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Patterns in biodiversity of macro-invertebrates in the littoral zones of lakes Alexandrina and Albert, South Australia 2003 - 2013

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Executive Summary

Macroinvertebrate surveys are but one component of a larger monitoring program designed for the Lower Lakes (Lake Alexandrina and Lake Albert) of the River Murray in South Australia. Objectives of the monitoring program sought to assess the impacts on benthic ecology that occurred from lowering water levels, salinities and soil acidification, and consider how the benthic community would recover from such anthropogenic impacts. Data from this monitoring program was comprehensively reviewed by Giglio (2011) and the regular monitoring of littoral habitats at eight core sites continued in 2012 and 2013.

With two years elapsing since the return of the Lower Lakes' water levels from those experienced pre-drought, the key question of this monitoring was to assess how benthic communities recovered. To this end, we evualute macroinvertebrate population abundance and diversity, and how it compares to what might have occurred before the drought of 2006-2010. The approach of the investigation described in this report was to seek out trends in the data record. Major biological changes occurred in response to changing water levels and associated effects of the drought. This report aims to assess the overall re-establishment of macroinvertebrates along the lakes' shorelines, given the considerable changes that have occurred in the recent post-drought years.

An exploratory approach was used. Groups of macroinvertebrates which demonstrated clear, interpretable responses over time were extracted from the broader data set. Their patterns demonstrated evidence of both losses and gains in biodiversity, as well as indicating species which seem to have largely endured in the lakes between 2003 and 2013.

Much of the macroinvertebrate fauna re-established in the year following refill of the lakes. This demonstrated that the fauna had considerable resilience to the habitat changes experienced. Provided that this degree of resilience is maintained, the capacity for species to respond or recover from another, similar drought in future would also be maintained.

Four categories of biodiversity response are discussed; these are summarised below :

RESPONSES :	**Biodiversity Loss**	**Tolerance**	**Opportunists**	**Biodiversity Gains**
Responders :	Midges (*Zavreliella*); Wetland bugs; False spider crabs.	Worms; Amphipods; Copepods; Ostracods; "Daphnias".	Microcaddisflies.	Shrimps; Murray prawns; Ecnomid caddisflies.

The majority of South Australia's freshwater environments are characterised by the repeated onset and cessation of watering. The freshwater benthic macroinvertebrates possess a resilience borne out by broad tolerance of environmental conditions and high responsiveness following the re-watering of habitats. The reinstatement of most of the biodiversity in littoral habitats of the lower lakes is consistent with the sequential recolonisation expressed across many of South Australia's freshwater environments.

Methods

Monitoring of the littoral zones in February 2012 and February 2013 was conducted at eight sites that have been sampled at least annually since 2009 (see Appendix for site map). Macroinvertebrate samples, water chemistry data and physical habitat assessments were collected from all sites in conformance with the methods undertaken in previous years, and described in Giglio (2011). Site details are provided in the Appendix. One of the current Lake Alexandrina sites (at Milang) was also included in the 2003 -2004 study of Madden and Corbin (2004) - who also sampled the lake further to the east at Clayton. The data and images of sampling sites for the 2012 and 2013 surveys have been provided separately to the EPA.

Data Treatments

A table was assembled incorporating all macroinvertebrate data (i.e. 2009 – 2013) from the EPA monitoring program. It should be noted that some surveys prior to 2013 also collected samples from other sites. Consistent with the approach of Giglio (2011), data from Madden & Corbin (2004) were included to represent a pre-drought baseline. The Madden & Corbin (2004) data was from the Milang and Clayton sites.

Compilation of the data for trend analysis involved consideration of the following factors: site location and type; interannual sampling frequency; month of collection, as well as the frequency of the various macroinvertebrate groups in the data set. Emphasis was placed on clear and readily-interpreted patterns and no attempt was made (or claim is implied) that the data treatments were exhaustive. The interpretative text in the Results section needs to be read in this context.

The trend analysis was undertaken by means of what we term a Biodiversity Sequence (refer Tables 1 - 3). Each sequence graphically represents the presence or absence of a macroinvertebrate group in a particular sample. Samples are represented as columns, with shading of a cell denoting the presence of the macroinvertebrate group in the corresponding row. A subset of 18 or 19 macroinvertebrate groups was selected from the more than 140 taxa collected from the lakes (c.f. Giglio (2011)). The groups were chosen to reflect clear patterns evident in the broader data set, and comprise groups that have been frequently and consistently collected – for at least one phase of the recent hydrological history of the lakes. For ready interpretation, common names are presented for the macroinvertebrates; corresponding scientific names are included in the Appendix.

Several biodiversity sequences are presented, in order to show different temporal and spatial aspects of data. The most condensed version (Table 3) was developed with the goal of reducing any bias attributable to the variations in data collection programs undertaken for the program. With the exception of Clayton, it includes only sites sampled in each year of the program. For all years except 2002, only data from February were included; the absence of a February survey in 2009 prompting the substitution of the only available data – collected in May of that year.

Results

Very few of the macroinvertebrates that have been frequently or consistently collected prior to or during the drought were collected in 2011 (Table 1). The suite of macroinvertebrates present as the lakes refilled did not closely resemble either what was there before or after that time. Considering the rows in the middle section of Table 1 (Snails to Damselflies, inclusive) the composition of macroinvertebrates in the 2012-13 surveys is comparable to those of 2009 – 2010. It can thus be concluded that these macroinvertebrate groups were substantially re-assembled after the refilling phase. At the scale of sites, it is apparent that a recovery towards the pre-drought (2003 – 2004) assemblages may be in progress; the richness of these common macroinvertebrates in samples from recent years (2012-13) has increased from that of 2009 – 2010, but was still lower than that in the 2003-2004 samples (Table 1).

Having acknowledged the profoundly reduced biodiversity during the post drought refilling phase, a biodiversity sequence excluding the 2011 data was constructed (see Table 2) as well as the condensed sequence of February-collected samples in Table 3. The following comments apply to trends in the latter two sequences.

Biodiversity Loss

Three macroinvertebrate groups demonstrated a severe reduction in their distributions. Midges from the genus *Zavreliella*, whose larvae construct portable cases, as well as wetland bugs (Naucoridae and Pleidae) and false spider crabs (*Amarinus lacustris*) have not been re-collected from the Lower Lakes since 2004 (Tables 2, 3), when the lakes (operated as regulated waterbodies) had experienced decades of relative stasis in their hydrological conditions.

As well as freshwater/brackish lakes, the false spider crab inhabits lowland river habitats (e.g. Johnston & Robson, 2005). Other locations in South Australia where this species has been collected include streams in the Lake Alexandrina catchment (Tookayerta Creek, Bremer River, Mitchell Gully Creek), coastal streams of the Fleurieu Peninsula and waterways of the Lower South East (AWQC, unpublished data). The freshwater crabs are likely to be slower moving and their migration depends on flow and waterbody connectivity. The wetland bugs, Naucoridae and Pleidae prefer well vegetated swamps and lakes and find habitat amongst plant debris and submerged macrophytes. Little is known of the life history traits of *Zavreliella*, which was rated as having a restricted distribution in South Australia, and has been collected from Woods Point on the lower River Murray (Madden *et al.,* 2003).

Tolerant taxa

Several macroinvertebrate groups proved to be resilient through the course of changes experienced at the Lower Lakes. These were worms, amphipods and members of the zooplankton (copepods, ostracods and "Daphnias". Of these, copepods were the most consistently collected group (Tables 2, 3). For the majority of occasions when the littoral habitats were watered, samples included these species. All these taxa have cosmopolitan distributions, wide physiological tolerance limits, flexible life histories and the ability to undertake opportunistic breeding and migration.

Opportunists

The microcaddisflies (Family Hydroptilidae) were most commonly encountered during 2011, being collected more consistently during the refill period than either before, during or since the drought (Tables 1, 3). These results suggest that they thrived in the very low water levels and minimal vegetation prevalent at that time. The higher abundances (up to an order of magnitude greater) of these species during the refill period (provided as appendices only to date) also support the view of an opportunistic response of microcaddisflies to the environmental conditions.

The life cycle of microcaddisflies entails the hatching of eggs into the first of a series of four instars (larval stages of development, each concluding with a moult of the exoskeleton) with a thin, spidery form, covered by many bristly hairs; these early larval stages feed on planktonic algae and can be found in the water column, rather than the benthos (Wells 1985). The fifth larval instar constructs a case of silk secretion (in which it remains until the adult emerges) switches to a diet of filamentous algae and those species collected in this study are known to then adopt a benthic habit.

The strong majority of microcaddisfly larvae in samples were of the species *Hydroptila losida* and *Hellyethira malleoforma* (see also Table A2). Wells (1985) characterised their respective microhabitats as: "..in moderately to slowly flowing water, brackish to fresh, on stones and rocks, generally among filamentous green algae." (*Hy. losida*) and (for *He. malleoforma*) "...being found on stems of macrophytes in lentic waters and slow streams." Both species are widespread on the Australian continent, indicative of their broad range of tolerance to water quality and physical habitat conditions. *Hy. losida* occurs continuously across the near-coastal drainage basins of eastern and southern Australia. *He. malleoforma* is more broadly distributed – being found throughout the east coast, the entirety of southeastern Australia and in southern Western Australia (Neboiss and Wells 2002)

Of significance, while both species co-occurred before and after the drought, the only species recorded during the refill period was *Hy. losida* – which is noted by Wells (1985, p. 6) as "..one of the more tolerant [to water quality and physical habitat] and widespread forms." [of the genus] and which is known to breed in South Australia at most times of the year. The dispersal of these larvae to the lake waters could have occurred via two modes: an aerial pathway - via deposition of eggs in refill water at lake, or via drift, being transferred with inflowing water from the River Murray.

Within the refilling lakes, it is speculated that these *Hy. losida* larvae encountered an environment where planktonic algae were abundant for their early instars and populations of filamentous algae sufficient to allow the growth and development through the final aquatic stages were present. Beyond speculation, this monitoring program has provided evidence that at this time, macroinvertebrate competitors for the algal resource and macroinvertebrate predators of *Hy. losida* were reduced.

Table 1. Biodiversity Sequence (of all available samples) from pre-drought (2003-04) to recent (2012-13). Each column represents a sample, and shading in a row indicates that the corresponding taxon was present in the sample from that site visit.

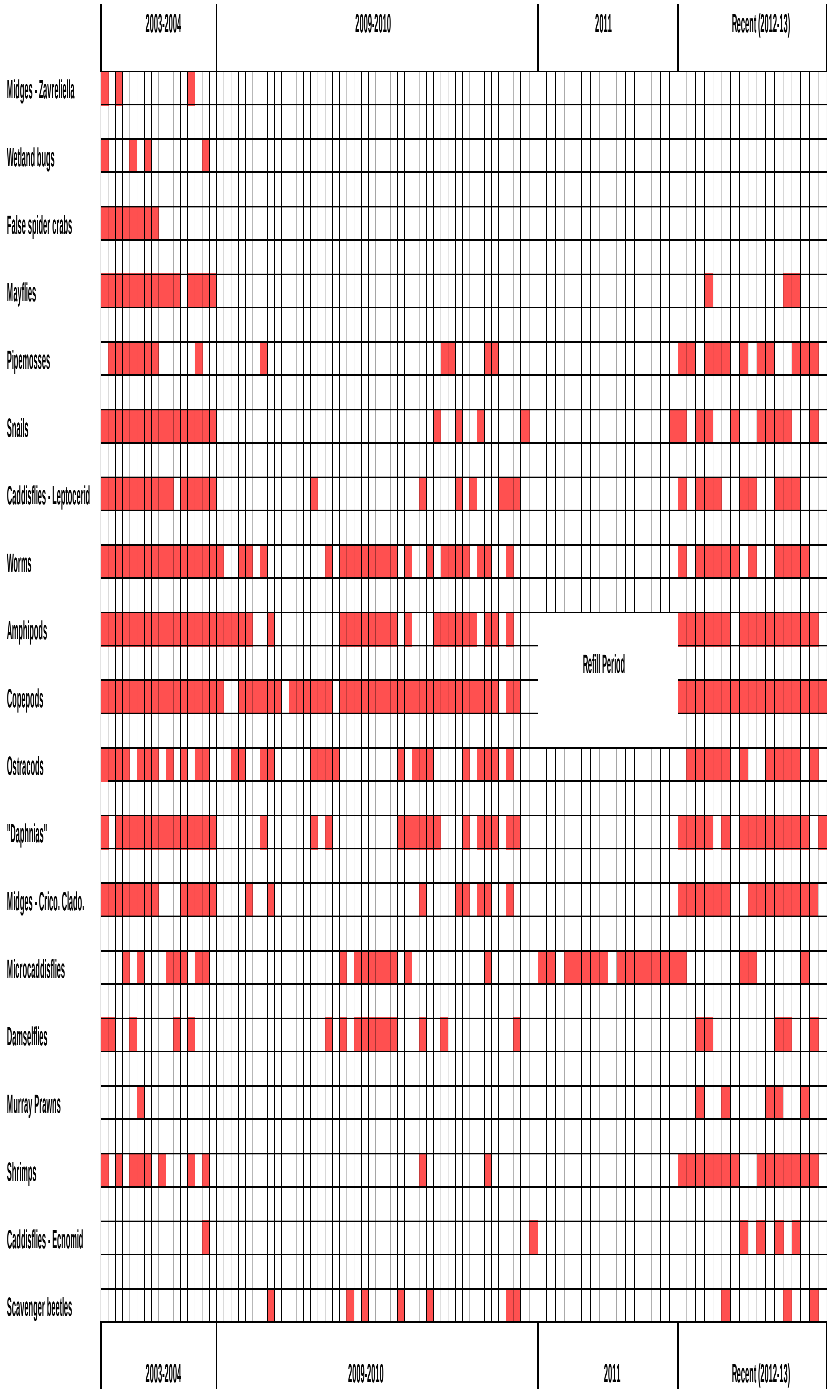


Table 2. Biodiversity Sequence (of all available samples) from pre-drought (2003-04) - excluding the Refill period (2011) - to recent (2012-13). Each column represents a sample, and shading in a row indicates that the corresponding taxon was present in the sample from that site visit.

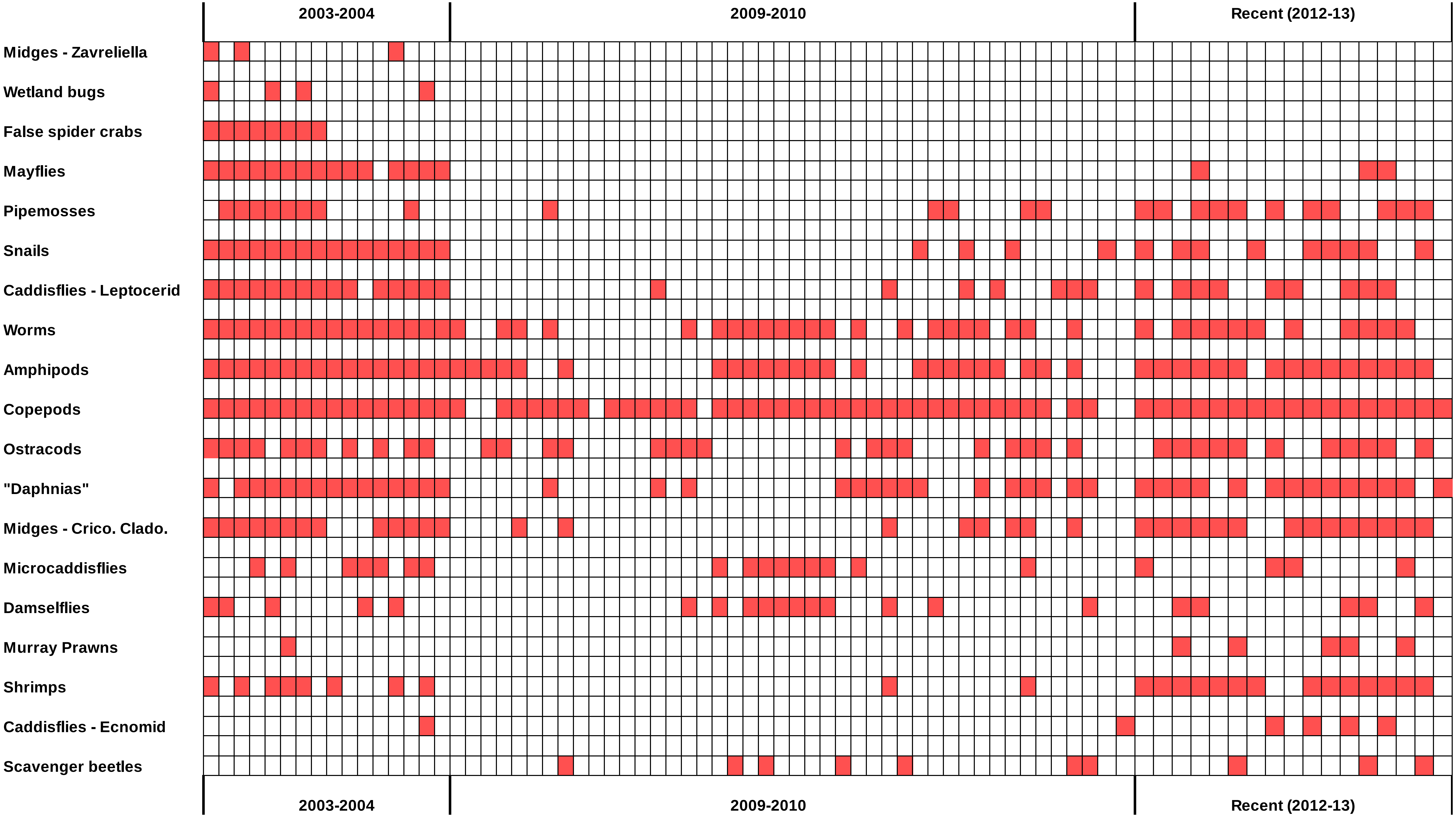
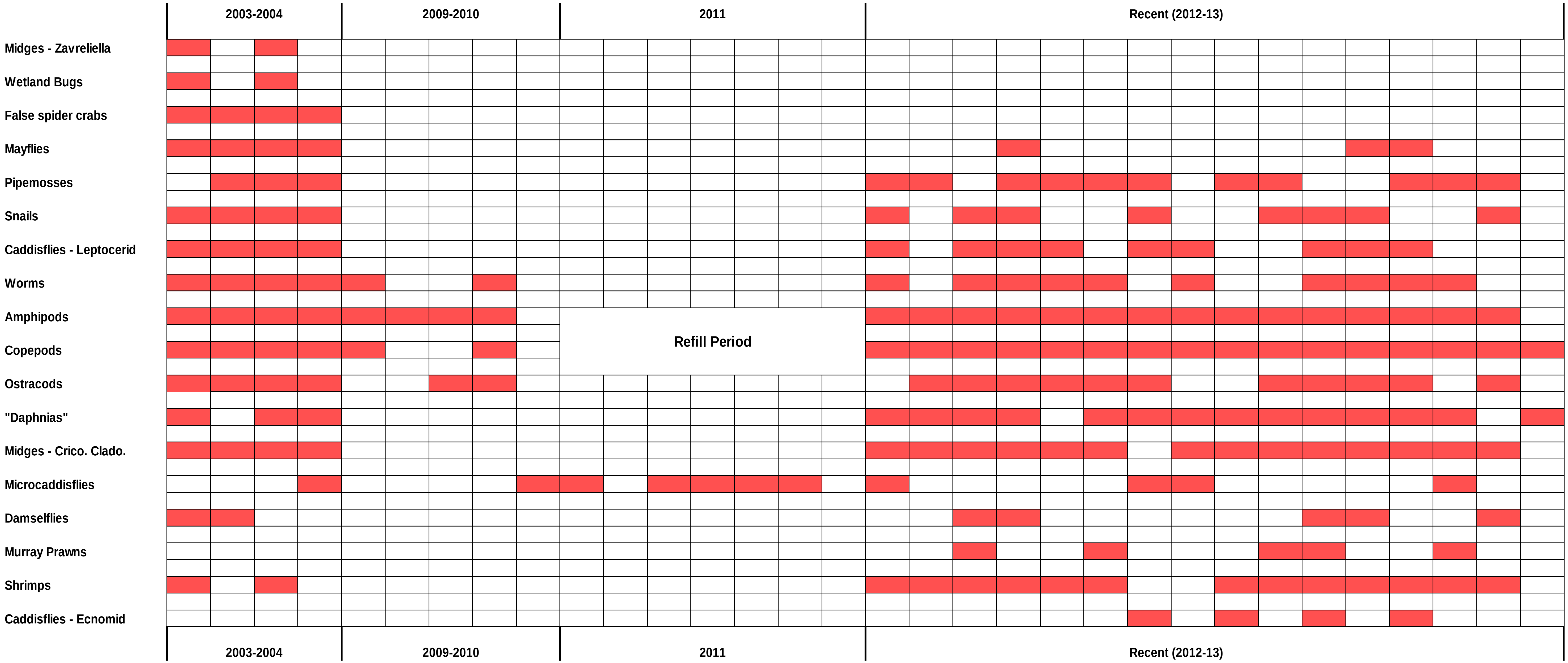


Table 3. Biodiversity Sequence of selected samples of macroinvertebrates collected during or around the month of February in the years 2003-2004 and 2009-2013. Each column represents a sample, and shading in a row indicates that the corresponding taxon was present in the sample from that site visit.



Biodiversity Gains

In comparison to earlier data, several macroinvertebrate groups have been more common in recent surveys. This applies to the shrimps, Murray prawns and caddisflies from the genus *Ecnomus* (Tables 2, 3).

Another pattern of interest was an absence of scavenger beetles in collections made prior to the drought but punctuated collections during 2009 - 10 and 2012 - 2013 (Tables 1, 2). Closer consideration revealed that the 2009 - 10 records were from different sites and times of the year to the recent records. As this resulted in a distorted pattern for the biodiversity sequence, scavenger beetles were excluded from Table 3.

Discussion

Biodiversity and drought

The progressive loss of habitat under drought conditions which culminated in the significant recession of the lake edge from the long-established shoreline was accompanied by significant declines in macroinvertebrate biodiversity. For most of the macroinvertebrate taxa investigated, by February 2012, the biodiversity was considered to have been largely reinstated, as it closely resembled data from 2003 – 2004. The results of the February 2013 survey were consistent with that from the previous year. Among some macroinvertebrate groups, the monitoring program has yielded evidence of changes in biodiversity that represent different categories of response, viz: loss; persistence; exploitation, and gains.

A risk for biodiversity management is the loss of specialist or sensitive species. Of the macroinvertebrate groups not re-collected since 2004, the false spider crabs (*Amarinus lacustris*) constitutes the greatest potential for consideration as evidence of species loss. The rationale for this position is that the species has a wide distribution at regional and continental scales, is commonly found at low altitudes, and can be locally abundant.

Further work that could be considered is some focussed monitoring of false spider crabs, addressing their recolonisation of the lakes ecosystem. This work could possibly involve placing some in the littoral habitats and tracking the outcomes.

As a data interpretation tool, the Biodiversity Sequence proved useful in demonstrating the 'bottleneck' effect of drought on taxonomic richness and diversity for the study. Partial reason for this was that the sequence permits interpretation of a simpler dataset.

A note of caution. Care should be exercised in interpreting the macroinvertebrate results from the 2011 surveys. While they represented the only available aquatic habitats, the locations sampled were clearly not within established littoral habitats, which were hundreds of metres distant. Essentially, the localities sampled in 2011 are not from the same sites in sense this term is usually employed. They certainly had a vastly different macroinvertebrate fauna. It is speculated that the contracted shoreline was a major driver in the absence in 2011 of those macroinvertebrates that have been frequently or consistently collected prior to or during the drought.

Predicted effects of future droughts

The following statements are made only in the context of the littoral macroinvertebrate monitoring program, and should not be extrapolated to other sections or elements of the lower lakes ecosystems.

Not all species present in the samples were analysed in the present study. Selection of those groups investigated was based on the greater confidence associated with interpreting their trends. The re-establishment of much of the fauna in the year following refill of the lakes demonstrates that the fauna had considerable resilience to the habitat changes experienced. Provided that this degree of resilience is maintained, the capacity for these species to respond or recover from another, similar drought in future would also be maintained.

Conceptual Models and Synthesis of Results

The majority of South Australia's freshwater environments are characterised by the repeated onset and cessation of watering (on the local scale) - with consequent variability in the extent to which their benthic habitats are inundated. That is to say (in the terms used by Larned *et al* 2010) they are *temporary* wetlands. Leigh *et al.* (2010) cite hydrological variability as a strong determinant of the structure of aquatic assemblages, noting that in Australia, dryland rivers are occupied by a suite of species adapted to dynamic conditions, and which have wide physiological tolerance limits, flexible life histories and the ability to undertake opportunistic breeding and migration. This aligns with the present authors' conceptualisation of the structuring of freshwater benthic assemblages in South Australia, which undergo booms in wet times. Alternately, busts occur under dry conditions. At least some species in each major group of macroinvertebrates of the State are tolerant of pollution (see Wade *et al.* 2004) and thus, they are tolerant of variation in water quality associated with such impacts (e.g. dissolved oxygen concentration, conductivity and temperature). The conditions under which this fauna evolved have played a part in this resilience to variations in both water quality and hydrological state (McEvoy and Goonan 2003). Additionally, Giglio (2011) noted that the evolution of the fauna has been shaped by frequent seasonal droughts.

A less influential driver is the seasonal cue in Spring – at least in streams of the region. Each Spring, the temperature/growing season conditions correlate with a further boom in local richness and abundance (and, by extension, productivity).

The above factors have promoted the property of resilience as among the key features of aquatic macroinvertebrates. In addition to the example provided in the present study of resilience to water scarcity, we have some of persistence in the face of water abundance. Intense floods of the Torrens, Onkaparinga (and other) rivers during the Spring of 2005 prompted concern among local ecologists that habitats had been "reset" – owing to the occurrence of major channel reshaping and in-channel maintenance, with the consequent reorganisation of species assemblages, invalidating those baseline data sets, collected in the prior Autumn, to evaluate anticipated changes in response to flow alteration. To address this possibility, McEvoy and Bald (2006) re-collected the baseline data and concluded that few significant modifications were experienced. In other local experience, McEvoy and Hicks (2011) tracked and surveyed river responses to even larger events, with spilling of metropolitan reservoirs and 7-12 GL of discharge (dependent on catchment) in a fortnight. When the 'after' surveys were made, it was concluded that, at the scale of a 100 metre long river section, sites appeared to be substantially the same as when first surveyed. These learnings informed development of hypotheses and expectations of ecologists regarding anticipated outcomes from

Western Mount Lofty Ranges environmental water trial – in which the likelihood and functionality of high flows making significant transformations (e.g. in reducing choking beds of emergent *Typha* and *Phragmites*) has been greatly downgraded.

To summarise, the freshwater benthic assemblages in South Australia largely conform to the Field of Dreams hypothesis (Palmer *et al.* 1997) – hypothesis: "if you build it, they will come." borne out. This is facilitated through a resilience borne out by broad tolerance of environmental conditions and high responsiveness following the watering of habitats at which macroinvertebrates were previously extirpated.

In conclusion, the substantial reinstatement of most of the macroinvertebrate biodiversity in littoral habitats of the lower lakes is consistent with the sequential recolonisation expressed following watering of previously dry habitats across many of South Australia's freshwater environments.

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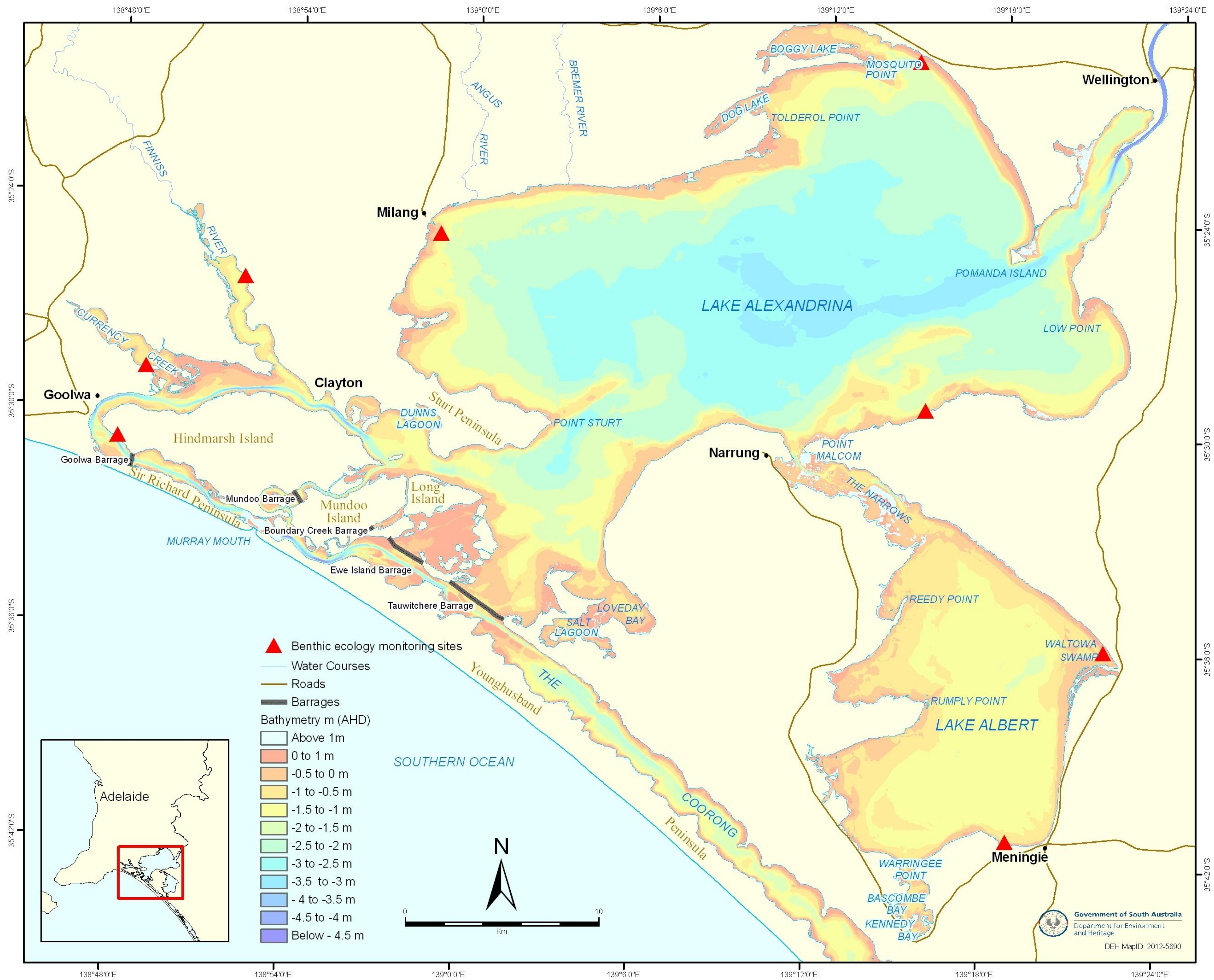
Appendix

Sites

Eight sites were sampled in 2012-2013, distributed relatively evenly around the lakes (see Appendix for site map and Table A1 for descriptions of site locations).

Table A1. Details of sites sampled during February of both 2012 and 2013.

Waterbody	Site
Finniss River	Glengrove Rd
Goolwa Channel	Opposite Goolwa on Hindmarsh Island
Currency Creek	No. 53 Fidock Rd
Lake Alexandrina	Western edge of Lake Alexandrina, south of Milang
Lake Alexandrina	At Poltalloch
Lake Alexandrina	Track off Wellington to Langhorne Ck Rd (opposite junction with Flagstaff Rd)
Lake Albert	North Waltowa, track off Princes Hwy, opp. junction of former Koorinpin Rd (now Granite View Rd)
Lake Albert	Warrengie Drive



2012-13 Monitoring sites

Table A2. Scientific names corresponding to the common names used in the report.

Common name in report	Scientific names
Midges - Zavreliella	Chironomidae: *Zavreliella* sp.
Wetland Bugs	Naucoridae: *Naucoris* spp. ; Pleidae: *Neoplea* sp.
Naucorid Bugs	Naucoridae: *Naucoris* spp.
False Spider Crabs	Hymenosomatidae: *Amarinus lacustris*
Mayflies	Caenidae: *Tasmanocoenis* spp.
Pipemosses	Clavidae: *Cordylophora* spp.
Caddisflies - Leptocerid	Leptoceridae: *Triplectides* spp., *Oecetis* spp., *Notalina spira*
Worms	Oligochaeta spp.
Amphipods	Ceinidae spp.; Corophiidae spp.; Eusiridae spp.
Snails	Hydrobiidae spp.; Lymnaeidae spp.; Physidae: *Physa acuta*; Ancylidae: *Ferrissia* sp.
Copepods	Copepoda spp.
Ostracods	Ostracoda spp.
"Daphnias"	Daphniidae spp.
Midges – Crico. Clado.	Chironomidae: *Cladotanytarsus* spp., *Cricotopus* spp.
Microcaddisflies	Hydroptilidae: *Hydroptila losida*, *Hydroptila scamandra*, *Hellyethira malleoforma*
Damselflies	Coenagrionidae: *Austroagrion* sp., *Ischnura* spp., *Xanthagrion erythroneurum*
Murray Prawns	Palaemonidae: *Macrobrachium australiense*
Shrimps	Atyidae: *Paratya australiensis*, *Caridina* spp.
Caddisflies - Ecnomid	Ecnomidae: *Ecnomus* spp.
Scavenger beetles	Hydrophilidae: *Berosus* spp., *Enochrus* spp., *Limnoxenus* spp.