Ōkere
OHAU CHANNEL DIVERSION WALL

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

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Cover photo: Inspection of the Ohau Channel diversion wall (Lake Rotoiti) on 8 October 2015.

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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 2014 to 2015 season and to investigate any long term trends over the entire study period (2005 to 2015).

2 METHODS

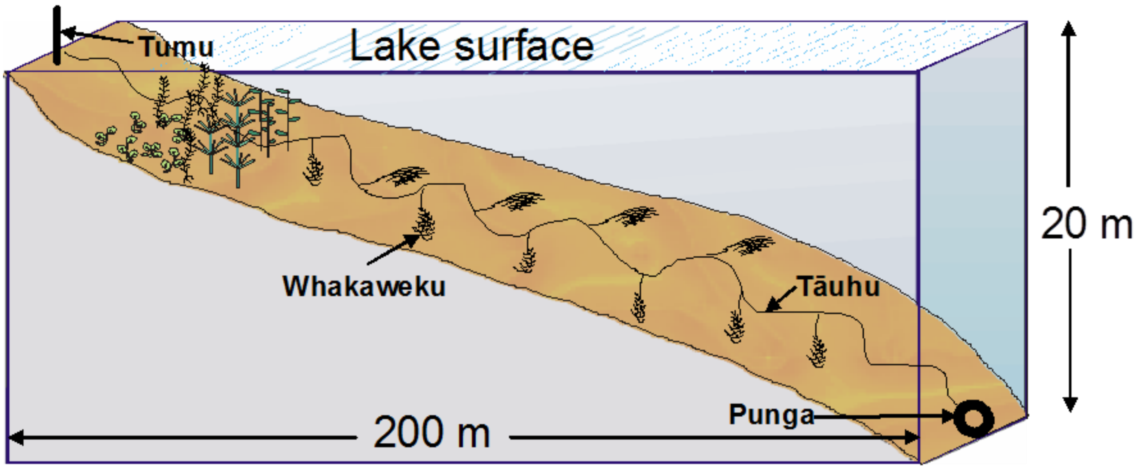
2.1 *Tau kōura location and lay out*

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 (2014 - 2015) were carried out on an approximate three monthly basis from 27 November 2014 to 11 August 2015.

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 one month to allow kōura to colonise the fern and retrieved every three 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 six months.

Figure 1 Kōura and kākahi monitoring sites, Lake Rotoiti, 2005-15. 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.

2.1.1 *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 (Kusabs, *et al.* 2015a). 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 (Kusabs, *et al.* 2015b).

2.2 *Kākahi*

Kākahi transects were located at five 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 2014 to 29 July 2015.

2.3 *Data analyses*

Time series analyses were performed for kākahi abundance at the five sampling sites and kōura at three 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 2647 kōura were collected from tau kōura set at Ōkere (*n* = 1256), Te Ākau (*n* = 451) and Manupirua Hotpools (*n* = 940), an increase of 8.8% on 2013/2014 (Table 2). As in previous years, kōura abundance varied markedly amongst the seasons, with the highest mean CPUE recorded at Ōkere in November, Te Ākau in February and Manupirua Hotpools in May (Table 2, Fig. 3).

Over the entire sampling period (2005 to 2015) there appears to have been significant declines in kōura CPUE at Ōkere ($P = 0.01$) and Te Ākau ($P = 0.002$) but no significant change at Manupirua Hotpools ($P = 0.78$) (Fig. 4). Interestingly, post 2008 data (since the wall became operational) shows no significant differences in mean CPUE at Ōkere ($P = 0.28$) or Te Ākau ($P = 0.24$).

Table 2 Mean CPUE (± SD) of kōura collected from tau kōura set at Ōkere, Te Ākau and Manupirua Hotpools from 27 November 2014 to 11 August 2015 and mean CPUE for the entire sampling period, 2005 to 2015.

	Mean CPUE					
Date	Ōkere	SD	Te Ākau	SD	Hot	SD
27 Nov 14	45.7	25.5	12.6	6.5	25.0	9.2
23 Feb 15	9.4	4.7	17.2	8.5	16.3	5.7
21 May 15	35.3	17.8	7.7	5.2	27.6	18.6
11 Aug 15	35.2	21.3	7.6	5.7	25.1	13.2
Mean 2005 - 2015	34.2	30	21.8	26.2	23.0	18.6

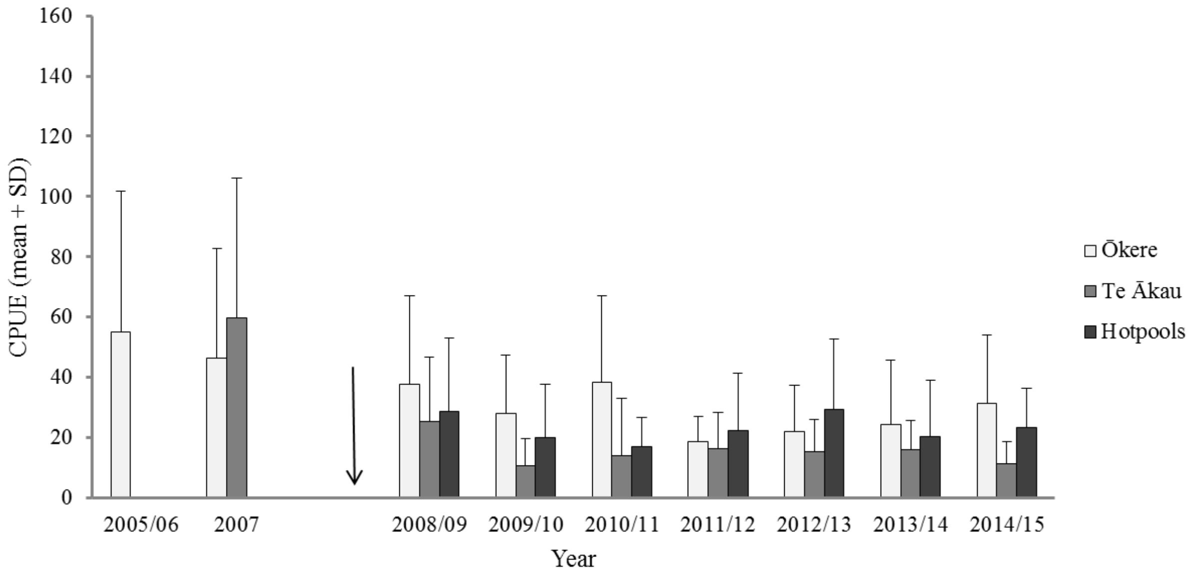


Figure 3 Mean catch per unit effort (CPUE) of kōura (± SD; n = 10) captured in tau kōura set in Ōkere Arm, Te Ākau and Manupirua Hotpools, Lake Rotoiti, 8 December 2005 to 11 August 2015. The arrow indicates when the Ohau Channel wall became operational.

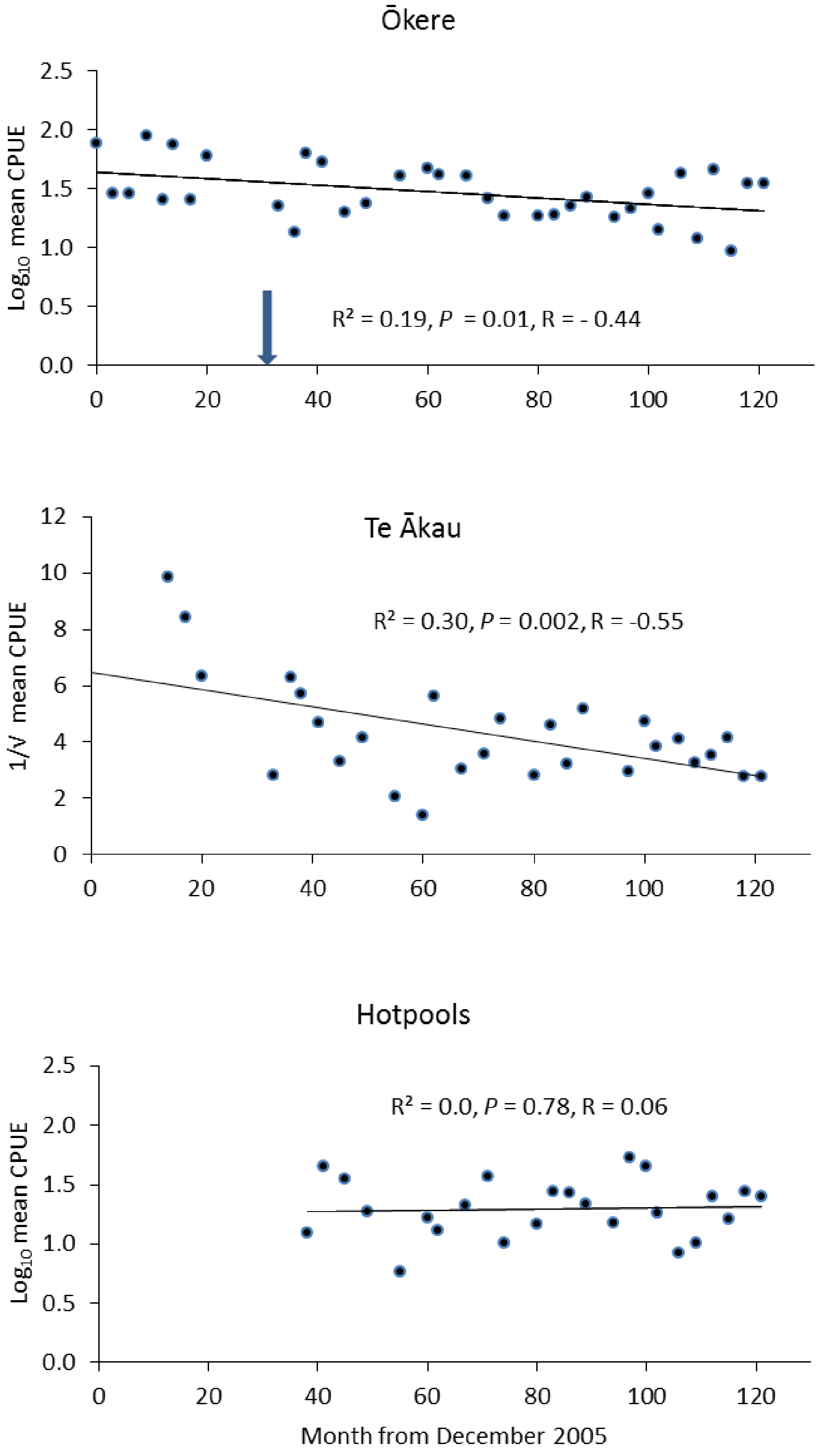


Figure 4 Relationship between mean CPUE of kōura Ōkere, Te Ākau and Hotpools and time. The arrow indicates when the diversion wall was completed at month 30 (July 2008).

3.1.2 *Kōura biomass*

In this year's survey, the mean biomass estimates (BPUE) ranged from; 432.3 g per whakaweku at Te Ākau, 422.1 g per whakaweku at the Hotpools, to 144.7 g per whakaweku at Ōkere (Table 3). This pattern is consistent with previous surveys with the highest BPUE typically documented at Te Ākau, Hotpools and Ōkere, respectively (Table 3, Fig. 5). Monitoring data from 2005 to 2015 suggest that there has been a decline in mean biomass (BPUE) of kōura at Ōkere (P = 0.005) but no significant change at Te Ākau or at the Hotpools (P > 0.5) (Fig. 6). However, post 2008 data does not show any significant changes in mean BPUE at Ōkere (P = 0.34).

Table 3 Estimated mean biomass (g; ± SD) per whakaweku of kōura collected from tau kōura (n =10) set at Ōkere, Te Ākau and Manupirua Hotpools from 27 November 2014 to 11 August 2015 and the mean BPUE for the entire sampling period, 2005 to 2014.

	Estimated mean biomass (g)					
Date	Ōkere	SD	Te Ākau	SD	Hot	SD
27 Nov 14	318.3	182.8	390.3	208.5	403.6	164.5
23 Feb 15	17.0	17.0	708.7	422.5	267.0	139.9
21 May 15	128.7	69.5	320.1	236.5	554.0	375.9
11 Aug 15	114.9	64.6	310.1	231.8	463.9	268.0
2005 - 2014	156.8	165.1	478.8	440.1	362.4	312.1

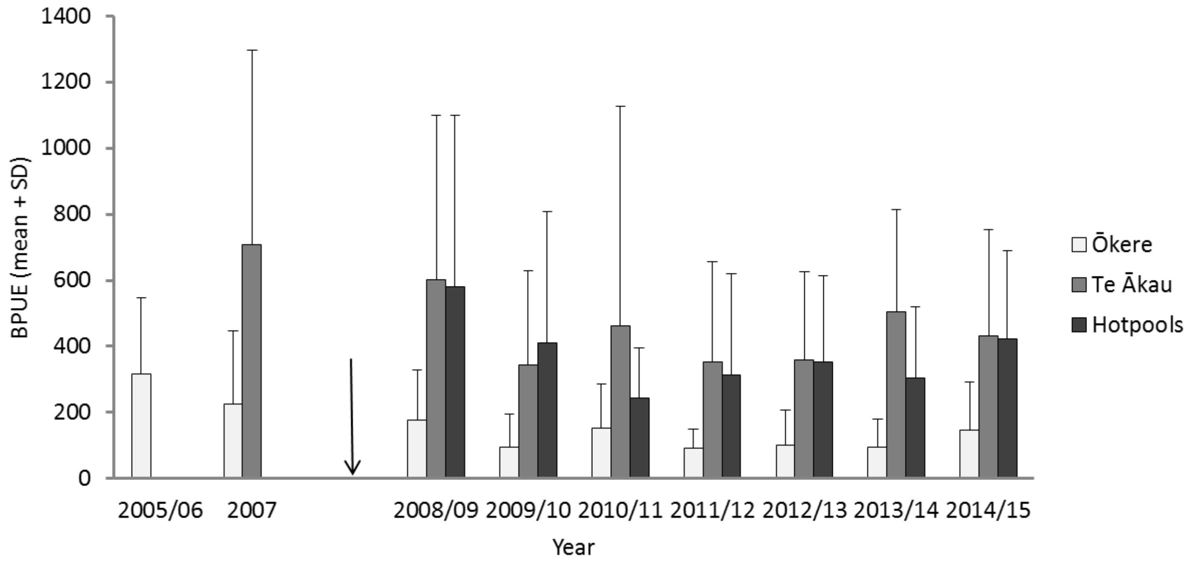


Figure 5 Mean Biomass Per Unit Effort (BPUE) of kōura (± SD; n = 10) captured in tau kōura set in Ōkere Arm, Te Ākau and Manupirua Hotpools, Lake Rotoiti, 8 December 2005 to 11 August 2015. The arrow indicates when the Ohau Channel diversion wall became operational.

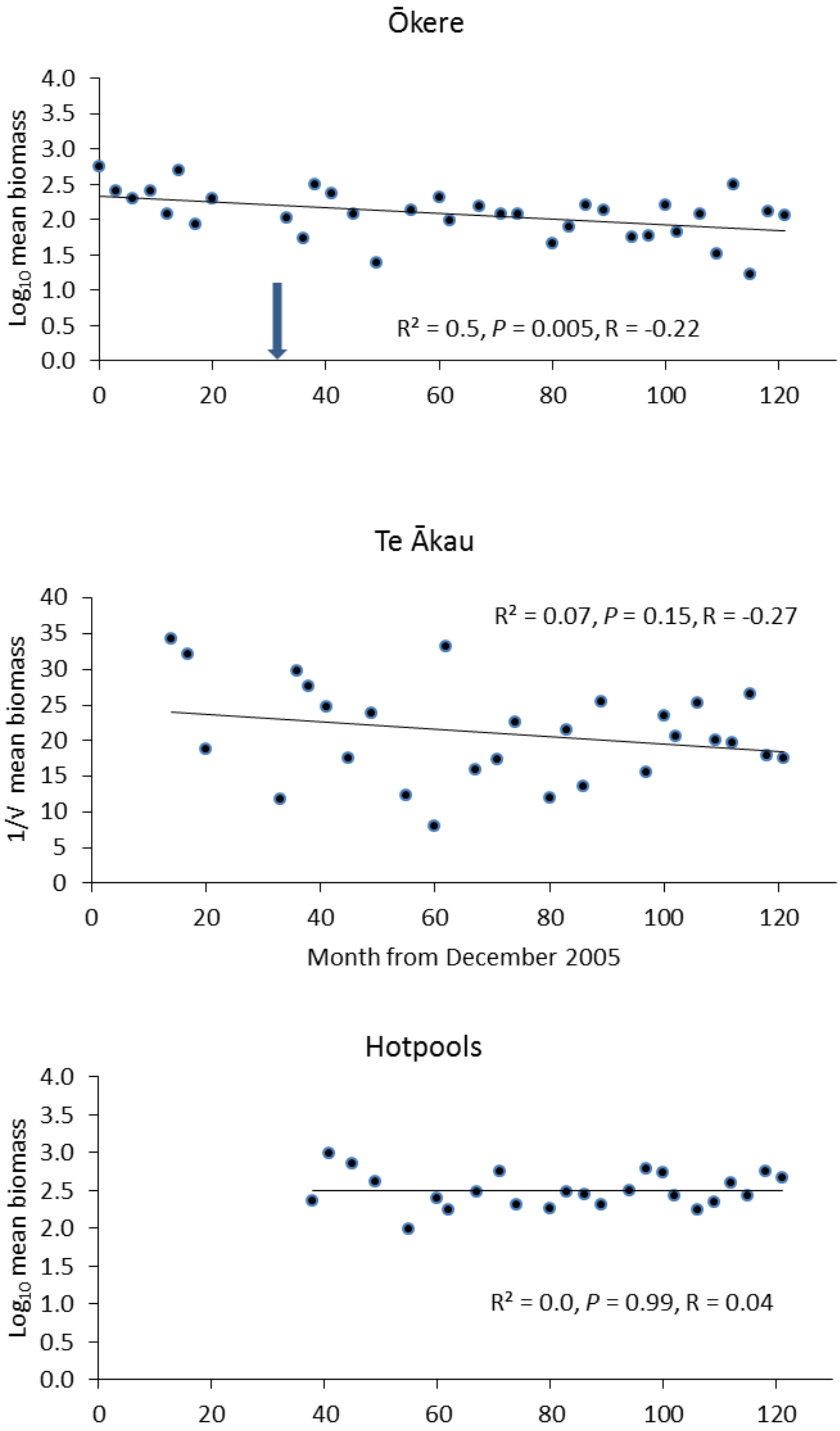


Figure 6 Relationship between estimated mean kōura biomass and time (sampling period beginning December 2005). The arrow indicates when the diversion wall was completed at month 30 (July 2008).

3.1.3 Kōura size

As in previous years, the largest kōura were found at Te Ākau, followed by the Hotpools, and the smallest at Ōkere (Table 4). The largest kōura yet recorded, a 55.5 mm OCL male with an estimated wet weight of 150 g, was captured at Te Ākau on in the November survey. Kōura ranged in size from 8 to 35 mm at Ōkere, 15 to 55.5 mm at Te Ākau and 8 to 42 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 mean OCL at Ōkere (P = 0.06) and at the Hotpools (P = 0.88) and an increase in mean OCL of Te Ākau (P = 0.15), kōura since surveys commenced in 2005 or post 2008 (Fig. 7).

Table 4 Mean OCL (mm ± SD) of kōura collected from tau kōura set at Ōkere, Te Ākau and Manupirua Hotpools from 27 November 2014 to 11 August 2015 and 2005 to 2015.

	Mean OCL (mm)						OCL Range (mm)		
Date	Ōkere	SD	Te Ākau	SD	Hotpools	SD	Ōkere	Te Ākau	Hotpools
27 Nov 14	19.9	5.0	31.6	7.4	26.5	5.1	12 - 35	15 - 51	15 - 36
23 Feb 15	11.3	4.3	35.7	6.3	27.8	5.9	8 - 30	17 – 55.5	8 - 40
21 May 15	15.6	5.1	35.8	5.4	28.0	4.9	10 - 35	24 - 48	8 - 42
11 Aug 15	15.5	4.5	35.0	7.2	27.5	6.0	8 – 32.5	18 - 48	13 - 41
2005 - 2015	16.3	2.6	30.0	4.2	26.2	2.2	6 - 44	6 – 55.5	6 - 47

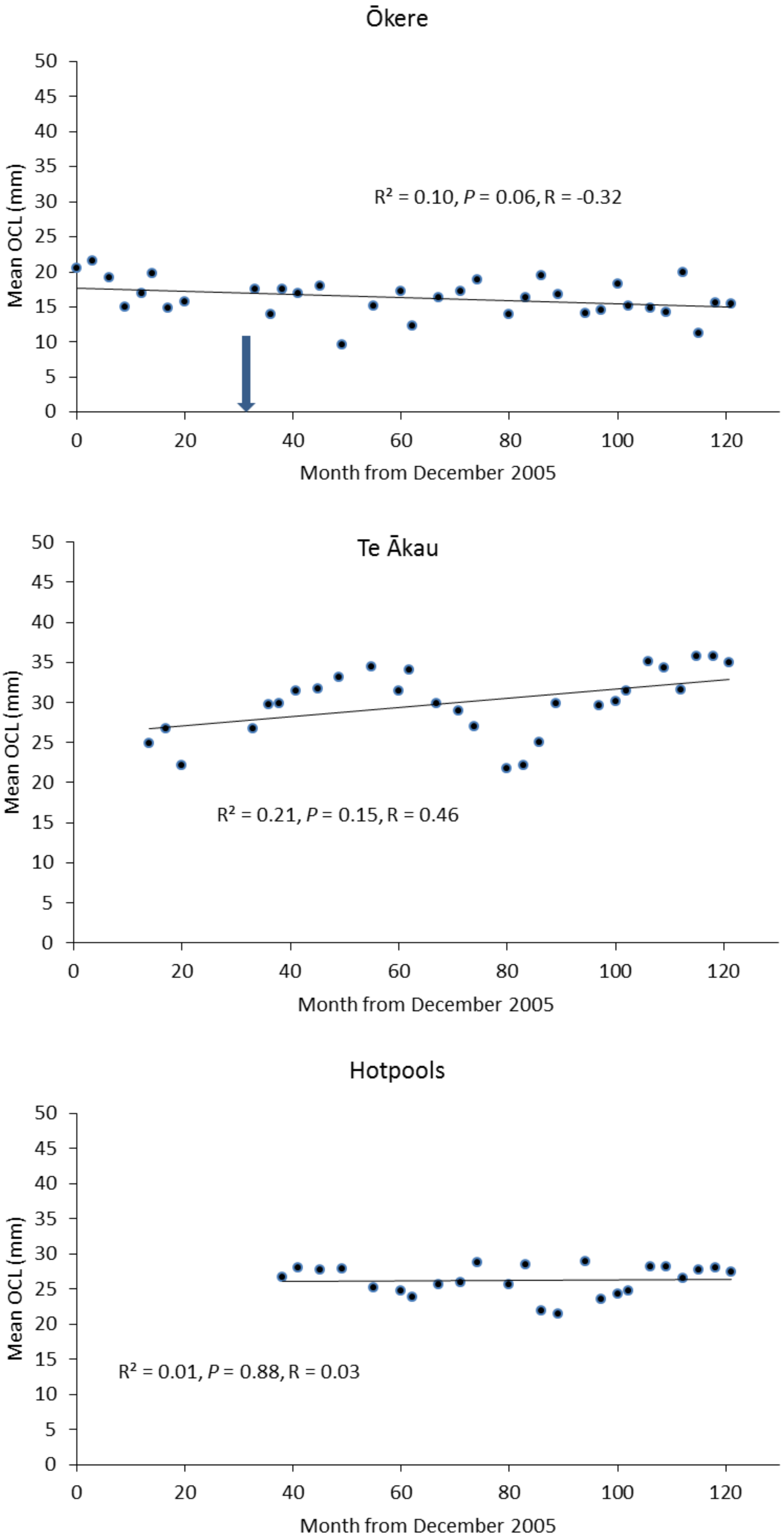


Figure 7 Relationship between mean OCL (mm) of kōura and time (sampling period beginning December 2005). Arrow indicates when the diversion wall was completed (July 2008).

3.1.4 Female to male ratio

The mean percentage of females in subsamples from Ōkere Arm, Te Ākau and Hotpools were 53 %, 46 % and 50 %, respectively. Female kōura comprised approximately 50% of all kōura analysed over the 2005 to 2015 study period (Table 5).

Table 5 Number of kōura analysed and percentage of female kōura (± SD) collected in samples from tau kōura set at Ōkere, Te Ākau and Manupirua Hotpools from 27 November 2014 to 11 August 2015. 2005 – 14; Total number of kōura analysed and mean % (± SD) of female kōura collected.

	Number of kōura analysed			% female		
Date	Ōkere	Te Ākau	Hotpools	Ōkere	Te Ākau	Hotpools
27 Nov 14	195	126	107	55.2	51.6	55.1
23 Feb 15	94	132	114	42.9	43.2	45.1
21 May 15	183	77	276	60	44.2	55.4
11 Aug 15	112	76	131	53.8	46.1	45.8
2005 - 2015	5374	3646	3871	53.2 ± 5.6	49.3 ± 9.0	48.6 ± 5.3

3.1.5 Egg-bearing times and moulting

Females with eggs or young were present throughout the year, particularly in November, May and August with few present in February (Table 6). The mean percentage of kōura with soft shells in subsamples from Ōkere Arm, Te Ākau and Hotpools were 3.2 %, 12.7 % and 14.7 %, respectively (Table 6).The highest proportion of kōura with soft shells, 33%, was recorded at the Hotpools in May (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 Ōkere, Te Ākau and Manupirua Hotpools from 27 November 2014 to 11 August 2015 and 2005 to 2015.

	% Breeding size females with eggs (n)			% soft shells		
Date	Ōkere	Te Ākau	Hotpools	Ōkere	Te Ākau	Hotpools
27 Nov 14	12.2 (5)	75 (48)	25.0 (13)	3.1	4.0	5.6
23 Feb 15	0	5.4 (3)	4.4 (2)	0	7.6	7.0
21 May 15	40.0 (8)	79.4 (27)	51.8 (74)	6.0	26.0	33.0
11 Aug 15	33.3 (2)	58.8 (20)	80.4 (41)	3.6	13.2	13.0
2005 - 2014				5.6 ± 6.5	8.4 ± 6.6	11.5 ± 7.0

3.2 Kākahi

Sampling conditions

Water clarity is an important consideration when counting kākahi and there has been a noticeable improvement in water clarity in Lake Rotoiti and the Ōkere Arm since monitoring began in 2005. However, this has been offset somewhat by the prolific growth of benthic algae over the past three years, which has compromised kākahi counts at all sites particularly at the Okawa Bay and Boat Ramp sites.

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 2015, 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) abundance of kākahi (per m^2) at five sampling sites (20 m^2), Lake Rotoiti from 20 November 2014 to 29 July 2015 and 2005 to 2015.

Date	Boat ramp	Rest Area	Ditch	Ōkawa Bay	Ruato Bay
20 Nov 14	6.35	4.70	2.60	13.70	3.35
28 Feb 15	1.10	5.75	4.05	3.80	0.85
20 May 15	1.10	3.50	4.10	15.20	2.10
29 July 15	1.20	2.20	5.50	10.00	1.35
2005 - 2014	2.74 ± 1.48	5.50 ± 3.23	14.01 ± 11.82	14.3 ± 6.00	1.80 ± 1.04

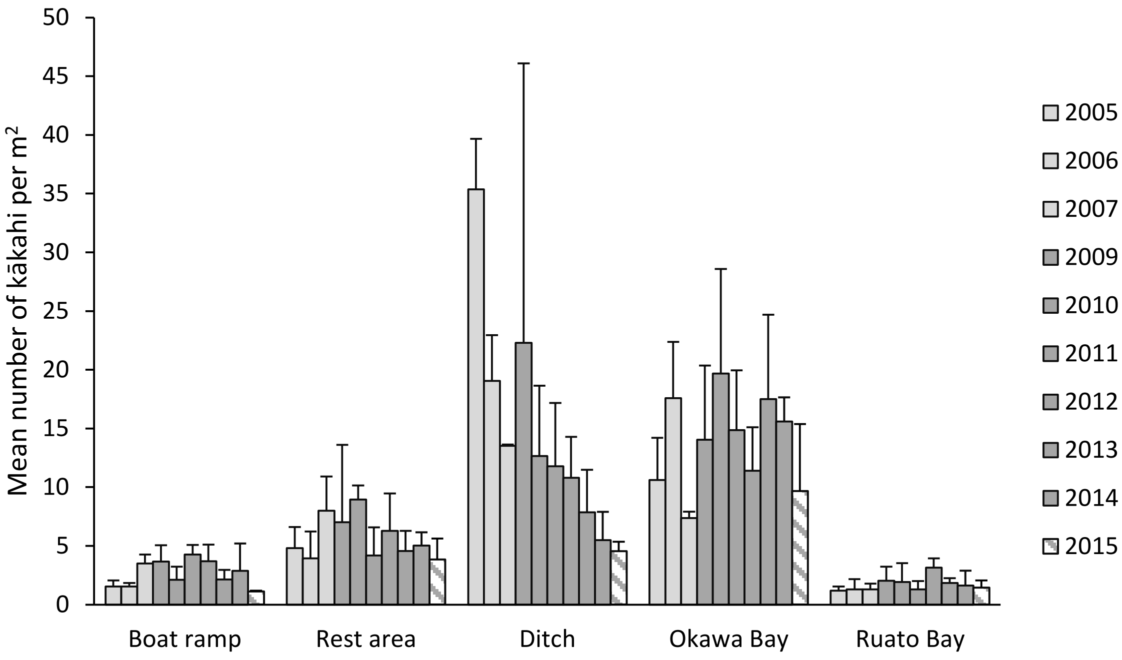


Figure 8 Mean annual kākahi counts (per m^2 ± SD) at five sampling sites, Lake Rotoiti from 2005 to 2014 (32 surveys). The light bars represent those counts recorded prior to completion of the Ohau channel diversion wall, dark bars, those counts after completion, and the patterned bars represent this year's count (November 2014 to July 2015).

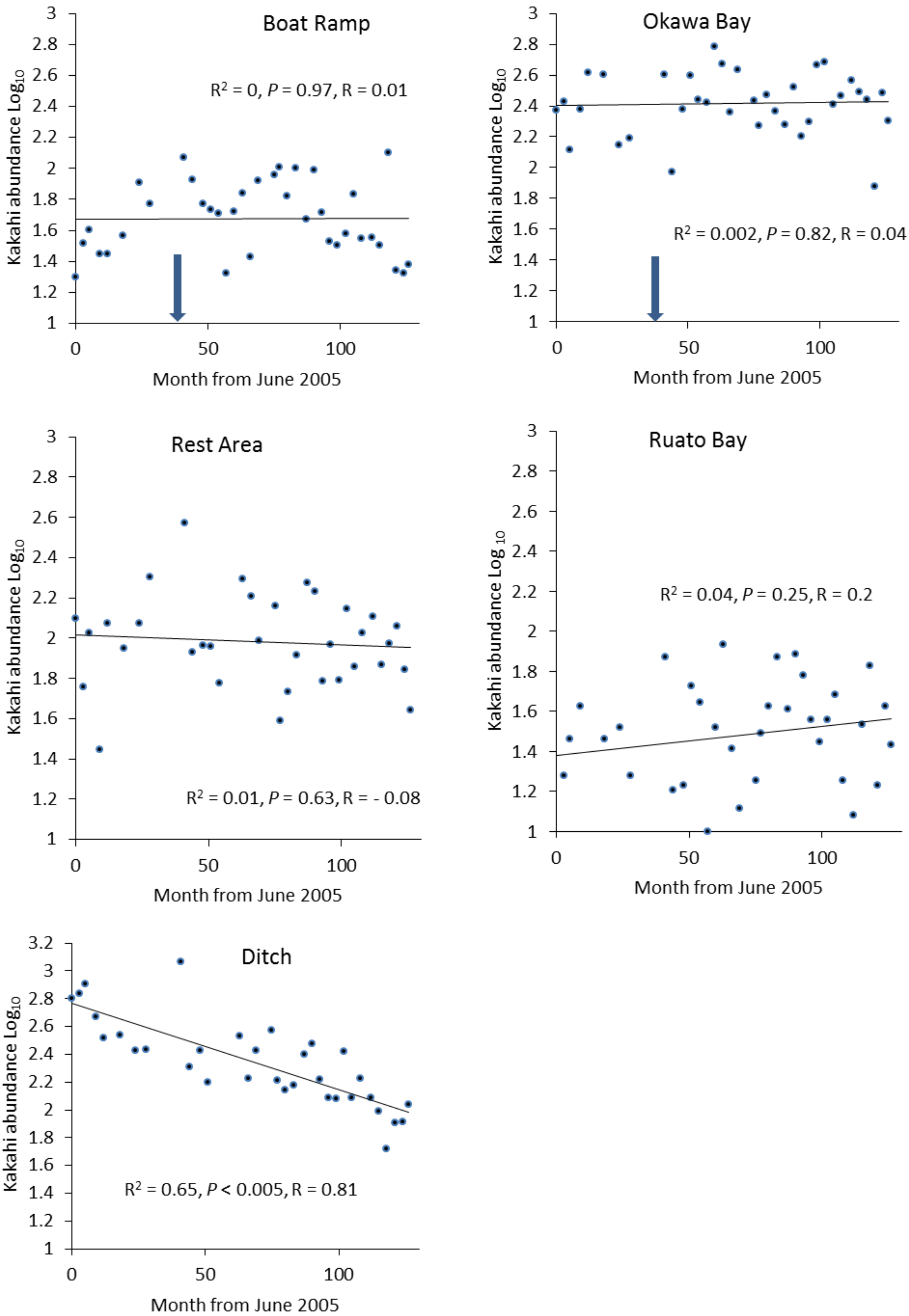


Figure 9 Kākahi abundance at 5 sites (0.5 m x 40 m transects) situated in Lake Rotoiti, over the sampling period June 2005 to August 2015. The arrow indicates when the diversion wall was completed on July 2008.

4 DISCUSSION

4.1 Kōura

Kōura are still abundant in Lake Rotoiti and the Ōkere Arm, seven years after the installation of the Ohau Channel diversion wall in July 2008. Data suggests that there has been a decline in the abundance and biomass of kōura at Ōkere (treatment) and in abundance at Te Ākau (control). The reasons for the apparent declines from 2005 to 2015 are unknown, however, they be related to improving water quality particularly in the Ōkere Arm/Te Ākau area (Western Basin). Since 2005 there has been a steady 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, with a decrease in algae production and an increase in water clarity[2] (Pers. comm. P. Scholes, BOPRC). The reduced primary production may have resulted in a decrease in food supply for kōura in Lake Rotoiti.

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 Ōkere Arm. 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.

Analysis of monitoring data collected post-2008 show no significant changes in the abundance, biomass or size of kōura at any of the sites, suggesting that the kōura populations in Lake Rotoiti and the Ōkere Arm may now have stabilised.

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.

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

5 SUMMARY

The Ōkere Arm and Lake Rotoiti continue to support abundant kōura and kākahi populations seven 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 2015). 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. Post-2008 data shows no significant differences in the abundance, biomass or size of kōura at any of the sites, suggesting that the kōura populations in Lake Rotoiti and the Ōkere Arm may now be relatively stable.

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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