Threatened Species Recovery Hub
National Environmental Science Programme

The impacts of bushfire ash and sediment on freshwater fauna

In brief

Bushfires can destroy riparian vegetation, and result in elevated water temperatures, stream bank erosion and an increase in ash-laden sediment entering the water. Addition of nutrient-rich sediment can promote algal blooms and bacterial growth, which decrease aquatic oxygen levels. There are currently no data available on how this impacts Australian freshwater fauna.

We assessed how exposure to ash and sediment impacted four freshwater fish species, four crustacean species and three frog species through a series of experimental trials.

We investigated impacts to fish and crustacean physiology, performance and gill structure and tolerance to elevated water temperatures and low oxygen levels. For frogs we investigated tadpole and frog growth, development and swimming performance.

Chronic ash and sediment exposure significantly reduced many fish and crustacean species' tolerance to high temperatures and low aquatic oxygen levels. It also reduced the survival of striped marsh frog embryos and increased the energy consumption of striped marsh frogs and graceful tree frogs.

Our results revealed that fish and crayfish species from cooler climates or high-altitude populations are at greater risk from bushfire-induced changes to aquatic thermal and oxygen levels than are more broadly distributed and/or lowland species.

Many fish, frog and crustacean species appear highly vulnerable to the indirect effects of bushfires, but the relatively high risk is species- and life stage–specific. This study can be used to inform freshwater management, particularly for highly threatened species impacted by bushfires.

Restricted species of crayfish from cooler climates or high altitude are likely at great risk from the impacts of bushfires. Image: Daniel McCawley

Background

With a warming climate and the associated increases in drought-like conditions, megafires such as those experienced in 2019–20 "Black Summer" are predicted to become increasingly frequent and severe. Although the impacts of fires on terrestrial ecosystems are well-researched, very little research investigates the effects of bushfires on aquatic ecosystems.

The burning of riparian (riverside) vegetation can have short- and long-term impacts for freshwater fauna. The loss of shade from trees can increase the solar radiation reaching the water's surface, which in turn warms the water and leads to more daily variation in water temperature. Toxic compounds can be produced and released from burning vegetation. If heavy rainfall follows a fire, and without the vegetation that previously acted as a buffer to erosion, significantly elevated levels of burned organic material, sediment and ash can be deposited into a waterway. Ash and sediment can remain suspended in waterways for many kilometres downstream, and for many months following fire events. This nutrient-rich material spurs on bacterial blooms and algal growth that can rapidly consume oxygen from the water.

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LEFT: *Rainfall following bushfires can inundate freshwaters with toxic ash-laden sediment. Image: Bradley Moggridge*

Background (continued)

The suspended ash and sediment can clog and damage the gills of aquatic breathing animals like fish, crustaceans and tadpoles, reducing their ability to respire. This, coupled with the reduced oxygen levels, further reduces their aerobic performance, which can have flow-on effects for the ecosystem.

Main aims of the research

We aimed to determine how exposure to ash and sediment from bushfire impacted the tolerance of various fish, crustaceans and frog species to elevated water temperatures and low oxygen levels, both separately and in combination. We also aimed to assess the impacts of ash and sediment exposure on the physiology, performance, and gill structure of fish and crustaceans.

What we did

The fish species we investigated were mountain galaxias (*Galaxias olidus*), southern pygmy perch (*Nannoperca australis*), crimson-spotted rainbowfish (*Melanotaenia duboulayi*) and Agassiz's glassfish (*Ambassis agassizii*). The crustaceans studied were the red-claw crayfish (*Cherax quadricarinatus*), freshwater prawn (*Macrobrachium australiense*), the strong crayfish (*Euastacus valentulus*) and the Conondale spiny crayfish (*Euastacus hystricosus*); and the frogs investigated were the graceful tree frog (*Litoria gracilenta*), ornate burrowing frog (*Platyplectrum ornatus*) and the striped marsh frog (*Limnodynastes peronii*). These study species have close relatives that are, or could be, highly threatened by bushfires, and may serve as surrogates for their more threatened relatives.

We purchased the crustaceans and several fish species from commercial suppliers for our laboratory experiments. Mountain galaxias were caught from a wild source population and donated to the project by The Queensland Department of Environment and Science. Frog egg clutches were collected under permit following heavy rainfall around Brisbane. We collected bushfire ash from a recently burned patch of eucalypt forest in Buderim, Queensland.

For each of the fish and crustacean species, we measured tolerance thresholds to high temperatures and low aquatic oxygen levels using standard physiological tests. We then used a combination of the two initial tests, measuring how their tolerance of high temperatures changed across a range of reduced oxygen levels. Each test used the non-lethal "loss of equilibrium" endpoint, where the animals are no longer able to right themselves in the water.

These same experiments were conducted following exposure to suspended ash and sediment. We used conservative doses compared to what has been shown to occur following large fires. This was done to investigate the sub-lethal impacts that may be occurring far downstream of fires, or for the many months following fire events. Sub-lethal impacts are likely to reduce the performance of individuals, which could have significant ecological and population-scale effects.

We investigated the impacts of ash and sediment exposure to oxygen uptake and delivery mechanisms, and aerobic performance. We measured swimming performance for two fish species, and then how exposure changed the capacity of blood to deliver oxygen around the body. We determined whether the gill structures in several fish and crustacean species showed evidence of damage.

We measured frog egg mortality rates following ash and sediment exposure and, in surviving embryos, we measured how many larvae developed with deformations. For tadpoles that survived without deformations, we measured rate of oxygen consumption, which indicates their metabolic rate and the energetic cost of living.

We reared 150 tadpoles in twenty 250 litre containers (mesocosms). We set up the mesocosms as naturalistic, fire-affected ponds with a range of ash, sediment and control treatments. After a month of ash and sediment exposure, we removed a sample of tadpoles from each of the mesocosms and measured their growth and swimming performance. We left the remaining tadpoles to metamorphose into frogs. After the frogs metamorphosed, we recorded their growth and jumping performance. This was done to investigate whether the impacts of ash and sediment exposure were carrying over from juvenile life stages, through metamorphosis, into adulthood.

RIGHT: The impacts of ash and sediment were life stage–specific for the frogs investigated. Image: Coen Hird

Key findings

Chronic ash and sediment exposure significantly reduced many fish and crustacean species' tolerance to high temperatures and low aquatic oxygen levels. It also reduced the survival of striped marsh frog embryos and increased the energy consumption of striped marsh frogs and graceful tree frogs. The severity of impacts varied with each species tested and was life stage–specific for the frogs investigated.

The critical upper temperature limit and lower oxygen limit varied for the fish and crustacean species in a way that reflected their natural ecology and distribution. More widely distributed species were generally more tolerant of high temperatures and low oxygen levels, whereas species from higher altitude distributions in cooler waters were less tolerant to high temperatures and low oxygen levels.

We found that most fish and crustacean species had oxygen-dependant thermal tolerances. When we lowered the amount of oxygen in the water, these animals were less able to withstand high temperatures. Importantly, we found that this effect was more pronounced following exposure to ash and sediment.

Agassiz's glassfish had nearly a 20% reduction in swimming performance after being exposed to ash and sediment. By comparison, the southern pygmy perch did not show any change in swimming performance in the experiment.

Changes to blood characteristics may help to explain some of the impacts to tolerances and performance. The southern pygmy perch were able to increase their volume of red blood cells, which are used to carry oxygen around the body. By comparison, mountain galaxias and Agassiz's glassfish showed no change in their blood metrics, which had significant negative impacts to ash and sediment exposure.

We found evidence of gill damage after long-term ash and sediment exposure in fish and crustaceans, which would have reduced their ability to respire (breath).

Frog embryos that were exposed to ash at concentrations ranging from 1–5 grams per litre had increased mortality rates and a higher occurrence of developmental abnormalities. Ash-exposed tadpoles also had higher rates of energy consumption than controls.

Algal blooms occurred in the mesocosms that we treated with ash and sediment, and the water chemistry and temperature were more variable. There was no effect of ash and sediment exposure on the rate of tadpole survival, size or physiological performance. In fact, tadpoles reared in ash- and sediment-treated mesocosms tended to metamorphose slightly earlier and at larger sizes than those from the control mesocosms. The algae growing in the treatment mesocosms might have provided a higher-quality food for the growing tadpoles.

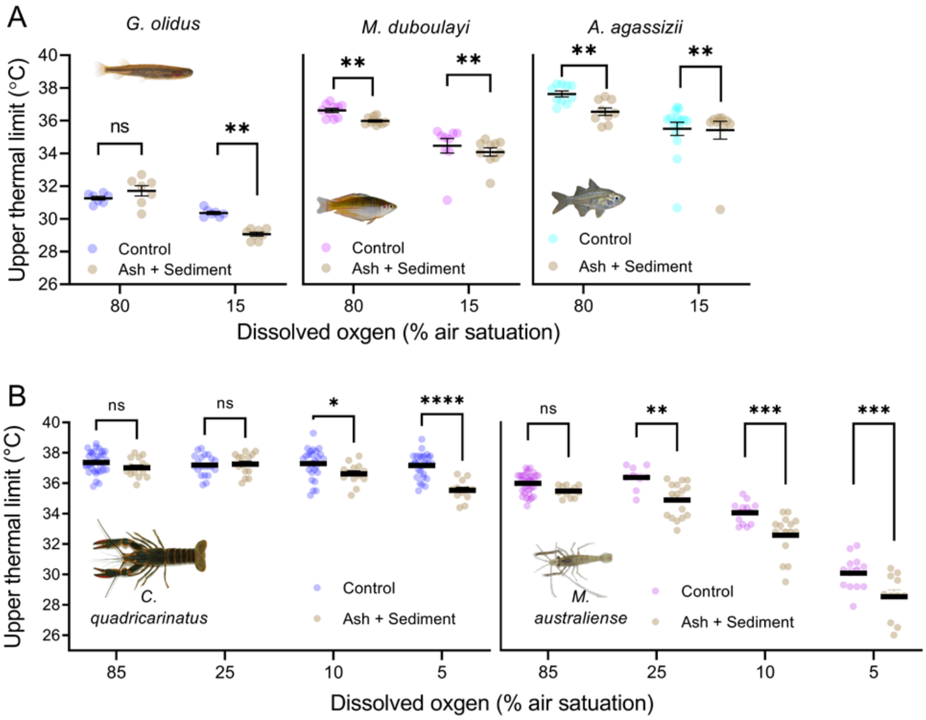

Figure 1: *Low oxygen levels and exposure to ash and sediment reduced fish and crustacean tolerances to high temperatures.*

Figure 2: *Comparison of mesocosm algal growth between a control (left) treatment and a sediment (right) treatment after five days of exposure.*

Implications

We have determined a suite of temperature and oxygen tolerance limits for several freshwater fish and crustacean species that should serve as intervention triggers for management. We also showed that even a conservatively low level of ash and sediment exposure has the potential to be devastating for populations of several fish and crustacean species. If water conditions exceed the limits of a species' tolerance, then severe ecological consequences and mortalities become likely.

We used the loss of equilibrium as an experimental endpoint that is close to an organism's lethal limits. To reduce negative impacts to a wild population, intervention triggers should be lowered by several degrees to prevent animals from experiencing those lethal limits.

Tolerances were highly species-specific but are also likely to be similar between closely related species. Given the paucity of information for most Australian freshwater fauna, our data can be used as a surrogate for closely related and data-deficient species. Knowing when water conditions become harmful to these animals means that, following environmental disturbance, our results can be used to guide the timing of emergency relocations and subsequent reintroductions.

The use of sediment barriers around sensitive species' habitats would help prevent some of the negative impacts of ash and sediment exposure. Similarly, targeted and controlled water releases would help to move sediment slugs away from, or quickly through, the habitat of more sensitive species.

The severity of impact for ash and sediment exposure was specific to the animals' life stage and the period of exposure. For the frog species we studied, early life stages were particularly sensitive to acute changes in water quality. In later life stages, low intensity and long-term exposure may have been beneficial for tadpole development. These contrasting effects underline how important it is to continue investigating the impacts of post-fire changes to water quality across many species and life-stages.

Many species of Galaxiids across south-east Australia are threatened by the impacts of bushfire ash and sediment. Image: Calum Mulvey

Cited material

Cramp, R., Mulvey, C., Cameron, J., Wintour, M., Gomez Isaza, D., and Franklin. C., 2021. Impacts of post-fire ash and runoff sediment on the physiological tolerances of Australian freshwater aquatic fauna. NESP Threatened Species Recovery Hub Project 8.3.7 report, Brisbane.

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Further Information

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