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, Ōkere Arm, Lake Rotoiti.

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1 INTRODUCTION

The macroinvertebrates, kōura (*Paranephrops planifrons*) and kākahi (*Echyridella menziesii*) are considered ‘keystone’ species in New Zealand waterways, and have various ecological functions that in turn influence other fauna and flora. They are considered “ecosystem engineers” because they modify aquatic habitat, making it more suitable for themselves and other organisms. Furthermore, kōura and kākahi increasingly feature as indicator species because of their important role in aquatic ecosystem food webs and their iconic and heritage values. In Lake Rotoiti, kōura and to a lesser extent kākahi, also support important customary fisheries for iwi members.

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, an eastern (the majority of the lake that has no Lake Rotorua influence) and a small western basin (the Ōkere Arm). The wall became fully operational 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). Monitoring surveys of kōura and kākahi have been carried out on a seasonal basis since July 2008. The aims of this study were to survey kōura and kākahi populations in Lake Rotoiti for the 2013 to 2014 season and to investigate long-term trends in these populations over time (i.e., 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, these were located at; Ōkere Arm (Ōkere), Te Ākau Point (Te Ākau), and Manupirua Hotpools (Hotpools) (Table 1; Fig. 1). The methods used in this study are described in previous reports (Kusabs, *et al.* 2010). Each tau kōura was composed of 10 whakaweku (dried bracken fern *Pteridium esculentum*), with c. 10 - 14 dried fronds per bundle, attached to a bottom line - a 250 m length of 10 mm nylon rope (Fig. 2). Tau kōura were set in the Ōkere Arm, Te Ākau and Hotpools in depths ranging from 4 to 7 m, 7 to 17 m and 11 to 27 m, respectively. The tau kōura were left for at least one month to allow kōura to colonise the fern and retrieved every three months from 12 December 2013 to 24 August 2014.

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).

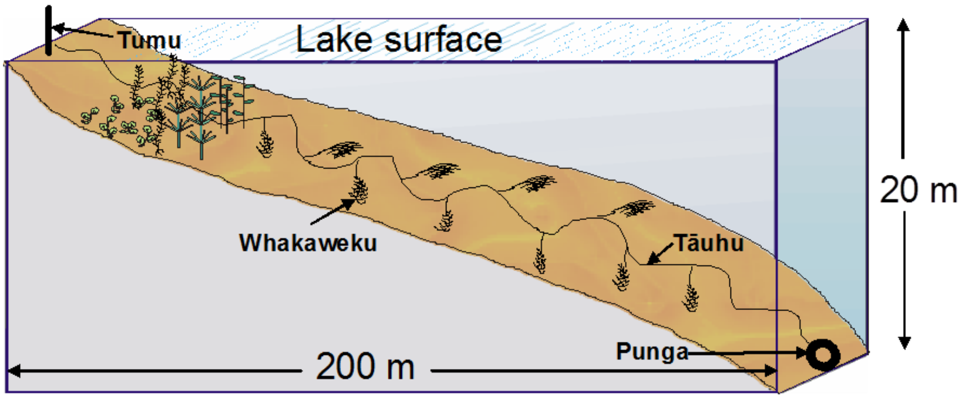

Figure 2. Schematic diagram of a tau kōura. The depth and length of tau are indicative and can be varied depending on lake bathymetry.

2.2 *Kōura measurements*

Orbit-carapace length (OCL) of each kōura was measured using vernier callipers (± 0.5 mm) and the sex of kōura (OCL >11 mm) assessed. A power regression equation 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.

2.3 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 three monthly basis from 20 November 2013 to 10 August 2014.

Table 1. Kōura and kākahi sampling sites, location and grid reference, Lake Rotoiti, 2005 to 2014.

Kōura/kākahi	Sampling site/	Location	Grid reference (NZ Geodatum)
Kōura	1. Ōkere	Ōkere Arm	E 2803800 N 6348162
	2. Te Ākau	Lake Rotoiti	E 2803747 N 6346463
	3. Manupirua hot pools	Lake Rotoiti	E 2806499 N 6345889
Kākahi	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

2.4. Data Analysis

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 inverse square root ($1/\sqrt{}$) transformed to approximate a normal distribution.

[1] Note: Counts at Tumoana Bay were discontinued in 2011 due to low numbers of kākahi 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 at Ōkere 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 Ōkere (P = 0.002) and Te Ākau (P = 0.004) but no significant change at Manupirua Hotpools (P = 0.9) (Fig. 4).

Table 2. Catch per unit effort (mean ± SD) of kōura collected from tau kōura set at Ōkere, 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	Hotpools	SD
12 Dec 2013	28.9	18.7	22.4	10.8	44.5	22.1
29 January 2014	14.1	9.9	14.8	5.7	18.1	8.6
27 May 2014	42.2	28.6	16.8	9.1	8.5	6
24 August 2014	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

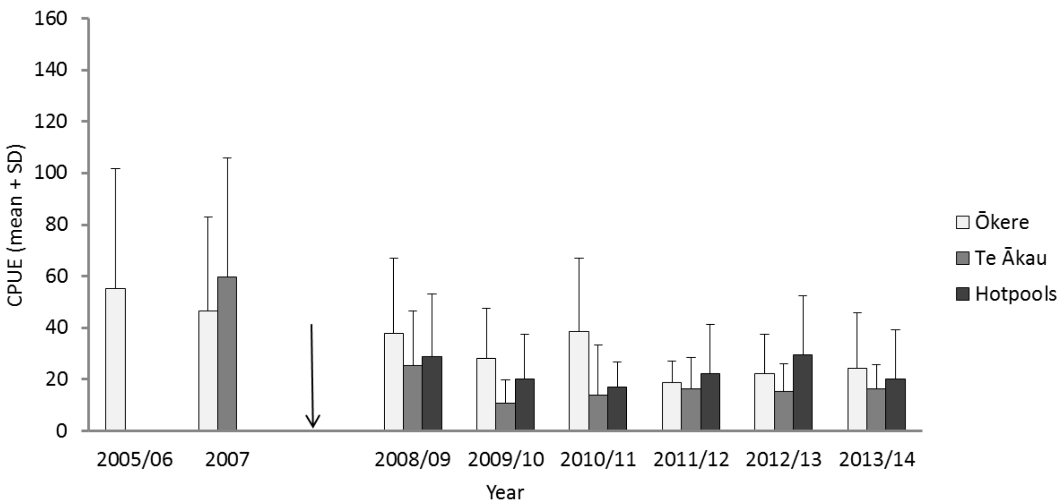

Figure 3. Annual catch per unit effort (CPUE; mean + SD) of kōura collected from tau kōura set in Ōkere Arm, Te Ākau and Manupirua Hotpools, Lake Rotoiti, 8 December 2005 to 24 August 2014. The arrow indicates when the diversion wall was completed at approximately month 30 (July 2008).

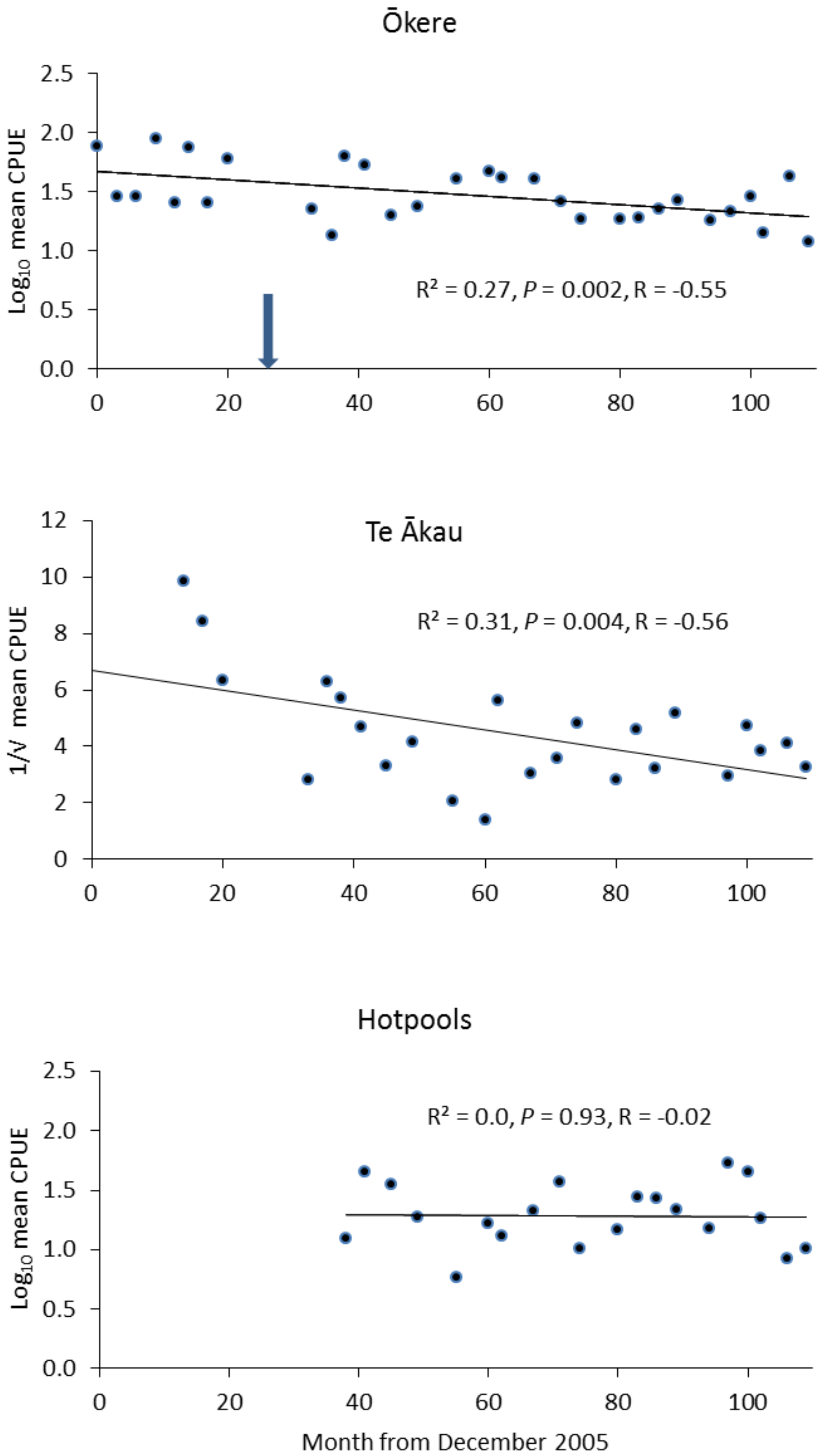

Figure 4. Relationship between mean CPUE of kōura Ōkere, Te Ākau and Hotpools and time. The arrow indicates when the diversion wall was completed at approximately month 30 (July 2008).

3.1.2 *Kōura biomass*

The highest 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 Ōkere, respectively (Table 3, Fig. 5). There appears to have been a significant decline in BPUE of kōura at Ōkere ($P = 0.002$) over the sampling period but no significant change at Te Ākau or at the Hotpools ($P > 0.5$) (Fig. 6).

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

	Estimated mean biomass (g)					
Date	Ōkere	SD	Te Ākau	SD	Hotpools	SD
12 Dec 2013	157	36.4	553.4	90.2	548.4	255.9
29 January 2014	67.6	13.0	421.0	55.8	272.4	34.5
27 May 2014	121.7	24.8	637.7	108	173.5	45.8
24 August 2014	33	6.6	405.5	122.5	219.6	30.4
2005 - 2014	158.5	123.3	495.2	317	351.7	221.8

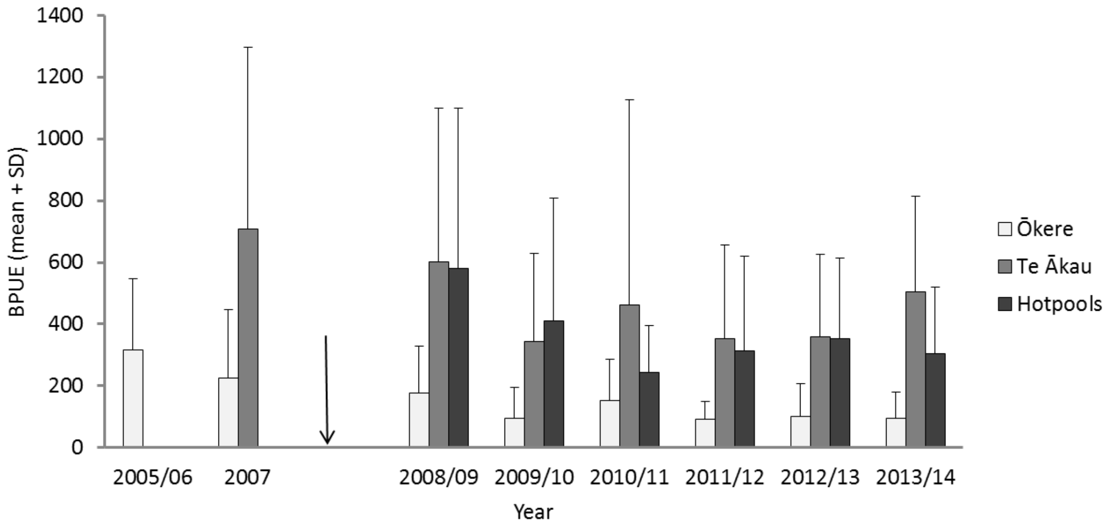

Figure 5. Annual biomass per unit effort (BPUE; mean + SD) of kōura collected from tau kōura set in Ōkere Arm, Te Ākau and Manupirua Hotpools, Lake Rotoiti, 8 December 2005 to 24 August 2014.

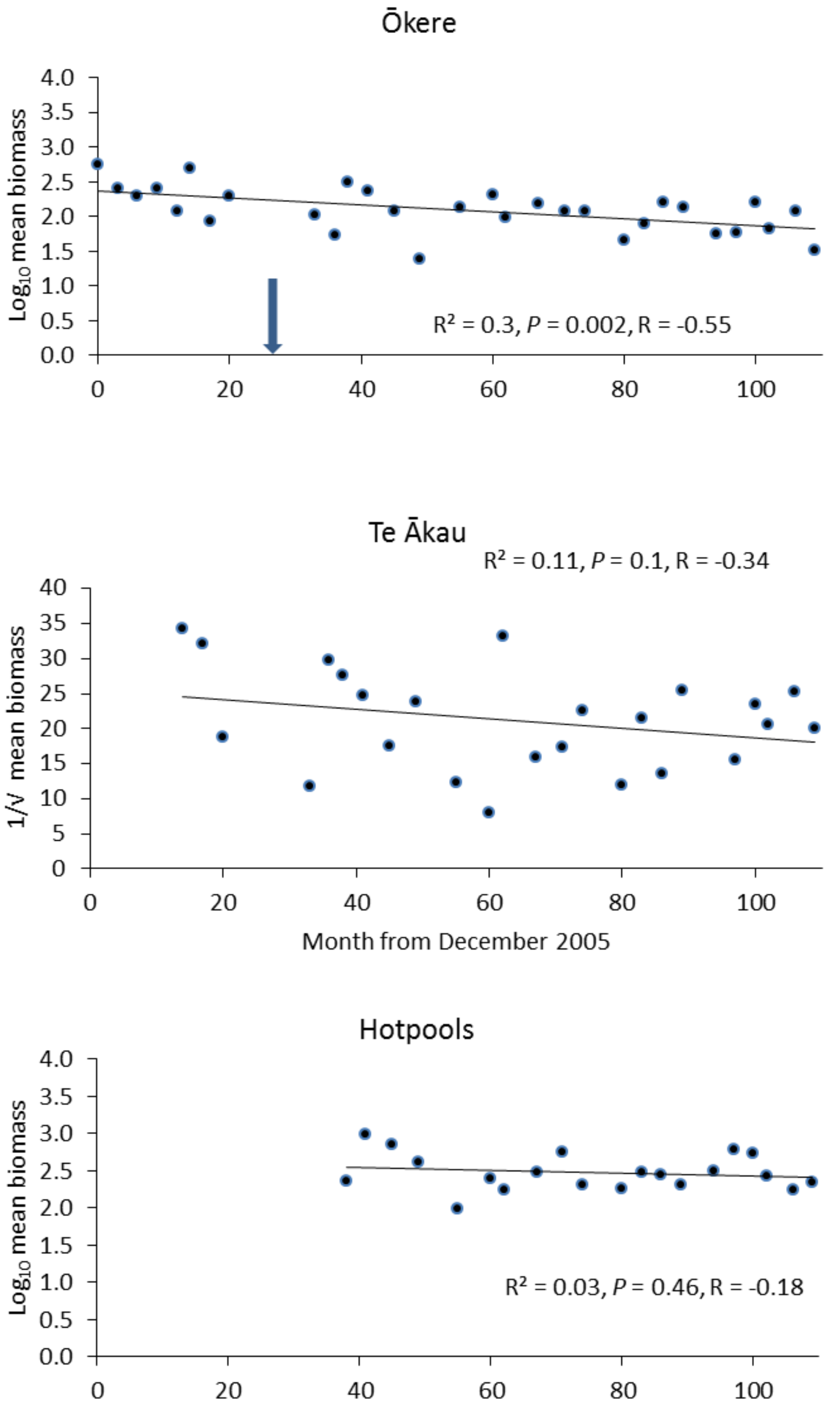

Figure 6. Relationship between estimated kōura biomass and time (sampling period beginning December 2005).

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 14 – 41 mm at the Hotpools.

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

Table 4. Orbit carapace length (OCL (mm); mean ± SD) of kōura collected from tau kōura set at Ōkere, 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	SD	Ōkere	Te Ākau	Hotpools
12 Dec 2013	18.30	5	30.2	6.5	24.3	5.7	12 - 33	15 - 54	13 – 37
29 Jan 2014	15.10	7	31.5	5.1	24.7	6.3	6 - 36	18 - 44	14 – 41
27 May 2014	14.90	4.6	35.1	5	28.2	4.9	8 - 30	21 - 46	15 - 41
24 Aug 2014	14.20	3.7	34.3	6.4	28.2	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

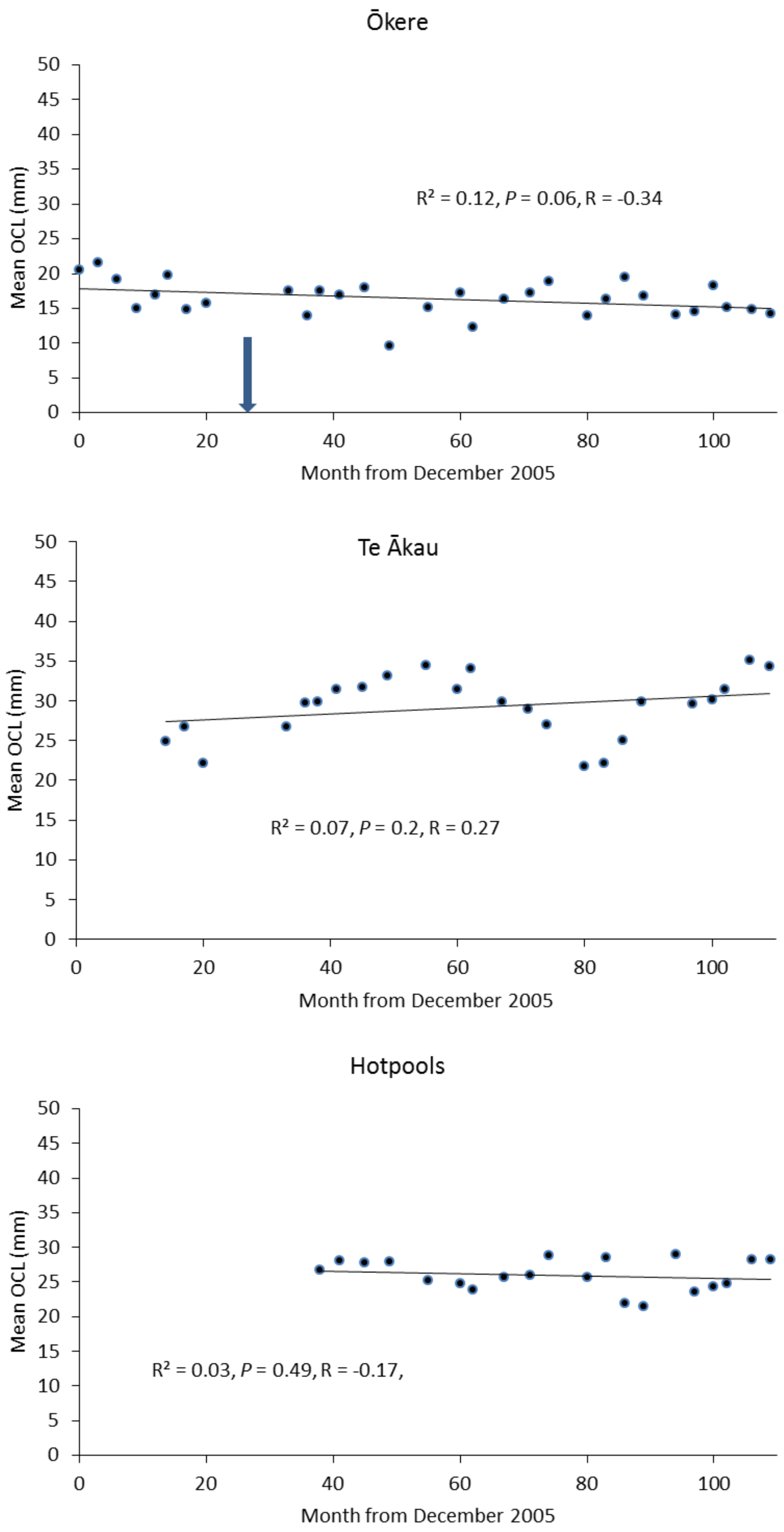

Figure 7. Relationship between kōura OCL (mean; mm) and time (sampling period beginning December 2005).

3.1.4 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 (mean ± SD) collected in samples from tau kōura set at Ōkere, Te Ākau and Manupirua Hotpools from 13 December 2013 to 24 August 2014 and 2005 to 2014.

	Number of kōura analysed			% female		
Date	Ōkere	Te Ākau	Hotpools	Ōkere	Te Ākau	Hotpools
12 Dec 2013	117	119	128	62.1	45.4	48.4
29 January 2014	141	148	181	46.3	45.3	42.5
27 May 2014	123	107	85	66.7	60.7	52.9
24 August 2014	118	108	102	53.4	55.1	49
2005 - 2014	4790	3235	3243	53.3 ± 5.5	49.8 ± 9.5	48.2 ± 5.3

3.1.5 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 collected in samples from tau kōura set at Ōkere, 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 Dec 2013	23.6 (4)	21.6 (11)	27.7 (13)	5.1	13.4	8.6
29 January 2014	0	0	5.2 (3)	4.3	9.5	10.5
27 May 2014	58.3 (7)	93.8 (61)	52.3 (23)	3.3	0	5.9
24 August 2014	50.0 (1)	80.7 (46)	63.8 (30)	10.2	2.8	13.7
2005 - 2014				5.9	7.7	10.9

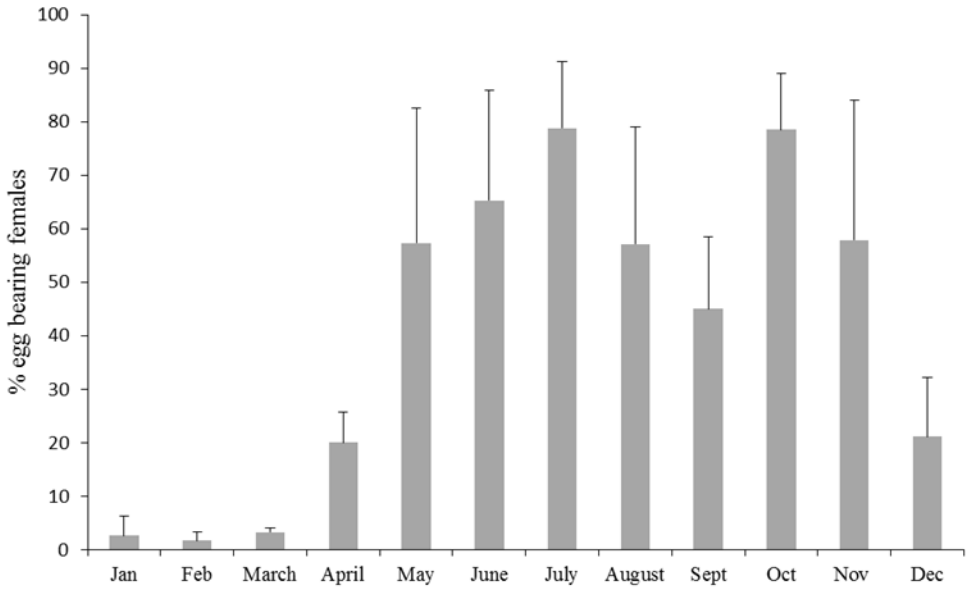

Figure 8. Percentage (mean + SD) of egg-bearing female kōura captured in tau kōura set in Ōkere Arm, Te Ākau and Manupirua hot pools, Lake Rotoiti, 8 December 2005 to 24 August 2014.

3.2 Kākahi

3.2.1 *Sampling conditions*

There has been a noticeable improvement in water clarity in Lake Rotoiti and the Ōkere Arm since 2005. In Lake Rotoiti, Secchi depth has increased from 4.6 m in 2005/06 to 7.3 m in 2013/14 (P. Scholes, BOPRC, unpublished data). Water clarity is an important consideration when counting kākahi, and in this year's survey, sampling conditions were excellent on all monitoring occasions.

3.2.2 *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

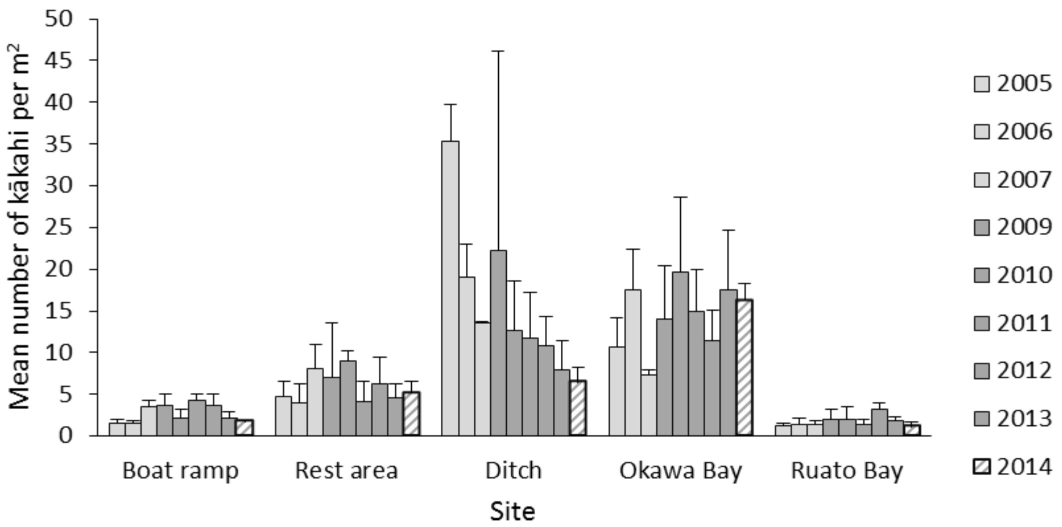

Figure 9. Annual kākahi counts (mean + SD) at five sampling sites, Lake Rotoiti from 2005 to 2014 (32 surveys). The light bars represent those counts recorded prior to completion of the Ohau channel diversion wall, dark bars, those counts after completion, and the patterned bars represent this year's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

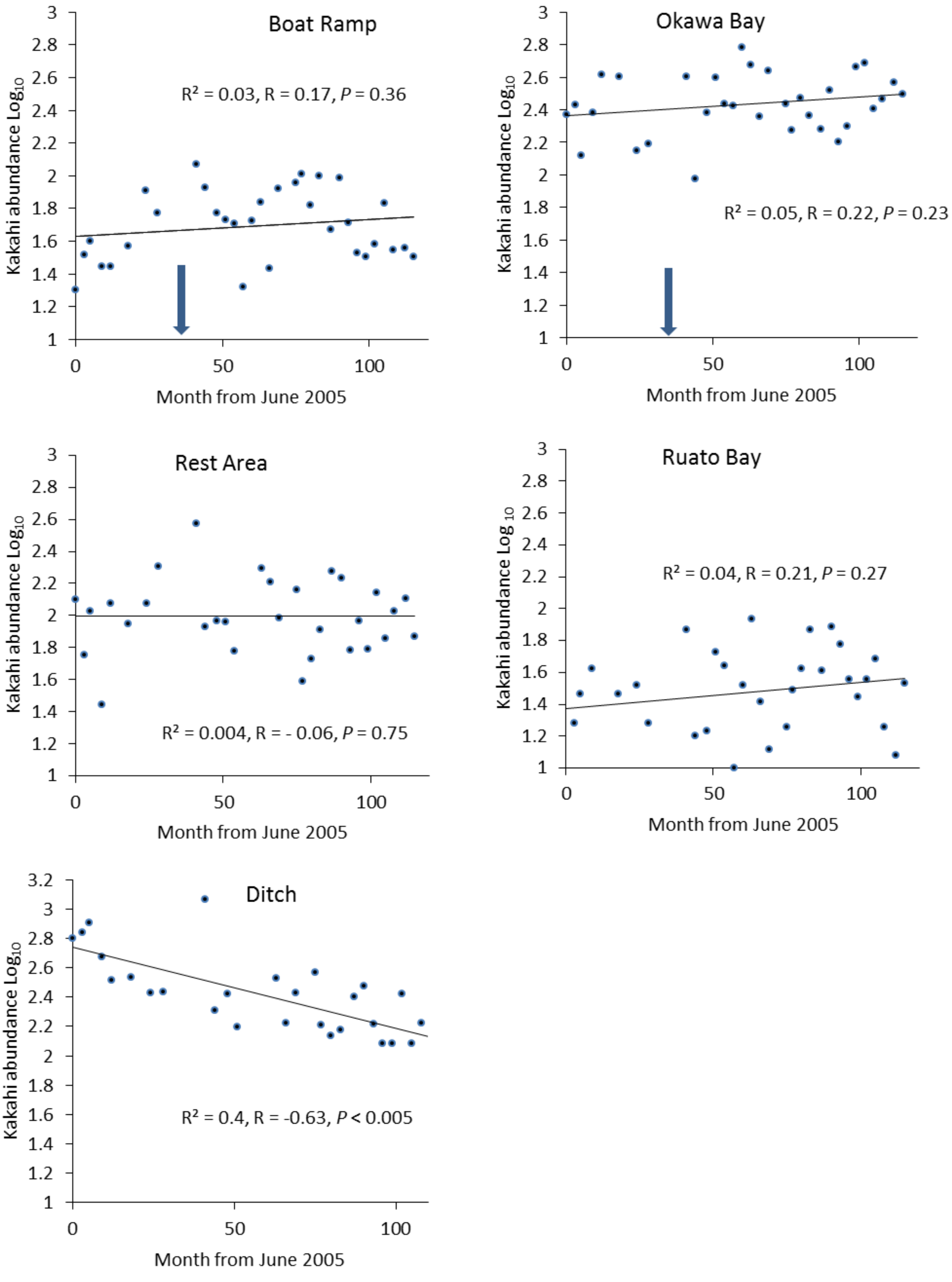

Figure 10. Kākahi abundance at five sites (0.5 m x 40 m transects) situated in Lake Rotoiti, over the sampling period June 2005 to August 2014.

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 kōura 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 this site was added to the monitoring programme.

The reasons for these declines 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 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 freshwater 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 Ōkere 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 Ōkere 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.

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[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).

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 (and whakaweku) for kōura to inhabit than at the shallower, Te Ākau and Ōkere sites (compared to 11.5 to 16 m at Te Ākau and < 7 m at Ōkere).

Kōura breeding in Lake Rotoiti is continuous with a main breeding period from April to December. This is similar to that reported in Lake Rotoiti in the mid 1970's by Devcich (1979). Moulting activity also appears to be continuous in Lake Rotoiti with no discernible peaks. This differs from that reported by Devcich (1979) who reported a main peak in moulting activity in March to early April and a smaller peak occurring from September to November. In general, kōura moult twice a year (sometimes once) in Lake Rotoiti, with moulting frequency decreasing with age (Devcich 1979).

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 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 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, respectively.

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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7 REFERENCES

Abrahamsson S. A. A. and Goldman C. R. (1970) Distribution, density and production of the crayfish *Pacifastacus leniusculus* Dana in Lake Tahoe, California - Nevada. *Oikos* **21**, 83-91.

Devcich A. A. (1979) An ecological study of *Paranephrops planifrons* (White) (Decapoda: Parastacidae) in Lake Rotoiti, North Island, New Zealand. In: p. 247. University of Waikato, Hamilton, New Zealand.

France R. L. (1985) Relationship of crayfish (*Orconectes virilis*) growth to population abundance and system productivity in small oligotrophic lakes in the experimental lakes area, Northwestern Ontario. *Canadian Journal of Fisheries and Aquatic Sciences* **42**, 1096-1102.

James M. R. (1985) Distribution, biomass and production of the freshwater mussel, *Hyridella menziesi* (Gray), in Lake Taupo, New Zealand. *Freshwater Biology* **15**, 307-314.

Jones P. D. and Momot W. T. (1981) Crayfish productivity, allochtony, and basin morphometry. *Canadian Journal of Fisheries and Aquatic Sciences* **38**, 175-183.

Kusabs I., Emery W. and Butterworth J. (2010) Ohau channel diversion wall – monitoring of the kōura and kākahi populations in the Ōkere Arm and Lake Rotoiti. In: p. 13. Report number 4 prepared for Bay of Plenty Regional Council. Ian Kusabs & Associates Ltd, Rotorua, New Zealand.

Kusabs I., Emery W. and Butterworth J. (2011) Ohau channel diversion wall – monitoring of the kōura and kākahi populations in the Ōkere Arm and Lake Rotoiti. In: p. 22. Report number 5 prepared for Bay of Plenty Regional Council. Ian Kusabs & Associates Ltd, Rotorua, New Zealand.

Kusabs I. A. and Emery W. (2006) Ohau Channel Diversion Wall - An assessment of the kōura and kākahi populations in the Ōkere Arm and Lake Rotoiti. In: Report prepared for Bay of Plenty Regional Council. Ian Kusabs and Associates Ltd, Rotorua, New Zealand.

Kusabs I. A. and Quinn J. M. (2009) Use of a traditional Māori harvesting method, the tau kōura, for monitoring kōura (freshwater crayfish, *Paranephrops planifrons*) in Lake Rotoiti, North Island, New Zealand. *New Zealand Journal of Marine and Freshwater Research* **43**, 713-722.

Stenroth P., Holmqvist N., Nyström P., Olof B., Larsson P. and Granéli W. (2008) The influence of productivity and width of littoral zone on the trophic position of a large-bodied omnivore. *Oecologia* **156**, 681-690.