INTRODUCTION

Riparian ecosystems are biophysically complex and highly diverse taxonomically, structurally and functionally (Naiman et al. 1993; Poff 2002; Nilsson and Svedmark 2002). They provide a disproportionate amount of ecosystem goods and services compared with the fraction of the landscape that they occupy (Capon et al. 2013) and play a critical role in maintaining regional biodiversity (Naiman et al. 1993). Riparian landscapes have been heavily modified by humans; in many parts of the world, this modification has taken place rapidly and has resulted in significant habitat degradation and biodiversity loss. Catchment clearing, impoundment and flow regulation have altered the hydrology of river systems globally (Nilsson and Berggren 2000). As demand for water increases with growing human populations, river systems are likely to become increasingly modified. Changing climatic conditions over the next century are also expected to cause shifts in hydrological patterns (Stocker et al. 2013). Predictions are regionally specific but similarly include changes to total discharge, flow seasonality and flow variability. In regions with projected increases in climatic variability, changes to the prevalence, intensity and timing of extreme flooding or drought events can be expected (Hennessy et al. 2008). This combination of flow regulation and alterations to baseline discharges may well produce dramatically altered future flow regimes, with significant consequences for the diversity and functional composition of riparian communities (Poff and Zimmerman 2010).

Due to their central role in maintaining diversity and ecosystem functioning at the landscape scale (Naiman et al. 1993), riparian ecosystems are the target of substantial management effort (Goodwid et al. 1997). Vegetation assemblages receive particular attention in riparian management as they set the coarse physical structure of biotic communities and play an important role in generating and maintaining the characteristic geomorphology of river systems (Richardson et al. 2007; Corenblit et al. 2007). Conservation planning in fluvial landscapes therefore requires context-specific understanding of environmental controls on plant community assembly.

*The importance of flow regime to riparian plant communities*

Flow regime is thought to be the dominant abiotic control on the composition and structure of riparian plant communities (Poff et al. 1997). Streamflows affect plant communities directly by causing flooding disturbance and driving variation in nutrient and moisture availability (Naiman and Decamps 1997), as well as by interaction with geomorphic processes (Corenblit et al. 2007). The inherently heterogeneous nature of fluvial interaction with vegetated landforms results in structurally complex, patchy landscapes containing strong energy and resource gradients (Naiman et al. 2005). Spatial and temporal heterogeneity in the magnitude, frequency, duration, timing, rates of change, and predictability of flow discharge (Poff et al. 1997; Kennard et al. 2010) translates to heterogeneous influence of streamflows on riparian patches (Poff et al. 1997; Naiman et al. 2008). Niche-oriented models of riparian ecology hold that it is this environmental heterogeneity which supports the high degree of biodiversity observed in riparian ecosystems (Palmer and Poff 1997; Bornette et al. 2008).

Given the profound influence of fluvial hydrology on riparian vegetation communities, determining specific flow-ecology relationships has long been a goal in riparian research (Auble and Friedman 1994; Lytle and Poff 2004). To date, this research has been largely driven by work on impacts of dams on vegetation (Goodwid et al. 1997; Nilsson and Svedmark 2002); the resulting insight into the comparative hydroecology of *Populus* and *Salix* *spp*. and invasive *Tamarix spp.* in North American river systems (Mahoney and Rood 1998; Shafroth et al. 2002) had led to significant advances in design of environmental flows to support indigenous assemblages (Shafroth et al. 2010). This approach is effective in western North America, where well-understood systems are dominated by a limited set of species. Approaches centred on deterministic species-specific flow response models are less practical in more diverse or less understood systems, however.

*The intersection between hydroecology and functional ecology*

In such cases, maintenance of biodiversity and ecosystem functioning may be a more appropriate conservation target than supporting the persistence of specific assemblages (Aerts and Honnay 2011; Cadotte et al. 2011; Montoya et al. 2012). Where sites harbour dissimilar species assemblages, comparison becomes challenging. Taxonomic descriptors of communities such as species richness or species diversity are widely used to compare communities across landscapes, but are unable to provide information about how elements of a community influence ecosystem functioning, provision of ecosystem services, or contribute to system resilience (Tilman et al. 1997; Dı́az and Cabido 2001; Díaz and Lavorel 2007).Describing communities in terms of functional traits - any morphological, physiological or phonological feature measurable at the individual level (Violle et al. 2007) - dissolves species distinctions and emphasises ecological strategies: what species do within their community and how they do it. This allows dissimilar communities to be compared in terms of how their component species both respond to and have an effect on their environment (Lavorel and Garnier 2002). A functional trait oriented approach, then, facilitates the search for regional generalities in hydrological controls on ecosystem processes and patterns of diversity.

Species are different, but not equally so, and the nature and extent of species differences characterise ecological communities. Data about appropriately selected quantitative functional traits (such as specific leaf area, wood density, seed mass etc.) can form the basis for mechanistic assessments of diversity which describe the range and distribution of ecological strategies in a community, and their associated environmental effects (Schleuter and Daufresne 2010). These indices of functional trait diversity are increasingly being employed in ecosystem assessment and management as a complement to traditional taxonomic metrics of diversity. Functional diversity indices provide a stronger basis for making inferences about ecosystem functioning, resilience and provision of ecosystem services as well as community assembly processes (Tilman et al. 1997; Díaz et al. 1998; Hooper et al. 2005).

Hydroecologically derived plant functional groups have been described for some time (e.g. Stromberg et al. 2010; Casanova 2011), but advances in quantitative plant ecology based on functional traits are only beginning to be applied to riparian systems. Notable early contributions to the quantitative riparian functional hydroecology literature include discussion of variation in functional traits according to species origin (i.e. native or exotic), geomorphology and fluvial disturbance (Kyle and Leishman 2009a; b), and evidence for reduced functional diversity trait in riparian wetlands in response to flow impoundment (Catford et al. 2011). Merritt *et al.* (2010) outlined a framework for defining riparian vegetation flow response guilds according to functional traits, and functional traits have been discussed as a means by which to predict riparian community responses to climate change (Catford et al. 2012; Kominoski et al. 2013). Momentum is now building for insights from plant functional ecology to be applied to riparian conservation planning and management.

*Anthropogenic impacts on riparian plant communities*

Rapid development of catchments has changed fundamental processes which create and maintain biodiversity in riparian ecosystems (Nilsson and Svedmark 2002), and as such, riparian management often takes place within this context of catchment modification. Environmental homogenisation of riparian landscapes by flow modification, land-use change and invasion by exotic plants has profound implications for riparian biodiversity. Given the dominance of flow regime in riparian systems, flow modification likely to have the greatest impact, although anthropogenic stressors are typically not independent from each other. Dams, weirs and diversions affect river systems in populated regions worldwide (Nilsson and Svedmark 2002), resulting in diminished discharge, reduced flow variability, dampening of flood peaks and changes to seasonality of flows (Graf 2006; Singer 2007). Depending on the magnitude of change, biogeomorphic simplification and weedy invasion may occur downstream of dams (Graf 2006; Naiman et al. 2008; Catford et al. 2011). These impact of these changes on riparian plant communities is likely to be compounded the deleterious effects of land transformation, primarily habitat fragmentation and loss of catchment alpha and beta diversity (Vitousek et al. 1997; Gerstner et al. 2014). Exotic invasion is closely associated with human activity (Vitousek et al. 1996) and itself represents a significant threat to riparian plant communities (Richardson et al. 2007).

Rising atmospheric carbon dioxide represents a further unexplored variable with the potential to alter future riparian plant communities. Atmospheric CO2 has also risen substantially over the past century, and a doubling of pre-industrial levels by 2100 is projected (IPCC, 2013). A substantial body of research describes dramatic effects of elevated CO2 (eCO2) on plant growth, physiology and community ecology (Curtis 1996; Poorter and Navas 2003; Reich et al. 2014). Typical responses to eCO2 include stimulation of photosynthetic carbon assimilation (Curtis 1996), reduced stomatal conductance (Ainsworth and Rogers 2007), greater water use efficiency (Holtum and Winter 2010; van der Sleen et al. 2014), greater biomass accumulation (Wang et al. 2012), altered biomass allocation (Nie et al. 2013), and changes to functional traits indicative of positions along economic spectra (Poorter and Navas 2003; Bader et al. 2010). The effects of eCO2 vary between species, and are often contingent on other environmental variables such as availability of water and macronutrients (Körner 2006; Manea and Leishman 2014; Reich et al. 2014).

Plants growing adjacent to stream channels enjoy the best access to water in the landscape, but the privilege is not free. Along with exposure to flooding disturbance, most riparian plants must at some point endure waterlogging or inundation (Tabacchi et al. 1998; Colmer and Voesenek 2009). Inundation represents a significant stress to riparian plants, and root zone anoxia is well established as the mechanism driving plant physiological and functional responses to waterlogging, impairing root metabolism and uptake of water and nutrients (Drew 1997; Piedade et al. 2010; Voesenek and Bailey-Serres 2015), altering root traits (Steffens et al. 2013) and disrupting mutualisms with soil biota (Dawson et al. 1989; Shimono et al. 2012).

Elevated atmospheric levels of CO2 and inundation appear likely to have opposing effects on plant growth, but the possibility that eCO2 may mitigate growth reduction under waterlogging warrants investigation of the interactive effects of these two important environmental variables. The limited literature describing interactive of eCO2 and waterlogging or inundation on plant growth presents an inconsistent picture, with effects varying widely between species (Megonigal et al. 2005; Shimono et al. 2012; Arenque et al. 2014). Generation of harmful reactive oxygen species has been shown to accompany reaeration after waterlogging (Drew 1997), and as such recovery from flooding represents a different stress to tolerance of the event itself. To date, no research has described the effects of eCO2 on recovery from waterlogging.

*Research questions*

In this thesis, I set out to identify the fundamental relationships between riparian plant communities and the various environmental controls and stresses which define them. To this end, I used concepts and tools from modern functional ecology to probe the mechanisms by which communities organise themselves along gradients of these environmental conditions.

In Chapter 2, I ask how wood density, a key plant functional trait integrating the trade-off between rapid growth and tolerance of physical disturbance and drought, varies along gradients of fluvial disturbance intensity and variability in water availability across 15 sites in natural landscapes of south-eastern Australia. Chapter 3 extends this research question, using the same set of sites to investigate relationships between functional diversity and environmental heterogeneity. In Chapter 4, data from sites spanning gradients of flow modification and land-use intensity in south-east Queensland, Australia, are analysed to determine the relative importance of natural and anthropogenic controls on taxonomic and functional diversity. This chapter is again guided by hypotheses about relationships between environmental variability and diversity. In Chapter 5, I describe manipulative experiment designed to ask how elevated atmospheric concentrations of CO2 might affect future responses of riparian trees to waterlogging.