7, appendix 1).

The mean percentage of kōura with soft shells in subsamples from Ōkere Arm, Te Ākau and Hotpools were 6 %, 9 % and 15 %, respectively (Table 2 & Table 7, appendix 1). The proportion of kōura with soft shells ranged from 0.7 % to 34.3 % at Ōkere, 0.7 % to 23.5 % at Te Ākau and 5.6% to 20.5 % at Hotpools over the sampling period (Table 7, appendix 1). The highest proportion of kōura with soft shells (34.3%) was recorded in the Ōkere Arm in November 2009 and the lowest proportion (0.7%) in Te Ākau February 2007 (Table 7, appendix 1).

Table 2 Sampling site, 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 tau kōura (comprised of 10 fern bundles) set in the Ōkere Arm (n = 19) Te Ākau (n = 14, and Hotpools (n = 9) sampling sites, Lake Rotoiti, 8 December 2005 to 2 November 2011.

Site	Number of kōura sampled	% Female ± SD	% Female Range	% Breeding size females with eggs ± SE	% Soft shells ± SE
Ōkere	3284	52 ± 5.0	42.1 – 59.8	23.7 ± 6.8	6.3 ± 2
Te Ākau	2136	52.1 ± 9.9	35.5 69	47 ± 10.6	9 ± 1.8
Hotpools	1771	48.4 ± 7.0	42.4 – 63.7	39.4 ± 9.9	15 ± 1.6

3.2 *Kākahi*

3.2.1 Abundance

A total of 16,717 were recorded in 20 surveys from June 2005 to September 2011 (Table 3). Prolific algae blooms in Lake Rotorua and the Ōkere Arm meant that kākahi counts in the Ōkere Arm (especially the Reserve and Ditch sites) were adversely affected by poor underwater visibility with counts compromised in December 2009 and again in March 2010 and June 2010 when no counts were possible. The highest densities of kākahi were recorded at the Ditch (treatment) and Ōkawa Bay (control) sites and the lowest counts at Tūmoana Bay (control; Table 3, Fig. 12).

Kākahi numbers varied markedly amongst sampling events, for example at the Ōkawa Bay site, kākahi numbers ranged from 94 to 608 per kākahi transect (20 m^2; Table 3). The highest count recorded was 1156 per kākahi transect (20 m^2) from the Ditch site in November 2008 (3-4 months after the completion of the diversion wall). Unusually high counts were recorded at all sites in November 2008 (Table 3).

Table 3 Number of kākahi counted, mean and standard errors for 0.5 m wide x 40 m long transects at the six sampling sites situated in Lake Rotoiti, June 2005 to September 2011. Shaded area indicates this year's sampling period. NI = not included in monitoring programme until September 2005. NC = no count possible due to poor water clarity. * = count compromised by poor water visibility.

Date	Boat ramp Ōkere Arm	Rest area Ōkere Arm	Ditch Ōkere Arm	Ōkawa Bay Control	Tūmoana Control	Ruato Bay Control
Jun-05	20	125	633	236	NI	NI-
Sep-05	33	57	686	269	0	19
Dec-05	40	106	803	131	9	29
Mar-06	28	28	471	240	4	42
Jun-06	28	119	329	413	3	7
Dec 06	37	89	343	402	0	29
May 07	81	119	269	140	0	33
Sep 07	59	201	272	155	2	19
Nov 08	118	374	1156	401	4	74
Feb 09	85	85	205	94	2	16
June 09	59	92	266	240	1	17
Sep 09	54	91	157	396	7	53
Dec 09	51	60*	57*	274	0	44
Mar10	21	NC	NC	265	1	10
June 10	53	NC	NC	608	0	33
Sep 10	69	196	338	472	0	86
Dec 10	27	162	168	229	0	26
Feb 11	83	97	269	434	0	13
July 11	91	144	372	273	0	18
Sep 11	102	39	163	187	2	31
Total	1139	2184	6900	5859	36	599
Mean ± SE	57 ± 6.4	121 ± 18.6	406 ± 65.4	293 ± 29.7	2 ± 0.6	32 ± 4.8

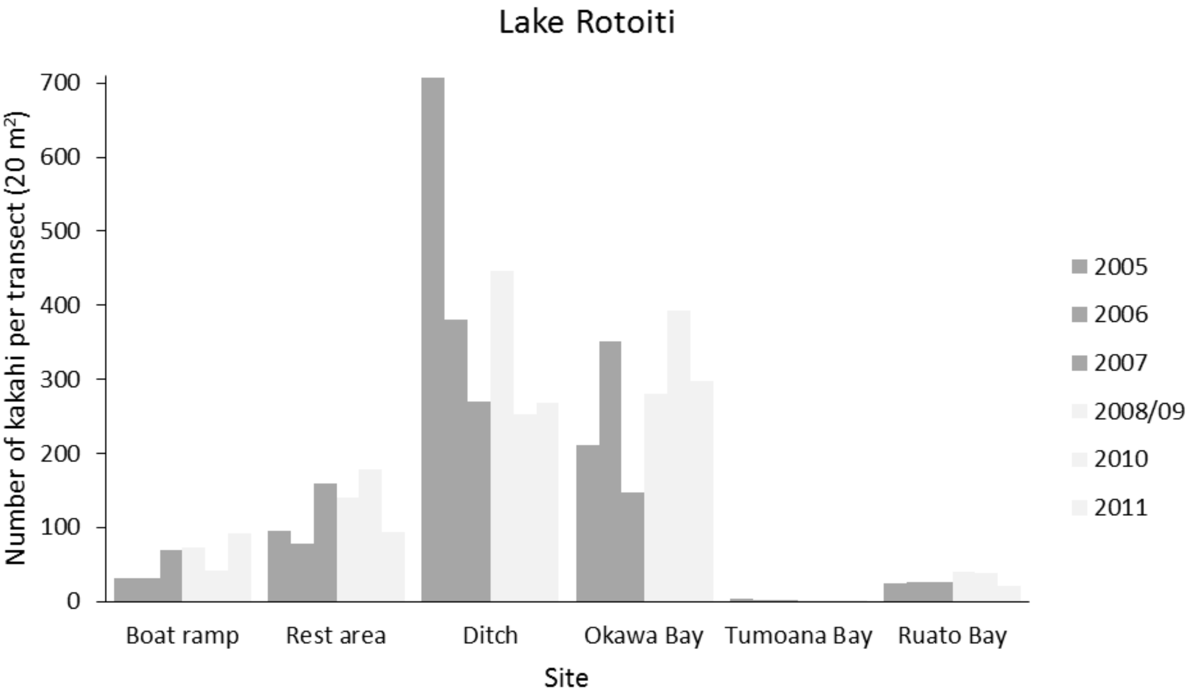

Figure 12 Annual kākahi counts (per 20 m^2) at six sampling sites, Lake Rotoiti from 2005 to 2011 (n = 20). Dark bars represent those counts recorded prior to the completion of the Ohau channel diversion wall and the light bars to counts post completion.

There was no significant difference in kākahi abundance at the treatment (n = 3 sites) or control sites (n = 2 sites) following the completion of the diversion wall (P = 0.071) (Note: Tūmoana Bay was excluded from the ANOVA because of the high number of zero counts). Moreover, there were no significant differences in kākahi abundance before and after wall completion at the individual sampling sites: Boat ramp (P = 0.32), Ditch, (P = 0.57), Ōkawa Bay (P = 0.94), Rest Area (P = 0.93) and Ruato Bay (P = 0.76). The very high counts recorded at all sites in November 2008 (shortly after the completion of the diversion wall) affected this analysis.

However, when kākahi abundance was examined over the sampling period (2005 to 2011) there were two significant relationships. At the Boat Ramp site (a treatment site) there was a significant positive relationship between kākahi abundance over the sampling period (R^2 = 0.27, P < 0.02; Fig. 13), and at the Ditch site (also a treatment site) there was a significant decline in kākahi abundance over the sampling period (R^2 = 0.337, P < 0.05; Fig. 12). There was no signifcant change in kākahi abundance at the Rest Area (a treatment site) or at any of the control sites (Fig. 13).

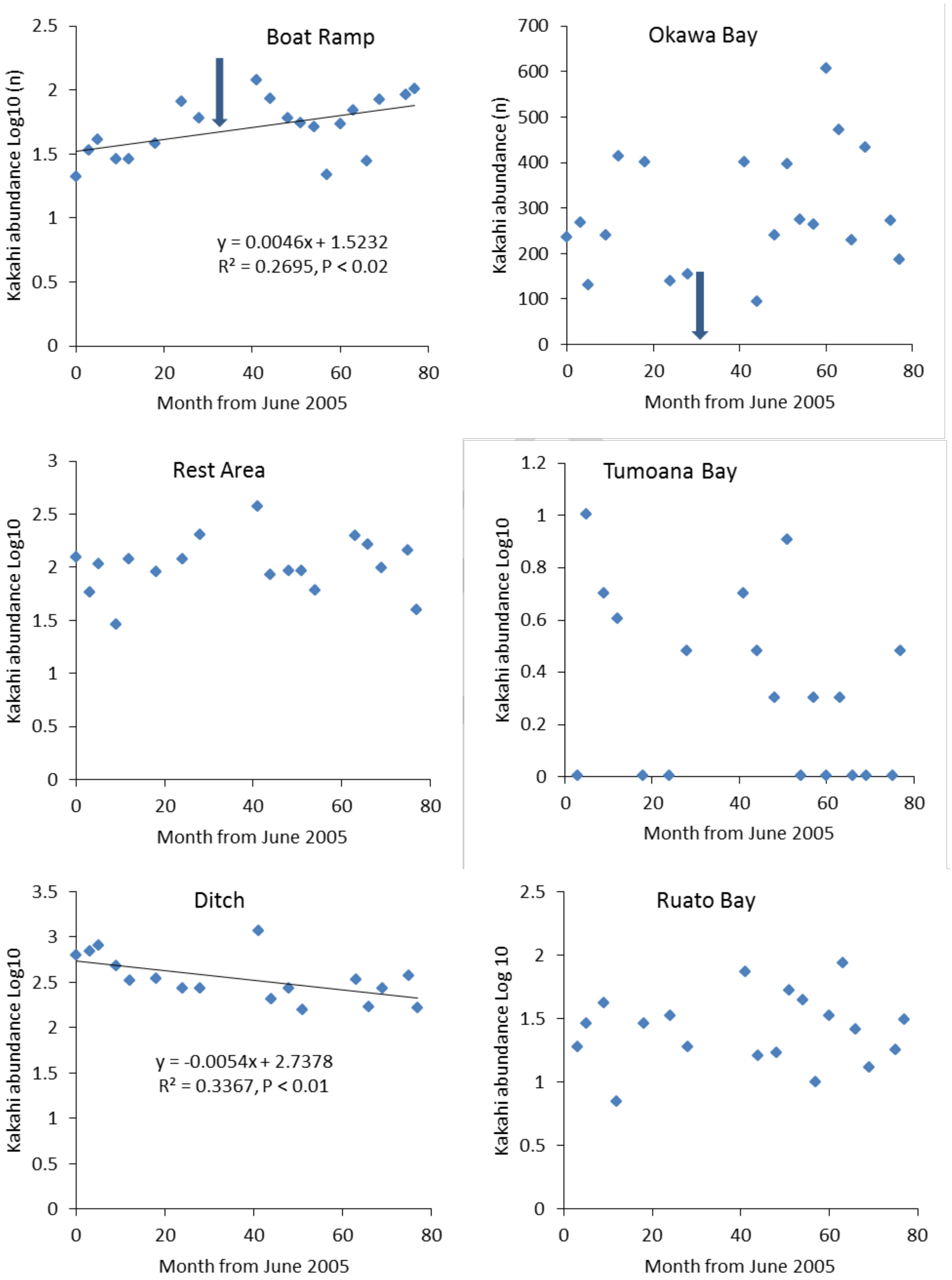

Figure 13 Kākahi abundance at 6 sites (0.5 m x 40 m transects) situated in Lake Rotoiti, over the sampling period June 2005 to September 2011. The arrow indicates when the diversion wall was completed on July 2008.

3.2.2 Kākahi condition

In 2007, prior to the completion of the diversion wall, Ōkere kākahi had a significantly lower condition factor than Ōkawa Bay kākahi ($p < 0.05$). However, in 2009, when the wall had been fully operational for over a year, there was no significant difference in kākahi condition factor between the two sites ($P = 0.06$). The mean and range of condition, shell dry weight and tissue dry weight for Ōkere Arm and Ōkawa Bay kākahi are outlined in Table 5 below.

Table 4 Shell dry weight, tissue dry weight and condition of kākahi collected from Ōkawa Bay and Ōkere Arm on 25 May 2007 and 14 September 2009.

Variable	Date	Mean (± SD)		Range	
		Ōkawa Bay	Ōkere Arm	Ōkawa Bay	Ōkere Arm
Shell dry weight (g)	2007	18.01 (5.75)	18.58 (4.30)	3.40 – 29.42	10.99 – 30.84
	2009	20.03 (6.65)	16.42 (4.42)	12.38 – 29.02	11.33 – 21.58
Tissue dry weight (g)	2007	1.78 (0.49)	1.45 (0.27)	0.42 – 2.65	0.98 – 1.94
	2009	2.30 (0.818)	1.62 (0.391)	1.44 – 3.21	1.15 – 2.04
Condition	2007	102.72 (20.69)	79.80 (14.72)	54.63 – 155.14	49.96 – 118.73
	2009	118.13 (32.78)	103.05 (27.10)	90.5 – 165.2	80.3 - 142.5

4 DISCUSSION

4.1 Kōura

The Ōkere Arm and Lake Rotoiti continue to support abundant kōura populations 3 years after the completion of the diversion wall. Although there has been no significant change in the abundance and yield of kōura in the Ōkere Arm (treatment) there has been a significant decline in kōura abundance at Te Ākau (control).

The decline in kōura abundance and biovolume (weakly significant) at Te Ākau may have been caused by hornwort invasion and deposition. In July and December 2010 the very low numbers of kōura captured at Te Ākau and at the Hotpools was due to the inundation of the whakaweku with large amounts of dislodged hornwort. Dead kōura were found in the whakaweku, suggesting that either low dissolved oxygen (DO) or some other toxic event killed them before they were able to leave. The adverse effect of hornwort on kōura is not unique to the Rotorua lakes. Parkyn *et al* (2006) also reported low catches and dead kōura in both traps and tau kōura smothered with hornwort in Motuoapa Bay, Lake Taupo.

Hornwort is a brittle, poorly attached plant (anchorage is by buried, modified leaves) and is prone to dislodgement by water currents, wave action and other disturbances. Because it is easily dislodged, hornwort can smother the whakaweku, not only restricting kōura access to the whakaweku (refer cover photo) but also leading to the rapid decay of the fern itself. Furthermore, weed proliferation and accumulation of decaying organic matter can markedly degrade the habitat quality of the surrounding lake bed. Prevailing wind conditions are therefore an important consideration when selecting suitable locations for tau kōura, especially in lakes which have large beds of hornwort. Poor site selection will result in excessive hornwort accumulation on the whakaweku.

The inundation of tau kōura at Te Ākau and Manupirua Hotpools with hornwort first occurred in early to mid 2010. It is possible that there has been an increase in hornwort biomass in Lake Rotoiti in recent years – an unintended consequence of the improvement in water quality (clarity). Although the impact of hornwort on lake-kōura populations has not been studied it is probable that excessive hornwort growth is adversely affecting kōura populations throughout Lake Rotoiti and in other central North Island lakes. In future surveys the easiest way to ensure that whakaweku are not smothered is to retrieve the tau kōura on a regular (2 monthly) basis or replace whakaweku 1-2 months prior to monitoring.

This study also shows that whakaweku can decay rapidly when they are situated in warm, nutrient rich water. This was apparent in the Ōkere Arm tau kōura in summer where whakaweku needed to be replaced at least every 6 months. Whakaweku condition may also vary from year to year depending on the variation in summer temperatures. The tau kōura is a new method and its use as a monitoring tool is still being researched. 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

Catch per unit effort of kōura at Ōkere, Te Ākau and Hot pools was comparable to that recorded in lakes Rotoma and Rotorua in a recent survey also using the tau kōura method, and was higher than that recorded in lakes Ōkaro, Ōkāreka, Tarawera and Rotokākahi (Table 5; Kusabs unpublished PhD data). . The CPUE of 62.7 recorded at Ōkere was the second highest recorded during an extensive survey of kōura populations in 7 Rotorua lakes.

Size

In general, kōura were larger at Te Ākau (and Hotpools) than at Ōkere, 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.

There was a significant decline in the mean size of Ōkere kōura over the sampling period. This may be due to an increase in the abundance of small-sized kōura captured in the surveys as there has been no significant decline in kōura abundance or biovolume. In contrast, there was a significant increase in the size of Te Ākau kōura over the same period. This is mainly attributable to a decline in the abundance of small sized kōura. This may also be due to the inundation of the Te Ākau tau kōura (and surrounding lake bed) by hornwort in recent years. It is possible that small sized kōura may be more sensitive to hornwort invasion (and accumulation of decaying organic matter) than larger kōura.

In addition, there appears to be a difference in the size structure of the kōura populations at Te Ākau and the Hotpools sites, with the Te Ākau 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 20 mm OCL. The low numbers of small sized kōura captured at Te Ākau may also be due to hornwort invasion.

Egg Bearing

Kōura breeding appears to be continuous in Lake Rotoiti, although the least likely time to find females with eggs is in February. In general the percentage of "breeding" size females with eggs or hatchlings peaked in the autumn and winter months with another rise in spring. This confirms the findings of Devcich (1979) who reported that breeding females were most common from May to July in a 1975/76 study in Lake Rotoiti.

Moulting

Moulting activity (proportion of soft shells) of adult kōura was continuous with no discernible patterns evident. This was not surprising as female and male crayfish often moult at different times and crayfish in deeper (cooler) waters are known to moult later than those in shallow water (Capelli and Magnuson 1975). At ecdysis, crayfish are most vulnerable to predation and seek the seclusion of burrows and shelters within which to moult. It is therefore possible that moulting kōura were over-represented in our whakaweku catches.

Devcich (1979) reported that the main peak of moulting for Lake Rotoiti kōura was in March or early April and a smaller peak from September to November. Kōura are normally aggressive but at moulting this aggressiveness has been found to be reduced and social hierarchy reduced. Devcich (1979) suggested that the difference in timing of pre-breeding moult activity between male and female kōura may be adaption to ensure that copulation is successful.

4.2 Kākahi

Kākahi numbers varied markedly between the monitoring sites and over the sampling period (2005 – 2011). In general, kākahi were most numerous at the Ditch (treatment site) and Ōkawa Bay (control site). There were no significant differences between kākahi abundance before and after the completion of the diversion wall although this was influenced by abnormally high counts recorded at all sites in November 2008. The reason for these high counts is unknown.

Kākahi counts in the Ōkere Arm (Ditch and Rest Area sites) were compromised by algae blooms in December 2009, and abandoned in March 2010 and June 2010. The occurrence of algae blooms (*Microcystis wesenbergii*) in Lake Rotorua in winter is a relatively new phenomenon and makes accurate counts in the Ōkere Arm challenging. Survey timing is now critical to obtaining accurate counts.

There were significant changes in kākahi abundance in the Ōkere Arm (treatment sites) over the sampling period. Kākahi abundance increased at the Boat Ramp site and declined at the Ditch site. There was no signifcant change in kākahi abundance at the Rest Area site (or at any of the control sites). Sediment type is an important determinant of mussel density in lakes (James 1985). Since the diversion wall has been in place there has been a noticeable accumulation of silt in the Ōkere Arm monitoring sites particularly at the Ditch site where the mean silt depth has increased 10-fold. This build-up of fine silt is most probably due to a combination of two factors: the absence of easterly wave action (due to the diversion wall) resulting in deposition of fine sediment in the shallows, and a change in the direction of water flow down the Ōkere Arm. The path (thalweg) of water flowing down the Ōkere Arm has most likely changed resulting in new areas of accretion and erosion. The Ōkere Arm is a dynamic environment and future changes in kākahi abundance are inevitable until equilibrium is reached.

5 SUMMARY

The Ōkere Arm and Lake Rotoiti continue to support abundant kōura and kākahi populations 3 years after the completion of the diversion wall. However, overall trends in kōura abundance and yield were difficult to determine because of hornwort invasion and inundation in Lake Rotoiti, while frequent algae blooms compromised kākahi counts in the Ōkere Arm (control). Nevertheless, there have been some significant changes in the kōura and kākahi populations in the Okere Arm and Lake Rotoiti over the sampling period (2005 to 2011).

Kōura

There was a significant decline in kōura abundance and yield (weakly significant) at Te Ākau (control), but no significant change in Okere (treatment) kōura, over the sampling period. This decline is most probably due to the inundation of the whakaweku with large amounts of dislodged, decaying hornwort. Because it is easily dislodged, hornwort can smother the whakaweku not only restricting kōura access to the whakaweku but also leading to the rapid decay of the fern itself. Furthermore, weed proliferation and accumulation of decaying organic matter can markedly degrade habitat quality. It is probable that excessive hornwort growth is adversely affecting kōura populations throughout Lake Rotoiti and in other central North Island lakes.

There was also a significant decline in the mean size of Ōkere kōura over the sampling period. This may be due to an increase in the abundance of small sized kōura captured in the surveys as there has been no significant decline in kōura abundance or biovolume. In contrast, there was a significant increase in the size of Te Ākau kōura over the same period. This may also be due to the inundation of the Te Ākau tau kōura (and surrounding lake bed) by hornwort in recent years. It is possible that small sized kōura may be more sensitive to hornwort invasion and decaying organic matter than larger kōura.

Egg bearing and moulting appears to be continuous in Lake Rotoiti, although the least likely time to find females with eggs is in February.

Kākahi

Kākahi remain abundant in the Ōkere Arm and Lake Rotoiti. While kākahi abundance has remained stable in Lake Rotoiti over the sampling period there have been a range of changes at the Okere Arm (treatment). In the Ōkere Arm there has been a significant increase in kākahi abundance at the Boat Ramp, no significant change at the Rest Area, and a significant decline at the Ditch. These changes in kākahi abundance are most probably in response to the change in wave action and flow patterns which have resulted in new areas of accretion and erosion in the Okere Arm. The Ōkere Arm is a dynamic environment and future changes in kākahi abundance are inevitable until equilibrium is reached.

Future monitoring

Careful site selection (with particular consideration given to prevailing wind conditions) and regular monitoring (at least every 2 months) of tau kōura are essential in lakes which have large beds of hornwort. In addition, survey timing (to avoid algae blooms) is critical in obtaining accurate kākahi counts in the Okere Arm.

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8 APPENDIX 1

Table 5 Mean CPUE (Catch Per Unit Effort), biovolume (l), wet weight (kg) of kōura captured in a tau kōura (comprised of 10 whakaweku) set in the Ōkere Arm (Ōkere), Te Ākau (T Ākau) and Manupirua hot pools (Hot) sampling sites 17 April 2009 to 17 July 2010. ND = no data collected. Shaded area indicates this report's sampling period.

Sampling date	Mean CPUE			Biovolume (l)			Wet weight (kg)		
	Ōkere	T Ākau	Hot	Ōkere	T Ākau	Hot	Ōkere	T Ākau	Hot
8 December 2005	80.3	ND	ND	14.9	ND	ND	ND	ND	ND
23 February 2006	28.6	ND	ND	5.7	ND	ND	ND	ND	ND
8 June 2006	28.8	ND	ND	7.98	ND	ND	ND	ND	ND
12 September 2006	97.2	ND	ND	12.3	ND	ND	ND	ND	ND
13 December 2006	25.6	ND	ND	9.7	ND	ND	1.0	ND	ND
14 February 2007	74.2	96.7	ND	17.4	38.5	ND	6.6	12.8	ND
9 May 2007	25.5	71.2	ND	2.7	44	ND	1.8	13.8	ND
13 August 2007	60.2	39.9	ND	6.6	16.1	ND	2.0	4.7	ND
21 November 2008	19.9	8	ND	3.5	3.4	ND	0.8	1.0	ND
4 February 2009	13.3	39.3	ND	3.3	26.4	ND	0.6	8.0	ND
17 April 2009	62.7	32.4	12.5	11.7	19.9	5.9	3.0	7.0	2
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	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
9 December 2010	46.3	1.9	16.6	8	2.7	6.8	2	0.55	2
24 February 2011	41.1	31.44	13	4.6	31.9	6.2	1	8.9	2.5
13 July 2011	40.3	9.2	21.44	8.7	7.2	8.8	1.5	1.6	2.6
2 November 2011	25.8	12.7	37.1	3.5	7.8	16.8	1.1	2.25	5

Table 6 Mean size OCL (orbital carapace length) and OCL range of kōura captured in a tau kōura (comprised of 10 whakaweku or fern bundles) set in the Ōkere Arm, Te Ākau and Manupirua hot pools sampling sites 8 December 2005 to 17 July 2010. Shaded area indicates this report's sampling period.

Sampling date	Mean OCL (mm + SD)			OCL range (mm)		
	Ōkere Arm	Te Ākau	Hotpools	Ōkere Arm	Te Ākau	Hotpools
8 December 2005	20.5 (5.9)	ND	ND	12-40	ND	ND
23 February 2006	21.6 (4.6)	ND	ND	9-36	ND	ND
8 June 2006	19.2 (6.4)	ND	ND	9-44	ND	ND
12 September 2006	15.0 (3.5)	ND	ND	9-29	ND	ND
13 December 2006	17 (4.0)	ND	ND	11-31	ND	ND
14 February 2007	19.8 (4.1)	24.9 (5.5)	ND	8-34	13 - 41	ND
9 May 2007	14.8 (4.3)	26.8 (6.2)	ND	9-29	6 - 47	ND
13 August 2007	15.8 (4.1)	22.2 (8.2)	ND	10-32	10 - 50	ND
21 November 2008	17.5 (3.7)	26.7 (4.8)	ND	10 - 32	15 - 42	ND
4 February 2009	13.9 (7.0)	29.8 (5.2)	ND	7 - 32	18 - 43	ND
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
9 December 2010	17.3 (3.8)	31.4 (8.6)	24.7 (6.5)	11 - 35	14 – 45	11 – 40
24 February 2011	12.3 (6.3)	34 (6.4)	23.9 (6.1)	6 - 38	19 – 51	14 – 47
13 July 2011	16.4 (4.9)	29.9 (8.1)	25.6 (5.7)	7 - 35	10 – 48	8 – 44
2 November 2011	17.2 (4.5)	28.9(7.6)	26.0 (5.5)	11 - 32	12 - 48	12 - 41

Table 7 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 Ōkere Arm (Ok), Te Ākau (TA), and Hotpools (Hot) sampling sites, Lake Rotoiti, 8 December 2005 to 2 November 2011. n = actual number of females with eggs or young. ND, no data collected. A breeding size female was defined as >23mm OCL. Shaded area indicates this report's sampling period.

Date	Number of kōura			% female			% Breeding size females with eggs (n)			% soft shells		
	Ok	TA	Hot	Ok	TA	Hot	Ok	TA	Hot	Ok	TA	Hot
8 December 2005	74	ND	ND	44.6	ND	ND	0 (0)	ND	ND	ND	ND	ND
23 February 2006	139	ND	ND	54.7	ND	ND	0 (0)	ND	ND	ND	ND	ND
8 June 2006	121	ND	ND	50.4	ND	ND	33(7)	ND	ND	14.8	ND	ND
12 Sept 2006	322	ND	ND	43.8	ND	ND	50(8)	ND	ND	7.8	ND	ND
13 December 2006	256	ND	ND	54.7	ND	ND	0(0)	ND	ND	3.5	ND	ND
14 February 2007	233	299	ND	55.4	52.8	ND	0(0)	0	ND	0.8	0.7	ND
9 May 2007	240	341	ND	51.6	45.7	ND	0(0)	36.8(45)	ND	1.6	6.2	ND
13 August 2007	123	200	ND	50.4	44.0	ND	100(2)	54.3(19)	ND	2.3	3.5	ND
21 November 2008	143	80	ND	58.7	46.3	ND	66.7(3)	18.2(6)	ND	0.7	1.3	ND
4 February 2009	57	113	ND	42.1	44.2	ND	0	0	ND	1.5	4.4	ND
17 April 2009	193	209	124	53.9	66	63.7	16(4)	16(21)	24(14)	6.2	13.4	5.6
13 July 2009	175	219	449	54.3	58.4	45.9	63.2(12)	87.2(109)	66(130)	1.7	7.3	9.4
8 November 2009	200	109	355	56	62.4	55.8	22(5)	82(55)	62(105)	34.3	14.7	14.6
17 March 2010	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 2010	244	42	59	59.8	69	42.4	42(5)	90(26)	77(13)	7.7	16.7	15.3
9 December 2010	148	18	166	55.4	35.5	43.4	0	100(5)	10(4)	4.1	23.5	20.5
24 February 2011	238	142	130	46.3	45.8	43.8	0	3.2(2)	3(1)	1.3	9.9	20
13 July 2011	157	92	173	53.1	62	44.5	42.9(3)	90.6(48)	62(34)	10.3	4.3	14.5
2 November 2011	143	98	128	55.9	50	48.4	14.3(1)	79.1(34)	48(22)	4.2	5.1	15.6