# **Supplementary Material**

**Time capsules of biodiversity: future research directions for groundwater-dependent ecosystems of the Great Artesian Basin**

Beasley-Hall, P. G.1,2\*, Murphy, N. P. 3, King, R. A.1,2, White, N. E. 4, Hedges, B. A.1, Cooper, S. J. B.1,2, Austin, A. D.1,2, Guzik, M. T.1, 2

**1 Speciose groups**

The majority of animals reliant on the SA GAB springs—ranging from completely aquatic taxa living in springs to terrestrial taxa reliant on the fringing wetland vegetation—are insects, comprising at least 72 taxa (DeBoo et al., 2019; Department of the Environment, 2022; T. Gotch et al., 2016; Mitchell, 1985; Perkins, 2005; Rossini et al., 2018). Taxonomic groups present include beetles, earwigs, flies, ants, true bugs, butterflies, lacewings, dragonflies, crickets, and booklice. Many of these records do not have corresponding species-level identifications or precise locality data. Moreover, the number of species known to be permanently associated with springs is likely far higher in actuality: several insect groups, such as the wasps and moths, have never been recorded at springs, presumably due to a lack of comprehensive surveys in the region, such surveys not taking into account seasonal differences in species compositions, and the failure to use a diverse range of sampling techniques. Members of the genus *Ochthebius*, minute moss beetles found in the Kati Thanda–Lake Eyre supergroup, are thought to be the only endemic insects to the SA GAB at the time of writing (DeBoo et al., 2019).

Compared to the insects, crustaceans have been characterized more comprehensively and comprise at least 65 taxa including amphipods, isopods, ostracods, decapods, cladocerans, and copepods (De Deckker, 1979; Guzik et al., 2012, 2019; King, 2009; King et al., 2014; Mitchell, 1985; Murphy et al., 2009, 2013, 2015; Page et al., 2007; Sokol, 1987; Stringer et al., 2019; Zeidler, 1991, 1997; Zeidler & Ponder, 1989). Notable endemics include three amphipod genera (*Arabunnachiltonia*, *Phreatochiltonia*, *Wangiannachiltonia*), two isopod genera (*Phreatomerus*, *Haloniscus*), and the ostracod *Ngarawa dirga*. Two potentially endemic, and undescribed, decapods also occur in the SA GAB: a morphologically distinct freshwater crayfish (*Cherax* sp.) found throughout the Dalhousie supergroup/complex (Zeidler & Ponder, 1989) and a shrimp (*Caridina* sp.) restricted to the Coward complex of the Kati Thanda–Lake Eyre supergroup (Mitchell, 1985). We note the latter may also occur in a locality outside of GAB springs based on preliminary molecular data, though this remains to be clarified using data from Coward complex specimens (Page et al., 2007).

**2 Other invertebrates**

**2.1 Arachnids**

Mites, spiders, and pseudoscorpions are relatively well-documented in association with the SA GAB springs. Eight different mite taxa, the bulk of which have not been identified to species level, occur in the Kati Thanda–Lake Eyre supergroup (Greenslade, 1985). Of note is the water mite *Mamersella ponderi*, presently thought to be restricted to a single spring group (Finniss Well), making it a short-range endemic to the extreme (Fensham et al., 2010; Harvey, 1990, 1998). The spider fauna in the SA GAB springs comprises 19 taxa and is almost entirely composed of wolf spiders (Framenau et al., 2006; T. Gotch et al., 2016; T. B. Gotch et al., 2008; Greenslade, 1985). One taxon, an unidentified species in the genus *Allocosa*, is currently only known from the Kingfisher group in the Dalhousie supergroup/complex (T. B. Gotch et al., 2008). Pseudoscorpions have also been recorded at the margins of springs within the Kati Thanda–Lake Eyre supergroup (Greenslade, 1985).

**2.2 Molluscs**

Snails and bivalves represent some of the most at-risk invertebrates within the SA GAB springs per current conservation listings (see the main text). Thirty-two snail taxa are known to occur across the Lake Eyre and Dalhousie supergroups, many of which represent very divergent lineages that potentially include undescribed species (Rossini et al., 2018). These are mainly composed of populations of *Fonscochlea* and *Trochidrobia*, but other genera are also present (Clark, 2009; Clark et al., 2003; Ponder et al., 1995; Zeidler & Ponder, 1989). An undescribed species of bivalve in the genus *Arthritica* also occurs within the Kati Thanda–Lake Eyre supergroup (Department of the Environment, 2022).

**2.3 Smaller taxonomic groups**

At least seven species of springtail (Collembola) (Greenslade, 1985), found in the Welcome (Wangianna) and Emerald groups of the Kati Thanda–Lake Eyre supergroup, and two species of flatworm (Sluys, 1986) occur in association with SA GAB springs. An unidentified species of *Temnocephala* flatworm is thought to be commensal with the crayfish *Cherax* sp. mentioned above (Zeidler & Ponder, 1989). Notably, the flatworm *Macrostomum palum* is a GAB spring endemic and potentially only found in the Coward complex in the Kati Thanda–Lake Eyre supergroup, though it might occur in two additional, unnamed complexes (Fensham et al., 2010). An unidentified species of rotifer (*Branchionus* sp.) is known from the Neales River complex in the Kati Thanda–Lake Eyre supergroup (Greenslade, 1985).

**3 Vertebrates**

**3.1 Birds**

Sixty-six bird species have been recorded around major spring complexes in South Australia (Badman, 1985; Kovac, 2003). Species range from putative spring residents–mostly waterbirds–to infrequent, opportunistic visitors with widespread global distributions. Resident nesting species (those that use the GAB springs for breeding) include the Australian shelduck (*Tadorna tadornoides*), Australian crake (*Porzana fluminea*), masked lapwing (*Vanellus miles*), and clamorous reed-warbler (*Acrocephalus stentoreus*), which occupy well-vegetated, fenced springs in the Kati Thanda–Lake Eyre supergroup (Badman, 1985). The sedge *Cyperus laevigatus* is thought to provide important bird habitat in this area, particularly for inland waders, as birds have been observed using the species for concealment, foraging, and roosting (Badman, 1985). Further north, rufous night herons (*Nycticorax caledonicus*) opportunistically roost in invasive date palms at Dalhousie (Kovac, 2003). The GAB notably overlaps with the Kati Thanda–Lake Eyre Basin which is a significant hotspot for migratory and Australian waterbirds, many of conservation significance. We consider it likely that many of these species that attend the Kati Thanda–Lake Eyre Basin also visit the SA GAB springs as refuges and have not yet been documented in surveys.

**3.2 Mammals**

Eight mammal species have been recorded in association with SA GAB springs from a single comprehensive survey (Zeidler & Ponder, 1989). Spring-associated mammal species include invasives (the domestic cat, European rabbit, and house mouse) in addition to multiple native species, such as the dingo (*Canus familiaris dingo*), Giles’ planigale (*Planigale gilesi*), long-haired rat (*Rattus villosissimus*), fat-tailed dunnart (*Sminthopsis crassicaudata*), and stripe-faced dunnart (*Sminthopsis macroura*). Notably, Giles’ planigales have been observed to use stands of *Phragmites* associated with springs in the Kati Thanda–Lake Eyre supergroup located on islands in the Lake Eyre South complex (Read, 1997). The European rabbit *Oryctolagus cuniculus* is endangered but is an introduced, invasive pest in the context of SA GAB springs (Villafuerte & Delibes-Mateos, 2018; Zeidler & Ponder, 1989). Invasive mammal species that pose a direct threat to the SA GAB springs via trampling include feral pigs and other grazers, elaborated on in *Section 5.2* of the main text.

**3.3 Reptiles and frogs**

Seventeen reptile species have been recorded in habitats in the vicinity of mound springs in South Australia, including 12 species from springs in the Kati Thanda–Lake Eyre supergroup (T. Gotch et al., 2016; Kinhill Engineers, 1997; Thompson, 1985; Zeidler & Ponder, 1989). Reptiles associated with springs include geckoes, skinks, monitors, and *Delma* legless lizards. Frogs are generally absent from SA GAB springs because of the salinity of the water (Kinhill Engineers, 1997), however the spotted grass frog (*Limnodynastes tasmaniensis*) has been reported as adjacent to many springs in the Dalhousie supergroup/complex (Zeidler & Ponder, 1989). The widespread desert tree frog *Litoria rubella* has been documented in association with all three SA GAB spring supergroups (T. Gotch et al., 2016).

**3.4 Fishes**

Nine fish species have been recorded in SA GAB springs, eight of which are native and one of which is introduced (mosquitofish, *Gambusia holbrooki*) (Kinhill Engineers, 1997). With the exception of the more widespread spangled perch(*Leiopotherapon unicolor*)and the Lake Eyre hardyhead (*Craterocephalus eyresi*), all species are endemic to the SA GAB springs and are at risk of decline (see *Section 3* of the main text) (Department of the Environment, 2022; T. Gotch et al., 2016; Rossini et al., 2018). The majority of endemic fishes are concentrated within the Dalhousie supergroup/complex. Fish species richness varies in different spring complexes throughout the SA springs, and native taxa occupy distinct microhabitats within individual springs (Kodric-Brown & Brown, 1993; Unmack, 2002; Zeidler & Ponder, 1989). *Gambusia* occurs within the Mount Dutton, Mount Denison, Neales River, and Peake Creek complexes within the Kati Thanda–Lake Eyre supergroup (T. Gotch et al., 2016; Rossini et al., 2018).

**4 Vascular plants**

At least 38 different plant species comprise the wetland vegetation in tails associated with SA GAB springs (Department of the Environment, 2022; Fensham et al., 2010; T. Gotch et al., 2016; Greenslade, 1985). One of these is an undescribed species of sedge (*Fimbristylis* sp.) that also occurs in association with GAB springs in Queensland (Department of the Environment, 2022). Of particular conservation concern is the salt pipewort, *Eriocaulon carsonii* subsp*. carsonii*, listed as Endangered under the EPBC Act. *E. carsonii carsonii* is endemic to the GAB springs more generally and also occurs in Queensland. Other native plant species such as *Gahnia trifida* display clear genetic signatures of restricted gene flow andextreme relictualization (Clarke et al., 2013). The native reed *Phragmites australis* is a common species associated with the springs and threatens spring flow (Lewis & Packer, 2020) and the survival of other SA GAB species, such as *Eriocaulon*, when shoot biomass is high (Davies, 2005). The coolibah and river red gum (*Eucalyptus coolabah* and *E.* *camaldulensis*) also occur in association with springs and are Near Threatened in the IUCN Red List (Fensham et al., 2019a, 2019b), but are common and otherwise widespread across Australia.

**5 Algae**

The non-vascular flora of the SA GAB springs comprise 68 different taxa, but little is known of this diversity. Algal records are largely concentrated within the Dalhousie supergroup/complex, with a small number also in Lake Eyre. Algal diversity in the springs ranges from blue-green algae (Cyanophyta, 31 taxa), microalgae (Euglenophyta, one taxon), green algae (Chlorophyta, 14 taxa), golden algae (Chrysophyta, one taxon), and diatoms (Bacillariophyta, 21 taxa) (Ling et al., 1989; Skinner, 1989). Notably, at Dalhousie there is an undescribed species of the diatom *Hyalodiscus* as well as a distinct morphological form of the colonial cyanophyte *Gomphospaeria* *aponina* similar to specimens recorded in Indonesia (Ling et al., 1989). Both of these taxa are apparently restricted to a single spring group (Donkey Flat and Ilpikwa, respectively).

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