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The enigmatic Salamanderfish in acidic, ephemeral peat swamps of south-western Australia

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The Salamanderfish (*Lepidogalaxias salamandroides*) was first described in 1961 and was tentatively placed in the Galaxiidae as a 'scaly-galaxiid' (Mees, 1961), however, it is clearly unique and has since been designated the sole member of the Lepidogalaxiidae (see Frankenberg, 1969; Rosen, 1974; McDowall and Pusey, 1983). The species' taxonomic position has been the subject of many studies and, based on mitochondrial genomes, it is currently regarded as occupying a basal position among all euteleosts (Li et al., 2010). The species is enigmatic, occupying a small band of acidic (pH 3-7.4), ephemeral peat swamps on the extreme south coast of Western Australia, where it undertakes an annual aestivation when these habitats dry during summer and autumn (Berra and Allen, 1989; Pusey, 1989, 1990; Morgan et al., 1998, 2000).

Remarkably, individual Salamanderfish must withstand one (26% of males, 28% of females) or two aestivation periods, lasting up to six months, prior to reproducing at the end of their first or second year of life (Pusey, 1990; Morgan et al., 2000). Fertilisation is internal and facilitated by a uniquely modified anal fin in males that is strongly folded to the left or right and bounded by a scaly sheath (McDowall and Pusey, 1983; Pusey and Stewart, 1989). While males attain 50 mm total length (TL), females grow much larger (80 mm TL) and fecundity is low (mean = 82 eggs) (Morgan et al., 2000). Spawning occurs between late autumn (May) and late winter (August) soon after individuals emerge from aestivation (Morgan et al., 2000). Larvae hatch after about three weeks at 5.5 mm TL with a fully functional mouth, well-developed and pigmented eyes, a moderate yolk sac, and well-developed pelvic fins that allow it to prop its head above the substrate to search for food (see Gill and Morgan, 1999). Additionally, the eyes are immovable, which is presumably linked to the ability of the Salamanderfish to bend its neck at right angles to aid in the search of food in highly tannin-stained waters (Berra and Allen, 1989). Ontogenetic changes in diet have been observed, with larvae (6-19 mm TL) consuming cladocerans, copepods, ostracods and dipteran larvae, with the range of prey items increasing in juveniles and adults (see Gill and Morgan, 2003).

Climatic drying over the last few decades has resulted in the habitats of this unique species receiving reduced rainfall, which has been implicated in its range being drastically reduced (Morgan et al., 1998; Ogston et al., 2016). For example, between the 1990s and 2016 the area of occupancy (AOO) declined from an already low 72 km^2 to just 21 km^2, while its extent of occurrence (EOO) decreased from 12,829 km^2 to just 2,640 km^2 (Ogston et al., 2016). The creation of additional pools, including those used to supply water for combatting wildfires, may be vital in preventing the foreseeable extinction of this species, along with the intrinsically sympatric Blackstriped Dwarf Galaxias (*Galaxiella nigrostriata*); the only other aestivating fish in this Mediterranean climatic region. Their recent, climate driven range reduction has led to both species being listed as Endangered by the International Union for the Conservation of Nature (Morgan and Beatty, 2019a, 2019b).

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Picture 1. A male Salamanderfish (*Lepidogalaxias salamandroides*) is readily distinguished from females by the presence of an enlarged and specialised anal fin modified for copulation (see McDowall and Pusey, 1983; Pusey and Stewart, 1989). While assuming a benthic position from hatching, the enlarged pelvic fins support the body and prop the head above the substrate to assist in the search for food, which, along with a bendable neck compensate for the fish having immovable eyes (Berra and Allen, 1989; Gill and Morgan, 1999, 2003). Photograph: Gerry Allen.

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Picture 2. The Blackstriped Dwarf Galaxias (*Galaxiella nigrostriata*), is usually sympatric with the Salamanderfish in ephemeral peat swamps along the south coast of Western Australia (Morgan et al. 1998; Ogston et al. 2016). They develop a bright yellow-orange lateral stripe bordered by black stripes during the late-autumn and early winter breeding period, and also aestivate during the dry summer and autumn months; however, there is little known regarding the mechanisms behind the aestivation process in this species. Photograph: Gerry Allen.

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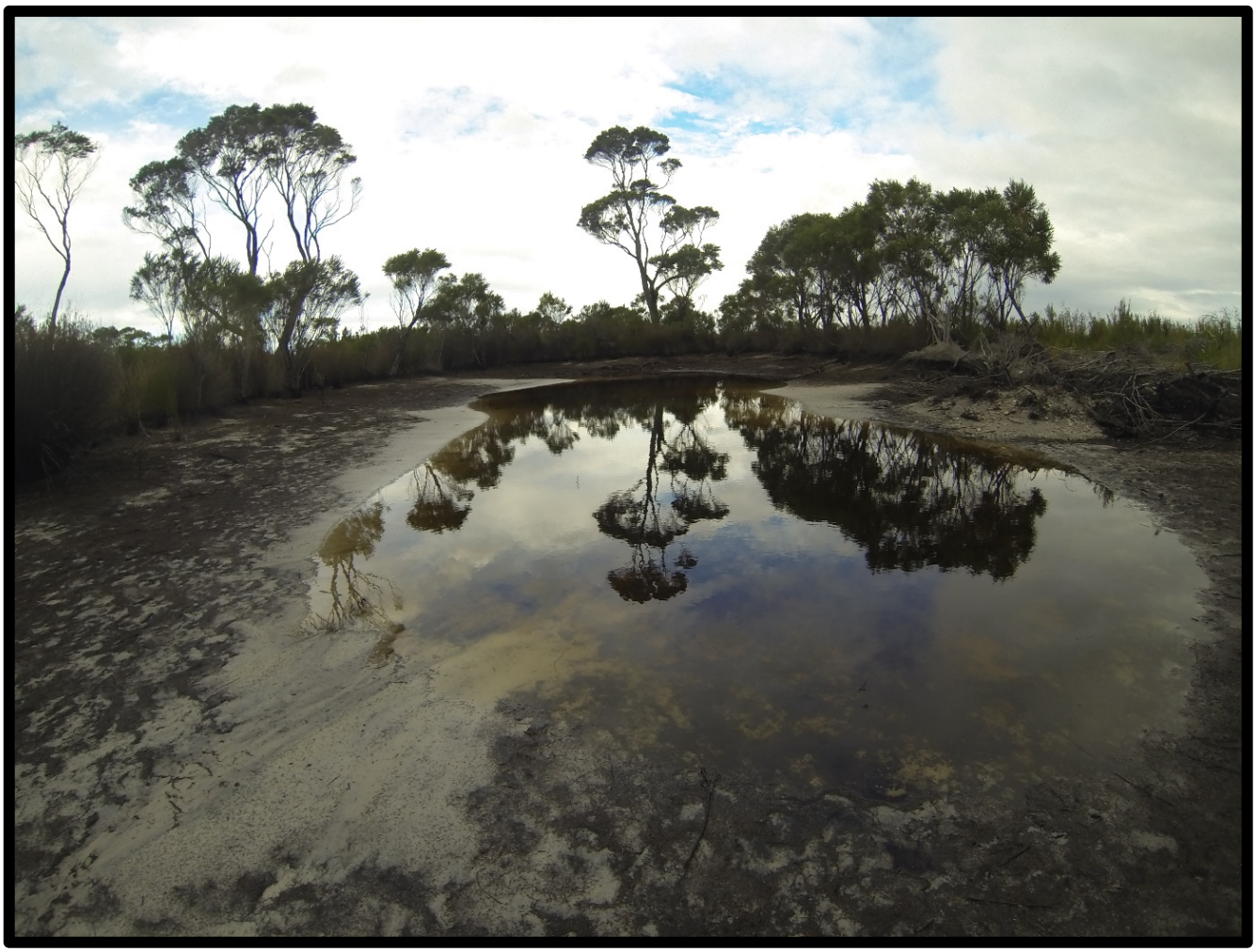

Picture 3. Typical habitat of the Salamanderfish (*Lepidogalaxias salamandriodes*) and Blackstriped Dwarf Galaxias (*Galaxiella nigrostriata*). Aestivation in Salamanderfish occurs during the long, dry summer and autumn period characteristic of the Mediterranean climate of south-western Australia. Burrowing and aestivation is facilitated by a robust, wedged shaped skull, gaps between the skull and first vertebra and between adjacent vertebra, reduced ribs (resulting in a flexible body) and an ability to secrete mucous over its body as it 'cocoons' itself in a U-shaped position underground (Berra and Allen, 1989; Pusey, 1989). Photograph: David Morgan.

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Picture 4. Typical appearance of Salamanderfish habitat during summer and autumn. After burrowing, aestivating Salamanderfish slow their metabolism and survive off stored lipids. Survival is facilitated by cutaneous respiration (Berra et al., 1989; Pusey, 1989, 1990; Martin et al., 1993). Photograph: Mark Allen.

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Picture 5. The typical habitats of Salamanderfish are darkly tannin-stained, highly acidic (pH as low as 3.4) and mostly ephemeral. Although much of the remaining habitats fall within national parks, such as the D'Entrecasteaux National Park (pictured), climate-driven decline in the number of occupied habitats has resulted in the species now having an AOO of only ~21 km^2 (Ogston et al., 2016). Many existing habitats are termed 'roadside pools' or firefighting waterpoints, which were originally dug to raise roads or to combat wild fires in this increasingly fire prone region (Morgan et al., 1998). It is suggested that dual purpose artificial habitats could be created throughout their range to aid in the prevention of the extinction of this endangered species while also providing access to water to control wild fires. Photograph: Stephen Beatty.

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