Science for Policy

Research findings in brief

Project 3.3.7

Threatened Species Recovery Hub

National Environmental Science Programme

Swimming performance traits of twenty-one fish species: A fish passage management tool for use in modified freshwater systems.

In brief

In Australia, freshwater fish populations have been severely impacted by habitat fragmentation due to the construction of in-stream structures like dams, weirs and culverts, which block native fish migration. The harmful impact of such infrastructure on fish populations is now well-acknowledged, and extensive efforts are being made to remedy their design and construction to reconnect fragmented waterways to facilitate fish passage.

Effective fish passage requires reliable data on swimming performance to ensure native fish can swim through existing waterway infrastructure or purpose built fishways. Unfortunately, such information has been lacking until recently for most Australian fish species. We undertook a comprehensive assessment of the swimming performance of 21 species of Australian native freshwater fish. Species were chosen to encompass a wide range of body shapes, swimming styles and lifestyles. We focused on small species and juveniles of larger growing fish as they typically cannot swim as fast as larger fish.

These 21 species are able to act as proxies for other untested, rare or Endangered species that share similar traits.

This research provides high-quality scientific data that is specific to Australian fish species to support the decisions of fisheries management and civil engineers designing culverts and other waterway infrastructure. The quantified values we established for fish swimming performance can be directly applied to set velocity guidelines when designing artificial instream structures.

Juvenile Australian bass ready to swim.
Photo: Jabin Watson

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Background (continued)

Freshwater ecosystems in Australia and around the world have been severely fragmented by artificial in-stream structures that are designed to manage water for human use. To address this impact, significant efforts have been made to reconnect freshwater systems to enable fish movement through the design and installation of dedicated fish passage structures (fishways), and by incorporating fish-friendly design features into waterways infrastructure, including culverts. Key to their success is ensuring that water velocities passing through the infrastructure don't exceed the swimming capacities of the native fish species they are designed to provide passage for.

Before this research, swimming performance data was scarce for Australian fish, which display a reduced swimming capacity compared to many North American and European species. What little data did exist was not collected with consistent equipment or protocols, meaning valid comparisons of swimming ability across species could not be made. This makes it difficult to understand what physical and/or behavioural characteristics contributed to, and could be used as a predictor of, swimming performance for native Australian species.

To help close this knowledge gap, members of the Franklin Eco-lab at The University of Queensland and Matthew Gordos of New South Wales DPI Fisheries undertook a study of the swimming performance capacities of 21 species of freshwater fish native to Australia, with a focus on species found in New South Wales and the Murray–Darling Basin. The work was conducted at The University of Queensland's Biohydrodynamics Laboratory, located at the St Lucia campus.

Research aims

We aimed to characterise the swimming capabilities of a range of freshwater fish species. The 21 species were selected to encompass a wide range of body shapes, swimming styles and lifestyles. This enabled us to identify what broad physical or behavioural characteristics could be used to help predict the swimming capacity of small Australian fish. As such, the species we chose can act as proxies for uncharacterised, rare or Endangered species that share similar traits, as we can infer their swimming performance from the performance of the studied species. Additionally, as small fish typically cannot swim as fast as larger fish, we focused on characterising the swimming performance of the weakest swimming size (< 10 cm) and age class (juveniles).

What we did

We collected multiple swimming performance metrics in order to build a comprehensive and cohesive picture of how small Australian fish swim. This included characterising the maximum sustainable swimming speed, sprint swimming speed, swimming endurance, and traverse success up a 12-meter channel. As the maximum sustainable swimming speed is a key metric used by fisheries managers and infrastructure engineers, we used it to test how common physical (e.g. water velocity) and behavioural (e.g. light) characteristics interacted with fish swimming performance, and whether they could be used to help predict the swimming ability of a species which had not been tested.

For the species we looked at, their common adult body size and locations (e.g. coastal or inland) are listed in Table 1. More details of the physical and behavioural characteristics of the study species are available in the paper listed at the end of this factsheet.

Three-cell box culvert at Tinderbox Creek field site, northern New South Wales.
Photo: Jabin Watson

Key findings

A summary of key swimming performance results for the 21 study species is presented in Table 1. Full details of the swimming performance data, including endurance times and velocities for fish swum in a 12 metre channel, are available in the paper listed at the end of this factsheet.

Our findings present the most comprehensive swimming performance characterisation available for Australian freshwater fish species. Looking at the maximum sustainable swimming speeds of the 21 species, freshwater mullet and silver perch were the best performing species, while flathead gudgeon and purple spotted gudgeon were the poorest swimmers.

While fish swimming performance data provide important information for the design of new fishways and remediation of existing waterways infrastructure, it is not feasible to obtain detailed data on the swimming capacities of every species and size class. We found that although body length is the best predictor of swimming performance, the ability to predict the swimming capacity of an unknown species can be improved by adding an additional characteristic, particularly the behavioural trait of the depth station at which the species lives, or the physical attributes of its body or tail shape. As fish size was found to be highly correlated with swimming performance, it is also feasible to cautiously make performance estimates for individuals outside the size range that we tested.

Table 1. Study species and their swimming performance

The study species and their mean prolonged speeds. Typically, both prolonged and burst swimming gaits are required for fish to successfully traverse upstream of man-made barriers.

Scientific name	Common name	Common adult size (mm)	Location	Mean prolonged swimming speed (ms^{-1})
Trachystoma petardi	Freshwater mullet	400	Coastal	0.85
Maccullochella peelii	Murray cod	700	Inland	0.46
Macquaria ambigua	Golden perch	500	Inland	0.32
Macquaria novemaculeata	Australian bass	400	Coastal	0.60
Bidyanus bidyanus	Silver perch	300	Inland	0.68
Leiopotherapon unicolor	Spangled perch	300	Inland	0.41
Galaxias brevipinnis	Climbing galaxiid	100	Inland	0.49
Retropinna semoni	Australian smelt	60	Coastal/Inland	0.66
Craterocephalus stercusmuscarum	Fly-specked hardyhead	55	Inland	0.49
Pseduomugil signifier	Pacific blue-eye	40	Coastal	0.46
Melanotaenia fluviatilis	Murray River rainbowfish	85	Inland	0.45
Melanotaenia duboulayi	Crimson-spotted rainbowfish	80	Coastal	0.63
Rhadinocentrus omatus	Ornate rainbowfish	40	Coastal	0.52
Ambassis ambassizii	Olive perchlet	60	Coastal/Inland	0.53
Nannoperca australis	Southern pygmy perch	60	Inland	0.35
Tandanus tandanus	Eel-tailed catfish	450	Coastal/Inland	0.41
Hypseleotris compressa	Empire gudgeon	80	Coastal	0.44
Hypseleotris galii	Firetail gudgeon	35	Coastal	0.38
Philypnodon grandiceps	Flathead gudgeon	80	Coastal/Inland	0.33
Mogurnda adspersa	Purple spotted gudgeon	80	Coastal/Inland	0.21
Redigobius bikolanus	Speckled goby	40	Coastal	0.34

Key findings (continued)

Limitations

Logistical constraints prevented us using wild-caught individuals for all species. We had to use captive-bred fish for 16 of the 21 species (the exceptions being Australian smelt, crimson-spotted rainbowfish, Pacific blue-eye, flathead gudgeon and speckled goby), which may mean that our reported swimming performance capacities are conservative, as other work has shown that the swimming performance of wild-caught fish can exceed that of captive-bred ones.

Further, fish swimming performance is greatly affected by temperature. Natural waterbodies have significant seasonal, daily and spatial variations in temperature that directly affect a fish's capacity to swim. We standardised our dataset by quantifying fish swimming performance at 25°C. While this temperature is typical for late spring or summer in most coastal Australian rivers when native fish often move, it may be not be optimal for some of the more temperate species that we tested.

Further reading

Watson, J. R., Goodrich, H. R., Cramp, R. L., Gordos, M. A., Yan, Y. Ward, P. J., Franklin, C. E. Swimming performance traits of twenty-one Australian fish species: a fish passage management tool in a modified freshwater system. *bioRxiv*, doi: https://doi.org/10.1101/861898

Implications

The findings will be of most importance to civil engineers who design in-stream structures such as culverts under roads, and fisheries managers who assess the requirements of local fish populations at development sites. This research means that the decisions of fisheries management and engineering can now be supported by high-quality scientific data that is specific to Australian fish species, the first comprehensive database of its kind.

The quantified values we established can be directly applied to set velocity guidelines when designing artificial instream structures. The guidelines for designing fish-friendly road crossings in New South Wales currently recommend maximum velocities of 0.3 $m s^{-1}$. This velocity was based on limited swimming performance data for Australian freshwater fish. Our findings support this maximum velocity during baseline flows, with only two of the species we tested unable to traverse 8 meters, a distance equivalent to a culvert under a typical two-lane rural road crossing, at a water velocity of 0.3 $m s^{-1}$.

Recommendations

While it will be possible to extrapolate our findings to other untested, rare or Endangered species, we recommend expanding the dataset to include more species and size classes.

Also, as the focus of the research is to improve habitat connectivity, the application of the findings may lead to fishways allowing invasive species into previously inaccessible habitats. We therefore propose including invasive species in future fish swimming performance trials.

Further Information

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Juvenile eel-tailed catfish. Photo: Jabin Watson

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This project is supported through funding from the Australian Government's National Environmental Science Program.