

Natural flows drive the ‘boom and bust’ ecology of fish in Cooper Creek, an arid-zone floodplain river

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Introduction

Why is the Lake Eyre Basin so special and why should we care so much about the future of its rivers and floodplain wetlands? It covers an area of more than 1 million km², about one-seventh of Australia (Habeck-Fardy and Nanson 2014), and is one of the world’s largest internally draining river basins, meaning its waters never reach the sea. In Cooper Creek, one of the main catchments of the basin, most stream flow is generated by summer monsoon rainfall in the headwaters of the Thomson and Barcoo Rivers and by periodic local rainfall (see Chapter 1). Episodic floods can inundate tens of thousands of square kilometres of floodplain, and reconnect channels, anabranches, and isolated channel and floodplain waterholes (Fig. 4.1), turning a fragmented river network into a mighty floodplain river, occasionally helping to fill Kati Thanda-Lake Eyre, the largest lake in Australia.

Lake Eyre Basin catchments have very high conservation values – high endemic biodiversity, Ramsar wetland listings, range-restricted species (e.g. the Cooper Creek catfish), relatively few alien fish species (i.e. species foreign to Australia) and few translocated species (see Chapter 3). Rivers and floodplain wetlands of the basin are in very good ecological condition relative to most of the world’s large developed river basins, and especially compared to the Murray–Darling Basin. Cooper Creek is a largely undeveloped catchment with a near natural and very erratic flow regime (Puckridge *et al.* 1998; see Chapter 2). Aquatic habitats exist for most of the time as isolated waterholes, connected occasionally by channel flows and large overland floods (Fig. 4.1). Rivers of the Channel Country, especially Cooper Creek, have been studied as model arid-zone floodplain systems for understanding the ‘boom and bust’ ecology of fish and other biota. This chapter demonstrates the importance of flow variability and the boom and bust cycle to fish, and outlines threats associated with changing the natural flow regime, concluding with scientific principles for the conservation and wise use of arid-zone rivers.

Cooper Creek fish

Twelve native fish species in eight families, two translocated species (Murray cod, *Maccullochella peelii*, and sleepy cod, *Oxyeleotris lineolata*) and two alien species (goldfish and mosquitofish) are known from the Cooper Creek catchment (Table 4.1). Both alien species and Murray cod are relatively rare in Cooper Creek, but the sleepy cod is becoming

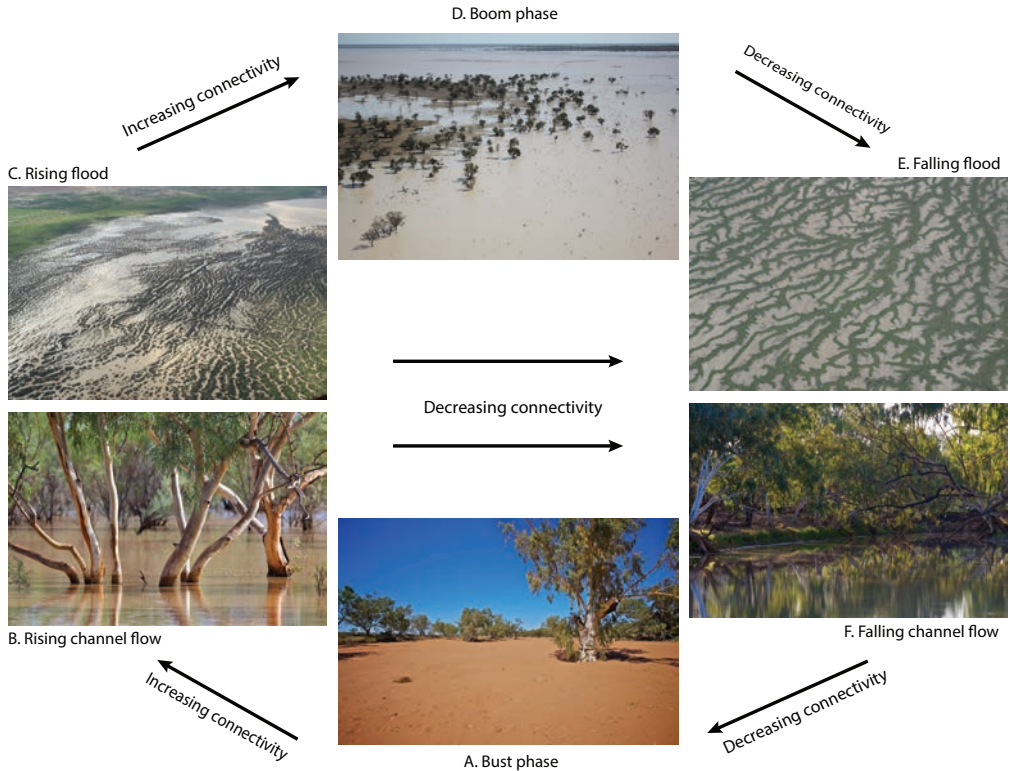


Fig. 4.1. Aquatic habitat conditions associated with the natural hydrological cycle in Cooper Creek, showing: (A) drying waterhole (bust phase, photo, A. Emmott), (B) rising channel flow (photo, A. Emmott), (C) rising flood and breakout onto floodplain (photo, R. T. Kingsford), (D) large flood in October 2016 (boom phase, photo, R.T. Kingsford), (E) falling flood (photo, R. T. Kingsford), (F) falling channel flow (photo, A. Emmott), sparse riparian vegetation, bare banks and exposure of habitat features such as fallen timber. Patterns of increasing and decreasing connectivity are represented. B and F show a rising channel flow becoming a falling channel flow rather than breaking onto the floodplain. C and E show a small flood receding off an inundated floodplain. In both cases connectivity pathways are limited compared to those achieved by a very large flood (D). Figure adapted from Arthington and Balcombe (2011).

more common (B. Cockayne, pers. comm.). The wider distribution patterns of Lake Eyre Basin fishes are also described elsewhere (Kerezszy *et al.* 2014).

The Cooper Creek fish fauna is not rich compared with Queensland’s coastal rivers (23–55 species; Pusey *et al.* 2004), but the native fishes are of ecological and conservation significance, and several are valued socially and economically for recreational fishing (e.g. yellowbelly). In 15 waterholes sampled in the Cooper Creek catchment in 2001 using standardised fyke-net sampling (Fig. 4.2), five widespread indigenous species contributed 96% of the total catch (Arthington *et al.* 2005). Proportional abundances were silver tandan (45.5%), north-west ambassis or glassfish (19.9%), spangled perch (12.5%), bony bream (9.7%) and Hyrtl’s tandan (8.4%). Seven species contributed the remaining 4% of catch. Sampling in four waterholes of the Windorah reach of Cooper Creek on eight occasions between April 2001 and December 2004 (Balcombe and Arthington 2009) yielded generally similar patterns

of abundance: silver tandan (~54% of total catch) and Hyrtl’s tandan (~14%), bony bream (~16%), two grunters (Welch’s grunter (~8%), Barcoo grunter (~6%)) and yellowbelly (~2%). A typical fish sample may include several of these species, as well as turtles (Fig. 4.3).

Fish ecology during the bust

The fish fauna spans a range of body sizes, physiological tolerances, habitat and dietary preferences, and breeding strategies (Table 4.1). These adaptations equip all species to tolerate the ‘bust’ conditions in drying waterholes, and to reproduce opportunistically, seasonally or on rising flows and floods, tracking changing habitat conditions and food resources (Fig. 4.1). Although all 12 native species are adapted to survive bust conditions, fish abundances and assemblage composition in waterholes change markedly during dry periods. Individual species suffered 50–100% reduction in numbers per waterhole, and across the entire fish fauna 93% of individuals were lost from 15 drying waterholes between April and September 2001 (Arthington *et al.* 2005). Each species responded to different environmental pressures during this dry period (Arthington *et al.* 2010). For the desert rainbowfish, low physical habitat diversity and susceptibility to decreasing water temperatures drove losses from 11 of 15 waterholes. The yellowbelly was lost from six of 15 waterholes, particularly those on the fringes of the floodplain that are rarely rewetted and reconnected. The Barcoo grunter did not persist in 11 waterholes with low levels of bed, bank and habitat complexity and less cover to protect them from predators. This grunter was also less likely to persist in waterholes on narrow floodplains, possibly because fish coming off narrow floodplains may not have accumulated the body lipids that govern condition, and probably survival, in isolated, drying waterholes (Puckridge *et al.* 2000). These natural pressures drive adaptation to flow variability over successive generations.

The fate of the uncommon Cooper Creek catfish in drying waterholes is particularly interesting. Waterholes that experienced increases in primary production over the dry season were able to sustain this catfish, which is the only species not found on the floodplains of Cooper Creek when they are inundated (Balcombe *et al.* 2007). During dry periods, a conspicuous, shallow ‘bathtub ring’ of benthic algae forms around the margins of isolated waterholes and this productive food resource sustains the entire fish community (Bunn *et al.* 2003). This is especially important for large species like the Cooper Creek catfish that feed on large-bodied invertebrates (crustaceans and snails), themselves sustained by high levels of algal production (Balcombe *et al.* 2005). However, without an energy subsidy from the food-rich floodplain, the Cooper Creek catfish would be totally reliant on the waterhole food web, and this is not very productive in steep-sided waterholes where the bath-tub ring of algae is usually less well developed (Arthington *et al.* 2010).

Fish ecology during the boom

High fish mortalities during the dry times in Cooper Creek are balanced by episodes of spawning and recruitment. Fish exhibit three main recruitment strategies in Cooper Creek (and other rivers of the Lake Eyre Basin), termed no-flow recruitment, seasonal recruitment, and flow or flood-dependent recruitment (Kerezsy *et al.* 2011). At least six of the 12 native

Table 4.1. Native and alien fish species found in Cooper Creek, showing maximum body length recorded, feeding habits, spawning seasons, spawning cues and life stages (L – larvae, J – juvenile, A – adult).Data drawn from Balcombe *et al.* (2005), Balcombe *et al.* (2007), Balcombe and Arthington (2009), Kerezszy *et al.* (2011), Cockayne *et al.* (2015).

Family/species	Common name	Maximum body size (S.L. mm)	Feeding habits (common foods eaten)	Spawning season and cues	Life stages using floodplains		
Native species							
Ambassidae							
<i>Ambassis</i> sp.	North-west ambassis	65	Pelago-carnivore (micro-crustacea)	No-flow or flow-related spawning			A
Clupeidae							
<i>Nematalosa erebi</i>	Bony bream	276	Benthivore (algae/detritus)	No-flow spawning, all year	L	J	A
Gobiidae							
<i>Hypseleotris</i> spp.	Carp gudgeons	28	Benthic-carnivore (zooplankton/dipteran larvae)	No-flow spawning, all year		J	A
Melanotaeniidae							
<i>Melanotaenia splendida tatei</i>	Desert rainbowfish	79	Pelago-carnivore (terrestrial insects)	No-flow spawning, all year		J	A
Percichthyidae							
<i>Macquaria</i> sp. B	Lake Eyre golden perch, yellowbelly	398	Pelago-macro-carnivore (large crustaceans)	No flow, seasonal or flow-related spawning	L	J	A
Plotosidae							
<i>Neosiluroides cooperensis</i>	Cooper Creek catfish	468	Benthic-carnivore (gastropods/crustaceans)	Summer spawning			
<i>Neosilurus hyrtlii</i>	Hyrtl's tandan	350	Benthic-carnivore (aquatic insects)	Summer spawning on rising flows and floods	L		A
<i>Porochilus argenteus</i>	Silver tandan	199	Benthic-carnivore (aquatic insects)	Summer spawning	L	J	A

Family/species	Common name	Maximum body size (S.L. mm)	Feeding habits (common foods eaten)	Spawning season and cues	Life stages using floodplains		
Retropinnidae							
<i>Retropinna semoni</i>	Australian smelt	65	Pelago-carnivore (aquatic insects/micro-crustaceans)	Mid-late winter spawning on rising water temperature	L	J	
Terapontidae							
<i>Bidyanus welchi</i>	Welch's grunter	263	Benthivore (molluscs, crustaceans)	Summer spawning on rising flows and floods		J	A
<i>Leiopotherapon unicolor</i>	Spangled perch	193	Pelago-carnivore (aquatic insects /crustaceans)	No flow, seasonal or flow-related spawning	L	J	A
<i>Scortum barcoo</i>	Barcoo grunter	280	Benthivore (molluscs, crustaceans)	Summer spawning on rising flows and floods		J	A
Alien species							
Cyprinidae							
<i>Carassius auratus</i>	Goldfish	132	Pelago-carnivore (micro-crustaceans)	Spring spawning, rising temperature			
Poeciliidae							
<i>Gambusia holbrooki</i>	Mosquitofish	43	Pelago-carnivore (micro-crustaceans, terrestrial invertebrates)	Summer spawning, no or low flows		J	A



Fig. 4.2. Catching fish using fyke nets in a waterhole of the Mulligan River in the Georgina River catchment of the Lake Eyre Basin (photo, A. Kerezszy).

species can complete their life histories within isolated waterholes during dry periods when there are no channel flows; these include yellowbelly, bony bream, spangled perch, carp gudgeons, rainbowfish and glassfish (Table 4.1). These opportunistic species can maintain recruitment or replace their populations in isolated waterholes irrespective of season, channel flows or floods, but if channel flow or flood events occur, new recruits are available to disperse or colonise newly available habitat (Balcombe and Arthington 2009; Kerezszy *et al.* 2011; Cockayne *et al.* 2015). Three fish species have a seasonal recruitment strategy. Australian smelt probably commence spawning in mid to late winter (July–August) in the Cooper Creek catchment when the timing of breeding is linked with seasonal temperature cues rather than flow conditions. Summer-cued recruitment is characteristic of silver tandan and Cooper Creek catfish. These species breed on an annual cycle, with spawning occurring in early summer, and spawning events take place irrespective of antecedent hydrology and flow conditions (Balcombe and Arthington 2009; Kerezszy *et al.* 2011). The remaining species are either dependent on, or heavily influenced by, the occurrence of channel flows or flooding (Hyrtl's tandan, Barcoo grunter and Welch's grunter). Recruitment of Hyrtl's tandan in Cooper Creek and other Lake Eyre Basin rivers is triggered by major flooding (Balcombe and Arthington 2009; Kerezszy *et al.* 2011). Similar recruitment patterns have been reported in populations of Hyrtl's tandan from the Murray–Darling Basin (Balcombe *et al.* 2006). Three members of the Cooper Creek fish fauna (yellowbelly, spangled perch and glassfish) show particularly flexible breeding patterns by spawning when there is no flow as well as demonstrating flow-related recruitment.



Fig. 4.3. In boom phases, the high productivity in waterholes and on floodplains provides opportunities for fish species – such as these spangled perch, Cooper Creek tandan, Lake Eyre golden perch, Barcoo grunter, silver tandan, Hyrtl’s tandan – to build up their populations. Fish catches were identified to species, counted, measured and weighed. Turtles and most fish were returned to the water alive (photo, S. Balcombe).

Although their spawning strategies vary, most native species in Cooper Creek benefit from rising channel flows and floods by moving into backwater habitats, flooded channels and floodplains to feed and grow in shallow, food-rich, warm-water habitats (Balcombe *et al.* 2007). Fish use backwaters and flooded areas as larvae, juveniles and adults. All native species other than Australian smelt and Cooper Creek catfish have been caught on the floodplain as adults, and nine species have been collected in the juvenile life stage. Sampling in floodplain habitats has also yielded the late stage larvae of six native species (bony bream, yellowbelly, Hyrtl’s tandan, silver tandan, smelt and spangled perch). The Cooper Creek catfish may be the only native species to spend its entire life history within waterholes and channels. Juveniles and mature individuals of the alien mosquitofish have also been recorded from floodplains; however, goldfish captures have been confined to waterholes.

Access to floodplains, feeding on diverse food items and high growth rates allow most Cooper Creek fish to build up large populations and significant biomass (Fig. 4.2). During the 2004 summer flood in Cooper Creek, shallow floodplain areas near Windorah supported high fish biomass in the range of 21–240 kg/ha. These biomass figures are comparable to production from important floodplain fisheries in Bangladesh (50–400 kg/ha), the Mekong (138–175 kg/ha) and the Amazon (24 kg/ha) (Balcombe *et al.* 2007). The global literature

records strong relationships between the magnitude and/or duration of the annual flood pulse, floodplain area inundated and fish production in the same or subsequent years (Welcomme *et al.* 2006). Similar relationships have been demonstrated in Cooper Creek after large floods. For example, the February 2000 flood in Cooper Creek flooded nearly 14 000 km² of floodplain, and was followed by a boom in fish numbers that remained evident in waterholes sampled 14 months later. The species most responsive to flooding were rainbowfish, silver tandan, spangled perch, yellowbelly and Barcoo grunter (Arthington *et al.* 2005). Similar increases in fish abundance following large floods have been reported in the intermittently flooded Coongie Lakes in the lower Cooper Creek catchment (Puckridge *et al.* 2000) and in other Lake Eyre Basin rivers (Kerezszy *et al.* 2011).

Most species in the Lake Eyre Basin move over considerable distances into the variety of aquatic habitats (Fig. 4.1), using channel flows or flood waters for dispersal and colonisation. Two patterns of movement behaviour identified in native fish from the ephemeral Mulligan River may be the norm for the fauna of the Lake Eyre Basin (Kerezszy *et al.* 2013). Extreme dispersing species (bony bream, spangled perch, silver tandan, desert rainbowfish and glassfish) move widely into intermittently wetted habitats, while conservative dispersing species (Barcoo grunter, Welch's grunter, yellowbelly and Hyrtl's tandan) do not move as far, tending to inhabit deep waterholes within mid-reaches of rivers that are likely to hold water for long periods. For the entire fish assemblage, the capacity to disperse and access periodically flooded habitats is an important life history trait enabling most species to build up sufficient numbers for at least some healthy individuals to persist through the bust period. These temporal population fluctuations and variable recruitment and movement strategies have many parallels in the fishes of other floodplain rivers around the world (Welcomme *et al.* 2006).

Alien species are scattered but not common in arid-zone rivers of the Lake Eyre Basin. The mosquitofish presents the greatest threat to native species (see Chapter 3), particularly small species with a preference for slow-flowing or still water habitats, similar feeding behaviour and no-flow recruitment strategies (e.g. the desert rainbowfish and Lake Eyre hardyhead). The small aggressive mosquitofish could become far more abundant over time, judging by its successful invasion and proliferation in floodplain wetlands of the Murray–Darling Basin (e.g. the Macquarie Marshes), where it often out-numbers small native species (Rayner *et al.* 2009; D. Cruz, pers. comm.). Efforts to eradicate the mosquitofish have focused on isolated springs of the Great Artesian Basin (Kerezszy and Fensham 2013), particularly Edgbaston Springs where extant populations of the endangered red-finned blue-eye (*Scaturiginichthys vermeilipinnis*) are at risk (see Chapter 3).

Implications of changing the natural flow regime

The role of the natural flow regime as an important driver of riverine ecology is spectacularly evident in the boom and bust ecology of fish in arid-zone rivers. Even so, a pronounced capacity to swing between low and high population levels does not imply resilience to human impacts, particularly changes in the flow regimes of arid-zone rivers (Arthington and Balcombe 2011). The fish assemblages of Cooper Creek and other arid-zone rivers are vulnerable to alteration of flow patterns and catchment characteristics in several important ways.

First, the absolute necessity for all fish species to be able to persist in ‘refuge’ aquatic habitats (e.g. waterholes) during dry periods makes them vulnerable to any process that may accelerate rates of water loss and reduce the number of waterholes that could sustain aquatic organisms over extended dry periods. Several natural factors influence water loss by evaporation; these include waterhole depth and surface area, the effective width for wind action (and evaporation), the degree of incision below levee banks, and the height and width of riparian vegetation (Hamilton *et al.* 2005). As waterholes decrease in depth and volume, prominent features like benches, bars, offtake channels and structural habitat (logs, riparian leaf litter and aquatic plants) become exposed and desiccated. Habitat loss reduces opportunities for fish to rest, feed and shelter from predators, leading to high mortality rates that deplete waterhole fish populations (Arthington *et al.* 2010). Waterholes that maintain depth, volume, habitat diversity and water quality during dry times provide refuges for fish, and their identification and protection from human interference is an essential part of fish conservation and river management during dry periods and drought (Bond *et al.* 2008; Silcock 2009).

Human activities can influence the amount of water in waterhole refugia and the duration of waterhole persistence between flow pulses. Hamilton *et al.* (2005) estimated that most of the named waterholes mapped along Cooper Creek would dry within 22 months if not replenished by channel flows or flooding; after 24 months of no flow, only four of the named waterholes along Cooper Creek would remain wet. However, a broader study identified over 200 waterholes in the Cooper catchment that have not dried in living memory (Silcock 2009). River flows can be altered by upstream impoundments, small-scale diversions for irrigation in the upper catchments or capture of runoff for agricultural use (water harvesting), and water can be withdrawn directly from waterholes during intervals between flows (Thoms and Sheldon 2000). Small impoundments, raised roads, or other disturbances of the geomorphological structure of anabranches can alter river flows through various channels and waterholes (Hamilton *et al.* 2005). Reduced flows, less frequent waterhole replenishment, and increased frequency and degree of waterhole desiccation could have deleterious ecological impacts, including reduction or local extirpation of fish and turtle numbers as well as reduced water availability for riparian trees, floodplain wildlife and livestock (Hamilton *et al.* 2005; Leigh *et al.* 2010; Sheldon *et al.* 2010).

As well as reconnecting, refilling and replenishing isolated waterholes, channel flows can provide cues for fish spawning, movement and dispersal into backwater habitats or anabranches, allowing opportunistic discovery of high quality habitats and rich food resources or avoidance of predators. With the probable exception of Cooper Creek catfish, all members of the Cooper Creek fish community use inundated floodplains for feeding, growth, recruitment and dispersal. Hydrological connectivity between channels and floodplains is vital to these processes (Fig. 4.1). Many of the world’s floodplain rivers have lost their natural floodplain and river connections, inhibiting the natural movement patterns of aquatic species and life stages (Tockner *et al.* 2010). Altered catchment configurations (e.g. levee banks, roads and infrastructure) can cut off or impede delivery of flows onto floodplains (Steinfeld and Kingsford 2013), and this reduces connectivity and inhibits fish movements into favourable habitats for feeding and growth. The disruption to connectivity between

waterholes and their floodplains has been implicated in recruitment failure of yellowbelly in the upper Murray–Darling Basin (Balcombe *et al.* 2011).

Although flooding is unpredictable in frequency, extent and duration in Cooper Creek, floods underpin similar processes to the predictable annual floods of tropical and subtropical floodplain rivers (Junk *et al.* 1989; Welcomme *et al.* 2006). Floods also enhance recruitment of frogs, turtles and waterbirds and support the high levels of pasture production that underpin the vitality and viability of the pastoral industry in dryland catchments of western Queensland (Morrish 1998; see Chapters 10, 11 and 17). Regulating, dampening or eliminating occasional large floods or smaller channel flows undermines the resilience of arid-zone ecosystems, and has been disastrous for the fisheries of the Aral Sea in Uzbekistan and Kazakhstan, the Mesopotamian Marshes, Lake Mono in California and the Macquarie Marshes in the Murray–Darling Basin, Australia (Kingsford *et al.* 2006).

Conclusion

We have substantially increased our understanding of arid-zone rivers through research and monitoring in Cooper Creek and other rivers of the Lake Eyre Basin. Fish are adapted to the extreme natural flow variability of floodplain rivers in the Australian arid zone, where the natural processes driving population booms and busts are broadly consistent with other studies in dryland floodplain rivers (Welcomme *et al.* 2006). Erratic floods and long dry spells underpin the spectacular boom and bust dynamics so characteristic of Cooper Creek fishes. Maintenance of natural flow variability, sequential flood pulses, complex habitat mosaics, floodplain–channel connectivity and environmental flows for valued species are key management principles for arid-zone rivers (Balcombe *et al.* 2005; Larned *et al.* 2010; Sheldon *et al.* 2010). Challenges for the future are to avoid developments that threaten native fishes, especially alterations to naturally variable flow patterns, habitat diversity, connectivity and water quality. Wise use of these complex, dynamic systems is essential if we wish to conserve their biodiversity and enjoy the benefits of healthy Lake Eyre Basin ecosystems in the future.

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