“Stable rivers breed dull communities”

“Variety breeds diversity: hydrological variability predicts functional diversity in plant riparian communities “

“Does hydrological heterogeneity drive functional heterogeneity in riparian plant communities?”

* Huston 1979 (ref from the role of riparian corridors in maintaining regional biodiversity paper)
  + Environmental heterogeneity => species richness ; Disturbance retards competitive exclusion. (Naiman & Decamps 1993)
  + **Coarse-scale plant species richness in relation to environmental heterogeneity**

INTRO ABOUT WHY RIPARIAN DIVERSITY IS IMPORTANT

Riparian ecosystems are biophysically complex and highly diverse taxonomically, structurally and functionally (Naiman, Decamps & Pollock 1993; Poff 2002; Nilsson & Svedmark 2002). They provide a disproportionate amount of ecosystem goods and services compared with the fraction of the landscape which they occupy (Capon *et al.* 2013), and play a critical role in maintaining regional biodiversity (Naiman & Decamps 1993). Riparian landscapes have been heavily modified by humans; in the New World, this modification has taken place rapidly and has resulted in significant habitat degradation and biodiversity loss. Impoundment and flow regulation has altered the hydrology of river systems globally, resulting in reductions to total discharge, reduced flow variability, dampening of flood peaks and changes to seasonality of flows (Nilsson & 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. 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 and intensity of extreme flooding or drought events can be expected. The combination of flow regulation and alterations to baseline discharges may well produce dramatically different future hydrologies, with significant consequences for the diversity and functional composition of riparian assemblages. An understanding of the processes that generate patterns of diversity and drive ecosystem functioning in riparian ecosystems must inform riverine conservation and rehabilitation efforts.

Conservation and ecological restoration activities increasingly aim to preserve the ecosystem functions associated with biodiversity (Cadotte 2011, Aerts &Honnay 2011, Montoya et al 2012 – emerging perspectives in the restoration of biodiversity based ecosystem services). Conservation management approaches oriented around patterns of taxonomic diversity may be problematic, however, as relationships between environmental conditions and community species composition can be difficult to generalise across landscapes. Where sites harbour dissimilar species assemblages, comparison becomes problematic. Compressed taxonomic descriptors of communities such as species richness or species-oriented metrics of 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 (Diaz??). **Brooks SS, Palmer MA, Cardinale BJ, Swan CM, Ribblett S. 2002. Assessing stream ecosystem rehabilitation: limitations of community structure data. Restoration Ecology 10(1): 156–168** – **not indicative of changes in underlying ecosystem function.** 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 for direct comparisons between communities that do not necessarily contain matching assemblages. In such a manner, communities can be compared in terms of how their component species both respond to and have an effect on their environment (Lavorel & Garnier 2002). A functional trait oriented approach, then, allows us to search for generalities in the influence of hydrology on ecosystem processes and patterns of diversity across disparate riparian plant communities. 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. 2013, Kominoski 2013). To date, however, functional approaches remain a novel tool in ecohydrology.

Functional traits can form the basis for mechanistic assessments of diversity that describe the range and distribution of ecological strategies within a community. While species richness (Whitaker 1972) has to date been the most commonly used metric of biodiversity for investigating the relationships between biodiversity and ecosystem functioning (Duffy 2009 – why biodiversity is important to the functioning of real-world ecosystems), functional diversity and composition are able to reveal the mechanisms underlying these relationships (Hooper 2005, Diaz 2001, E.J. O’Gorman, et al. Loss of functionally unique species may gradually undermine ecosystems Proc. R. Soc. Lond. B, 278 (2011)), and may be useful in diagnosing degradation before species loss occurs (Mouillot et al. 2013). Assessments of ecosystem service production have also begun to give functional diversity privilege over simple taxonomic metrics of diversity (Diaz et al 2007 – incorporating plant functional diversity effects in ecosystem service assessments).

HOW TO WE MEASURE FUNCTIONAL DIVERSITY?

Two requirements must be satisfied to achieve a functionally informed mechanistic understanding of biodiversity-ecosystem function relationships. Firstly, traits should be selected carefully so as to capture the spectrum of ecological strategies within a community, with specific ecological relevance to the study system (Petchey & Gaston 2006, Gallagher et al. 2013). Secondly, an appropriate metric of functional diversity must be selected for analysing the community according to the chosen traits. Numerous metrics of functional diversity have been described in the literature; consult Schleuter et al. (2010) for an introduction to the subject. These metrics typically take multidimensional trait data as an input and output a single value describing various properties of this data. The framework described by Villeger et al. (2008) consisting of functional richness (the volume of the convex hull circumscribing range of trait values), functional divergence (divergence in the distribution of abundance within traitspace) and functional evenness (the evenness of this distribution in traitspace) has been commonly used to describe functional diversity (e.g. Clarke et al 2012, Biswas & Malik 2010, Pakeman 2011, Savage et al. 2012). Functional dispersion, defined as the mean distance of individual species to the centroid of all species in the community, represents an improvement on this framework (Laliberte & Legendre 2010). This metric is useful as it allows for consideration of species abundances while integrating functional richness and functional divergence, and is independent of species richness by construction.

*What is known about drivers of diversity in riparian plant communities?*

A common goal of community ecologists and conservationists has been to find general rules that explain patterns of ecological diversity. Heterogeneity in the riparian patch mosaic results from the sculpting action of hydrological processes across the biogeomorphic template. In riparian environments, it is this intrinsic environmental heterogeneity which fosters structural, taxonomic and functional heterogeneity within vegetation communities ((Naiman *et al.* 1993; Corenblit *et al.* 2007; Bornette *et al.* 2008)).

Local hydrology is widely considered to be the master determinant of community composition and functioning in riparian plant assemblages, as it dictates patterns of disturbance by flooding as well as soil moisture availability (Poff, Allan & Bain 1997) (more REFs). Flooding may retard competitive exclusion by resetting the patch structure of parts of the landscape, and thereby enhance diversity (Huston 1979, Naiman & Decamps 1993), or constrain assemblages to species which have ecological strategies adapted to flooding, thereby decreasing diversity (Díaz, Cabido & Casanoves 1998). General support has been found for the intermediate disturbance hypothesis (Connell 1978), with respect to the relationship between flooding intensity and taxonomic richness in riparian plant communities (Bendix 1997; Bendix & Hupp 2000; Lite et al. 2005, *Nakamura, F., Swanson, F.J., Wondzell, S.M., 2000. Disturbance regimes of stream and riparian ecosystems – a disturbance – cascade perspective. Hydrological Processes 14, 2849–2860.; (Pautou et al., 1997; Piégay, 1997) and lowland rivers (Ward and Stanford, 1983a,b; Salo et al., 1986; Shields et al., 2000 – see Corenblit 2007,* ) This support is not equivocal, however (Nilsson 1989 (see Baker 1990 ref), Baker 1990), and it should be noted that at within-reach scales, the geomorphic template is also a strong control on diversity (Bendix 1997, O’Donnell et al. 2013). In regions where riparian plants experience periodic water stress, soil moisture availability may be driven largely by hydrology (Castelli, Chambers & Tausch 2000; Nilsson & Svedmark 2002). Resource availability hypotheses predict that diversity should be lowest at either very low or very high levels of water availability (Grime 1973). This pattern has been demonstrated in taxonomic diversity across spatial gradients of water availability in dryland river systems of South Western North America (Lite et al. 2005) and Egypt (Ali et al. 2000), where water availability is especially limiting. Seasonal and interannual variability in patterns of disturbance and water availability are known influence species richness (Greet et al. 2011, Catford et al. 2014, Catford et al. 2012 – novel riparian ecosystems), and this effect may be exacerbated for summer flows in hot or dry regions (Garssen et al. 2014). A study investigating drivers of riparian vegetation community structure and composition in subtropical eastern Australia identified variability in dry season (summer) flows as the hydrological variable which was most strongly associated with variation in species richness (Arthington *et al.* 2012).

Understanding of drivers of plant functional diversity in riparian communities is nascent. Catford et al. (2011) showed how flow impoundment along a large river system in south eastern Australia was associated with greater cover of exotic species and reduced functional diversity in riparian wetlands. Their study used multiple unidimensional metrics of diversity to support its findings rather than a multidimensional index, however. Another study looked at functional diversity in riparian vegetation communities along gradients of disturbance associated with management for logging, and found support for the intermediate disturbance hypothesis (Biswas & Malik 2010). Some further insights into the impact of disturbance on functional diversity in general come from work on gradients of land use intensity. Land use intensification has been linked with lower functional diversity across an international dataset (Laliberte et al 2010), and the authors associated this effect with a reduced ability to of communities to respond to disturbance. On the west coast of Scotland, increasing anthropogenic disturbance in arable fields, grazed grasslands, moorlands and woodlands was associated with reduced functional richness and increased functional evenness (Pakeman 2011). A trend is apparent from these studies where functional diversity is inversely associated with environmental homogeneity. At a meeting of the North American Benthological Society in 1995, the attendees of a symposium on ecological heterogeneity urged stream researchers to “examine hetereogeneity from a functional perspective” (Palmer & Poff 1997). Progress on this front has been sparse, and confirmation of an opposite trend – i.e. where functional diversity increases with environmental heterogeneity – would be a significant development for riparian ecology and conservation.

We hypothesised that the environmental heterogeneity induced by repeated floods and fluctuating soil moisture levels should be reflected in the functional composition of plant communities adapted to the riparian environment. To this end, we investigated the relationship between hydrologically driven environmental heterogeneity and functional diversity in riparian plant communities. Specifically, we asked the following questions:

1. Is functional diversity related to the frequency and magnitude of flooding disturbance?
2. Is functional diversity related to variability in seasonal water availability in the riparian zone?

South-eastern Australia was used as a sandbox, as a broad spectrum of hydrological heterogeneity is present within a relatively compact, contiguous landscape (Finlayson & McMahon 1988; Peel, McMahon & Finlayson 2004).

Communities adapated to more heterogeneous hydrologies should contain

Where hydrology is more heterogeneous, communities may be l

> FRAMEWORK

FRAMEWORK AND HYPOTHESES

Summary of existing knowledge on functional diversity in riparian systems.

Hydrological heterogeneity -> functional heterogeneity

Hypotheses

WHAT TRAITS TO USE? > methods

ECOSYSTEM GOODS AND SERVICES, RESILIENCE (talk about needing a good metric of resilience when discussing which FD metrics to use.)

Specifically, the array of plant functional traits present within a community determines ecosystem properties, in terms of the size of pools of resources and rates of flux of these resources.

Ecosystem functioning comprises ecosystem properties (sizes of pools of matter and rates of processes), and the production of ecosystem goods and ecosystem services (Hooper 2005).

Functional redundancy, measured as the is also suggested to contribute to (Standish et al 2014).

In the riparian context, ecosystem functioning must take into account the ability of a community to respond to HYDROLOGY / GEOMORPHOLOGY.

Establishment of woody riparian vegetation in relation to annual patterns of streamflow, Bill Williams River, Arizona Patrick B. Shafroth, Gregor T. Auble, Juliet C. Stromberg, Duncan T. Patten

Simulated recruitment of riparian trees and shrubs under natural and regulated flow regimes on the Wisconsin River, USA Mark D. Dixon†\* and Monica G. Turner

Managing river flows to restore floodplain forests Stewart B. Rood 1, Glenda M. Samuelson 1, Jeffrey H. Braatne 2, Chad R. Gourley 3, Francine MR Hughes 4, and John M. Mahoney

AUSTRALIA Predicting potential impacts of environmental flows on weedy riparian vegetation of the Hawkesbury–Nepean River, south-eastern Australia Jocelyn Howell† andDoug Benson (see refs for NZ refs)

EUROPE Allocation of River Flows for Restoration of Floodplain Forest Ecosystems: A Review of Approaches and Their Applicability in Europe -Francine M. R. Hughes, Stewart B. Rood (ALSO SEE ABSTRACT – CONTAINS AUS and SA refs)

INVASION

* Exotic invasive black willow (Salix nigra) in Australia: influence of hydrological regimes on population dynamics (Kate E. Stokes)
* Shifting dominance of riparian Populus and Tamarix along gradients of flow alteration in western North American rivers David M. Merritt 1,2,5 and N. Le Roy Poff 3,4
* Water table decline alters growth and survival of Salix gooddingiiand Tamarix chinensis seedlings Jonathan L. Horton, , Janelle L. Clark
* (populus in Canada) Factors affecting the regeneration and distribution of riparian woodlands along a northern prairie river: the Red Deer River, Alberta, Canada
* L. D. Cordes1, F. M. R. Hughes2,\* andM. Getty1
* CATFORD INVASIONS paper? Or later?

“rules are bad” – In the absence of detailed empirical information of environmental flow requirements for rivers, we propose a generic approach that incorporates essential aspects of natural flow variability shared across particular classes of rivers that can be validated with empirical biological data and other information in a calibration process. THE CHALLENGE OF PROVIDING ENVIRONMENTAL FLOW RULES TO SUSTAIN RIVER ECOSYSTEM Angela H. Arthington 1,4, Stuart E. Bunn 1, N. LeRoy Poff 2, and Robert J. Naiman 3

WE KNOW QUITE A BIT ABOUT TAXONOMICALLY OR REGIONALLY SPECIFIC FLOW-ECOLOGY RELATIONSHIPS. C.F. ELOHA, RECRUITMENT BOX MODELS, MEDITERRANEAN, ETC. THIS SORT OF RESEARCH LARGELY COMES FROM NORTH AMERICA OR EUROPE AND IS BASED ON A SMALL SET OF DOMINANT TAXA SUCH AS SALIX, POPULUS AND TAMARIX. THE CHALLENGE NOW IS TO GENERALISE OUR UNDERSTANDING ACROSS REGIONS THAT MAY NOT NECESSARILY HAVE THE SAME SPECIES POOLS (OR FUNCTIONAL ATTRIBUTES?). cue species richness isn’t great argument

The ELOHA framework (Poff et al. 2010) put forth a comprehensive framework aimed at understanding the ecological consequences of hydrological alteration for the purposes of flow management in regulated systems. This framework urges the development of regionally specific models of flow-ecology relationships.

A plethora of statistical metrics can be generated to describe ecologically relevant components of hydrology. Broadly, these can be grouped into five categories, describing the central tendencies and variability of: magnitude, frequency, duration, timing, and rates of change of discharge events.

SEASONALITY OF FLOWS IS IMPORTANT”:

**The importance of seasonal flow timing for riparian vegetation dynamics: a systematic review using causal criteria analysis**

**JOE GREET1,2, J. ANGUS WEBB1,2 andROGER D. COUSENS1**

* *Hydrologic heterogeneity* <-> vegetation heterogeneity <-> geomorphic heterogeneity
  + “Biogeomorphic heterogeneity in the riparian patch mosaic results from a highly contingent interplay between hydrology, ecology and geomorphology over diverse spatial and temporal scales.” “A framework for interdisciplinary understanding of rivers as ecosystems”, Corenblit, Gurnell
  + Vegetation heterogeneity = population structure diversity \* functional / taxonomic diversity
  + We know these relationships hold for taxonomic diversity, right?
    - Hydrology - Riparian plant species richness along lateral and longitudinal gradients of water stress and flood disturbance, San Pedro River, Arizona, USA;
    - Landscape structure and diversity in riparian plant communities: a longitudinal comparative study ;
    - The role of riparian corridors in maintaining regional biodiversity ; Huston, M. 1979. A general hypothesis on species diversity. |
    - Biological (species richness), landscape (hab- itat mosaic) and functional (nutrient flux) diversity in the high flood-frequency zone can be maintained or even increased by flood disturbances (Barnes, 1997; Naiman and Décamps, 1997; Hughes et al., 2001;Ward and Tockner, 2001). – from Corenblit 2007
    - Geomorph - Jess paper digging deep for diversity – geomorphic implications for species richness, also see her references in intro re: species richness & geomorphy
* Are riparian systems resilient?
  + To individual disturbances and/or dry periods, yes, due to the nature of rivers as dispersal corridors, and intrinsic ecological heterogeneity providing refugia and a diverse patch mosaic a template for recovery (Naiman decamps Pollock 1993). However, riparian communities can be finely tuned to patterns of disturbance / low flows.
    - “Dispersal of propagules, colonisation and establishment of many plant species within the resulting patch mosaic is intimately tied with flooding cycles and temporal variability of flows.
    - Also quote dams literature

**A functional approach reveals community responses to disturbances.**

* Synthetic / framework proposing paper that I can’t get my head around.

**Species diversity and functional diversity relationship varies with disturbance intensity**

* Looked at species and functional diversity in anthropogenically disturbed (managed for timber extraction) upland and riparian plant communities. Found support for the intermediate disturbance hypothesis in both diversity and richness.

**Land-use intensification reduces functional redundancy and response diversity in plant communities**

* Land use intensification associated with significantly lower functional redundancy (number of species in each functional group) and response diversity (FDis within each group).

**Flow regulation reduces native plant cover and facilitates exotic invasion in riparian wetlands** (catford et al 2011) – didn’t use a multivariate index but did look at trait diversity in relation to hydrological modification. Wetlands also. Hydrological alteration was associated with greater exotic cover and reduced functional diversity.

**Functional diversity indices reveal the impacts of land use intensification on plant community assembly**

**A guide for using functional diversity indices to reveal changes in assembly processes along ecological gradients**

* So what happens to functional diversity in post-disturbance terrestrial systems?
  + What about systems that are just exposed to strong abiotic constraints?
  + Intermediate disturbance hypothesis? (can cite Jess)
* WHAT IS THE RELATIONSHIP BETWEEN SPECIES RICHNESS, ECOSYSTEM FUNCTION And FUNCTIONAL DIVERSITY? – SEE CADOTTE ET AL 2011.