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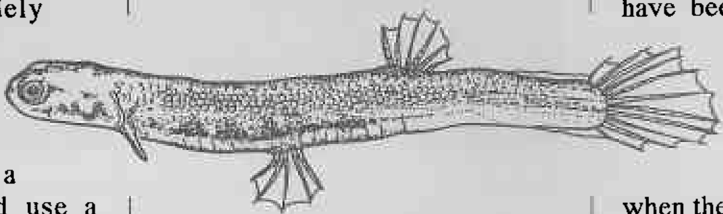
THE AESTIVATING SALAMANDERFISH

WHERE DO ALL THE FISH GO?

by Graham Thompson and Philip Withers

MANY species of fish have been reported to hibernate in response to cold, or aestivate (a form of hibernation to avoid desiccation) in response to heat and dryness; aestivation is particularly common for fish in ephemeral water bodies. The most widely reported aestivating fish are the African and South American (but not the Australian) lungfish. These large fish form a cocoon in the mud and use a modified swim bladder (lung) for aerial respiration.



L. salamandroides

There are eight endemic species of fish in the rivers, creeks, and waterways of the southwest of Western Australia as well as a number of exotic species. The endemic fish fauna of the south-west is unique in many ways, with at least two of these species aestivating when the ponds and creeks dry up in summer.

The two small fish known to aestivate are the salamanderfish (*Lepidogalaxias salamandroides*) and the black-striped minnow (*Galaxiella nigrostriata*). Both fish are found in shallow, ephemeral, peaty swamps that are characterised by low pH and high dissolved organic content. When the small peaty swamps and creeks dry up, the two fish "disappear"; they return when the depressions fill with water during the subsequent winter months. The stimulus that triggers these fish to burrow and aestivate, and their associated physiological responses, is not well understood.

The salamanderfish has a wedge-shaped skull and very flexible vertebral column to facilitate burrowing into the peaty sands of the area. In addition, males internally fertilise the eggs of females, which is perhaps an adaptation to the acidic environment. Most fish live for two years but some can survive for up to four years. Females spawn in August September, with juveniles increasing in size until they mature with a snout to vent length of 67mm. They feed on mainly aquatic crustaceans. The lack of permanent water means that in most habitats the salamanderfish has no large fish predators. However, the abundant freshwater crayfish (*Cherax preissii*) will certainly eat them, as will wading birds.

Less is known about the black-striped minnow. These fish have not be shown to aestivate in captivity (as has the salamanderfish), nor have they been dug up from the mud. They do, however, appear shortly after the first rains or when pools have been artificially filled with water. It has been suggested that this fish might use the extensive subterranean burrows of the freshwater crayfish when the surface water disappears, rather than aestivating in dry soil. They feed primarily on flying ants and aquatic crustaceans. Spawning occurs between June and September.

Aestivating fish face a number of major physiological problems, including water balance, excretion or accumulation of metabolic wastes, and economy of energy. The high content of decaying organic materials in the ephemeral swamps of the southwest of Western Australia is likely to reduce the availability of oxygen in some of these waterways.

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A shallow, ephemeral pond typical of the habitat of L. salamandroides. *The water is generally black or darkly stained so there is no possibility of seeing the fish in the water.*

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Our study investigated the metabolism of these fish in water and in air, and under conditions of decreased oxygen availability as might be experienced in their natural environment. We found that when lying still in water, the salamanderfish has a metabolic rate of approximately double that in air. As available oxygen is reduced, metabolic rate decreases in both water and in air. It is not known for how long the salamanderfish can sustain these low levels of oxygen consumption as carbon dioxide production remains high. These high carbon dioxide production rates compared with the oxygen consumption rates suggests that at low oxygen concentrations, the salamanderfish is either depending on oxygen stored in the swimbladder, or on anaerobic energy sources which can not be sustained indefinitely because of the progressive build up of lactic acid, which inhibits nerve and muscle function and promotes carbon dioxide excretion.

The lower metabolic rate of the salamanderfish in air may be due to a physiological inability to supply oxygen or, it may reflect a lower demand for oxygen. In moist air, salamanderfish will generally remain motionless on the substrate. The transfer of gases is presumably across the skin, therefore there is no requirement to pump water or air across the gill filaments, consequentially saving in the energy requirement.

Many animals that aestivate (e.g., desert frogs and snails) can reduce their metabolic rate to about a fifth of their basal level as an energy conservation strategy.

During extended periods of inactivity confined to a small burrow, it would be advantageous for the salamanderfish to conserve its energy reserves by reducing its metabolic rate. Earlier research suggests that the salamanderfish uses its lipid (fat) reserves as the primary energy source during

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extended period of aestivation. Lipids are also the energy resource used by females for egg production within a couple on months of emerging from aestivation. The long term survival of the species would be enhanced by increased egg production, and therefore minimising the metabolic demand and stored lipids during aestivation could increase fecundity.

Where to from here? Nothing is known of the trigger that causes salamanderfish to aestivate. Large fish often disappear first, long before the ponds are completely dry suggesting that the stimuli for aestivation might not be the drying up of the ponds. Efforts to induce the fish to aestivate in a laboratory have been unsuccessful. The exact location of aestivating salamanderfish is also unknown, as our excavations of the dried mud in the areas of the last surface water failed to locate any fish. The next stage of our research is therefore to locate aestivating salamanderfish. This will give us the opportunity to explore further the physiological adaptations of these fish that have evolved to enable survival for months out of water, perhaps in a moist burrow, in a thick layer of mucus, with a lowered metabolic rate. Laboratory studies of animals can not always replicate what is actually occurring in the field. It is therefore important to confirm the results from laboratory studies with field data.

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