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Temporal Changes in the Macroinvertebrate Fauna of Two Glacial Lakes, Cootapatamba and Albina, Snowy Mountains, New South Wales

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Temporal changes in the Macroinvertebrate Fauna of two Glacial Lakes, Cootapatamba and Albina, Snowy Mountains, New South Wales

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Before 2003, unique assemblages of aquatic invertebrates in Lake Cootapatamba and Lake Albina lived in a fishless environment. A sequence of events in 2003 following a large-scale bushfire in the area allowed the native Mountain Galaxias *Galaxias olidus* to enter Lake Cootapatamba. This study determines the extent of any temporal changes in the invertebrate assemblages of each lake and whether the introduction of fish into Lake Cootapatamba affected these assemblages. The littoral and benthic fauna of both lakes were found to have changed since the earliest studies of these lakes in 1997/1998 and 1976, respectively. In particular, there has been a large decrease in the abundance of the isopod *Metaphreatoicus australis* and planarians, and the gastropod *Glacidorbis hedleyi* and amphipod *Neoniphargus* sp. have apparently disappeared. The effect is greatest in the benthos and in Lake Cootapatamba, so while fish seemed to have affected some invertebrates in some habitats, other factors may be acting. Sometime since 1976, the exotic worm *Lumbriculus variegatus* arrived into Lake Albina. Shifts in the representation of other taxa, such as ephemeropterans, plecopterans, tricopterans, dipterans and coleopterans, are thought to reflect natural year-to-year fluctuations but more data are needed.

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KEY WORDS: benthos, fish predation, *Galaxias olidus,* littoral rocks, *Lumbriculus variegatus, Metaphreatoicus australis,* Neoniphargus sp.

INTRODUCTION

The five lakes (i.e. Lake Cootapatamba, Lake Albina, Blue Lake, Club Lake and Hedley Tarn) of the Snowy Mountains alpine area (sensu Costin 1957) support a unique assemblage of invertebrates (Bayly 1970; Timms 1980a; Benzie 1984; Hancock et al. 2000; Suter et al. 2002), with a few species endemic to these lakes (e.g. *Daphnia nivalis*) and others to alpine regions (e.g. *Tillyardophlebia alpina*) (Benzie 1984; Dean 1999). Before 2003, the two west draining lakes, Lake Cootapatamba and Lake Albina, did not contain fish and as a result had a different assemblage of invertebrates, both in species composition and relative numbers, compared to other alpine lakes in the region (Bayly 1970; Timms 1980a; Hancock et al. 2000). Specifically the isopod *Metaphreatoicus australis* and amphipod *Neoniphargus* sp. were more common in the fishless lakes, particularly in the benthos, while the chironomid *Chironomus oppositus*? was only common in two lakes with fish. The summer zooplankton was dominated by the conspicuous *Daphnia nivalis* and *Boeckella montana* in the two fishless lakes, but both were absent in Blue Lake with fish (Timms 1980a; Hancock et al. 2000).

With global warming already affecting the Snowy Mountains alpine area and its lakes (Green and Osborne 2012), it is important that biodiversity is monitored over time and that the possible influence of other extraneous environmental factors is also investigated. Following the landscape scale fires of January-February 2003, log jams formed pools beneath waterfalls in many creeks throughout the Snowy Mountains (Ken Green unpublished data). The native Mountain Galaxias *Galaxias olidus* (previous identified as *G. findlayi*), possibly utilized such pools beneath previously un-scalable waterfalls in the outflowing creek to gain access to Lake Cootapatamba (Green 2008). These fish are known to prey on various terrestrial and aquatic invertebrates (reviewed in Green and Osborne 2012) and it was assumed that by 2012 any influence these predatory fish had on the invertebrates of Lake Cootapatamba would have had time to be expressed. It is fortunate that Lake Cootapatamba had been part of a 'biodiversity blitz' ten years earlier (Timms 2002) so, together with Timms (1980a) and Hancock et al. (2000), baseline data were available previous to the fish invasion. At that time both Lake Cootapatamba and the nearby Lake Albina had a similar assemblage of invertebrates with high abundances of isopods and amphipods (Hancock et al. 2000), which are known prey items of *G. olidus* (reviewed in Green and Osborne 2012).

This study aimed to reassess Lake Cootapatamba and Lake Albina to determine temporal changes in their invertebrate assemblages and whether the introduction of fish into the former lake has affected these assemblages. It was assumed that the invertebrate assemblages in Lake Cootapatamba would have changed significantly since the arrival of *G. olidus*, notably with expected reductions in the abundance of isopods and amphipods, but this would not have occurred in Lake Albina over the same timeframe since it remains inaccessible to fish.

METHODS

The littoral fauna of Lake Cootapatamba and Lake Albina (Fig. 1) were sampled on two occasions in 2012 (14 February and 3-4 December). Established sampling protocols used by Timms (1980a) and Hancock et al. (2000) were employed including, where possible, the same sites used in these previous studies to allow temporal comparisons (Fig. 1). The effect of season on comparing the results of the present and past studies was minimised by all sampling occurring within the summer months of December to February. Littoral fauna were sampled at each site using cobble picks and net sweeps in waters of approximately 10-50 cm depth. Cobble picks consisted of selecting ten cobbles of approximately 20-40 cm diameter. A net was used to capture escapees when each cobble was overturned and these along with all invertebrates picked from the under-surface of the cobble were combined into a single replicate. Cobbles resting on other cobbles were selected as those resting on sediment were found not to have epifauna beneath them. The area of the under-surface of each cobble was estimated by measuring perpendicular diameters and counts were converted to abundances per m^2. Net sweeps consisted of a single 'kick' sample at each site where a net, mesh size 0.5 mm, was immediately swept through the water above sediment that was disturbed over a 10 x 1 m area and abundances were recorded as individuals per m^2. Benthic fauna to a depth of 5 cm were sampled at each site (Fig. 1) with four replicate Birge-Ekman grabs of 225 cm^2 gape in shallow (0.5 m) and deep (2-3 m) water depths. Collected sediment was passed through a 0.4 mm sieve and the remaining benthos was sorted live and preserved in 70% alcohol for later counts and identification in the laboratory. Benthic fauna were collected on a single occasion at Lake Cootapatamba (14 February) and Lake Albina (3-4 December). In March 2013 a household sieve, mesh size ca. 1 mm, was used to check for the presence of *Lumbriculus variegatus* in the littoral of the other lakes. Biomasses were estimated by blotted wet weights using a Sartorius top loading electronic balance (±0.001 g). The shells of molluscs and cases of caddis fly larvae were removed before weighing.

Assemblages associated with littoral cobbles, littoral sweeps and benthic fauna were compared with past studies, namely Timms (1980a), Hancock et al. (2000) and Timms (2002), and differences were visualised separately for each habitat using non-metric multidimensional scaling (nMDS) ordination plots in PRIMERv6 (Clarke and Gorley 2006). Separate nMDS plots for littoral cobbles and sweeps were also used to visualise differences in assemblages among sites at Lake Albina and Lake Cootapatamba for each sampling occasion in 2012. Before analyses, data for littoral sweeps and cobbles were square-root transformed, and data for benthic fauna were fourth-root transformed to reduce the influence of numerically abundant species and increase the importance of rare species. For littoral cobbles and sweeps, a two-way nested ANOSIM (Analysis of Similarities) (Clarke and Gorley 2006), with sampling occasions nested within lakes, was used to test the null hypotheses that assemblages did not differ between Lake Albina and Lake Cootapatamba in 2012, and that assemblages in each lake did not differ between the February and December sampling occasions. In ANOSIM tests, the magnitude of the associated R-statistic value was used to offer an absolute measure of difference between paired groups. In general, if $R>0.75$, groups

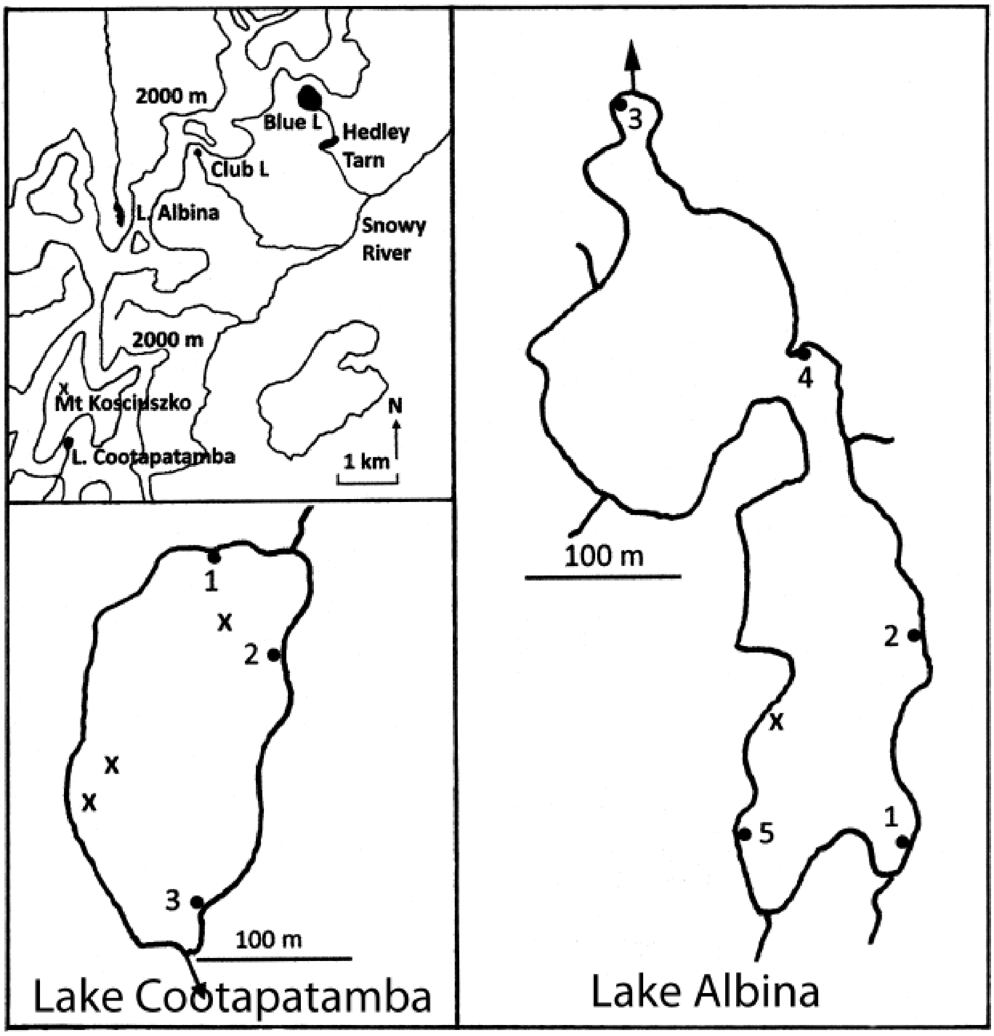


Figure 1: Index map of part of the Snowy Mountains region showing the locale of the five alpine lakes, including Lake Cootapatamba and Lake Albina. Littoral sites in these are marked with an ● and benthic sites with an x.

are clearly distinguishable, if *R*>0.5, groups overlap but are clearly different, and if *R*<0.25, groups are typically indistinguishable (Clarke and Gorley 2006). Generated *p*-values for comparing assemblages between lakes were not useful in the two-way nested ANOSIM design due to an insufficient number of permutations (i.e. 3), so a one-way ANOSIM was used instead. Both tests produced comparable *R*-statistic values but a sufficiently high number of permutations (i.e. 999) in the one-way ANOSIM provided for meaningful interpretations of *p*-values.

RESULTS

Littoral fauna

In total thirty-five taxa were found in the littoral of Lake Cootapatamba and Lake Albina with twenty-one of these occurring in both cobbles and sweep samples (Tables 1 and 2). In the littoral cobbles of both lakes there has been a substantial reduction in the abundance of platyhelminths and the isopod *Metaphreatoicus australis* since 1997-98, and the gastropod *Glacidorbis hedleyi* and the amphipod *Neoniphargus* sp., which were once especially abundant in Lake Cootapatamba, are now apparently absent from both lakes. In Lake Cootapatamba, the abundance of the trichopteran *Archeophylax ochreus* has increased and the trichopteran *Economus* sp. is now present but was not reported in previous studies (Tables 1a and 2a). In Lake Albina, plecopterans, tricopterans and dipterans have become especially abundant since Dec 97/Mar 98, and the oligocheate *Lumbriculus variegatus* is now common despite not being present in previous surveys (Tables 1b and 2b).

Table 1: Abundance of littoral fauna under cobbles in Lake Cootapatamba and Lake Albina over several years represented as numbers/m².

		a) Lake Cootapatamba				b) Lake Albina		
		Dec 97/ Mar 98#	Jan 02*	Feb 12	Dec 12	Dec 97/ Mar 98#	Feb 12	Dec 12
Platyhelminthes	Unidentified planarians	55.1	69	3.8	0.2	21.1		2.2
	Temnosewellia sp.		3					
Oligochaeta	Various tubificids[1]	1.5	5		0.2	3.5	2.1	
	Lumbriculus variegatus						2.1	16.7
Mollusca: Bivalva	*Pisidium kosciusko*		6			1.3		4.0
Mollusca: Gastropoda	*Glacidorbis hedleyi*	32.9	3			10.6		
Crustacea: Isopoda	*Metaphreatoicus australis*	19.6	61	0.7		61.6	3.3	2.2
Crustacea: Amphipoda	*Neoniphargus* sp.	128	107			0.9		
Insecta: Ephemeroptera	*Ameletoides lacusalbinae*	1.5	3		0.2	26.6	18.7	7.5
	Other Ephemeroptera[2]	31.5		20.2	14.1	11.4	4.0	18.5
Insecta: Plecoptera	*Eusthenia venosa*						1.1	0.5
	Notonemourid nymph			4.3	1.5		26.2	22.0
Insecta: Trichoptera	*Ecnomus* sp.			16.9	14.5	7.5	30.0	32.2
	Plectrocnemia sp.	5.4	2	4.1		4.3	15.5	15.4
	Austrorheithrus sp.						1.2	23.6
	Leptocerid larvae							0.1
	Archaeophylax ochreus	38.3	11	53.5	100	0.9		
	Triplectides varius		2					
Insecta:Diptera	*Procladius viliosimanus*		19			4		
	Other Chironomidae[3]					2.6	0.5	
	unidentified ceratopogonid				0.05			
Insecta: Coleoptera	*Sternopriscus* adults					1.3	1.1	4.2
	Sternopriscus larvae					5.3		
	Sclerocyphon sp.			0.7				
	Elmid adults (2 spp)					7.1		
	wet biomass (g/m²)	3.9	n/a	5.9	1.2	3.9	4.6	19.4

from Hancock et al. (2000);
* from Timms (2002)
1 includes *Antipodrilus davidis, Antarctodrilus proboscidea* and *Dero furcatus*
2 includes *Nousia* sp., *Tasmanophlebia lacuscoerulei* and *Tillyardophlebia alpina*;
3 includes *Tanytarsus* sp.

Table 2: Abundance of littoral fauna in sweeps in Lake Cootapatamba and Lake Albina over several years represented as numbers/m².

		a) Lake Cootapatamba				b) Lake Albina		
Taxa	Species (if known)	Dec 97/ Mar 98#	Jan 02*	Feb 12	Dec 12	Dec 97/ Mar 98#	Feb 12	Dec 12
Platyhelminthes	Unidentified planarians		1		0.4	1.5		0.2
Oligochaeta	Various tubificids[1]	0.3	3	3.4	0.7	0.2	5	7.3
	Lumbriculus variegatus						12.4	18.4
Mollusca: Bivalva	*Pisidium kosciusko*	0.2	2	6.2	0.2	10.7	4.3	0.2
Mollusca: Gastropoda	*Glacidorbis hedleyi*					5.4		
Crustacea: Isopoda	*Metaphreatoicus australis*	16.8	25.4	4	1.3	32.1	2.3	10.3
Crustacea: Amphipoda	*Neoniphargus* sp.	11	5.2			0.3		
Insecta: Ephemeroptera	*Ameletoides lacusalbinae*	0.2			0.8	1.7	1.3	11.8
	Other Ephemeroptera[2]	0.5	1	0.4		1.1		16.4
Insecta: Plecoptera	Notonemourid nymph	0.05		1.3	0.2	0.1	0.8	3.2
Insecta: Hemiptera	*Micronecta* sp.						1	
	Sigara sp.	0.05						
Insecta: Trichoptera	*Ecnomus* sp.			0.13	0.4	0.2	0.6	7.9
	Plectrocnemia sp.	0.1		0.23		0.3	1.3	4.1
	Austrorheithrus sp.	0.05				0.1		
	Kosreithrus sp.		1					
	Leptocerid larvae					0.1	0.5	6.4
	Archaeophylax ochreus		1					
Insecta:Diptera	*Procladius villosimanus*		2	2.3	1.4	0.5	22	12.5
	Polypedilum sp.	0.1			0.1	0.2		3.2
	Chironomus sp.		1	10.3	0.3			1
	Other Chironomidae[3]					0.4	49	15.7
	Tipulid larvae					0.05		
Insecta: Coleoptera	*Antiporus femoralis*	0.05	1	0.05	0.2			
	Unidentified Scirtid larvae	0.05						
	Unidentified Curculionid		1					
	Sternopriscus adults					0.2	2.5	1
	Sternopriscus larvae					2.6		1
	Elmid adults (2 spp)					0.4		
	Elmid larvae					0.2		
	wet biomass (g/m²)	2.6	n/a	3.6	1.8	7.8	5.3	7.6

from Hancock et al. (2000); * from Timms (2002)
1 includes *Antipodrilus davidis, Antarctodrilus proboscidea* and *Dero furcatus*
2 includes *Nousia* sp., *Tasmanophlebia lacuscoerulei* and *Tillyardophlebia alpina*;
3 includes *Tanytarsus* sp.

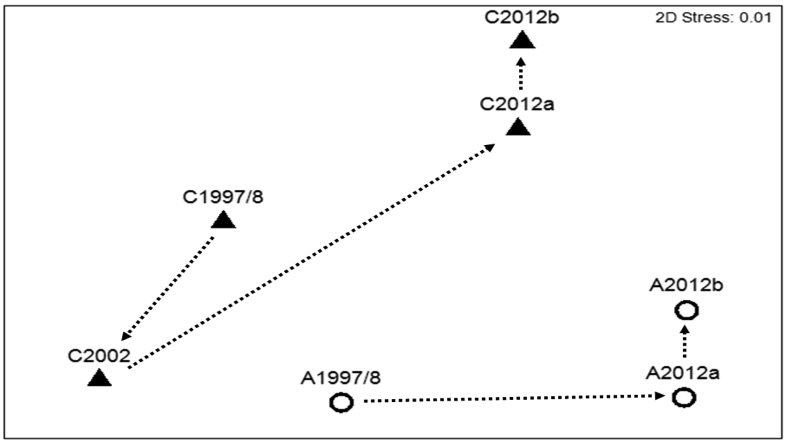
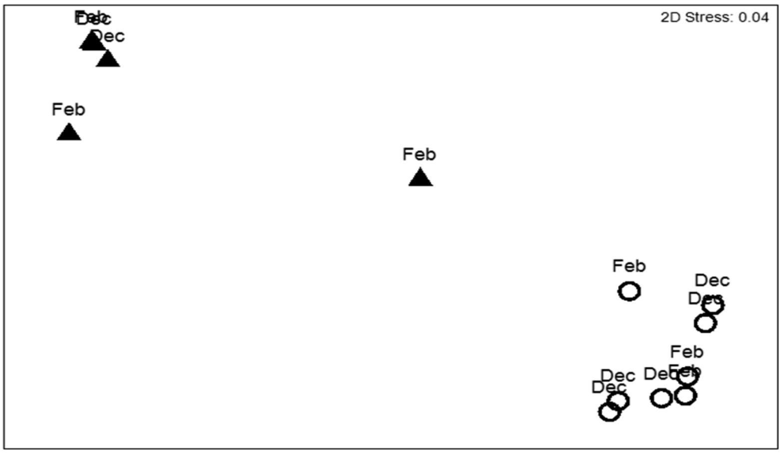


Figure 2: Assemblages associated with littoral cobbles in Lake Cootapatamba (▲) and Lake Albina (○) comparing: [a, left] previous overall assemblages (i.e. 1997/98 and 2002) with those in the present study and [b, below] site assemblages in both lakes on the two sampling occasions in 2012. In Fig. 2a, the February and December surveys in 2012 are represented as 2012a and 2012b, respectively, and arrows show progression through time.



These shifts in littoral cobble and sweep assemblages are illustrated in figures 2a and 3a, respectively, where points representing assemblages in Dec 97/Mar 98 are located toward the left of each plot and those for 2012 are located toward the right.

Proximity of points on the nMDS plot of Figure 2a revealed that the cobble assemblages of Lake Cootapatamba and Lake Albina have not diverged since Dec 97/Mar 98, as indicated by these lakes remaining a similar distance apart on the nMDS in 2012, suggesting that the magnitude of changes in the overall assemblages of one lake is reflected in the other (Fig. 2a). Assemblages collected from sweeps did reveal a divergence of points for each lake since Dec 97/Mar 98 (Fig. 3a). This divergence reflects the occurrence of taxa in Lake Albina since Dec 97/Mar 98 that are not in Lake Cootapatamba (e.g. *Lumbriculus variegatus*) and high abundances in Lake Albina of ephemeropterans, trichopterans and various dipterans in 2012 which did not occur in Lake Cootapatamba (Table 2).

The nMDS showing sampled sites at both lakes in 2012 revealed the points representing littoral assemblages in Lake Cootapatamba were located on the left side of the plot and separated from those of Lake Albina on the right for both the cobble and sweep samples (Figs 2b and 3b). ANOSIMs revealed the cobble and sweep assemblages to be different between lakes with Global R-values of 0.984 and 0.951 (both p=0.1%), respectively, and differences occurred between the February and December 2012 samples in both lakes for cobbles and sweeps with Global R values of 0.491 (p=1.8%) and 0.525 (p=0.3%), respectively.

Whilst all species are unevenly distributed around the shores associated in part with the variation in rock size and nature of the substrate (Hancock et al. 2000), numbers of *Lumbriculus variegatus* were particularly variable. It was most common along the southern shores of the Lake Albina (sites 1, 2, and 5 in Fig. 1) and almost absent for the more wave washed rocks of the northern shore and peninsula (sites 3 and 4 in Fig. 1).

Littoral biomasses in Lake Cootapatamba have remained about the same before (3.9 g/m^2) and after (1.2-5.9 g/m^2) fish gained access, with the losses due to the lower numbers of isopods and amphipods made up by increases in trichopterans and chironomids (Table 1). The same applies in Lake Albina, though in some cases values are much higher (to 19.4 g/m^2), due to many more trichopterans and *Lumbriculus variegatus* (Table 1).

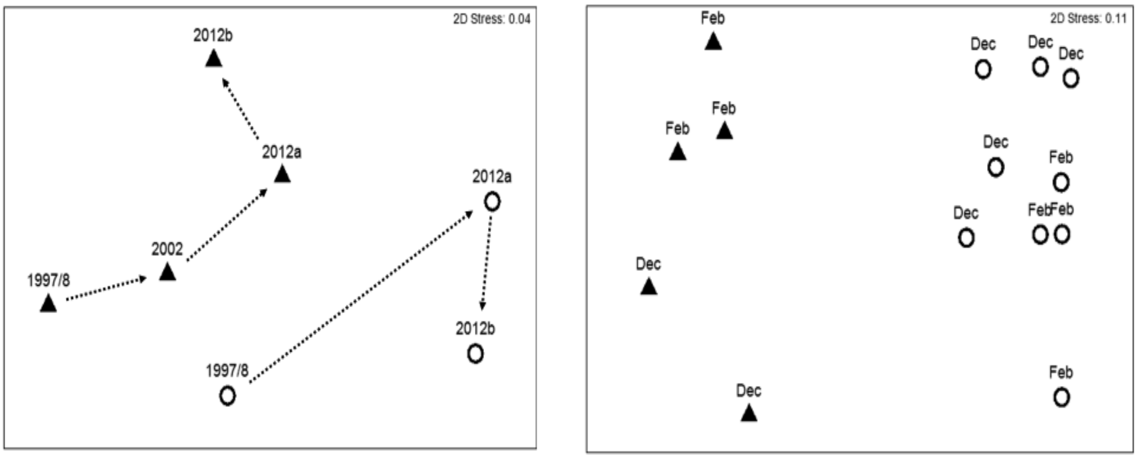


Figure 3: Assemblages associated with littoral sweeps in Lake Cootapatamba (▲) and Lake Albina (○) comparing: [a, left] previous overall assemblages (i.e. 1997/98 and 2002) with those in the present study and [b, right] site assemblages in both lakes on the two sampling occasions in 2012. In Fig. 3a, the February and December surveys in 2012 are represented as 2012a and 2012b, respectively, and arrows show progression through time.

Benthic fauna

A total of fourteen taxa was found in the benthos of Lake Cootapatamba and Lake Albina with only six shared by both lakes (Table 3). Since 1976 there has been a substantial reduction in the abundance of tubificid worms in both lakes and amphipods, which were present in previous studies, were absent from both lakes in 2012. Lake Cootapatamba had a higher abundances of chironomids in 2012 comparable with previous studies, but some of the changes (fewer tubificids and more *Procladius villosimanus*) occurred by 2002 before fish entered (Table 3). In Lake Albina the chironomid *Procladius villosimanus* and the oligochaete *Lumbriculus variegatus* are now common, the latter not being a component of the benthic fauna in 1976. Despite these changes, the nMDS plot for benthic fauna showed that overall there has been little change in the assemblages within Lake Albina since 1976 (Fig. 4). This is due largely to the presence of similar taxa in 1976 and 2012, and little change occurring in the abundance of most of these taxa (Table 3b). Major shifts have occurred in the assemblages within Lake Cootapatamba since 2002 (Fig. 4) as there has been a substantial change in the representation of taxa and in the abundance of most taxa (Table 3a).

DISCUSSION

Fish have an important role in structuring communities in lakes, none more so than changes effected by the introduction of non-native fish into naturally fishless mountain lakes (Knott et al. 1978; Donald et al. 2001; Parker et al. 2001). Historically, the three lakes in the Snowy Mountains with a long history of fish occupation (i.e. Blue Lake, Club Lake and Hedley Tarn) lack large zooplankton such as *Daphnia nivalis*, and the isopod *Metaphreatoicus australis* and amphipod *Neoniphargus* sp. are uncommon whilst the chironomid *Chironomus oppositis*? is more abundant than in Lake Cootapatamba and Lake Albina (Bayly 1970; Timms 1980a; Benzie 1984; Hancock et al. 2000). The absence of *Neoniphargus* sp. and reduced numbers of *M. australis* in Lake Cootapatamba in the present study could be attributed to fish being present post 2003 but, surprisingly, both species have suffered a similar fate in Lake Albina which still lacks fish. However, changes in *Metaphreatoicus australis* are more pronounced in the benthos where there is a major decrease in Lake Cootapatamba and none in Lake Albina. Also the change in *Neoniphargus* sp. is from a much lower number in Lake Albina and is too small to be of significance. Changes in the littoral fauna of *M. australis* in Lake Albina could have other causes: one is the additional presence of the worm *Lumbriculus variegatus* which is also a detritus feeder and another is a change in littoral aquatic plants. The latter are thought to be favoured by *M. australis* and it is possible littoral plants are less common in Lake Albina since the removal of the Albina hut and its septic system, thus reducing nutrient input (B. Timms pers. obs).

Despite evidence that the Mountain Galaxias, *G. olidus*, eats isopods and amphipods (reviewed in Green and Osborne 2012) and despite abundant evidence

Table 3: Abundance of benthic fauna in Lake Cootapatamba and Lake Albina over several years represented as numbers/m².

Taxa	Species (if known)	a) Lake Cootapatamba Feb 76# (0.5-3 m)	Jan 02* (0.3-3 m)	Feb 12 (0.3-3 m)	b) Lake Albina Feb 76# (3 m)	Dec 12 (2 m)
Platyhelminthes	Unidentified platyhelminthes				11	
Oligochaeta	Tubificid worms[1]	1096	258	274	344	110
	Lumbriculus variegatus					886
Mollusca: Bivalvia	*Pisidium kosciusko*	236	253	340	732	440
Mollusca: Gastropoda	*Glacidorbis hedleyi*				22	
Crustacea: Isopoda	*Metaphreatoicus australis*	355	704	174	444	555
Crustacea: Amphipoda	*Neoniphargus* sp.	275	11		11	
Insecta:Plecoptera	Unidentified notonemourid			7		
Insecta:Tricoptera	*Austreithus* sp.	11				
Insecta:Diptera	*Procladius villosimanus*	45	582	573	211	1100
	Chironomus ?oppositus	5	11	136		
	Chironomus sp.				33	44
	Other chironomids[2]		5	2111	322	180
Nematomorpha	Unidentified nematomorphian			22		
	wet biomass (g/m²)	9.1	14.8	7.4	7.3	10.1

from Timms (1980a); * from Timms (2002)
1 includes *Antipodrilus davidis, Antarctodrilus proboscidea* and *Dero furcatus*;
2 includes *Tanytarsus* sp.

that introduced fish in overseas mountain lakes reduce the diversity of aquatic insects, amphipods and other crustaceans (Hannelly 2009; Messner, 2013), it cannot be stated for certain that fish predation is responsible for the changes observed in Lake Cootapatamba because of some similar changes in Lake Albina. However, severe reductions in Lake Cootapatamba in the abundance of the amphipod *Neoniphargus* sp., which were historically rare in Lake Albina (Hancock et al. 2000), and the reduction of *M. australis* in the benthos of Lake Cootapatamba where they are most easily preyed upon are likely to be attributed to the introduction of *G. olidus*. Similarly, in keeping with numerous observations that large zooplankton species suffer from the introduction of fish in mountain lakes (Donald et al. 2001; Parker et al. 2001), there is strong evidence to suggest that the abundance of the large plankter *Daphnia nivalis* has been severely adversely affected in Lake Cootapatamba by the predatory activities of *G. olidus* (T. Kobayashi pers. comm.). However, in the absence of this predator, *D. nivalis* is still abundant in Lake Albina (B. Timms pers. obs.).

Surprisingly, the snail *Glacidorbis hedleyi* has apparently disappeared from both Lake Cootapatamba and Lake Albina in recent years. It is unlikely this is due to fish predation, as this snail historically occurred in fish and fishless lakes alike (Hancock et al. 2000), and also it is not a recorded prey item of *G. olidus* (Green and Osborne 2012). Numbers could be fluctuating naturally or possibly this is an expression of climate change, but data are needed on other Snowy Mountain lakes to confirm this. Given it occurs in upland areas of New South Wales and Victoria and is a coldwater species (Ponder and Avern 2000), it is a likely candidate to be affected by climate change.

Chironomids have increased in recent years in Lakes Cootapatamba and Albina. Some of the increase occurred before the fish reached Lake Cootapatamba, but *Chironomus* sp. (it may be *C. oppositus*) has definitely increased in Lake Cootapatamba since fish

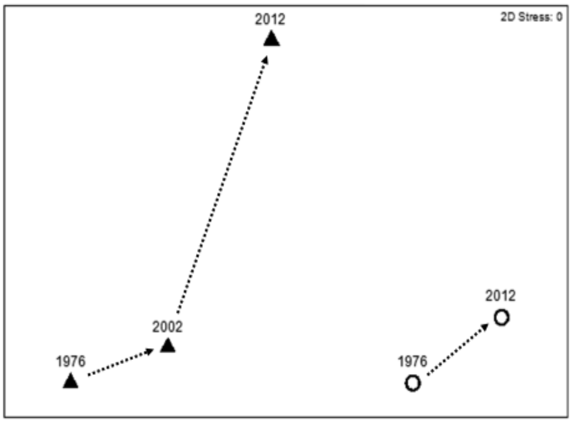


Figure 4: Assemblages of benthic fauna in Lake Cootapatamba (▲) and Lake Albina (○) comparing previous overall assemblages (i.e. 1976 and 2002) with those in the present study. Arrows show progression through time.

arrived. Given its abundance in Club and Blue Lakes with fish, this is expected. Increases in other species, largely unidenitified, are not so easily explained. Neither is the reduction in planarians on cobbles in both lakes. Some invertebrates such as the caddises *Ecnomus* sp. and *Plectrocnemia* sp. had increased numbers in 2012 compared to previous studies. The reason for these changes is not currently known but it is likely to represent natural fluctuations in the abundances of these taxa.

There is no doubt that the exotic worm *Lumbriculus variegatus*, which is still absent from Lake Cootapatamba, and also Club and Blue Lakes and Hedley Tarn, is a recent immigrant to Lake Albina. It has a widespread distribution occurring in many Australian urban ponds and streams largely due to thoughtless disposal by aquarists (A. Pinder pers. comm.), but this is the first record of its presence in the benthos of an Australian lake (Timms 1980b). *L. variegatus*, which is common in many New Zealand lakes where it often dominates (Timms 1983), is not yet abundant throughout Lake Albina, but it could well be in time. Future studies are needed to determine how this species interacts with other lake inhabitants; for instance it could be at least partly responsible for some of the changes observed in other species in Lake Albina.

Besides some major changes in abundances of some taxa over the fourteen years that sampling has occurred in Lake Cootapatamba and Lake Albina, some species appear sporadically. Such species include *Eusthenia venosa, Micronecta* sp., limnephid larvae, *Chironomus* sp., tipulid larvae and elmid beetles in Lake Albina, and *Temnoswellia* sp., *Sigara* sp., *Austrorheithrus* sp., *Kosrheithrus* sp., *Triplectides varius*, *Polypedilum* sp., a ceratopogonid, *Sclerocyphon* sp., and a curculionid in Lake Cootapatamba. Intensive sampling is needed to establish more reliable data on these species.

Whilst seasonal changes in the abundance of various invertebrates occurred in Lake Cootapatamba and Lake Albina in the present study and in the study by Hancock et al. (2000), seasonal effects on results between previous years and 2012 have been minimised by sampling at almost the same times. Assuming littoral ice is injurious to most littoral inhabitants, differential timing of winter ice breakup is likely to be important in timing the occurrence of littoral fauna. However, in the years that Lake Cootapatamba and Lake Albina have been studied this affect is probably minimal. Although the dates of ice breakup has been collected irregularly for these lakes, ice break up on the regularly monitored Blue Lake occurred within the same 7 day period in late October (Ken Green, unpublished data). However, in 1905 ice break up in Blue Lake has been calculated to have been in mid December, it was recorded in early to late November in the 1970s and now usually occurs in October (Green, 2011); these long term changes could well have affected the littoral and benthic communities. With the ice-free period increasing in the lakes with climate change (Green 2011), and with greater input of spring solar radiation into extremely clear waters unprotected by a cover of ice and snow, invertebrate life cycles and abundances could be changing, but there are no long term data to show this.

It was the aim of this study to reassess Lake Cootapatamba and Lake Albina to determine temporal changes in their invertebrate assemblages and whether the introduction of fish into Lake Cootapatamba in 2003 has since affected these assemblages. The littoral fauna and benthic fauna of both lakes was found to have changed since the earliest studies of these lakes in 1997/1998 and 1976, respectively, with increases in the abundance of some taxa, decreases in others, the apparent disappearance of some taxa and the addition of *Lumbriculus variegatus*. None of these changes can be unequivocally attributed solely to the arrival of fish into Lake Cootapatamba as the fishless Lake Albina has experienced some similar trends. However, it is likely *M. australis* and *Neoniphargus* sp. have been adversely affected, especially in habitats of simple structure where they would be more susceptible to predators. Other factors could be operating, including effects associated with warming waters and changes to ice formation/melting cycles in association with climate change, so future monitoring of these lakes is of great importance.

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