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Determining the ecohydrological character of aquatic refugia in a dryland river system: the importance of temporal scale

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Abstract

Aquatic refugia are important features of riverine landscapes; providing habitat for biota during extremes and facilitating the recovery of biota from disturbance. The persistence and quality of aquatic refugia is intricately linked to the hydrological regime of their parent rivers. Knowledge of the influence of hydrology on refugia is essential for understanding their role in the functioning of riverine ecosystems. A hierarchical framework is used to investigate the hydrological character of refugial waterholes in a dryland river system at multiple temporal scales. The study demonstrates that temporal variability is matched by a high level of spatial variability in hydrological character and that spatial patterns in hydrological character varied according to the temporal scale at which hydrological characterisation was made. The findings of this study have important implications for dryland river ecosystems because of the fundamental importance of hydrology as a driver of riverine ecosystems.

Key words: ecohydrology, refugial waterholes, hierarchical framework, dryland rivers.

1. Introduction

Aquatic refugia play an important ecological role in riverine systems that experience variable hydrological regimes (Lancaster, Belyea 1997; Lake 2003). During disturbances such as high flows, low flows and no-flow periods, persistent aquatic floodplain habitats and in-channel waterholes remain and serve as important refugia that provide habitat, shelter and protection for water-dependent biota (Morton *et al.* 1995; Magoulick, Kobza 2003) and contribute to the recovery of river-floodplain ecosystems following such disturbances (Poff, Ward 1990; Sedell *et al.* 1990). Extended periods of no flow are common in dryland river systems (Graf 1988) and the utilisation of refugia by aquatic organisms is often the key to the survival of populations (Balcombe *et al.* 2006), and strongly influences the capacity of populations and ecosystem processes to recover (Lake 2003; Arthington *et al.* 2005).

The persistence and quality of refugial waterholes is intricately linked to their hydrological regime which governs their connectivity with other refugia within the riverine landscape (Lake 2003), provides water and renews waterhole resources. Knowledge of the influence of hydrology on refugia is essential for understanding their role in the functioning of riverine ecosystems (Lancaster, Belyea 1997; Magoulick, Kobza 2003). However, the highly variable and unpredictable hydrological nature of dryland rivers means that it is difficult to determine their hydrological character (McMahon, Finlayson 2003). Moreover, hydrological processes operate at a variety of spatial and temporal scales, all of which have the potential to generate different ecological responses (Poff *et al.* 1997; Dollar *et al.* 2007). In light of this, a temporal flow hierarchy has been proposed to meet the challenges of characterising hydrology in dryland river systems (Puckridge *et al.* 1998; Puckridge *et al.* 2000; Thoms, Sheldon 2000). Three temporal scales are recognised in the hydrological hierarchy as being important for river ecosystem function: flow regime, flow history and flow pulse. Regime-scale hydrology operates over hundreds of years and represents the long-term statistical generalisation of flow behaviour. History-scale hydrology operates between one and one hundred years and incorporates the sequence of floods and dry-spells during that time. Finally, the pulse-scale represents conditions at the scale of single flow events.

Although low-flow periods and no-flow events are characteristic of dryland ecosystems and are essential to the long-term functioning of these ecosystems (Graf 1988; Walker *et al.* 1995; Humphries, Baldwin 2003), water resource development has significantly changed their hydrological character (Kingsford 1999; Thoms, Sheldon 2000; Bunn *et al.* 2006b). Climate change is predicted to further increase the intensity and frequency of low and no-flow periods in these regions, and with continued water resource developments, the pressure on aquatic refugia will become even more influential on the continued resilience of aquatic ecosystems (Lake 2003). For this reason, the role of the entire hydrological regime in maintaining refugia, especially in relation to low-flow periods and no-flow events, need serious consideration (Lancaster, Belyea 1997; Bunn *et al.* 2006a).

This study uses the hierarchical framework of Dollar *et al.* (2007) and James and Thoms (2010) to investigate the hydrological character of refugial waterholes in a dryland river system. The knowledge gained from this study provides the hydrological context for further studies that examine how hydrology across a range of temporal scales influences ecosystem character and food web structure.

2. Materials and methods

2.1. Study Area and Methods

A series of waterholes located in the Lower Balonne Floodplain region of the northern Murray-Darling Basin, SE Australia were utilised for this study. The Lower Balonne Floodplain ecosystem extends from St George in Queensland (QLD) to the Barwon-Darling River in northern NSW and covers an area of 19 800 km^2. It is an extensive floodplain wetland complex (Thoms *et al.* 2002) comprised of four principal channels – the Culgoa, Birrie, Bokhara and Narran rivers – as well as a maze of smaller channels, flood runners, numerous permanent and ephemeral billabongs, swamps and waterholes. The region has been categorised by Thoms and Sheldon (2002) as the anastomosing zone of the Condamine-Balonne. Low-level private weirs along the Culgoa, Birrie, Bokhara and Narran provide stock and domestic supply. River regulation for mostly cotton irrigation, controls approximately 30% of the Condamine-Balonne river channel and Jack Taylor Weir (10,100 ML) at St George controls flow to the Lower-Balonne (Thoms, Parsons 2003). Water is also pumped from the rivers and distributary channels of the Lower Balonne during flow events and flood overflows are diverted to storages by levees and drains on the floodplain (Cullen *et al.* 2003).

Discharges of the five main channels in the Lower Balonne differ. A large proportion of average flows occur in very wet years and during major floods. Variability in flow is also high: coefficients of variation (CVs) for annual flows range from 103 to 200 and median annual flows can be less than 30% of mean annual flow. Flows (both annual volumes and flood peaks) generally decrease downstream towards the end of the system because of a lack of tributary contributions and high evaporation, a characteristic feature of Australian inland river systems (Thoms, Sheldon 2002). There have been changes in the hydrological regime of the Lower Balonne over the last 100 years, with the period prior to the 1900s and since the mid-1940s being wetter, on average. This has been associated with greater runoff and flood activity than for the period 1900 to 1945. These changes reflect the shift in the geographical pattern of correlation between precipitation and the Southern Oscillation Index (SOI) for the years before the 1950s compared with the years since the 1950s.

Potential refugial waterholes on the Lower Balonne were identified through examination of aerial photographs and topographic maps, and consultation with local communities and landholders.