FISH, FLOODS AND FALLACY

For many freshwater fish, floods are considered to be the best time to spawn but Martin Mallen-Cooper and Ivor Stuart have overturned this long-held belief.

Imagine being a fish in a river during a long, drawn-out drought. There's been little flow for years, food is scarce and you've managed to survive by remaining within the deeper pools in the main river channel. Finally, the drought breaks and the spring floods arrive. The river bursts its banks and inundates the floodplains, where plankton now blooms, aquatic plants grow and waterbirds breed. It is a dynamic period and the best time for you to breed because your young will have plenty of food and survival will be high.

Simple, neat story – good for scientists, good for managers. In the Murray–Darling river system in south-eastern Australia, as for many other rivers worldwide, this model of fish spawning during floods has, for the major large fish species, been the dominant paradigm for scientists and managers for over three decades. However, recent research indicates that the picture is not so clear, and floods and floodplains may be only part of the story.

The link between fishes and floodplains started in the mid-1960s when a pioneering fish biologist, aptly named John Lake, did a series of manipulative experiments in purpose-built ponds at Narrandera, New South Wales. These experiments changed the face of fish ecology in the Murray–Darling river system and set the framework for a generation of researchers. For the first time, Lake induced a range of native fish species to spawn by raising the water level in the ponds and inundating artificial floodplains adjacent to the ponds.

Lake hypothesised that fishes, like waterbirds, use the increases in food, such as plankton, during the inundation of floodplains to increase the survival of their young. Other researchers then added to this idea and later termed it the "flood-recruitment model". Recruitment refers to the survival of young fishes from the high-mortality phases of egg, larvae and fingerlings (less than 6 months old) to

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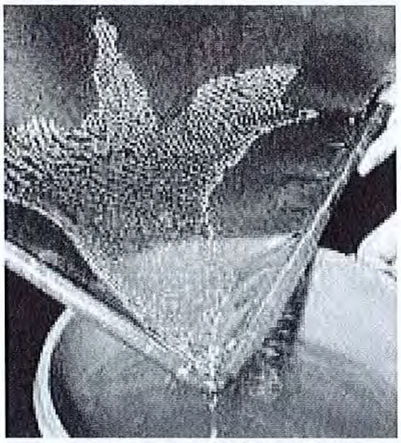


Golden perch produce 500,000 eggs each.

maturity. The flood-recruitment model was, and still is, the framework that many fish researchers commonly use for the management of floodplain rivers worldwide.

The Murray–Darling Basin is well known for its droughts and extensive floods. In the last several thousand years these dry periods have very likely been much longer and more severe than they are today. The fishes have adapted to these extremes. Small, short-lived (2–4 years) species need to breed in the consecutive years of low flow, but the longer-lived species have a choice: they can wait for the next flood. And that's where the flood-recruitment model comes in.

We started our work in the 1990s when we were assessing a new fishway (fish ladder) on the Murray River at Torrumbarry Weir, near Echuca, 200 km north of Melbourne. A fishway is an artificial passage of water around an obstruction in a river that enables fish to pass – it is usually a channel divided into pools and the fish ascend by swimming from pool to pool.

As part of the fishway assessment project we were recording the species, size and age structure of the migrating fish population. We were particularly interested in golden perch (*Macquaria ambigua*) and silver perch (*Bidyanus bidyanus*), two large species (commonly up to 50 and 40 cm long, respectively) that John Lake found had spawned in floodplain ponds.

The age data for these fishes led to some surprises. We estimated age using a common technique where the ear bones (otoliths) of the fishes are sectioned, revealing growth rings (like the rings of a tree trunk).

The first surprise was that these two species lived longer than previously thought. Both were up to 26 years of age. This more than doubled the previously recorded maximum age for the golden perch, although some species in the same family (Percichthyidae) are long-lived. However, the maximum age of the silver perch was unexpectedly high for its family (Terapontidae), which has typically short-lived species (less than 10 years).

The longevity of these fishes was consistent with the model of waiting for the big flood to spawn, as 26 years would be long enough to outlast the worst of droughts. These species also have high fecundity (number of eggs produced per fish) with up to 300,000 eggs for silver perch and 500,000 for golden perch – certainly enough, it would appear, to compensate for the long wait between floods and part of a reasonable strategy to put all your eggs in one basket.

We sampled the river and fishway every month over two-and-a-half years. At the end we looked at all our age assessments and could see some obvious year-classes. At that point we went back and triple-checked the data because what we saw was not a general pattern of recruitment in flood years. golden perch, in fact, had the opposite pattern, with strong year-classes from non-flood years where the river fluctuated in flow but was contained within the banks, and very few representatives of age-classes from flood years. Silver perch were different again, with some level of recruitment in all years.

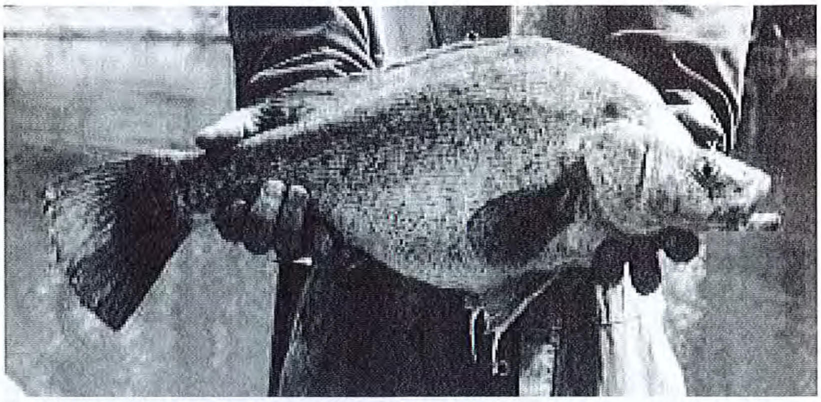
We were so surprised that we went

back and examined all the published primary data (direct observations of fishes) before and after John Lake's work, looking for examples of spawning in the wild and recruitment (year-class representation) of these two species.

Interestingly, although Lake provided the model for flood recruitment, in over three decades not a single refereed scientific paper had provided primary data on recruitment for these two major species. There are numerous records of spawning in the wild but whether these resulted in high survival of larvae and young is unknown.

The only previous data on year-classes were for golden perch from a detailed 1976 article in a commercial-fishing magazine by South Australian Fisheries biologist Fred Reynolds. They are the only primary data used since John Lake's study to support the flood-recruitment model in the wild. However, when we re-examined Reynolds' data we found that, apart from recruitment during floods, recruitment also occurred in years when flows were within the river channel. And during the 1956 flood – the biggest since 1878 when records were first kept – recruitment was unexpectedly poor.

In assessing a fishway and systematically resampling the fish population in the river, we had inadvertently provided, for the first time, evidence of year-specific recruitment of golden perch and silver perch in the wild. Although we found very few golden perch from flood years, interpreting this data was complicated by the fact that there is another weir 500 km downstream from our study site at Torrumbarry Weir. This means that any eggs or larvae that might have been carried down the river and past this second weir in a flood may have been unable to re-enter the study area, so recruitment of golden perch in flood years might have been greater than we observed. Observations of gonad development and spawning during floods by other researchers certainly suggest that this species does spawn during floods. But one thing is now clear: the idea that golden perch only spawn during floods is incorrect.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Other large species in the Murray–Darling river system have also proved to have more flexible reproductive strategies than just relying on floods. Stuart Rowland (NSW Department of Primary Industries) studied Murray cod (*Maccullochella peelii peelii*), the largest fish in the system, and showed that this species spawns in response to rising water temperature in spring every year. He recorded some recruitment of Murray cod in droughts but considered that floods were the most likely time of major recruitment. Certainly this makes sense for a fish that can possibly live for 50 years!

The interesting management implication from Rowland's work is that, in river systems where flow is regulated, providing for the survival of larvae to maturity is more important than providing river conditions to stimulate spawning. In a recent study, John Koehn of the Arthur Rylah Institute in Victoria collected larvae of Murray cod, golden perch and silver perch for the first time from the main channel of the Murray River. These larvae would not survive if they were diverted from the river into irrigation networks and pumped onto agricultural land. Managing methods and periods of water extraction in the future is one option to keep more larvae in the river and improve survival.

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Bony herring (*Nematalosa erebi*) is another large species (up to 40 cm long) that spawns in spring in any flow conditions. Jim Puckridge of the University of Adelaide also found that recruitment could occur in a range of flows but that the species could potentially take advantage of floods. The maximum age of this species is not known but closely related herring species in North America typically live for only 4–6 years. In the worst droughts of the Murray–Darling river system, their short life-span would be exceeded by the long intervals between floods, hence their ability to spawn and recruit during non-flood years.

Given the reproductive strategies of Murray cod and bony herring, it is not completely surprising that golden perch

and silver perch are more flexible than previously thought. In an interesting ecological twist, recent radio-tracking of common carp (*Cyprinus carpio*), an introduced and abundant pest fish, has revealed a strong reliance on floodplains for spawning, which reveals a potential Achilles heel in the life cycle: migration bottlenecks between the river and floodplains, which can be used to target control efforts. One way to do this would be by installing the award-winning carp-separation cage into fishways. This cage catches common carp as they migrate upstream by exploiting their jumping ability. Native fishes, which do not jump, are automatically separated and released unharmed to continue their migration.

Where does all this information leave the flood-recruitment model for native fishes, and what are the impacts for management? The model still remains but with the addition of within-river channel recruitment. The major question now is whether within-river channel recruitment is the fundamental process that ultimately sustains the populations of these fishes, or whether it is a fall-back mechanism to keep the population ticking over until the next big flood, when the magnitude of recruitment may be much greater.

Relaxing the emphasis on any one recruitment mechanism opens up important new opportunities for river management. Rather than thinking that fishes only recruit during major floods, which have limited scope for manipulation and management, we now know at least some species recruit in regulated flows within the main river channel and during smaller floods, and there is significant potential to optimise this. The challenge now is to incorporate this new knowledge into environmental flow strategies, and fund research to refine the characteristics of within-river channel flows that result in strong recruitment and sustainable populations of these fishes.

In the present case study, the uncritical acceptance by researchers and managers of the flood-recruitment model has had a major impact on the way we manage native fish populations. Since European settlement, regulation and modification of rivers has coincided with a decline in silver perch populations by up to 95% and in golden perch by up to 50%. If John Lake's model had been tested in the field soon after his pond experiments, it would likely have led to a greater understanding of processes within the main river channel and contributed to the conservation of these species. The good news is that this is happening now.

Dr Martin Mallen-Cooper, of Fishway Consulting Services, has 20 years experience in research on freshwater fiishes and the design of fiishways. Ivor Stuart is a Senior Scientist with the Freshwater Ecology Group at the Arthur Rylah Institute for Environmental Research in Melbourne. Much of the research discussed in this article was done while the two authors were at the Cooperative Research Centre for Freshwater Ecology, NSW Department of Primary Industries.