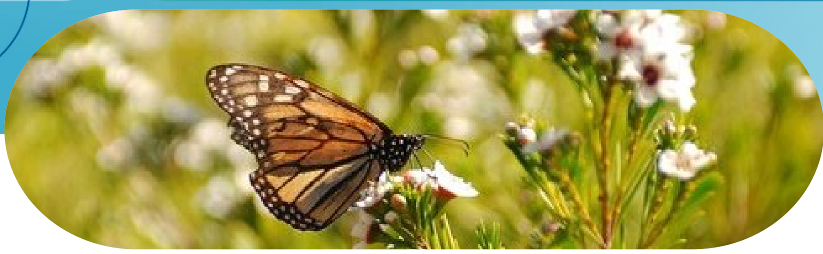
Wungong Catchment Trial

Temporal persistence in northern jarrah forest aquatic macroinvertebrate communities

Preliminary investigation of response to declining rainfall

July 2012



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Acknowledgements

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ISBN 1 74043 796 9 July 2012

Temporal Persistence in Northern Jarrah Forest Aquatic Macroinvertebrate Communities: Preliminary Investigation of Response to Declining Rainfall

Quantification of the degree of temporal variability in faunal communities is important for monitoring and predicting ecosystem responses. It is especially relevant for the management and monitoring of freshwater streams in the northern jarrah forest, which are typically characterised by seasonal and annual extremes of flow. In the south-west of Western Australia, declining rainfall over the last 25 years has seen many perennial streams stop flowing in summer, whilst the proportion of seasonally flowing streams has increased, with flow duration in these streams becoming shorter. Seasonal streams tend to be less biodiverse, with a fauna adapted to avoid desiccation, as opposed to the fauna of perennial streams, many of which require permanent flows and take longer to complete life cycles. Ultimately, perennial stream fauna could be threatened if the majority of streams in the jarrah forest were to dry.

Collated survey data that span 27 years were analysed to assess constancy (persistence) of aquatic macroinvertebrate species assemblages in upland streams of the northern jarrah forest. Data were derived from replicated, quantitative samples collected seasonally (spring & summer) from four creeks, sampled initially in the mid-1980s and again in the mid- to late-2000s. All of the creeks were once permanently flowing but now appear to be increasingly seasonal in flow (Table 1). Although from a discontinuous time series, these data provide insight into both short- and long-term trends, with data available from periods of higher (1980s) and lower (2000) rainfall, as well as winters of exceptional low rainfall (2006), which have affected stream flows.

Table 1. Stream sites in the northern jarrah forest.

Catchment	Study sites	Sampling period	Flow permanence
Wungong Brook	Wungong Brook at Vardi Road gauging station	2005-2010 (6 years)	Perennial but increasingly seasonal; dried for the first time on record in summer 2007
Canning River	31 Mile Brook at 31 Mile Road gauging station	1984-1987, 2005-2010 (10 years)	Perennial but has dried in some summers since the early 1990s
North Dandalup River	Foster Brook at Sharp Road	1985-1990, 2005-2010 (12 years)	Perennial but increasingly seasonal since the early 1990s
North Dandalup River	Wilson Brook at Reynolds Road	1985-1987, 2007-2010 (7 years)	Perennial but increasingly seasonal since the early 1990s

Analyses showed high seasonal and interannual variability in species richness and abundance at all sites. Of most note were, i) a recent shift in species assemblages at 31 Mile Brook, Foster Brook and Wilson Brook (Fig. 1), and ii) significant declines in species richness and abundance in Wungong Brook at Vardi Road (Fig. 2) following particularly low annual rainfall in 2006/07 (Fig. 3) and subsequent drying of the stream channel, for the first time on record, during summer 2007.

Pairwise percentage similarity (Bray-Curtis[1]), which provides a measure of statistical 'distance', was used for time series analysis of the overall change faunal assemblages in spring (Sept./Oct.) relative to baseline condition when first sampled (Fig. 2). Comparison with historic (1985-1990) data suggests faunal assemblage similarity has recently (2006-2010) shifted away from the pre-1990 condition, by up to 10% at 31 Mile Brook and up to 25% at Foster and Wilson brooks. Flow in these previously perennial brooks is believed to have become increasingly seasonal since the early 1990s and the difference in community structure appears to reflect a change in flow permanence at these sites.

In Wungong Brook, there has been only a slight net shift (5%) in species similarity away from the spring 2006 baseline condition (Fig. 1). This was despite a 44% decrease in species richness and 66% decrease in species abundance between 2006 and 2008 (Fig. 2). The shift was driven by small changes in abundance of a large number of less common species, including species

[1] Bray-Curtis similarity matrices generated using PRIMER multivariate analysis.

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considered sensitive to environmental disturbance. As the similarity measure is weighted by numerically ‘common’ taxa, this manifest as large fluctuations in total species richness and abundance but only small fluctuations in community assemblage similarity. The fact that the river channel at Vardi Road dried for the first time on record in summer 2007, was seen as the most likely explanation for the large declines at this site. These were echoed to a lesser degree at Foster Brook. In 2009 and 2010, there were signs that the fauna was recovering, even though rainfall (and by association, streamflow) was again low in winter and spring 2010 (Fig. 3).

The current shift in species assemblages at these sites is not considered to signify a major ecological response, but rather a change in relative abundance of a few taxa that are more sensitive to environmental disturbance. It is probable that warmer stream temperatures in autumn and early winter, reduced winter rainfall and increased late spring rainfall all combine to alter life history patterns of aquatic macroinvertebrates. Effects will vary between species, disadvantaging some and benefiting others.

Amongst sites, the most consistent responses were, i) decreased abundance of taxa more typically associated with higher water velocities and fast-flowing reaches (*i.e.* simulids, caddis-flies, baetid mayflies, several midge species and the synthemistid dragonfly *Austrosynthemis cyanitincta*), ii) increased abundance of species more common to seasonal and/or slow flowing waters (*i.e.* ostracods, acarines and/or the chironomid *Cricotopus annuliventris*) and iii) increased abundance of gripopterygid stoneflies and the leptophlebiid mayflies (*e.g. Nyungara bunni*). However the magnitude of these changes was highly variable amongst species, sites and years, with individual species contributing less than 10% to the overall change in similarity from historic/baseline condition.

Changing abundance of gripopterygid stoneflies and synthemistid dragonflies is of particular conservation interest, as species from these families represent relict or Gondwanic elements that have survived from an age that was typically more humid and wetter, with a less markedly seasonal climate. The gripopterygid stoneflies and synthemistid dragonflies of the south-west appear to have evolved through both wetter and drier periods than prevail today (Bunn 1988). At present, they are found predominantly in perennial and seasonally-flowing, forested headwater streams, including streams in both the northern and southern jarrah forest. In general, Gondwanic biota are considered important and unique elements of the jarrah forest, *i.e.* they have significant conservation and National Estate value (Main 1996).

Also of note was a trend toward declining abundance of stygal paramelitid amphipods in samples from Vardi Road between 2005 and 2009. Over the same period, the authors recorded a similar decline in numbers of these amphipods in headwater streams of the Serpentine and South Dandalup rivers. These amphipods are obligate groundwater species that require permanent water in order to survive. Change in their abundance may reflect frequency and/or duration of connectivity between ground and surface waters. Where there is strong connectivity between ground and surface waters it is assumed they frequent surface waters in search of food, particularly during wetter periods. However, declining water tables in the northern jarrah forest are well documented, and may result in less connectivity between groundwater and surface streams, with a concomitant reduction in the abundance of amphipods in surface waters. As these amphipods are vagrants in surface waters, targeted sampling of groundwater bores would be required to confirm any long-term population trends of these species in groundwaters.

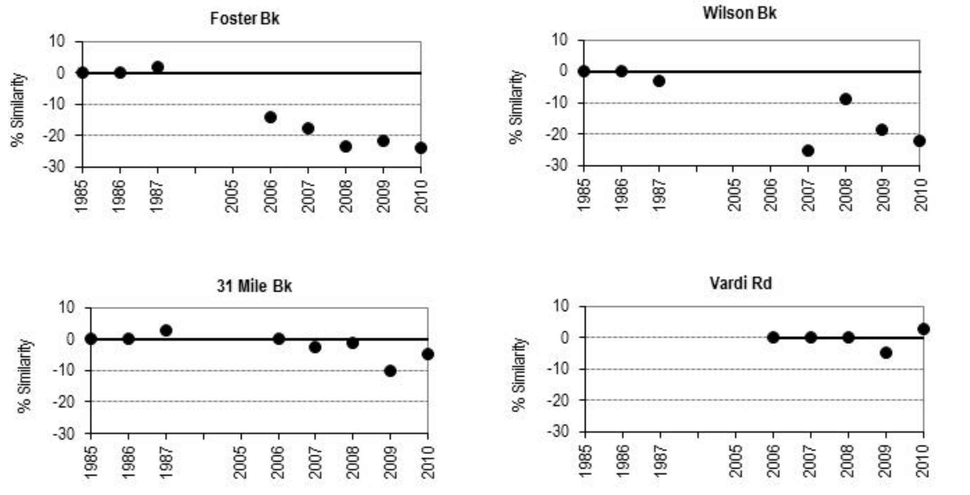


Figure 1. Change in similarity of macroinvertebrate species assemblages relative to their historic (baseline) condition. Baseline condition is indicated as the solid dark line and is derived from spring 1985 data for 31 Mile, Foster and Wilson brooks, or spring 2006 data for Vardi Road. All data are percent similarity values determined from pairwise Bray-Curtis distance matrices (PRIMER) based on species abundance.

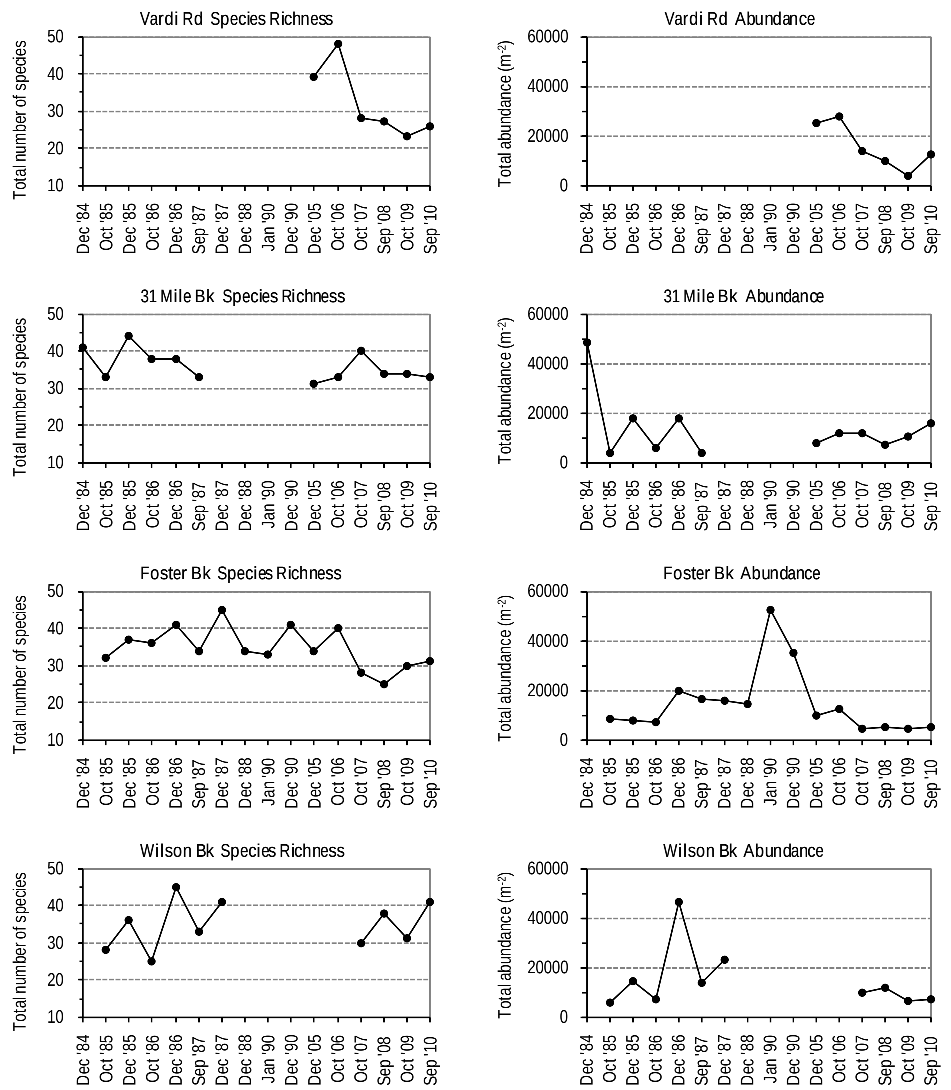
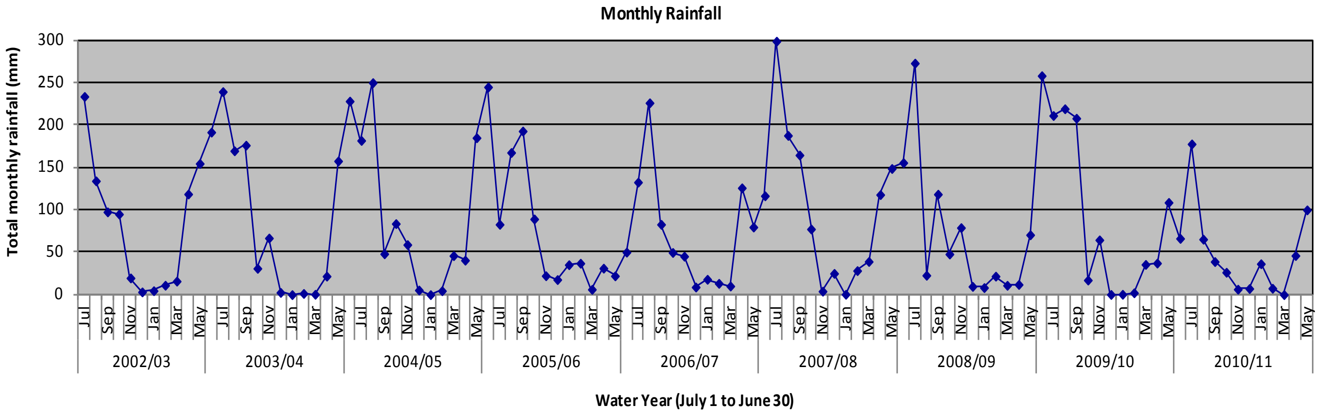


Figure 2. Examples of annual variability in macroinvertebrate species metrics (total richness & total abundance) at Vardi Road in the Wungong catchment compared with 31 Mile Brook in the Canning catchment and Foster and Wilson brooks in the North Dandalup catchment. Taxonomy has been standardised across years.



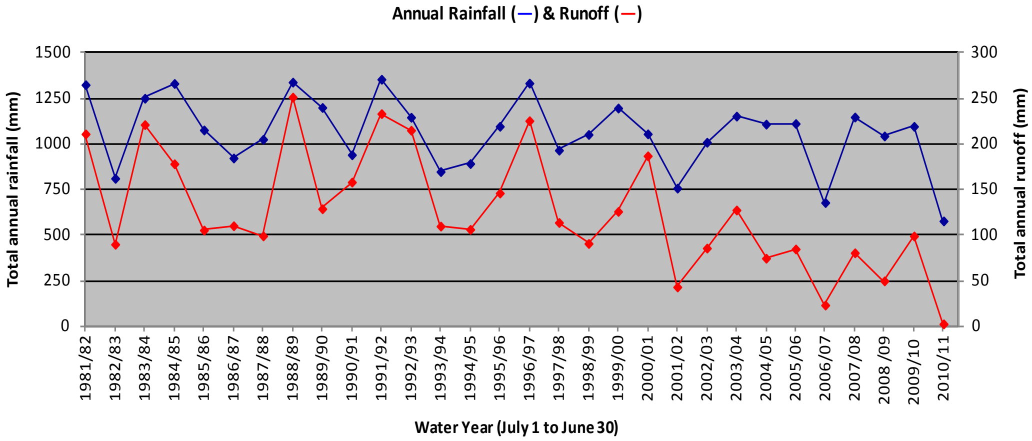


Figure 3. Rainfall (Stn 509269 - Seldom Seen Brook - Gardens) and runoff (Stn 616041 - Vardi Road) in the Wungong catchment.

Faunal response to a drying climate is unlikely to be linear whilst drought refugia, such as permanent pools, persist along the same or adjacent creeks. In the initial phases, dominance patterns may change little year to year for common macroinvertebrate species in perennial streams. Temporal and spatial unevenness ('noise') will predominantly be driven by the more sensitive (and typically less common) species, at least in the early stages when stream drying is infrequent. This may explain why the observed shift in overall species assemblages has been greater at Foster and Wilson brooks than at 31 Mile Brook and Vardi Road. Although the degree to which seasonality of flow has increased at Foster and Wilson brooks relative to 31 Mile Brook, and the persistence of upstream drought refugia has not been investigated.

Some species, such as the stoneflies and leptophlebiid mayflies, may be better able to cope by way of extended periods of egg hatching and the ability to alternate between slow and fast larval development dependent on environmental conditions. The apparent increase in stoneflies and leptophlebiid mayflies at study sites may be a response to changes in stream temperature regime as much as changes in flow regime. Temperature (as well as flow) is known to play a critical role in hatching, larval development and adult emergence (Bunn 1988, Sutcliff *et al.* 2002).

Studies conducted by Bunn (1988) during the early 1980's in the Wungong and North Dandalup catchments, demonstrated that some macroinvertebrate species that inhabit perennial streams have fast and slow univoltine[2] life cycles or are capable of cohort splitting. Consequently community structure in south-west streams is less complex and has a higher degree of seasonality than is typical of temperate streams of Australia and New Zealand. The higher degree of seasonality in the fauna, with distinct periods of recruitment synchronised to winter rainfall, implies many species evolved during periods when the south-west was drier than it is today (Bunn 1988).

[2] Univoltine = breeding once per year; semivoltine = having a lifecycle that takes longer than one year to complete.

Briers *et al.* (2004) similarly established a relationship between climatic conditions and the growth of aquatic insects in North American streams. Mayfly nymphs were found to grow faster during warmer years when stream temperature was warmer (*i.e.* they had a shortened life cycle), with emergence of adults varying by almost two months between 'warm' and 'cold' years. By contrast, Briers *et al*. (2004) found no relationship between growth in stonefly nymphs and climate variation. This was considered to be due to the fact that they were less dependent on temperature and they displayed a semivoltine lifecycle.

In the headwater streams of the Serpentine and South Dandalup rivers, the authors have observed altered growth patterns in chironomid midge larvae that appear to be a response to declines in seasonal rainfall. Early emergence of adult phases was recorded, implying shortened larval development times and possibly more numerous and overlapping cohorts. A decline in total species richness and abundance and a shift in community assemblages was also recorded in these streams between 2007 and 2009 (Davies & Storey, unpubl. data). Taxa contributing most to between-year differences in species assemblage differed from those in the current study, possibly reflecting inherent differences in habitats between the catchments.

Although many species inhabiting south-west perennial systems may already be pre-adapted to drought conditions, having evolved under a climate oscillating between wetter and dryer periods, it is predicted that on-going decline in rainfall will have a pronounced effect on community structure. Prolonged drought, the late onset of flows and short flow duration are likely to result in loss of species richness and abundance as some species will not be able to complete their life-cycles. Boulton (2003) found prolonged drought "eliminated or decimated" atyid shrimps, stoneflies and caddis-flies. Although these taxa persisted through early stages of drought, they did not recruit successfully the following year, even with a return to higher-than-baseflow conditions. Similarly, in Wungong Brook at Vardi Road, the large decline in species richness and abundance observed in 2007 was attributable to poor recruitment following a dry winter in 2006 and late onset of flows in 2007. The relatively short flow duration in 2007 would likely have prevented some species completing their life cycles.

In recent studies by Murdoch University (Klunziger *et al.* 2011), freshwater mussels (*Westralunio carteri*) in the Swan-Canning catchment were found to be sensitive to drought, elevated temperatures and hypoxia. Mortality of *W. carteri* occurred following the draining of the Lower Helena Reservoir which left mussels stranded in drying sediments. Though mussels occur in seasonal, as well as perennial streams, they appear to require at least some permanent surface water and are intolerant of drying that lasts more than a few days (Klunzinger *et al*., in review). As part of the current study, *W. carteri*, which is a listed species (IUCN, vulnerable), was opportunistically recorded from Vardi Road, together with the listed Gondwanic freshwater snail *Glacidorbis occidentalis* (IUCN vulnerable; DEC P4). Neither species has been recorded from Vardi Road since 2006. Their absence may be an artefact of the sampling technique, which is habitat-specific (*i.e*. riffles), but it may equally be due to reductions in flow, particularly for mussels.

Apart from mussels, other iconic macroinvertebrates that inhabit upland streams in the northern jarrah forest are the native freshwater crayfish (gilgies & smooth marron). Only gilgies (*Cherax quinquecarinatus*) have been recorded from the current study area and, to date, there has been no observed change in their relative abundance. *C. quinquecarinatus* occurs in both seasonal and perennial waterbodies throughout the northern and southern jarrah forests and though capable of burrowing to avoid summer drying, soils must remain moist to ensure their gills stay hydrated.

In contrast to *C. quinquecarinatus*, smooth marron *C. cainii* are believed far more sensitive to environmental fluctuations and require permanent water to survive. As early as the late-1970s, Morrissy (1978) theorised that extinction of some natural populations of smooth marron in marginal upland areas of the northern jarrah forest was due to drought-related recruitment failure. The current range of *C. cainii* in both the northern and southern jarrah forest, has retracted to the middle and lower reaches of rivers where deep pools and/or summer flow persist. The range is limited by water quality and loss of in-stream and riparian habitat due to agricultural land use and surface water management (de Graaf *et al.* 2010, Beatty *et al.* 2011). Continued reductions in streamflow associated with climate change are expected to further restrict the range, leading to further declines in the productivity of the south-west Recreational Marron Fishery, as river flow is positively correlated to *C. cainii* catches (de Graaf *et al.* 2010).

Conclusions

As flow in perennial streams becomes seasonal and flow in seasonal streams becomes episodic, critical thresholds in flow duration needed to allow successful completion of life cycles will be reached, resulting in loss of biodiversity. The distributions of many freshwater species will become increasingly restricted, including conservation significant species such as Gondwanic dragonflies, stoneflies, the tiny freshwater snail *Glacidorbis occidentalis*, and iconic species such as marron, gilgies and freshwater mussels. Distribution of these species in upland areas has already contracted due to declines in habitat and water quality related to land use and water management practices.

Large reductions in macroinvertebrate abundance will impair the functioning of aquatic ecosystems. Macroinvertebrates play a vital role in freshwater food webs. They are an important food source for native fish and freshwater crayfish, as well as contributing to nutrient and carbon re-cycling. As filter feeders, large populations of mussels are believed to help maintain water quality in pools where native fish and crayfish take refuge over summer. Mussels are also an important dietary component for both freshwater cobbler (*Tandanus bostocki*) and water rats (*Hydromys chrysogaster*). In 2006 at the Vardi Road weir, the authors observed a water rat feeding platform littered with the shells of freshwater mussels and crayfish. Water rats are a listed species (DEC P4) occurring in a wide variety of freshwater habitats, from inland waterways to lakes, swamps and farm dams throughout Western Australia. Populations associated with temporary water can be highly unstable because water rats are subject to heat stress and are unable to survive high temperatures without large amounts of water (Watts & Aslin 1981).

Breeding habitat for native freshwater fish will also be reduced as seasonal streams become episodic. Western minnows (*Galaxias occidentalis*), pygmy perch (*Nannoperca bostocki*) and nightfish (*Bostockia porosa*) occur in upland streams throughout the northern jarrah forest. These species preferentially migrate into and breed in seasonal tributaries and their capacity to successfully breed and recruit in backwaters and shallow reaches of larger permanent rivers is unknown. Reduced flow duration in these seasonal creeks will limit the ability of these fish to breed successfully, which will affect the viability of local populations.

None of the species discussed in the current report are believed restricted to the northern jarrah forest. However, the current extent of Gondwanic species in the south-west is poorly researched. Until relatively recently, Gondwanic species tended not to be well-represented in conservation reserves because their preferred habitats, being poorly-defined swamps and headwater tributaries, were often overlooked for inclusion in stream reserve systems (Trayler *et al*. 1996). However, all of these habitats that are in south-west forests managed by the Department of Environment and Conservation (DEC) are now protected in existing or proposed formal or informal reserves under current forest management plans (Conservation Commission of Western Australia2003, DEC 2009). If widespread drying is confined to the northern jarrah and does not extend to the southern jarrah forest, then it is expected that loss of species diversity will be localised. Though associated loss of genetic diversity will still be at the south-west regional scale.

One species of conservation significance that may be restricted to the northern jarrah forest, is the endemic western petaltail, *Petalura hesperia*. This giant dragonfly belongs to a relictual (ancient) family of dragonflies, the Petaluridae. It has a typical body length of 8 - 10 cm and a wingspan commonly 11 - 12 cm (Jan Taylor, pers. obs.). Petalurids have existed since at least the Jurassic Era and extant members exhibit a number of primitive morphological features. This species is currently considered rare, though the full extent of its distribution, and hence conservation status, is unknown, as only one systematic survey for it has been conducted in the south-west (Barrett & Williams 1998). Populations in headwaters of the Serpentine River were still known to exist when surveyed in December 2007 (WRM 2007), but no additional formal surveys have been undertaken. *P. hesperia* occur only in boggy headwater marshes or seepages, where the larvae remain underground for up to 6 years (Watson 1965). The burrows extend down to the water table and must remain continually moist. The adults emerge in November/December to mate, after which they die (Taylor 2006). Systematic drying of the northern jarrah forest, with concomitant declines in water tables has the potential to lead to local, regional, or even total extinction of this relict species.

In the northern jarrah forest, forestry and mine-site rehabilitation practices that lessen groundwater recharge will exacerbate the effects of a drying climate, by further lowering water tables and reducing the volume of 'refuge' pools that support water rats, fish, marron and other aquatic species in upstream reaches during summer. Reductions in pool size will reduce water quality (through evapo-concentration effects) and limit habitat availability and hence carrying capacity. Declining groundwater levels pose considerable risk to burrowing and interstitial fauna (*e.g.* gilgies, petalurids & stygofauna), if burrows/soils dry completely. Beatty *et al.* (2011) also considered that predicted increases in summer rainfall may only serve to worsen water quality in upstream reaches (through unseasonal runoff of nutrients and tannins *etc* from the catchment), resulting in recruitment failures and/or deaths of marron, further reducing their upstream range. This would also apply to other aquatic species that cannot tolerate or escape poor water quality conditions.

Further studies

There is likely to be a minimum flow duration, below which fauna cannot complete their life-cycles. Even fauna that are pre-adapted to seasonal flow may not survive if the duration of flow falls below a critical minimum duration. To date, there has been little research on critical flow duration thresholds in south-west streams and rivers below which fauna adapted to seasonal (as opposed to episodic) flow regimes would be lost.

Concurrent with the sampling of 31 Mile Brook in the mid to late 1980s, a number of seasonal creeks were also sampled throughout the upper Canning catchment, including Kangaroo Gully, Poison Gully Creek, Death Adder Creek and the upper Canning River at Glen Eagle. Significant reductions in flow duration are believed to have occurred at these sites in recent years and it is likely flow durations are now below critical periods for some/many species. This would be easily tested by re-sampling the fauna at these sites to evaluate how it has responded to increasingly ephemeral flow regimes. This would provide an indicative measure of the likely future condition of other seasonal systems as their flow duration is further reduced, and help quantify the potential loss of biodiversity under a drying climate.

Acknowledgments

The authors would like to acknowledge the Water Corporation of Western Australia for funding this work, in particular Michael Loh for his support and overall project management on behalf of the Water Corporation. Keith Barrett (Water Corp.) and Frank Batini (Consultant) are also thanked for constructive discussions.

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