The Influence of Fluvial Geomorphology on Riparian Vegetation in Upland River Valleys: South-Eastern Australia

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A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy.

June 2003.

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ACKNOWLEDGMENTS

I would like to thank, my supervisors, David Williams and Martin Thoms, for their advice, insight and the reading of many drafts of this PhD thesis. Peter Guenther, John and Carolyn Evans for their assistance, patience and understanding whilst I was completing my thesis. Sarah Evans for helping me with field work and providing graphic design advice. Thank you to my Grandparents, Norm and Dulcie for their support and constant belief that I could finish my PhD. I am also grateful for the assistance and support that the Vocational Rehabilitation Unit at the Canberra Hospital gave me, especially Virginia Moore and Dr Farnback, for helping during the long recovery period after the accident and for never saying that I wouldn't be able to do it!

Thank you to Janine Conway, Tony Bu, Peter West, Sean Grimes, Dan Mawer, Peter Guenther, Melissa Parsons, Kylie Peterson, Carolyn Evans and John Evans for help in the field. Mike Palmer-Allen, Adam Scott, Ben Kropp, UC Ecochemistry Laboratory staff and Denise Nobbs for their technical assistance. Richard Norris, Mani Berghout, Bruce Gray and Clare Finlay for commenting on portions of my thesis. The scientific editor, Kim Wells, for providing editorial comment on a paper copy of the abstract, Chapter 1 and 2. Judy Frankenburg and Jim Hone for help with some aspects of experimental design. Gail Ransom, Wayne Robinson, Julie Coysh, Paul Blackman and Paul Wallace for their assistance and tuition with wayward statistical packages. The staff at the Australian National Botanical Gardens for assistance with plant identification. The Federal Department for the Environment and Heritage for supplying the base maps for this thesis and allowing me time off work for study. The New South Wales Department of Land and Water Conservation and the Australian Capital Territory's Ecowise Environmental for supplying hydrological data and advice. The Australian Defence Force Academy in Canberra for providing support and allowing me to use the flumes in the Civil Engineering Department.

I would also like to thank the Cooperative Research Centre for Freshwater Ecology for contributing to my scholarship, providing resources and assisting me to attend conferences, both in Australia and overseas. I am grateful also to the Applied Ecology Research Group for the support, desk space and conference funding provided. This project was also supported by an Australian Postgraduate Award.

ABSTRACT

Healthy riparian vegetation has a positive impact on the adjacent river. Unfortunately, riparian vegetation is often threatened by human impacts such as dam construction and clearing. To gain the knowledge underlying the effects of such impacts and to aid riparian rehabilitation, the objective of this thesis was: *to determine riparian vegetation association with, and response to, variation in fluvial geomorphology over several scales and consequently to fluvial disturbance.* Only woody riparian plant species were considered. Flood disturbance was the unifying theme of this thesis. Linked to this theme and arising from the main objective was the supposition that *plant interactions with the abiotic environment, but not biotic interactions between species, control riparian species distribution because of frequent fluvial disturbances.*

Woody riparian vegetation and riverine environmental variables were recorded along the upper Murrumbidgee River at three spatial scales based on a geomorphic hierarchy for Chapter 2. Multivariate analysis was used to group species and to associate environmental variables with vegetation at the three spatial scales. Observations at the two larger scales, of river segment (site) and riparian reach (transect), identified a river-longitudinal species-composition gradient associated with geology, river width and stream channel slope. Observations at the smallest scale of geomorphic units (plot) identified a lateral riparian gradient and also the longitudinal gradient; these gradients were associated with geomorphic variation, land use, plot elevation and also river longitudinal variables.

Using the same data set, but varying the spatial scale of analysis caused the species composition pattern to change between scales. Increase in scale of observation, that is from geomorphic unit to reach and segment scales, resulted in disproportionate importance of rarer species and decreased importance of some key riparian species at the larger scales. It would appear that in this instance the geomorphic unit scale best described patches of different species composition because this scale had high spatial resolution and was also able to identify multiple gradients of environmental variation. It was recommended that riparian sampling take place at scales that represent dominant gradients in the riparian zone. These gradients are represented by geomorphic scales, indicating the appropriateness of using geomorphic based scales for observation of riparian vegetation.

Chapter 3 considered whether there is a geomorphic template upon which riparian vegetation is patterned and whether it is associated with process variables, such as flooding and soil type. This question was investigated at different spatial scales in three ways: i) by an experiment to determine whether soil nutrient condition affects plant growth; ii) by graphical analysis of trends between geomorphic units, species and process variables; and iii) by analysis of vegetation distribution data.

The smallest scale (meso) found experimental differences in plant growth because of soil type. Plants growing in sand had the lowest performance, with an average plant Relative Growth Rate (RGR) of 0.01, compared to plants growing in soils with small amounts of silt or clay particles, with an average plant RGR of 0.04. This pattern was attributed to differences in nutrients. Clear relationships were demonstrated at the larger geomorphic unit scale between species distribution and process variables. For example, hydrology and substratum type were found to be associated with geomorphic units and species. The largest scale considered in Chapter 3 was the riparian reach scale. At this scale species were clearly grouped around reach type. Therefore, geomorphology was considered to be a template for riparian species distribution. Findings in this chapter suggested that geomorphic variables should be good predictors of riparian species distribution. This hypothesis was tested and supported in Chapter 6.

The experiments reported in Chapter 4 aimed to determine whether inundation depth and duration affected plant performance and survival for five common riparian zone species. Riparian seedling patterns in the field were also compared with experimental results to test whether species performance was reflected by field distribution. The experiments that were conducted included an inundation period and depth experiment, and a survival period test whilst under complete inundation. Biomass and height relative growth rates were determined, and the results were analysed using factorial Analysis of Variance. Obligate riparian species (*Callistemon sieberi*, *Casuarina cunninghamiana*, *Leptospermum obovatum*) were found to be tolerant of inundation duration and depth, to the point where inundation provided a growth subsidy. On the other hand, non-obligate riparian species (*Acacia dealbata*, *Kunzea ericoides*) were either just tolerant of inundation or showed a negative growth response. For instance, *C. sieberi* demonstrated an average height RGR of 0.04 after complete inundation and 0.007 when not inundated, while *A. dealbata* had an average height RGR of 0.001 after complete inundation and 0.01 when not inundated. These experimental findings were found to closely reflect both seedling and adult plant distribution in the field such that inundation tolerant species were found close to the river and intolerant species further away. Thus, the conclusion was drawn that riparian species establishment and distribution is affected by inundation and that change to the flood regime could have serious impacts on riparian zone plant composition.

The other aim of this chapter was to determine whether optimum germination temperatures were associated with flood or rainfall. Growth chamber germination trials were conducted at air temperatures of 15°C, 20°C and 25°C to determine the 'best' germination temperature. These germination patterns at different temperatures were then related to annual variation in field temperature, flooding period and rainfall. No evidence was found to suggest a relationship between ideal germination temperature and flood season, rather it was suggested that germination was patchy through time and may simply reflect recent rainfall.

Investigations that were reported in Chapter 5 aimed to elucidate relationships between species and flow velocity variables. Two experiments were conducted: i) a flume experiment to determine the effect of flow velocity on plant growth; and ii) an experiment to observe the response of plants to damage (imitating flood damage) and inundation. Field observations of species distribution and flow velocity related variables were also conducted to put the flume results into a real-world context.

Treatments for the flume experiment were fast flow velocity (0.74 $m\ s^{-1}$), slow velocity (0.22 $m\ s^{-1}$) and no velocity (control) but still inundated. All treatments were flooded completely for four days. Subsequent biomass and height relative growth rates were determined, and the results were analysed using factorial Analysis of Variance. Results were unexpected, given that obligate species exposed to the fastest velocity had the highest growth rate with an average height RGR of 0.046, compared to plants in still water, which grew the least with an average height RGR of 0.013. It was hypothesised that this response was because relatively greater carbon dioxide and oxygen levels were available in the moving water compared to the still water. With regard to shoot damage, the species that were non-obligate riparian species lost more leaves from velocity treatment than the obligate riparian species. The cut and flood experiment found growth of the obligate species (*Casuarina cunninghamiana*) to be greater after cutting than the non-obligate species. Flooding was not found to have an effect in the cut and flood experiment, probably because the period to sampling after flood treatment was longer (4 weeks) than other flooding experiments (3 weeks).

Field observations were found to support the experimental findings, with a gradient of species across the riparian zone that reflected potential flood velocities. Therefore, velocity is one of a suite of riparian hydrological factors that are partially responsible for the gradient of species across the riparian zone. Potentially the absence of flooding could result in a homogeneous mix of species, rather than a gradient, except on the very edge of the river.

The study that was reported in Chapter 6 investigated a technique for predicting riparian vegetation distribution. One of the aims of this investigation was to address a current riparian rehabilitation shortfall, which was how to objectively select species to plant for rehabilitation. Field data were collected from three confined river valleys in south-eastern New South Wales. Using data on plant species occurrence and site and plot measures of soils, hydrology and climate, an AUSRIVAS-style statistical model, based on cluster and discriminant analysis, was developed to predict the probability of species occurrence. The prediction accuracy was 85 % when tested with a separate set of plots not used in model construction. Problems were encountered with the prediction of rarer species, but if the probability of selection was varied according to the frequency of species occurrence then rarer species would be predicted more often. Various models were tested for accuracy including three rivers combined at the geomorphic unit (plot) scale and riparian reach (transect) scale in addition to a Murrumbidgee River plot scale model. Surprisingly, the predictive accuracy of the all rivers and single river models were approximately the same. However, the difference between the large scale and small scale models pointed to the importance of including small scale flood-related parameters to predict riparian vegetation.

When these riparian predictions were compared to predictive outcomes from a hill slope model, which was assumed to be affected by fewer disturbances (i.e. flooding), predictive accuracies were not very different. Overall though, predictive accuracy for riparian vegetation was high, but not good enough to support the supposition that riparian vegetation is abiotically controlled because of frequent flood disturbance. Nevertheless, geomorphology and consequently flood effects are still important for the determination of the riparian community composition.

Overall, riparian vegetation was found to be closely linked to its environment (evidenced in Chapters 2, 3, 4, 5) in a predictable manner (Chapter 6). Species pattern relied on flood disturbance affecting species distribution. Some riparian species were found to be highly tolerant of flooding and gained a growth advantage after flooding (Chapters 4 and 5). Therefore, flood tolerance was important for the formation of a species gradient across the riparian zone. These species tolerances and growth requirements reflect riparian geomorphic pattern (Chapter 3), which was suggested to form a template on which riparian vegetation is structured.

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