Influence of water regime on growth and resource allocation in aquatic macrophytes of the Lower River Murray, Australia

by

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Summary

Water regime is the principal factor determining pattern and process in vegetation in rivers and wetlands in semi-arid environs. It is a complex variable, encompassing the depth, duration, frequency and timing of flooding and exposure, and the rate of change in water level. The influence of water regime on macrophytes of the Lower River Murray, Australia, was investigated at the level of the community, population and tissue. The aim of the study was to examine the effects of water regime on growth, vegetative recruitment, resource allocation and photosynthesis in selected perennial species, and the adaptations permitting them to tolerate sub-optimal regimes.

The composition of littoral plant assemblages along weir Pool 5 was correlated with gradients in water regime established by weirs. Species with competitive and ruderal traits (cf. Grime, 1979) occurred in the hydrologically stable lower pool (*Vallisneria americana, Typha domingensis*), whilst species with stress-tolerant and ruderal traits predominated in mid and upper pools where flooding and exposure were common (*Cyperus gymnocaulos, Cynodon dactylon, Muehlenbeckia florulenta*). Vegetation was significantly correlated with the number of days flooded to 0-20 and 20-60 cm, and days exposed to $\geq$100 cm. Five species groups were suggested by clustering, reflecting broad water regimes and species abundance: common (*e.g. Paspalidium jubiflorum, Muehlenbeckia*) and uncommon floodplain species (*Eleocharis acuta, Pseudoraphis spinescens*), species from the infrequently (*Phyla canescens, Bolboschoenus caldwellii*) and permanently flooded littoral (*Vallisneria, Typha*), and widespread, common species broadly tolerant of flooding and exposure (*Phragmites australis, Cyperus* and *Bolboschoenus medianus*). Half of the 26 species occurred in four or more of seven water regime groups suggested by clustering of sites based on indices of water regime, suggesting selection for adaptations to a variable hydrologic regime are common. In contrast, 4 species occurred only in the stable lower pool.

Growth and resource allocation in the emergent sedge *Bolboschoenus medianus* (Cyperaceae) and submersed herb *Vallisneria americana* (Hydrocharitaceae) were examined in response to changes in water regime in pond and field experiments. Morphological and photosynthetic adaptations to resource limitation were studied: access to CO_2, O_2 and water in *Bolboschoenus*, and to light in *Vallisneria*. Results were used to interpret the changes in community composition of littoral vegetation along gradients of water regime in the Lower Murray, Australia.

Experiments determined optimum water regimes for *Bolboschoenus* and *Vallisneria*, and how they responded to sub-optimal conditions. RGR was greatest when the water surface was within ±20 cm of the sediment in *Bolboschoenus* in a pond experiment. With increasing depth, net assimilation rate (NAR) and hence RGR declined. Leaf area ratio (LAR) remained remarkably constant however, due to stem elongation, more vertical orientation of submersed leaves and higher leaf recruitment when partially flooded. Tuber biomass and emergent leaf area were inversely linearly related, indicating below-ground biomass is allocated to stems as depth increases, producing up to a three-fold increase in above:below ground biomass. Carbon assimilation and stomatal conductance of emergent leaves were highest in partially flooded plants. Assimilation declined due to lower

conductance in plants exposed by 20 cm, which reduced culm recruitment. A field experiment found RGR, culm recruitment and flowering was greatest in plants shallowly flooded then slowly exposed at 2.5 cm day^{-1}. The temporal juxtaposition of top-flooding followed by rapid exposure (10-12 cm d^{-1}) reduced growth and reproduction.

Vallisneria was grown at turbidities of 90, 209 and 504 NTU (producing rates downwelling light extinction of 6.48, 12.59 and 21.92 m^{-1}, respectively) at various depths in a pond experiment. RGR declined with decreasing light penetration and increasing depth, calculated as $\bar{I}$, the average irradiance between the water surface and sediment. The whole-plant RGR-$\bar{I}$ response followed a P-I curve, and integrates photosynthesis at all irradiances across all depths in the canopy over time. The reduction in RGR was due to lower NAR as less of the canopy received greater than compensating irradiances. However, LAR peaked at low $\bar{I}$ due to the production of long thin leaves, indicating morphological plasticity at low light. The RGR-$\bar{I}$ model successfully simulated growth in field populations under a range of extinction coefficients and depths. Such models may be useful for predicting the effects of elevated turbidity levels on submersed macrophytes.

Oxygen evolution experiments with leaf pieces found similar or lower I_c and I_k than reported elsewhere for *Vallisneria* (3-35, and 40-180 $\mu mol\ m^{-2}\ s^{-1}$ respectively), presumably due to adaptation to low light penetration in the Murray. Photosynthetic efficiency α was relatively high: 0.005-0.1 mg C g $dw^{-1}\ h^{-1}$ ($\mu mol\ m^{-2}\ s^{-1})^{-1}$. Carbon assimilation depended on leaf age and depth. No evidence of shade acclimatization (increasing α with depth) was observed.

Modelled daily canopy carbon assimilation indicates the importance of canopy formation in highly turbid water. Plants in shallow water (24 cm) placed 42% of their canopy at the surface, and had high canopy carbon assimilation (21.2 mg C d^{-1}). Plants at 82 cm had 87% of the canopy below the maximum depth of penetration of compensating irradiances, and had a negative carbon balance (-2.2 mg C d^{-1}). Carbon balances correlated well with observed growth: RGRs of 15 and -2 mg g d^{-1}, respectively.

Vallisneria died when exposed for >14 days in spring and summer in a field experiment which investigated growth in stable and variable water regimes. RGR was greatest at 0.5 m in stable conditions, and declined in shallower and deeper water due to exposure and light-limitation, respectively. These data concur with the distribution of *Vallisneria* in the Murray in the early 1990's: depths of 10-80 cm in lower weir pools.

A computer model used by South Australian water agencies for flood forecasting, the *River Murray Hydraulic Model*, was evaluated for its use in researching the effects of flooding on littoral vegetation in the Murray. Prediction accuracy for water levels was often within 10 cm, but linear interpolations between weirs proved simpler and more effective when stage data are available. Recommendations are made for improving the model or future models for ecological research and environmental flow management.

Table of Contents