OHAU CHANNEL DIVERSION WALL

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

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Cover photo: Joe Butterworth counting kākahi at the 'Boat Ramp' site, Okere Arm, Lake Rotoiti.

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1 INTRODUCTION

Kōura (*Paranephrops planifrons*) and kākahi (*Echyridella menziesii*) support important customary fisheries in Lake Rotoiti where they are harvested for human consumption. 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 from December 2005 to September 2007 showed that kōura and kākahi were present in high numbers in both the Ōkere Arm and Lake Rotoiti(Kusabs and Emery 2006). Following the completion of the diversion wall in July 2008 monitoring surveys of kōura and kākahi have been carried out on a seasonal basis in Lake Rotoiti. The aims of this study were to survey kōura and kākahi populations in Lake Rotoiti for the 2013 to 2014 season and to investigate any long term trends over the entire study period (2005 to 2014).

2 METHODS

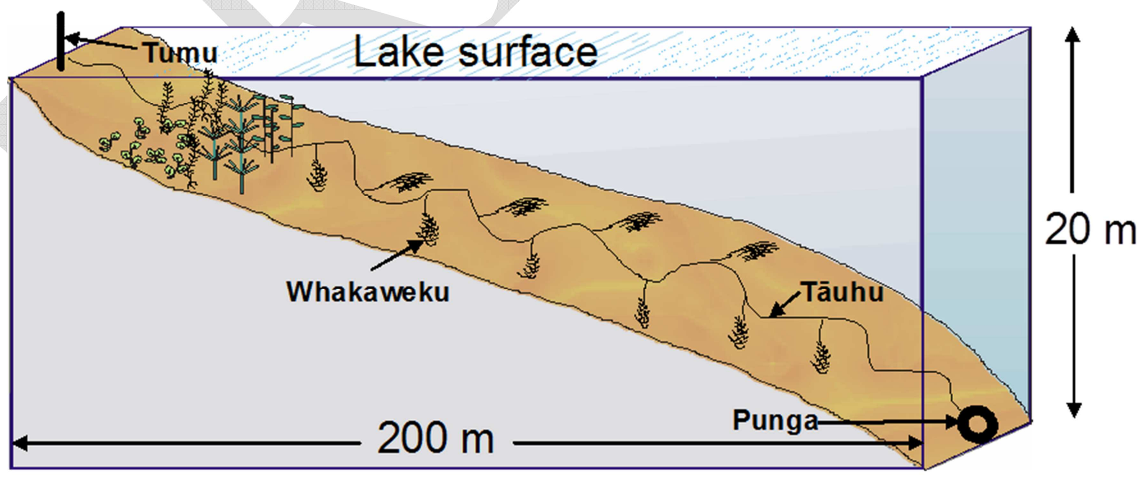
2.1 Tau kōura location and lay out

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 and Quinn 2009). Three tau kōura were set in Lake Rotoiti, located in the Ōkere Arm (Ōkere) at NZMG E 2803800 N 6348162, off Te Ākau Point (Te Ākau) at E 2803747 N 6346463, and near Manupirua Hotpools (Hotpools) at E 2806499 N 6345889, (Fig. 1). Koura surveys for this monitoring period (2013 - 2014) were carried out on an approximate 3 monthly basis from 12 December 2013 to 24 August 2014.

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 in the Ōkere Arm, Te Ākau and Hotpools in depths ranging from 4 to 7 m, 7 m to 17 m and 11 m to 27 m, respectively (Fig. 2).

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.

Figure 1 Kōura and kākahi monitoring sites, Lake Rotoiti, 2005-14. Numbers in red boxes (1 = Ōkere Arm, 2 = Te Ākau, 3 = Hotpools) show the approximate locations of the kōura monitoring sites and numbers in black circles indicate kākahi sites (refer Table 1 for kākahi site names).



B.

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

2.1.2 *Kōura measurements*

Orbit-carapace length (OCL, mm) of each kōura was measured using vernier callipers (± 0.5 mm) and the sex of kōura (OCL > 11 mm) assessed. A power regression equation (previously determined by B. Hicks and P. Riordan, University of Waikato) was used to determine kōura wet weight. After processing, all kōura were returned to the water in close proximity to the tau kōura. Catch Per Unit Effort (CPUE) was defined as the number of kōura per whakaweku and Biomass Per Unit Effort (BPUE) as estimated wet weight (g) of kōura per whakaweku.

2.2 *Kākahi*

Kākahi transects were located at 5 sampling sites in Lake Rotoiti (Fig. 1, Table 1) [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. Kākahi surveys for this monitoring period (2013 - 2014) were carried out on an approximate 3 monthly basis from 20 November 2013 to 10 August 2014.

2.3. *Data Analysis*

Time series analyses were performed for kākahi abundance at the 5 sampling sites and kōura at 3 sites (Ōkere and Te Ākau) over the sampling period (2005 to 2014). Where necessary, data were $\log_{10}$ or Sqrt transformed to approximate a normal distribution.

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)
1. Boat Ramp	Ōkere Arm	E 2802931 N 6346315
2. Rest area	Ōkere Arm	E 2803075 N6346554
3. Ditch	Ōkere Arm	E 2803237 N 6346621
4. Ōkawa Bay	Lake Rotoiti	E 2802903 N 6345642
5. Tūmoana Point	Lake Rotoiti	E 2805639 N 6345842
6. Ruato Bay	Lake Rotoiti	E 2811245 N 6343779

[1] Note: Kākahi counts at Tumoana Bay were discontinued in 2011 due to the very low numbers present.

3 RESULTS

3.1 Kōura

3.1.1 Kōura abundance

A total of 2431 kōura were collected from tau kōura set at Ōkere (*n* =970), Te Ākau (*n* = 648) and Manupirua Hotpools (*n* = 813), in this year's survey (Table 2). As in previous years kōura abundance varied markedly amongst the seasons, with the highest mean CPUE recorded in the Okere Arm in May, and Te Ākau and Hotpools in December (Table 2, Fig. 3).

Over the entire sampling period (2005 to 2014) there appears to have been significant declines in kōura CPUE at Okere (p = 0.002) and Te Ākau (p = 0.004) but no significant change at Manupirua Hotpools (p = 0.9) (Fig. 4).

Table 2 Mean CPUE (± SD) of kōura collected from tau kōura set at Okere, Te Ākau and Manupirua Hotpools from 13 December 2013 to 24 August 2014 and 2005 to 2014.

	Mean CPUE					
Date	Ōkere	SD	Te Ākau	SD	Hot	SD
12-Dec-13	28.9	18.7	22.4	10.8	44.5	22.1
29-Jan-14	14.1	9.9	14.8	5.7	18.1	8.6
27-May-14	42.2	28.6	16.8	9.1	8.5	6
24-Aug-14	11.8	7.4	10.8	9.1	10.2	4.3
2005 - 2014	77.4	21.4	23.3	21.7	22.9	13.6

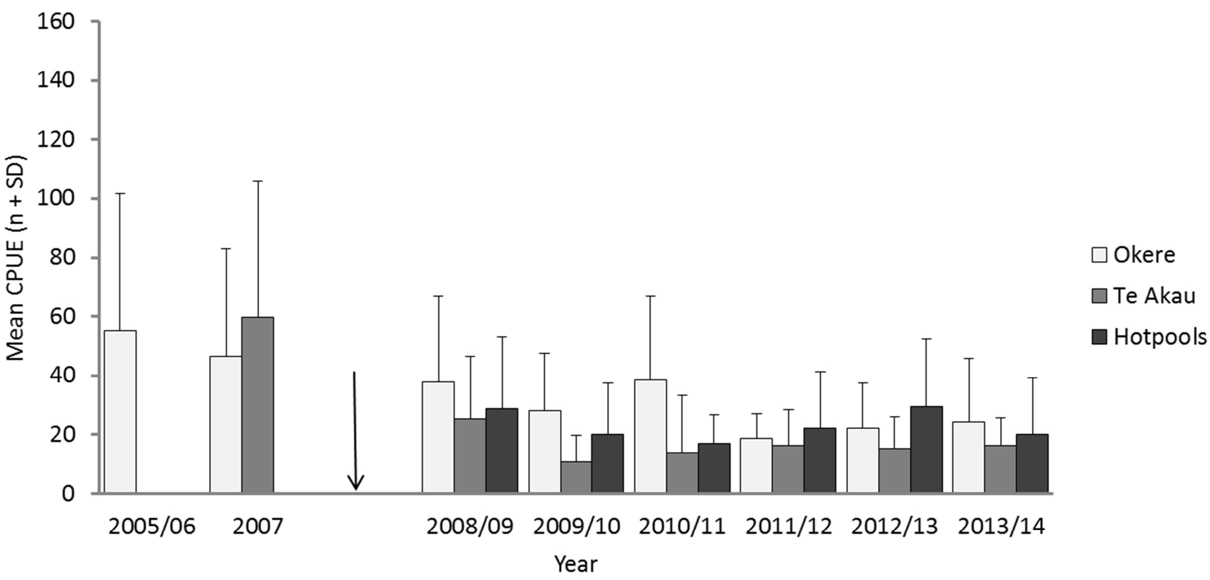


Figure 3 Mean catch per unit effort (CPUE) of kōura (± SD; n = 10) captured in tau kōura set in Ōkere Arm, Te Ākau and Manupirua Hotpools, Lake Rotoiti, 8 December 2005 to 24 August 2014. The arrow indicates when the Ohau Channel wall became operational.

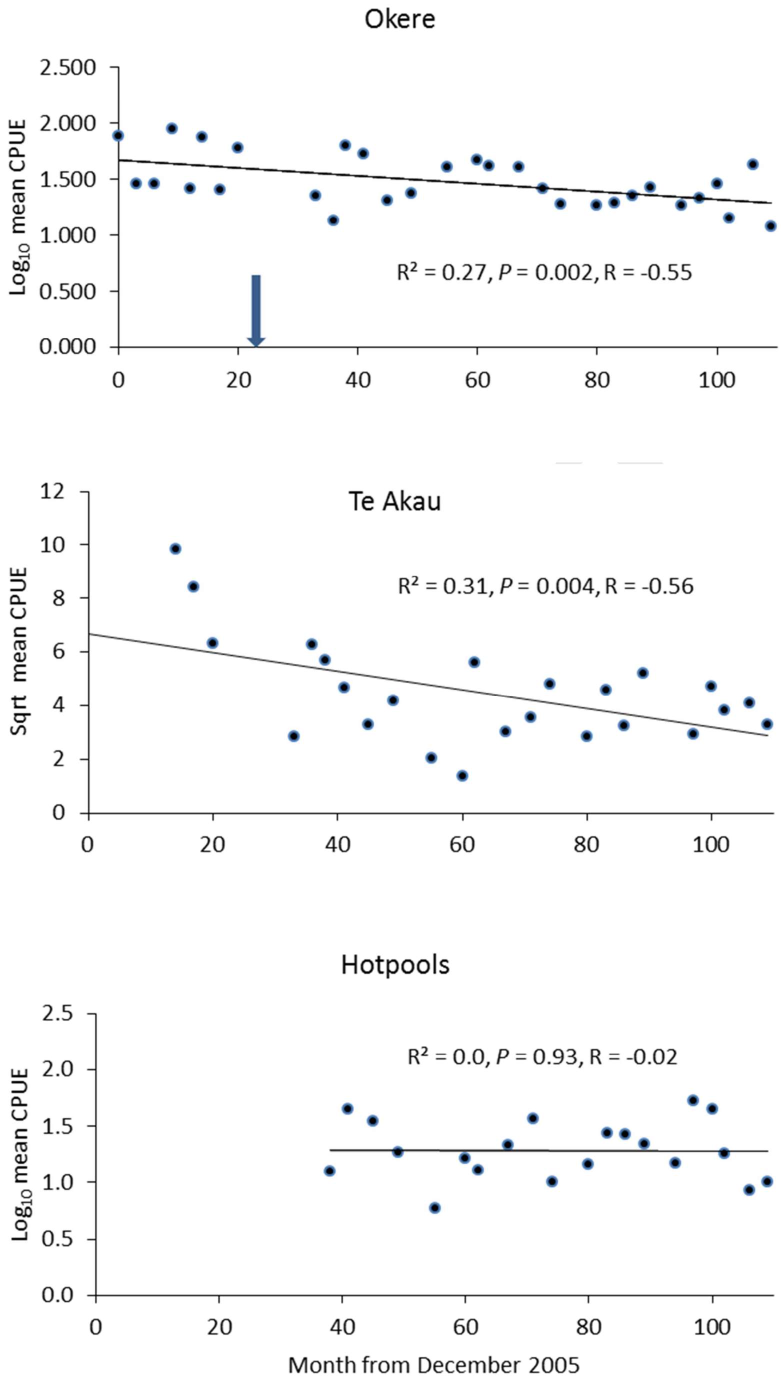


Figure 4 Relationship between mean CPUE of kōura Ōkere, Te Ākau and Hotpools and time. The arrow indicates when the diversion wall was completed at month 30 (July 2008).

3.1.2 Kōura biomass

The highest estimated mean biomass (BPUE) of kōura was recorded at Te Ākau (504 g per whakaweku), followed by the Hotpools (304 g per whakaweku), with the lowest at Ōkere (95 g per whakaweku) in this year's survey (Table 3).

This pattern is consistent with that recorded over the entire sampling period (2005 to 2014) with the highest BPUE documented at Te Ākau, Hotpools and Okere, respectively (Table 3, Fig. 5). There appears to have been a significant decline in the mean estimated biomass (BPUE) of kōura at Okere (P = 0.002) over the sampling period but no significant change at Te Ākau or at the Hotpools (P > 0.5) (Fig. 6).

Table 3 Estimated mean biomass (± SD) of kōura collected from tau kōura set at Okere, Te Ākau and Manupirua Hotpools from 13 December 2013 to 24 August 2014 and 2005 to 2014.

	Estimated mean biomass (g) per whakaweku (BPUE)					
Date	Ōkere	SD	Te Ākau	SD	Hot	SD
12-Dec-13	157	36.4	553.4	90.2	548.4	256
29-Jan-14	67.6	13	421	55.8	272.4	34.5
27-May-14	121.7	24.8	637.7	108	173.5	45.8
24-Aug-14	33	6.6	405.5	123	219.6	30.4
2005-2014	158.5	123	495.2	317	351.7	222

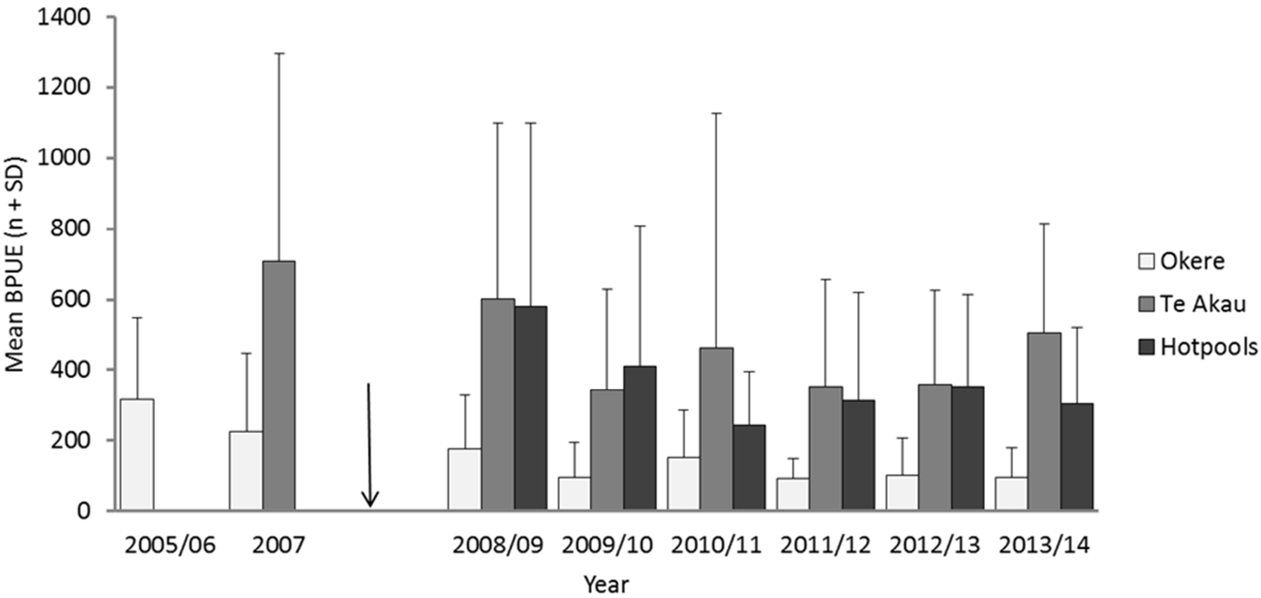


Figure 5 Mean Biomass Per Unit Effort (BPUE) of kōura (± SD; n = 10) captured in tau kōura set in Ōkere Arm, Te Ākau and Manupirua Hotpools, Lake Rotoiti, 8 December 2005 to 24 August 2014. The arrow indicates when the Ohau Channel wall became operational.

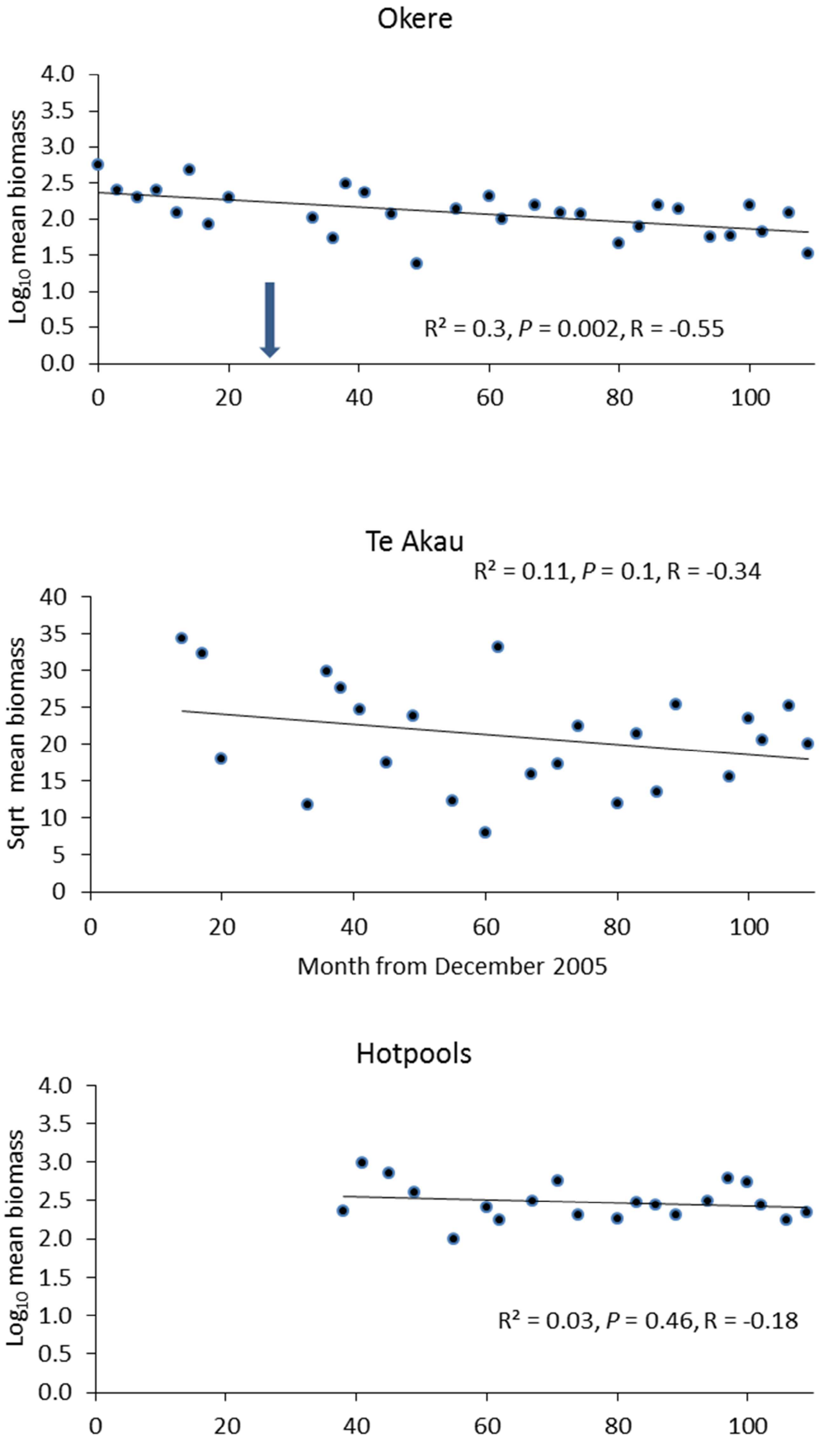


Figure 6 Relationship between estimated mean kōura biomass and time (sampling period beginning December 2005). The arrow indicates when the diversion wall was completed at month 30 (July 2008).

3.1.3 *Kōura size*

As in previous years, the highest mean OCL of kōura was recorded at Te Ākau, followed by the Hotpools, with the smallest kōura at Ōkere (Table 4). The largest kōura yet recorded, a 54 mm OCL male with an estimated wet weight of 137 g, was captured at Te Ākau on 12 December 2013. Kōura ranged in size from 6 to 36 mm at Ōkere, 9 to 54 mm at Te Ākau and 13.5 – 40.5 mm at the Hotpools.

There has been no significant change in kōura size at any of the sites, however, there appears to have been a gradual decrease in the mean OCL of Okere and Hotpools kōura and an increase in mean OCL of Te Ākau kōura over the sampling period (Fig. 7).

Table 4 Mean OCL (mm ± SD) of kōura collected from tau kōura set at Okere, Te Ākau and Manupirua Hotpools from 13 December 2013 to 24 August 2014 and 2005 to 2014.

	Mean OCL (mm)						OCL Range (mm)		
Date	Ōkere	SD	Te Ākau	SD	Hotpools	SE	Ōkere	Te Ākau	Hotpools
12-Dec-13	18.30	5	30.20	6.5	24.30	5.7	12 - 33	15 - 54	13 - 37
29-Jan-14	15.10	7	31.50	5.1	24.70	6.3	6 - 36	18 - 44	13.5 - 41
27-May-14	14.90	4.6	35.10	5	28.20	4.9	8 - 30	21 - 46	15 - 40.5
24-Aug-14	14.20	3.7	34.30	6.4	28.20	6.3	8.5 - 32	9 - 46	15 - 42
2005-2014	16.4	2.6	29.2	4	26	2.3	6 - 44	6 - 54	6 - 47

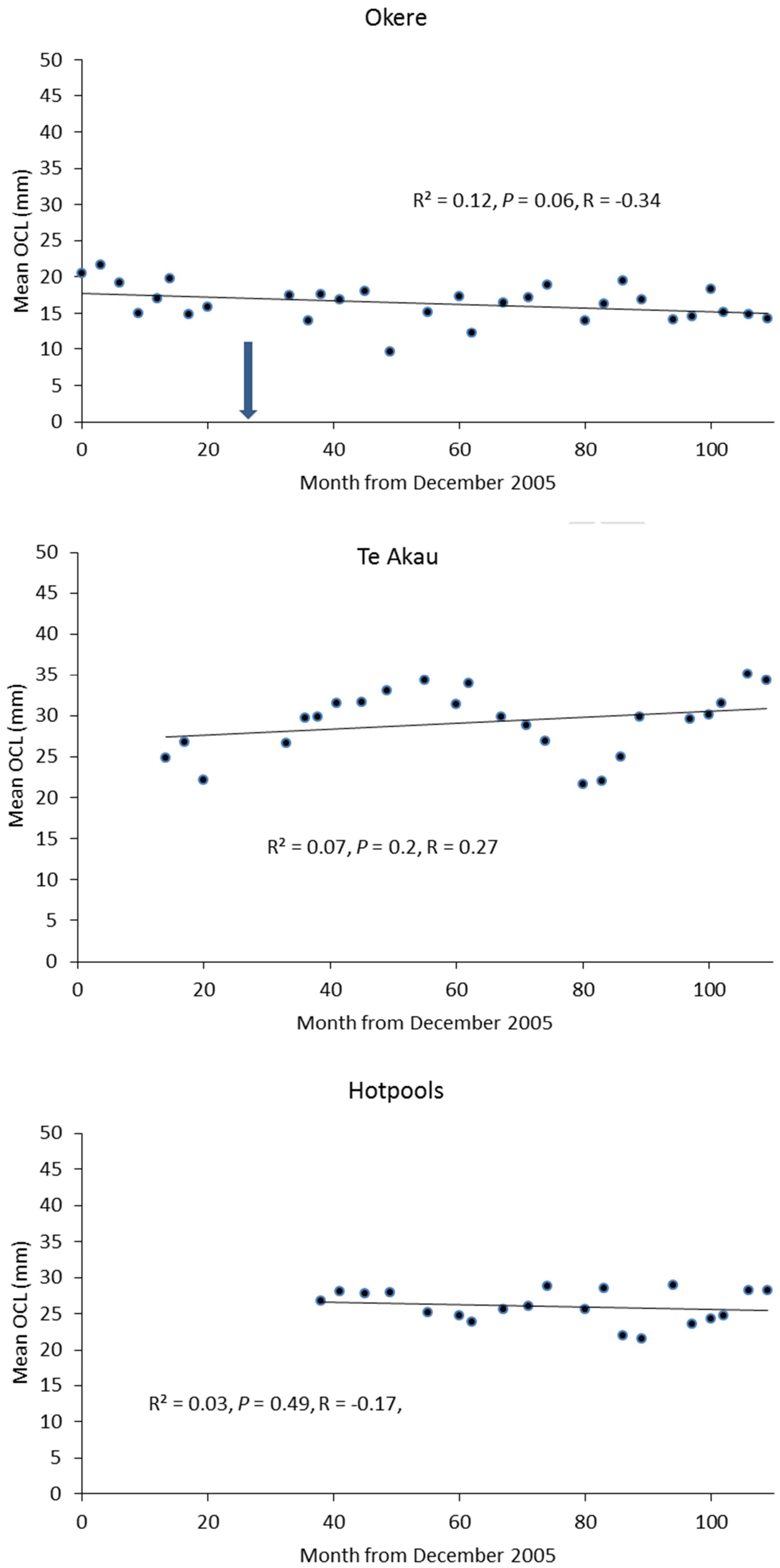


Figure 7 Relationship between mean OCL (mm) of kōura and time (sampling period beginning December 2005). Arrow indicates when the diversion wall was completed (July 2008).

3.1.6 Female to male ratio

The mean percentage of females in subsamples from Ōkere Arm, Te Ākau and Hotpools were 57 %, 52 % and 48 %, respectively. Female kōura comprised approximately 50% of all kōura analysed over the 2005 to 2014 study period (Table 5).

Table 5 Number of kōura analysed and percentage of female kōura (± SD) collected in samples from tau kōura set at Okere, Te Ākau and Manupirua Hotpools from 13 December 2013 to 24 August 2014 and 2005 to 2014.

	Number of kōura analysed (*n*)			% Female (mean ± SD)		
Date	Ōkere	Te Ākau	Hotpools	Ōkere	Te Ākau	Hotpools
12-December 13	117	119	128	62.1	45.4	48.4
29-January 14	141	148	181	46.3	45.3	42.5
27-May 14	123	107	85	66.7	60.7	52.9
24-August 14	118	108	102	53.4	55.1	49
2005-14	4790	3235	3243	53.3 ± 5.5	49.8 ± 9.5	48.2 ± 5.3

3.1.7 Egg-bearing times and moulting

Females with eggs or young were present throughout the year, with the highest percentage of breeding sized females with eggs or hatchlings highest from May to November (Fig. 8).
The mean percentage of kōura with soft shells in subsamples from Ōkere Arm, Te Ākau and Hotpools were 5.7 %, 6.4 % and 3.7 %, respectively. The proportion of kōura with soft shells ranged from 5.9 % at Ōkere, 7.7 % to 10.9 % at Te Ākau and 2.4 % to 6.7 % at Hotpools over the entire sampling period, 2005 to 2014 (Table 6).

Table 6 Percentage (%) and actual number (*n*) of breeding sized females with eggs and percentage (%) of soft shelled kōura (± SD) collected in samples from tau kōura set at Okere, Te Ākau and Manupirua Hotpools from 13 December 2013 to 24 August 2014 and 2005 to 2014.

	% Breeding size females with eggs (*n*)			% soft shells		
Date	Ōkere	Te Ākau	Hotpools	Ōkere	Te Ākau	Hotpools
12-December-13	23.6 (4)	21.6 (11)	27.7 (13)	5.1	13.4	8.6
29-January-14	0	0	5.2 (3)	4.3	9.5	10.5
27-May-14	58.3 (7)	93.8 (61)	52.3 (23)	3.3	0	5.9
24-August 14	50 (1)	80.7 (46)	63.8 (30)	10.2	2.8	13.7
2005-2014				5.9 ± 6.8	7.7± 6	10.9± 5.7

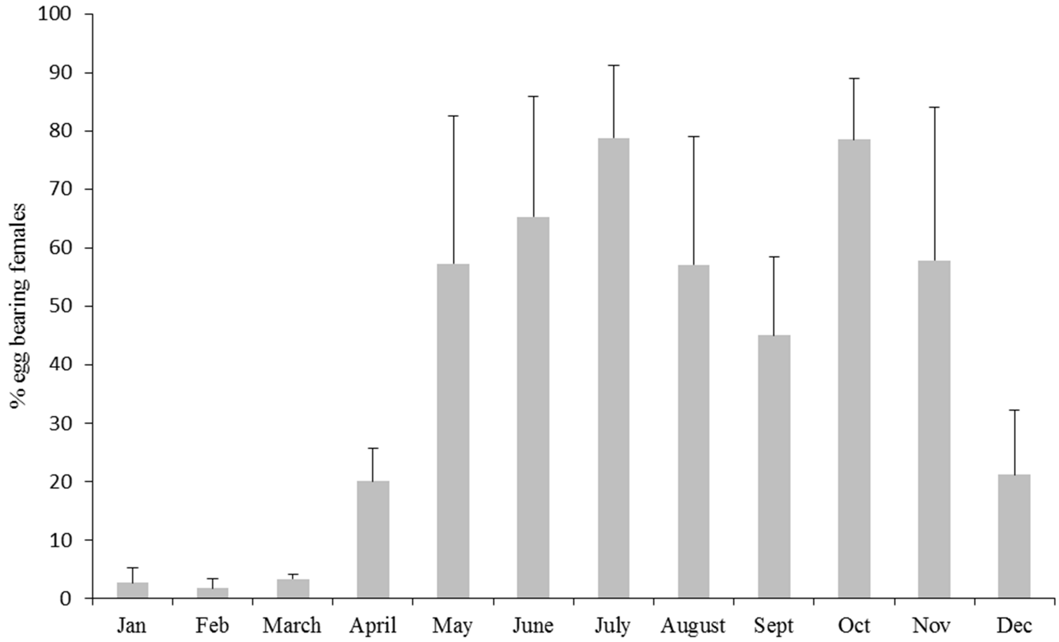


Figure 8 Percentage of egg bearing female kōura (+ SD) captured in tau kōura set in Ōkere Arm, Te Ākau and Manupirua hot pools, Lake Rotoiti, 8 December 2005 to 24 August 2014.

3.2 Kākahi

Sampling conditions

There has been a noticeable improvement in water clarity in Lake Rotoiti and the Okere Arm over the past 2 years or so. Water clarity is an important consideration when counting kākahi, and in this year's survey, sampling conditions were excellent on all monitoring occasions.

3.2.1 Kākahi abundance

The highest densities of kākahi in this year's survey were recorded at Okawa Bay (control) sites and at the Ditch (treatment) (Table 7, Fig. 9). Kākahi abundance has generally increased in Lake Rotoiti, over the sampling period (2005 to 2014, Fig. 7), except at the ditch site (inside the diversion wall) where there has been a significant decline ($P < .005$) (Fig. 10).

Table 7 Mean (± SD) number of kākahi counted (per 20 m^2) at five sampling sites, Lake Rotoiti from 20 November 2013 to 10 August 2014 and 2005 to 2014.

Date	Boat ramp	Rest Area	Ditch	Ōkawa Bay	Ruato Bay
20 November 13	68	72	122	255	48
19 February 14	35	106	167	294	18
15 May 14	36	128	123	369	12
10 August 14	32	74	98	311	34
2005 - 2014	55.5 ± 26.9	113.8 ± 67.2	307.6 ± 239.6	295 ± 120.4	35.6 ± 20.9

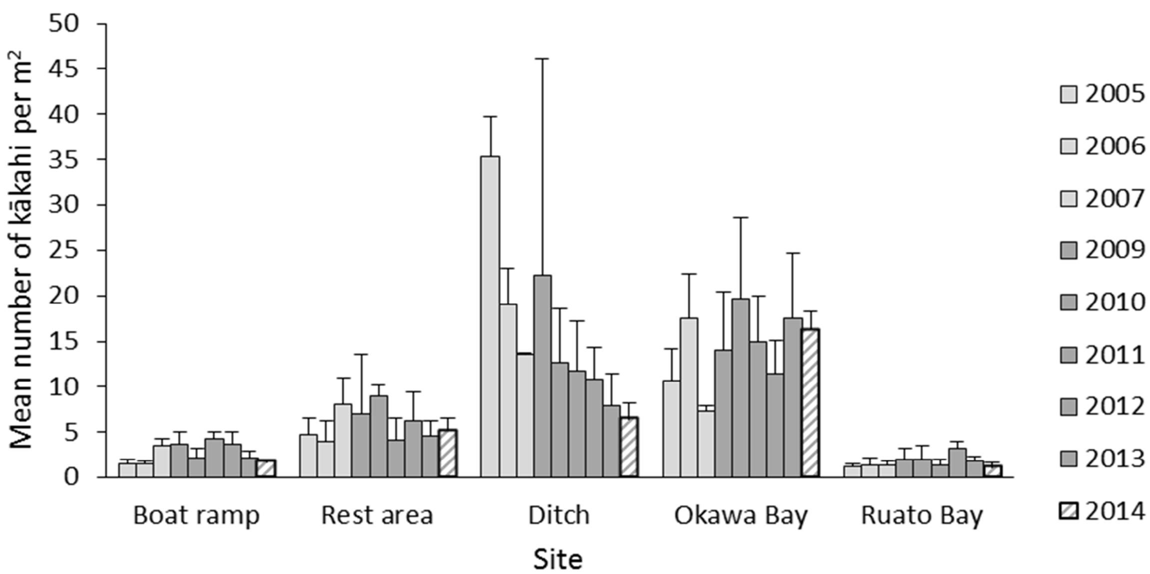


Figure 9 Mean annual kākahi counts (per m^2 ± SD) at five sampling sites, Lake Rotoiti from 2005 to 2014 (32 surveys). The light bars represent those counts recorded prior to completion of the Ohau channel diversion wall, dark bars, those counts after completion, and the patterned bars represent this year's count (November 2013 to August 2014).

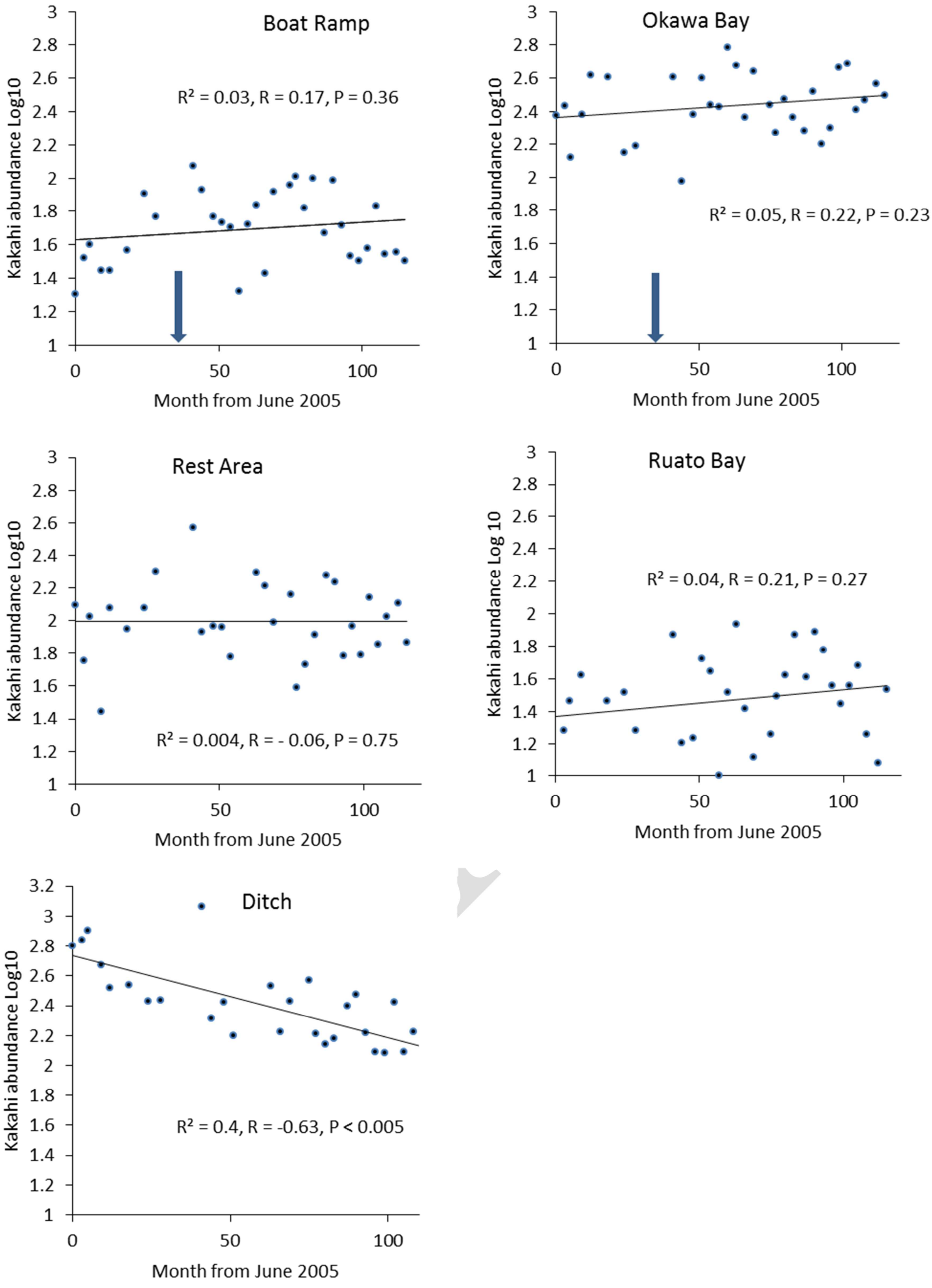


Figure 10 Kākahi abundance at 5 sites (0.5 m x 40 m transects) situated in Lake Rotoiti, over the sampling period June 2005 to August 2014. The arrow indicates when the diversion wall was completed on July 2008.

4 DISCUSSION

4.1 Kōura

Kōura are still abundant in Lake Rotoiti and the Ōkere Arm six years after the installation of Ohau Channel diversion wall (July 2008). However, there appears to have been a significant decline in abundance and biomass at Ōkere (treatment) and in abundance at Te Ākau (control). In contrast, there has been no significant change in abundance, biomass or size of kōura at Manupirua Hotpools (control) since 2009 when monitoring at this site commenced.

The reasons for these declines are unknown, however, they be related to improving water quality particularly in the Okere Arm/Te Ākau area (Western Basin). Since 2005 there has been a marked improvement in water quality in both lakes Rotoiti and Rotorua. In Lake Rotoiti the trophic level index (TLI) has decreased from 4.4 in 2004 to 3.4 in 2014, while in Rotorua, over the same period, the TLI has decreased from 4.8 to 4.2 (Pers. comm. P. Scholes, BOPRC). There has also been a decrease in algae production and an increase in water clarity[2]. The reduced primary production in the lakes may have resulted in an overall decrease in food supply for kōura in Lake Rotoiti and particularly the Ōkere Arm (as it receives water from both Rotorua and Rotoiti). Correlative studies overseas have shown that crayfish in productive lakes generally have high abundances, growth rates and fecundity (Abrahamsson and Goldman 1970; Jones and Momot 1981; France 1985). This has been attributed to increasing trophic status causing an increase in the primary consumer density, i.e., higher prey availability for crayfish in eutrophic lakes (Stenroth, *et al.* 2008).

Improvement in water quality has also resulted in an increase in water clarity which has coincided with a noticeable increase in hornwort production, particularly at Te Ākau and in the Okere Arm. 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 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. The inundation of tau kōura at Te Ākau and Manupirua Hotpools with hornwort first occurred in early to mid-2010. In addition, the decrease in kōura abundance and biomass in the Okere Arm may have been caused by increased production of hornwort which may have reduced the efficacy of the whakaweku which are now positioned on top, or amongst, the weed beds.

Hornwort may have less of an impact at Manupirua Hotpools where whakaweku were set at depths ranging from 12 to 25 m. This greater depth may provide more weed-free areas

[2] Secchi depth has increased in Lake Rotoiti from 4.6 m in 2005/06 to 7.3m in 2013/14 (P. Scholes, BOPRC, unpublished data).

(and whakaweku) for kōura to inhabit than at the shallower, Te Ākau and Okere sites (compared to 11.5 to 16 m at Te Ākau and < 7 m at Okere). There has been no significant change in mean OCL of Ōkere, Te Ākau or Hotpools kōura over the sampling period.

4.2 Kākahi

Kākahi abundance examined over the sampling period has generally increased at all study sites in Lake Rotoiti except at the ditch site (a treatment site) where there was a significant decline. 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 (Kusabs, *et al.* 2011). Interestingly, over the past three 3 years or so this silt has been colonised by extensive growths of low growing turf species e.g. *Glossostigma elatinoides*. This has resulted in the consolidation of the lake bed, creating habitat more suitable to kākahi. It is possible that the establishment and proliferation of these turf plants is due to the shelter provided by the diversion wall which has markedly reduced easterly wave action.

5 SUMMARY

The Ōkere Arm and Lake Rotoiti continue to support abundant kōura and kākahi populations six years after the completion of the diversion wall. Nevertheless, there appears to have been some significant changes in the kōura and kākahi populations over the sampling period (2005 to 2014).

There has been a significant decline in kōura abundance and biomass at Ōkere (treatment) and in kōura abundance at Te Ākau (control). The reasons for these declines are unknown but could be due to improvements in water quality and clarity which may have resulted in a decrease in food supply for kōura and an increase in hornwort production.

Kākahi remain abundant in the Ōkere Arm and Lake Rotoiti where high densities are present. Although, kākahi abundance has varied markedly over the study period, kākahi densities have generally increased over the study. The Ōkere Arm is a dynamic environment and future changes in kākahi abundance are inevitable until equilibrium is reached.

6 ACKNOWLEDGEMENTS

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