WATER USE STRATEGIES OF A DOMINANT RIPARIAN TREE SPECIES (EUCALYPTUS COOLABAH) IN DRYLAND RIVERS

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Riparian and floodplain tree communities are often the dominant woodland assemblage in the arid zone and have high ecological value. The assessment of how groundwater or streamflow changes may affect riparian trees is hampered by two coinciding knowledge gaps: (i) water use requirements of arid zone, riparian trees, and (ii) unconfined groundwater depth and salinity. Data on riparian tree (predominantly *Eucalyptus coolabah*) transpiration patterns were collected using sap flow loggers from a number of trees in the Neales and Finke River catchments of western Lake Eyre Basin, between May 2013 and March 2015, and related to streamflow events and groundwater conditions, where data were available. The mean annual evapotranspiration (ET) rates for trees with probable access to groundwater (i.e. water table within 5-8 m of the surface and salinity <20 g/L) were in the range of 70-140 mm, compared to mean annual rainfall ranges of 140-220 mm. The *E. coolabah* responded to both rainfall and streamflow events but sap flow rates returned to background levels within 10-20 days of rainfall events while remaining elevated for two or more months following streamflow events. The results indicate that *E. coolabah* has root systems with the capacity to switch between shallow soil moisture stores (e.g. rainfall and streamflow infiltration) and deeper groundwater stores. The switching occurs immediately after rainfall/streamflow and higher transpiration rates will be sustained while the shallow soil moisture stores remain available. This flexible strategy enables *E. coolabah* to persist in riparian zones of ephemeral rivers with highly variable flow regimes.

1 INTRODUCTION

Riparian and floodplain tree communities of ephemeral rivers are often the dominant woodland assemblage in the arid zone due to the increased provision of water in comparison to surrounding areas reliant on rainfall. Streamflow replenishes soil moisture stores of the channel system and floodplain and provides a significant source of groundwater recharge, often resulting in unconfined or perched groundwater levels that are sufficiently shallow to be accessed by phreatophytic trees [1]. The availability of these water resources (soil moisture and unconfined groundwater) is susceptible to anthropogenic activities, such as flow regulation and groundwater pumping, and climate change affecting the frequency of flow events. Therefore, identifying the range of water sources that can be utilised by the dominant riparian tree species is a critical question for the sustainable management of arid zone rivers and associated riparian ecosystems.

The assessment of how groundwater or streamflow changes affect riparian trees is hampered by two coinciding knowledge gaps. Firstly, the water use requirements and the capacity to switch between water sources of many arid zone riparian tree species are not known, as most work in this area has been done on semi-arid, regulated, perennial rivers with poor tree health on their floodplains [2, 3]. The second knowledge gap is that the depth and salinity of groundwater in many arid regions is poorly defined because of a lack of monitoring bore networks. Being able to link the water use requirements of trees to groundwater states (levels and water quality) and streamflow measures (e.g. frequency, duration) provides an avenue to identify areas within a catchment where hydrological changes will result in significant detrimental changes to the riparian tree communities. In this paper, the water use requirements of the dominant riparian tree, *Eucalyptus coolabah*, of the arid zone catchments of the Lake Eyre Basin (LEB), Australia, are investigated.

2 METHODS

The study area included floodplain sites from two large unregulated ephemeral river systems of the arid LEB of central Australia; Finke River and Neales River. The catchments range in area from 34,000 km^2 (Neales) to 100,000 km^2 (Finke) and both flow towards the endoreic Lake Eyre North (Figure 1) and have ephemeral, summer-dominant flow regimes. The study reaches coincide with the arid core of Australia with median annual rainfall of 147-176 mm and mean annual pan evaporation loss of 3360-3580 mm (Australian Bureau of Meteorology). The rivers are sparsely monitored with an upstream gauging station on the Finke but only stage monitoring occurring on the Neales (Figure 1). The study period of May 2013 to May 2015 coincided with drought conditions in both catchments broken by a flood event in January 2015. The Neales River had no streamflow events occurring for a two year period from February 2012 to February 2014, the longest period of no flow in its 15 year record [4], while the Finke had no flow from February 2012 to January 2015. A relatively large rainfall event occurred in January 2015 and had the most influence in the Finke catchment, while only generating small flows in the Neales, the latter also experiencing small flows in February and April 2014. The study reaches have generally sparse riparian woodlands dominated by *E. coolibah* and subordinate *Acacia* species, except for the Finke site, where moderately dense woodland occurs on a poorly channelized floodplain. *E. coolibah* is a flood propagated species occurring in riparian and floodplain habitats with a wide distribution across arid and semi-arid zones of Australia [5].

Heat pulse sap flow meters (SFM1, ICT International) were installed into seven locations (Figure 1) between May 2013 and May 2015 with varying length of record (Table 1). The sap flow meters were installed into *E. coolabah* at all sites except for meters installed into two *Acacia* spp. at the Neales C site. Raw temperature data were recorded at a 10 min time-step and converted to sap flow velocities using ICT proprietary software (Sap Flow Tool) and information from 1-4 cores collected per tree to determine sapwood characteristics. The key measurements of each instrumented trees were used to determine sapwood dimensions (e.g. circumference at the sap flow meter, bark thickness, sapwood thickness) and thermal diffusivity (e.g. sapwood wet and dry core weight and dimensions). Quadrats were measured at the sites (except for those with only individual trees, e.g. Neales A, B, D) to characterise the tree assemblage and to allow some up-scaling of evapotranspiration rates established from the sap flow data. Within each quadrat (50x50 m at the Finke site and 60x30 m at the Neales C site), the tree circumference and type were measured.

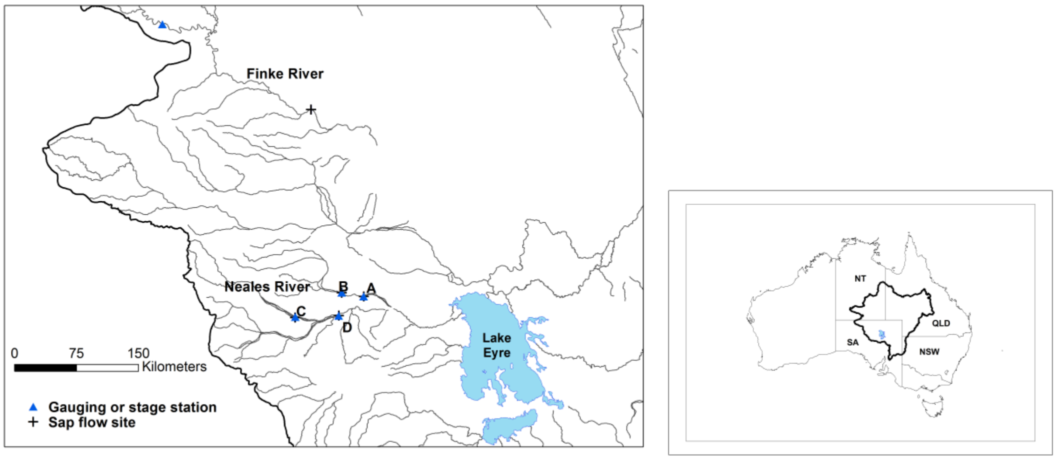

Figure 1. Location of sapflow monitoring sites on the Finke River and Neales River of the Lake Eyre Basin.

3 RESULTS

The differing monitoring periods at both catchments coincided with drought conditions and so provide insights into base-level transpiration flux requirement of *E. coolabah* for the period May 2013 to November 2014 (Table 1). The largest and most variable unit area fluxes were at the Neales A site, and to a lesser extent in a short 3-day record from Neales D site. These high fluxes coincided with relatively shallow groundwater (3-6 m depth) of moderate - high salinity (15-20 gL^{-1}). The Neales B and C sites had stable or declining fluxes of <30 cm with low variability coincided with sites with hypersaline groundwater (>100 gL^{-1}, Neales B) or probable depths to groundwater exceeding 10 m (Neales C). Two of the Finke River trees showed similar, low flux rates, despite a relatively shallow water table (7.5 m depth, salinity unknown but likely of stock quality <5-10 gL^{-1}), but this was in contrast to higher fluxes shown by two nearby trees. A 30 m x 60 m quadrant at the Neales C site contained 19 coolabah stems (total sapwood area of 0.28 m^2) and 292 acacia stems (total sapwood area of 1.02 m^2) resulting in mean daily acacia sap flux per unit area of 0.206 m^3 and 0. 266 m^3 for coolabah. Over the quadrant, this equated to a total ET loss from the trees of only 57.8 mm per year or 0.16 mm per day. At the Finke site, three 50 x 50 m quadrats showed that the number of coolabah stems varied between 37-144 for total sapwood areas of 2.84-3.89 m^2. The mean sap flow flux per unit area for the four instrumented trees was 0.803 m/day and this resulted in annual evapotranspiration (ET) rates over the quadrats of 71-138 mm. These ET rates at both the Finke and Neales C site are more than an order of magnitude less than the mean annual areal potential ET of 1300-1400 mm, and less than the median annual rainfall for the areas of 147 mm (Oodnadatta) to 219 mm (Kulgera). Areal evapotranspiration was not estimated for sites occurring as isolated trees (e.g. Neales A, B and D).

Table 1. Characteristics of trees instrumented with sap flow meters. Daily sapflow fluxes per unit area are shown for instrumented trees in the three catchments during drought periods with no streamflow (May 2013 – February 2014 and May 2014 – November 2014). nm – not measured.

Location	Species	Circum. (m)	Time period	Mean unit area sap flow (cm)	SD – unit area sap flow (cm)	Areal ET rate (mm)	Max daily rain (mm)
Neales A	*E. cool.*	1.20	5/13 – 10/13	169.4	44.4	nm	1.8
Neales B	*E. cool.*	1.37 / 1.06	5/13 – 1/14	26.6	16.3	nm	5.6
Neales C	*E. cool.*	1.37 / 0.52	5/13 – 1/14	23.4	11.5	58	5.6
Neales C	*Acacia* spp.	0.36	5/13 – 1/14	18.0	4.5	58	5.6
Neales D	*E. cool.*	1.37 / 0.49	5/13	80.5	52.7	nm	0.0
Finke 2	*E. cool.*	0.93	8/14 – 11/14	37.9	18.6	138	3.6
Finke 3	*E. cool.*	0.57	8/14 – 11/14	93.1	12.2	98	3.6
Finke 5	*E. cool.*	0.80	8/14 – 11/14	85.1	8.0	71	3.6
Finke 6	*E. cool.*	1.35	8/14 – 11/14	27.6	13.6	71	3.6

Only three of the Neales sap flow loggers (Neales B and C sites) were operational during a streamflow event in February 2014. One logger from the Neales B site showed a large relative response to a small flow event (peak stage 0.7 m on 16th February) that occurred within one day of rainfall (13 mm), increasing unit area sapflow by 200%, albeit from a very low base rate (Figure 2). This logger did not show any response to a similar sized rainfall event that occurred 12 days earlier on 3rd February (14 mm) and which did not generate streamflow. The Neales C site experienced a larger magnitude flow event in February 2014 (peak stage 1.2 m on 16th February) but no flow in response to two rainfall events in April 2014 that did not result in streamflow. The sap flow response at Neales C differed from that at Neales B with a short-term decrease to negative flux values in response to the February flow before a return to the very low base level fluxes of this site, and then a second short-term decrease in response to April rainfall. However, this tree experienced a large, short-term spike in flux rates in June 2013 (not shown in Figure 2) that coincided with a small rainfall event (2 mm) measured at the nearest rain gauge.

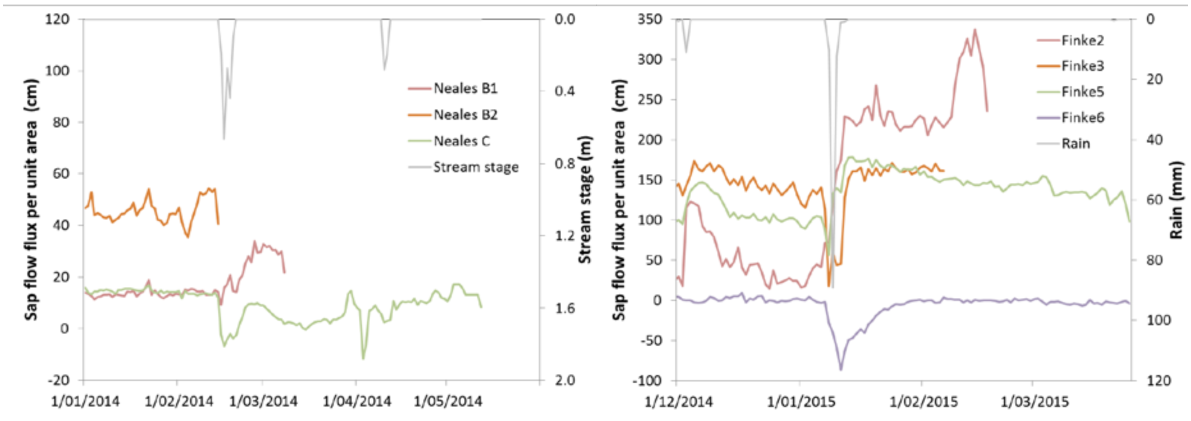

Figure 2. Left – sap flow responses per unit area of mature *E. coolabah* trees in the Neales catchment to streamflow events in 2014. Right – sap flow responses per unit area of mature *E. coolabah* trees in the Finke catchment to a large rainfall event and subsequent streamflow in January 2015.

The Finke site experienced a moderate rainfall event in December 2014 (11 mm) and a heavy rainfall event in early January 2015 (112 mm over three days), followed by the arrival of a streamflow pulse on 16th January. Two of the four instrumented trees (2 and 5) showed large increases in sap flow fluxes in response to both rainfall (e.g. early December) and streamflow (mid-January). The relatively small rainfall event of early December 2014 resulted in enhanced sap flow rates but these returned to background levels within 10-20 days. These two trees responded strongly to the heavy rainfall of early January but the arrival of a flow pulse did not lead to any further significant response. The combined response to the rainfall and flooding event in January 2015 was more pronounced and sustained compared to the December rainfall response. For example, Tree 5 (distal to main flow path and uncertain if directly inundated) showed peak sap flow rates on 14th January 2015 but returned to background sap flow fluxes by March. Tree 2 (close to the main flow path and directly inundated) remained at a new high sap flow flux post-flooding and showed a second increase in sap flow rates in mid-February that did not coincide with any rainfall but may be the response to the arrival of the wetting front in the soil. Three of the trees (3,5,6) showed significant immediate decreases in sap flow fluxes in response to the heavy rainfall event of early January 2015. In the case of Tree 5, this decrease was short-term and then the sap flow flux showed a positive increase above its 'base-level' for a period of time. Tree 3 returned to a small increase above its pre-rainfall base-level sap flow flux within 5 days. For Tree 6, the flux turned negative (i.e. reversal of sap flow direction) for approximately 15 days before returning to near zero sap flow rates.

4 DISCUSSION AND CONCLUSIONS

The estimated areal transpiration rates for *E. coolabah* are very low compared to other non-eucalypt arid zone riparian trees, for instance rates of 0.6-1.5 myr^{-1} have been measured in the Australian wet-dry tropics [6]. However, semi-arid zone riparian eucalypts on regulated rivers have shown a similar range of transpiration rates to *E. coolabah* (e.g. *E. largiflorens* <0.11 myr^{-1} [2]; *E. camaldulensis* 0.01-0.56 myr^{-1}, [3]) that are determined by the flooding frequency, groundwater salinity and tree health. Groundwater uptake at two of the Neales sites (A, D) showed that groundwater uptake was occurring at depths of 3-6 m below the surface and salinities of approximately 15-20 gL^{-1}. Groundwater uptake was also likely at the Finke site, where groundwater was <7-8 m below the surface, based on the consistent sap flow fluxes during periods of no streamflow or significant rainfall. Uptake of groundwater is common in arid zone, riparian trees [1, 2, 3] but a key characteristic of *E. coolabah* is that the base level of transpiration is very low for a phreatophyte.

The field data from this study indicates that *E. coolabah* is an opportunistic phreatophyte in response to varying depths and salinities of the unconfined groundwater resource in its arid zone environment. The quick responses of *E. coolabah* to both small rainfall events and more significant flow events (both sub-bankfull and with some floodplain inundation) indicates the species has root systems with the capacity to switch between shallow soil moisture stores (e.g. rainfall and streamflow infiltration) and deeper groundwater stores. The switching occurred immediately after rainfall/streamflow and higher transpiration rates were sustained for some period of time while the shallow soil moisture stores remain available. The negative flux rates shown by some trees in response to rainfall and streamflow events also indicates that *E. coolabah* can optimize the availability of soil moisture by hydraulic redistribution of shallow soil moisture to deeper levels. These flexible strategies enable *E. coolabah* to persist in riparian zones of ephemeral rivers with highly variable flow regimes and would increase their resistance to increases in no-flow periods from regulation or climate change.

5 ACKNOWLEDGMENTS

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