The enigmatic Salamanderfish: living on burrowed time

case study

A male Salamanderfish (*Lepidogalaxias salamandroides*).
Note the modified anal fin, which acts to convey sperm for the internal fertilisation of female fish
(Photograph: Gerry Allen)

The Salamanderfish, *Lepidogalaxias salamandroides,* is the sole member of the Lepidogalaxiidae, an ancient family of teleost fish with links to Gondwana that was first discovered in 1961 in the ephemeral pools and ditches of the acid peat flats of south-western Australia's southern forests (Mees, 1961).

Restricted to shallow pools and wetlands between the Blackwood and Kent Rivers, it was listed in 2016 under the Wildlife Conservation Act 1950 as Endangered, as a result of a recent decline in its range.

The enigmatic Salamanderfish has puzzled scientists since its discovery, its name *Lepidogalaxias*, meaning 'the scaled galaxiid' led to the placement into its own family due to no previously recognised galaxiids having scales (Paxton & Eschmeyer 1998).

This strange little fish has many unusual features, including eyes that are 'fixed' in place, unable to move in their orbits, as the skin is continuous from the surface of the head and over the eyes and there is no circumorbital sulcus (which allows rotation of the eyeball) around the eyes, which is found in almost all vertebrates, and it lacks external eye muscles (McDowall & Pusey 1983).

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The reasons for this rare morphological adaptation are unknown, but perhaps it may be related to the ephemeral, tannin stained and highly acid habitats in which it lives.

To overcome the constraint of having immovable eyes, this fish has developed the ability to bend its neck at right angles to search for food; facilitated by large gaps between the first few vertebrae behind the head (Frankenberg 1969).

The Salamanderfish is commonly named for the ability to survive the seasonal drying of its habitats, which may remain dry for up to at least 6 months (Morgan et al. 1998, 2000).

It survives desiccation by burrowing into the substrate and aestivating, which is aided by the secretion of a mucous sheath around its body (Pusey 1989).

Burrowing may be either facilitated by the head or tail first and the constructed burrow considered pear-shaped and connected to the surface by a thin tube, within which the fish assumes a U-shaped posture (McDowall & Pusey 1983).

Burrowing is believed to be aided by a robust wedge-shaped skull, a flexible vertebral column and a reduced number of ribs (Berra & Allen 1989).

Cutaneous respiration, atypical sperm morphology, internal fertilisation via a uniquely modified anal fin in males, large eggs with low fecundity and large size at hatching where they almost resemble miniature versions of their adult morphology have aided in persisting in the peat swamp ephemeral habitats (McDowall & Pusey 1983; Leung 1988; Morgan *et al*. 2000; Gill & Morgan 1999).

Breeding occurs almost immediately after the first autumn or winter rains inundate their previously desolate habitats, which vary from small ditches, to large pools and flood waters of some of the regions pristine lakes (Morgan *et al*. 1998, 2000).

The females (maximum size of 80 mm in total length) grow much larger than the diminutive males, which rarely exceed 50mm; their longevity is not beyond 5 years, and most individuals must aestivate through at least one summer before breeding (Morgan *et al*. 2000).

Typical Salamanderfish habitat in the D'Entrecasteaux National Park
(Photograph: David Morgan)

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Past, present and future

Since the 1970s rainfall in south-western Australia has declined by 10- 15% percent (Charles *et al*. 2010). This has been associated with declines in both stream flows and wetland depths in the region that are proportionally greater than the reduced rainfall.

Across the broader south-west, wetland depths have declined by about 3 cm per year over the last 20 years (Lane *et al*. 2017 with additional analyses in progress).

This is a concerning trend given that most wetlands in the south-west rarely exceed 2 metres in depth. This has often resulted in more frequent wetland drying, increased salinity and occasionally acidification through exposure of acid sulfate soils (e.g. Cale & Pinder, 2018).

Flows in streams and rivers have similarly declined over this period and this has largely been attributed to declining rainfall.

Many species of plants and animals are dependent on the present of surface water in streams or wetlands. In the south-west of Western Australia this includes a range of fish and frogs, a large number of invertebrates (including several crayfish species) and a component of the south-west's renowned plant diversity.

Some of these are listed as threatened species and they are increasingly imperilled by reduced water availability and declining water quality.

The Salamanderfish exclusively occupies wetlands within this drying climatic region. The species has suffered a severe decline in its range through the loss of populations in the last two decades (Morgan *et al*. 1998; Ogston *et al*. 2016).

The persistence of remnant populations of the species is directly associated with the local climate (Ogston *et al*. 2016). Specifically, persistence of populations is positively associated with depth of wetlands and negatively associated with the length of the period of drying.

Stable isotope analysis found the hydrology of the pools were influenced by winter rainfall rather than deep aquifers thus the projected ongoing decline in winter and spring rainfall will continue to negatively impact the species.

Conservation & on-ground actions

While there have not been any documented on-ground actions undertaken for the species, prioritising remnant populations for protection is crucial.

More fine-scale surveys to monitor existing distribution are also required, in addition to wide spread surveys of remote and often inaccessible (due to seasonal flooding) habitats.

Artificial habitat creation may also help the species along with potential captive breeding.

Threats

Past and continued reductions in rainfall reducing the depth of wetlands and the depth to groundwater of ephemeral systems is the main threat.

Other impacts include riparian destruction, introduced species (e.g. feral pigs) salinisation, deforestation, and increased frequency and intensity of bushfire are all additional threats to the species.

Trend, condition & information reliability

Trend: Severe loss of extent of occurrence (79% reduction) and area of occupancy (70% reduction population) over the past 40 years.

Condition: Poor ~25 %

Information reliability: Good. Past historical surveys including Morgan et al. (1998) and recent peer-reviewed study by Ogston et al. (2016) compared past and current distribution. The latter study modelled factors explaining species persistence.

Reasonable biological information on biology exists.

Knowledge gaps include refining the thresholds for survival (depth to groundwater, maximum aestivation periods) under reduced rainfall and groundwater level scenarios and spatially identifying populations most at risk by undertaking species distribution modelling in relation to groundwater models.

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Lakes Smith, Wilson and Jasper. Salamanderfish were recorded by Morgan *et al.* (1998) in the ephemeral floodwater east of Lake Smith (foreground)
(Photograph: Stephen Beatty)

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