The Ecology of Wet and Dry Phases of Temporary Waterways

With the recent publication of the National guidance for Assessing and Managing Water Quality in Temporary Waters (ANZG 2020), and the forecast 2020-2021 La Nina wet season – when expected higher than average rainfall will likely increase flows in waterways (including temporary waterways) – it's timely to consider the ecology of wet and dry phases of temporary waterways.

Background

Adopting the definitions of ANZG (2020), temporary waterways are systems that have a defined stream channel and alternate between flowing and either no-flow (i.e. disconnected waterholes) or dry stream bed states (Figure 1, Figure 2).

Two sub-classes of temporary waterways are recognised, with each of these sub-classes having a further recognised flow pattern:

1. intermittent waters: are predictably inundated each year (during a wet season), although the duration for which they retain water may be highly variable.
    - seasonal waters: are predictably inundated in one or more seasons in most years.
2. ephemeral waters: contain water only after irregular rainfall or flow events.
    - episodic waters: contain water only after rare rainfall or flow events; such as many arid zone systems.

Figure 1: Temporary waterway in completely dry state.

Figure 2: Temporary waterway with disconnected waterhole.

Brief periods of flow in temporary waterways are generated by rainfall and runoff in upper catchment areas, with flows ceasing shortly after runoff ceases. In contrast, flows in perennial systems (i.e. those that have flows / hydrological connectivity for (almost) all of the time) are typically generated by significant groundwater discharge to the waterway, creating baseflow, with rainfall and runoff increasing water levels and flow magnitudes in perennial systems from baseflow state to high flow or flood flow states.

Disconnected waterholes in temporary waterways are often temporary themselves, frequently comprising only residual water from the most recent flow event in sections of the channel where geomorphology allows more significant pooling of water, with such waterholes soon lost to seepage and evaporation. However, longer-persisting disconnected waterholes in temporary waterways may be sustained by localised groundwater inputs, also called baseflow; however, it is important to appreciate the significant ecological and hydrological differences between 'localised' baseflow that

sustains isolated waterholes in temporary waterways during periods of no rain versus 'regional' baseflow that creates perennial or near-perennial flow and hydrological connectivity along significant lengths of stream and river. Disconnected waterholes in temporary waterways may also be sustained by localised upwelling of hyporheic flows (i.e. water moving downstream within stream bed sediments), such as at locations where outcrops of underling bedrock push hyporheic flows up to the surface.

A large proportion of Australia's waterways are temporary, with climate change and future increases in human demand for water predicted to increase the proportion of temporary waterways globally (Steward et al. 2012; Stubbington et al. 2017), although in other cases water resource development has converted temporary waterways to perennial or near perennial systems. Thus, understanding the ecology of wet and dry phases of temporary waterways is foundational to defensible environmental management.

Ecology of Dry States

Dry stream beds are the predominate habitat type in temporary waters, and these support diverse terrestrial and semi-aquatic invertebrate (TSAI) communities that differ significantly from invertebrate communities in adjacent riparian areas, although the riparian fauna is more diverse than that of dry stream beds (Steward et al. 2011). While most TSAI taxa are shared between dry stream beds and adjacent riparian areas, approximately 20% of morpho-species appear to be unique to dry stream beds (Steward et al. 2011).

Commonly encountered TSAI taxa include ants (Formicidae), beetles (Coleoptera), springtails (Collembola), mites (Acarina), flies (Diptera), bugs (Hemiptera), cockroaches (Blattodea) and spiders (Lycosidae) (Steward et al. 2011), although shortly after drying the taxa present may also include a range of semi-aquatic taxa on still-saturated sediments, such as some types of tolerant semi-aquatic insect, snails and crustacean (Steward et al. 2012, 2017). Coarse substrates provide more favourable habitat for most TSAI species because of the larger interstitial species available, and are typically associated with higher abundance and diversity of TSAI species, although some TSAI species (such as those that can dig to avoid predation) prefer sandy substrates (Steward et al. 2017).

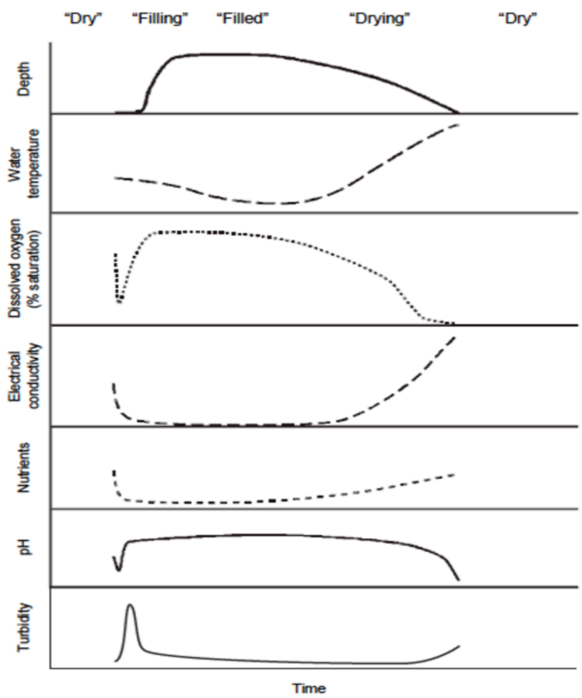
Ecology of Wet States

First-flush flows, especially those of high velocity, may entrain some TSAI taxa and naturally deplete TSAI communities if flows are not rapidly followed by drying (Steward et al. 2017), although resistance traits to flows used by some TSAI include: flotation, swimming, flight, climbing and novel respiration mechanisms, and others have strong abilities for recolonisation (i.e. wide-spread dispersal) (Steward et al. 2017), indicating that these taxa may have relatively large geographical distributions.

Some aquatic invertebrates, such as fairy shrimp and tadpole shrimp, have desiccation-resistant eggs that lie dormant in dry streambed sediments until flows / wet states trigger their emergence (Williams 1980). Thus, wet season flows in temporary waterways initiate the brief life cycle of these types of aquatic invertebrate, with desiccation-resistant eggs one of a range of adaptive traits used by stream fauna that inhabit temporary waterways. Some other types of aquatic invertebrate may find refuge beneath stream bed sediments in the hyporheic zone during periods of no surface flow, only to undertake return vertical migration to the stream surface during wet states (Stubbington 2012). Finally, aquatic invertebrates may re-colonise from elsewhere, with the colonisation pathway dependent on whether or not there is direct hydrological connectivity with source populations (Mackay 1992). Where there is direct hydrological connectivity, then colonisation can be via active or passive 'swimming' (e.g. passive downstream drift or active upstream rehotaxis movement), with fully aquatic invertebrates (e.g. shrimps, molluscs) able to recolonise over a range of spatial scales. In contrast, where there is no direct hydrological connectivity, re-colonisers must fly in from elsewhere (e.g. stream insects with winged adults stages capable of flight; such as water boatmen, water striders and whirligig beetles) or be carried for example on the feet of waterbirds.

For aquatic invertebrates that have fully aquatic larval / nymph stages and fully aerial adult stages (e.g. dragon flies, mayflies, caddisflies) the success of colonisation of temporary waters is dependent on how long the water persists, because the water must persist for long enough for adults to fly in and lay eggs, for the eggs to hatch and the larvae to develop. In many cases, temporary waterways do not hold water for long enough for these life cycles, and so the macroinvertebrate communities of these waterways never attain an a 'mature' state before they dry. Most (but not all) temporary waterways have lower macroinvertebrate diversity than comparable perennial systems (Boulton & Suter 1986), with macroinvertebrate diversity (and the sensitivity of macroinvertebrate taxa present) further influenced by changing water quality conditions of temporary pools (see Figure 3) and stream bed sediment composition (i.e. diversity lower in temporary streams with sandy bed substrates compared to temporary streams with coarser substrate composition; Davis et al. 2015).

Flows in temporary waterways are also critical cues for migration and breeding by many species of fish (Kerezsy et al. 2013), particularly where flows connect refuge and breeding locations. These brief opportunities for fish migration in temporary waterways are vulnerable to water extraction and waterway barriers, and so provision of fish passage around instream infrastructure is particularly critical in temporary waterways because failure of fish passage may mean it is many months (or even years in some cases) before another flow event provides an opportunity for fish migration. Permanent and near-permanent disconnected waterholes in temporary waterways are also key breeding habitats for some species, such as bony bream, in which breeding is triggered by low or no flow condition (Balcombe et al. 2006). Furthermore, such waterholes are refugia for fish (and other aquatic fauna, including turtles) in systems that are otherwise extensively dry for much of the time; thus, enabling aquatic species to persist in the landscape.



Adapted from Boulton et al. (2014) as presented in ANZG (2020).

Figure 3: A conceptual model of possible water quality changes in a temporary pool.

Conclusion

While the discussion provided here is necessarily brief and simplified, it can be seen that the dry–wet–dry transitions in temporary waterways create dynamic and varied habitats for a range of fauna that respond to these hydrological changes in a variety of ways over a range of spatial and temporal scales. Understanding these varied ecological responses is fundamental to sound environmental management of temporary waterways, from the design of rigorous aquatic ecological baseline surveys and monitoring programs, to the interpretation of field data and the development of defensible management responses.

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