The role of hydrology in determining the distribution patterns of invasive willows (*Salix*) and dominant native trees in the Lower River Murray (South Australia)

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To the Willow-tree

1. Thou art to all love lost the best,
   The onely true plant found,
   Wherewith young men and maids distrest,
   And left of love, are crown'd.

2. When once the Lover's Rose is dead,
   Or laid aside forlorne;
   Then Willow-garlands 'bout the head,
   Bedew'd with teares are worne.

3. When the Neglect, (the Lover's bane)
   Poor Maids rewarded be
   For their love lost; their onely gaine
   Is but a Wreathe from thee.

4. And underneath thy cooling shade,
   (When weary of the light)
   The love-spent Youth, and love-sick Maid,
   Come to weep out the night.

Robert Herrick

(1648)

Salix babylonica (Weeping Willow)

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Abstract

This thesis explores the hydrological factors that may contribute to the observed distribution patterns of invasive willows (*Salix*) and native trees (*Eucalyptus camaldulensis, E. largiflorens* and *Acacia stenophylla*) along the Lower River Murray (LRM) in southern Australia. An initial survey, establishing the diversity and flowering biology of *Salix* taxa was carried out to ascertain the extent of invasion, and the likelihood of hybridisation, which may accelerate invasion. *S. babylonica*, *S. fragilis*, *S.* × *chrysochoma* and *S.* × *rubens* occur in the study region, each represented by a single gender. None were present on floodplains, but the most dominant taxon, *S. babylonica*, occurred along the entire length of the main channel. No seed or seedlings were observed; hence reproduction is likely to be asexual.

More detailed survey work was then carried out to characterise the distribution patterns of the dominant *S. babylonica* and co-occurring natives (*Eucalyptus camaldulensis, E. largiflorens* and *Acacia stenophylla*) along a hydrologic gradient produced by the extensive weir system in the LRM. In weir pools, variation in daily water levels of weir pools is low (± 0.1 m) immediately upstream of the weir, but higher immediately downstream (0.2-1.0 m daily). The distribution of natives was uniform across weir pools, while *S. babylonica* was more abundant above weir structures, suggesting low tolerance to variable water regimes.

Hypotheses relating to the observed distribution patterns were then tested experimentally on juveniles of the *S. babylonica*, *E. camaldulensis* and *A. stenophylla*. The experiment was carried out in outdoor ponds using an orthogonal design, with four elevations in relation to water level (-25 cm, 0 cm +25 cm, + 50 cm) under each of three water regimes. Experimental water regimes manipulated the magnitude of daily water level changes (static, 0 m day^{-1}; moderate, ± 0.05 - 0.15 m day^{-1}; high, ± 0.2 -0.5 m day^{-1}) to mimic typical hydrological conditions across weir pools in the LRM. Final biomass and mean relative growth rates (*S. babylonica*, 0.0403 ± 0.002 g m^{-2} day^{-1}; *A. stenophylla*, 0.0249 ± 0.0017 g m^{-2} day^{-1}; *E. camaldulensis*, 0.0204 ± 0.0016g m^{-2} day^{-1}) of all 3 species were unaffected by water regimes (i.e. water fluctuations), but were affected by elevation. Survival of both *S. babylonica* and *A. stenophylla* was lowest at low elevations where inundation was high. At higher elevations (+25 cm, +50 cm) the RGR of *S. babylonica* juveniles was much higher than the native juveniles.

To test if the persistence of adults of each species along hydrologic gradients were associated with differing tolerances to water deficits and water use characteristics, *S. babylonica* and native species were examined under typical hydrological conditions in the field and during an unusual drawdown. *S. babylonica* occurring at the lowest elevations on riverbanks, had the least negative predawn

shoot water potential ($\psi_{predawn}$), followed by the natives, which were at higher elevations. *A. stenophylla* had the lowest stable carbon isotope ratio ($\delta^{13}C$) values (by 1.7 ‰) on the riverbank; suggesting more profligate water use than *S. babylonica* and *E. camaldulensis*. However, all riverbank trees had significantly less negative $\psi_{predawn}$ and lower $\delta^{13}C$ than native trees on floodplains, consistent with higher water availability on riverbanks. The position and stable oxygen isotope ratio ($\delta^{18}O$) values were consistent with riverbank *S. babylonica* sourcing their water directly from the river or from shallow soil-water sources (<0.25 m). In floodplain habitats, depth to water was > 2.5 m, and groundwater was 5 times more saline (4.97 ± 0.88 dS m^{-1}) than river-water. Native trees with deep roots, the ability to lower water potentials and alter water use efficiencies may be at an advantage in this habitat relative to *S. babylonica*.

Extreme low flows in the LRM, over a 6-month period, provided an opportunity to assess how *S. babylonica* and *E. camaldulensis* responded to a river-water drawdown. During the drawdown, river-water levels fell at a rate of ~2 – 2.5 mm day^{-1} and dropped to a minimum of 0.42 m below the designated pool level. *S. babylonica* and *E. camaldulensis* maintained high $\psi_{predawn}$ across the drawdown period, most likely because riverbank soil water availability was not limited; as depth to water table only decreased marginally (≤0.15 m) and soil water content and soil water potential were high (<1.1 MPa). However, an above average rainfall in February 2003 significantly increased soil water potential in the upper 0.25 m of the riverbank, which correlated with a significant increase in $\psi_{predawn}$ in *E. camaldulensis*, suggesting they were able to use shallow, precipitation derived soil-water sources whereas *S. babylonica* were not. Also under hot, dry conditions, *S. babylonica* had higher transpiration rates and lower instantaneous water use efficiencies than co-occurring *E. camaldulensis*. This suggests that *S. babylonica* may consume larger volumes of water per unit leaf area than natives, if access to water is maintained.

Dedications

For my grandmother, *Elsie 'Carney' Logue*

I could not begin a study of willows without first consulting the extensive work done by Kurt Cremer. He was renowned for highlighting the magnitude and impact of willow infestation in Australian streams and rivers. We met at the Dunkeld Arboretum, Victoria where I spent days learning firsthand all the intricacies of willow field identification. Kurt's passion originally inspired many aspects of this thesis and his ongoing updates, advice and encouragement was invaluable. Unfortunately Kurt passed away on the 2nd June, 2005, and I hope this work honours him.

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Photo by Maya Linnell

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