**Hydrological data analysis**

Hydrological data pertaining to each field site were collated from the PINNNENA CW 10.1 database (NSW Office of Water, Department of Primary Industries) and the NSW Office of Water Continuous Water Monitoring network website (<http://realtimedata.water.nsw.gov.au/water.stm>) (for NSW sites), and the Victoria State Government’s Water Measurement Information System website (<http://data.water.vic.gov.au/monitoring.htm>). Daily discharge rate data arrives as timestamped average daily flow datapoints in units of megalitres per day. Where possible 30 year time series were obtained, spanning years 1983 – 2012. Records were truncated for three sites, spanning 15, 19 and 28 years. Missing data were approximated using the Time Series Manager module in River Analysis Package (REF). Consistency of the resulting outputs were checked by visual inspection of hydrographs. For Mammy Johnson’s River, Mann River, Sportsman’s Creek and Wallagaraugh River, multiple linear regression was chosen as the most appropriate method. Linear interpolation was used for Jilliby Creek data.

A minimal set of hydrological metrics was pared from the full set described by Kennard et al. (2010). These metrics were chosen to be representative of variability in high flow magnitude and frequency as well as predictability and consistency of water availability in the riparian environment (see Table X for a description). We used the Time Series Analysis module in River Analysis Package to generate these metrics. Means and coefficients of variation were calculated for most metrics to indicate central tendency as well as spread within the data. Low and high spell metrics were thresholded at the 5th and 95th percentiles, respectively, with a flood independence criterion of 7 days between peaks events 20 year average return interval (ARI) flood magnitude was also calculated with a flood independence value of 7 days between peaks. Colwell’s Indices were calculated using mean values over monthly time periods and a class distribution of 11 flow classes. Metrics of flow magnitude were normalised by mean daily flow to allow for comparison between different sizes of river.

*Flood frequency and magnitude*

High spells are periods of flow above the 95th percentile on the flow duration curve. We were interested in how frequently these conditions occurred over the time series as well as the mean magnitude of peak flows during these periods. 20 year average return interval (ARI) floods are extreme flow events that have the potential to resculpt the fluvial landscape. Together, these metrics indicate the intensity and frequency with which mechanical stress is applied to plants in the riparian zone. Abbreviations: HSPeaknorm, CVAnnHSPeak, AS20YrARInorm, MDFAnnHSNum, CVAnnHSNum.

*Rise and fall rates*

Rise and fall rates represent flow flashiness. Fast rise rates are associated with flood waves and intense mechanical stress to plant stems. Slow fall rates keep exposed substrate moist for longer periods, which may produce favourable conditions for germination. Historical discharge records are unfortunately limited to daily resolution, so are unable to fully capture flood discharge shapes. High variability between years indicates the occurrence of extreme events which may not have been captured by the mean value. Abbreviations: mean values - *MRateRise*, *MRateFall*, coefficients of variation - *CVAnnMRateRise*, *CVAnnMRateFall*

*Baseflow index*

Baseflow index is calculated using the ratio of flow during average conditions to total flow. It is a useful metric of consistency of water availability, in that it is maximised when average flow conditions dominate, and minimised when total flow is dominated by above average flow events. Intra-annual variability in baseflow index measures how predictable baseflow index is between years. Abbreviations: BFI, CVAnnBFI

*Low flow magnitude, frequency and duration*

Low spells are periods of flow below the 5th percentile on the flow duration curve. We were interested in how frequently these conditions occurred over the time series as well as the mean and variability in magnitude and duration of low flows during these periods. Abbreviations: LSPeaknorm, CVAnnLSPeak, MDFAnnLSNum, CVAnnLSNum, LSMeanDur, CVAnnLSMeanDur, MDFAnnUnder0.1, CVAnnMDFUnder0.1

*Colwell’s indices*

Colwell’s indices provide a measure of the seasonal predictability of environmental events. Constancy (M) measures uniformity of flow across seasons, and is maximised when flow conditions do not differ between seasons. Contingency (M) is a measure of interannual uniformity in seasonal flow patterns, and is maximized when seasonal patterns of flow are consistent between years.  We generated Colwells indices for both average flow conditions and minimum flows conditions. Abbreviations: C\_MDFM, M\_MDFM (average conditons), C\_MinM, M\_MinM (minimum flow conditions).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameter** | **Abbreviation** | | **Units** | **Description** |
| *Flood frequency and magnitude* | | | | |
| Mean magnitude of high spells\* | HSPeaknorm | dimensionless | | High spells are periods of flow above the 95th percentile on the flow duration curve. We were interested in how frequently these conditions occurred over the time series as well as the mean magnitude of peak flows during these periods. 20 year average return interval (ARI) floods are extreme flow events that have the potential to resculpt the fluvial landscape. Together, these metrics indicate the intensity and frequency with which mechanical stress is applied to plants in the riparian zone. |
| CV of all years’ mean high spell magnitude | CVAnnHSPeak | dimensionless | |
| 20 year ARI flood magnitude\* | AS20YrARInorm | dimensionless | |
| Mean of all years’ number of high spells | MDFAnnHSNum | year-1 | |
| CV of all years’ number of high spells | CVAnnHSNum | dimensionless | |
| *Rise and fall rates* | | | | |
| Mean rate of rise \* | MRateRisenorm | dimensionless | | Rise and fall rates represent flow flashiness. Fast rise rates are associated with flood waves and intense mechanical stress to plant stems. Slow fall rates keep exposed substrate moist for longer periods, which may produce favourable conditions for germination. Historical discharge records are unfortunately limited to daily resolution, so are unable to fully capture flood discharge shapes. High variability between years indicates the occurrence of extreme events which may not have been captured by the mean value. |
| Mean rate of fall \* | MRateFallnorm | dimensionless | |
| CV of all years mean rate of rise | CVAnnMRateRise | dimensionless | |
| CV of all years mean rate of rise | CVAnnMRateFall | dimensionless | |
| *Baseflow index* | | | | |
| Baseflow index | BFI | dimensionless | | Baseflow index is calculated using the ratio of flow during average conditions to total flow. It is a useful metric of consistency of water availability, in that it is maximised when average flow conditions dominate, and minimised when total flow is dominated by above average flow events. Intra-annual variability in baseflow index measures how predictable baseflow index is between years. |
| CV of all years Baseflow Index | CVAnnBFI | dimensionless | |
| *Low flow magnitude, frequency and duration* | | | | |
| CV of all years’ mean low spell magnitude | LSPeaknorm | dimensionless | | Low spells are periods of flow below the 5th percentile on the flow duration curve. We were interested in how frequently these conditions occurred over the time series as well as the mean and interannual variability in magnitude and duration of low flows. |
| CV of all years mean of low spell magnitude | CVAnnLSPeak | dimensionless | |
| Mean of all years number of low spells | MDFAnnLSNum | year-1 | |
| CV of all years’ number of low spells | CVAnnLSNum | dimensionless | |
| Mean duration of low spells | LSMeanDur | days | |
| CV of all years’ low spell mean duration | CVAnnLSMeanDur | dimensionless | |
| Mean days per year under 0.1ML/day flow | MDFAnnUnder0.1 | days\*year-1 | |
| CV of all year’s days per year under 0.1ML/day flow | CVAnnMDFAnnUnder0.1 | dimensionless | |
| *Colwell’s indices* | | | | |
| Constancy based on monthly mean daily flow | C\_MDFM | dimensionless | | Colwell’s indices provide a measure of the seasonal predictability of environmental events. Constancy (M) measures uniformity of flow across seasons, and is maximised when flow conditions do not differ between seasons. Contingency (M) is a measure of interannual uniformity in seasonal flow patterns, and is maximized when seasonal patterns of flow are consistent between years.  We generated Colwells indices for both average flow conditions and minimum flows conditions. |
| Contingency based on monthly mean daily flow | M\_MDFM | dimensionless | |
| Constancy based on monthly minimum daily flow | C\_MinM | dimensionless | |
| Contingency based on monthly minimum daily flow | M\_MinM | dimensionless | |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| *Parameter* | *Definition* | *Units* |  |  |
| CV of all years mean rate of rise | Coefficient of variation over annual mean rates of flow rise. | This metric represents inter-annual variation in flow ‘flashiness’ over the time series. |  |  |
| CV of all years mean rate of rise | Inter-annual variation in mean rates of flow fall. | This metric represents inter-annual variation in flow ‘flashiness’ over the time series. |  |  |
| Mean magnitude of high spells\* | High spells are periods of flow above a certain threshold. This metric describes the mean magnitude of flows above the 95th percentile. Flood independence criterion = 7 days between peaks. |  |  |  |
| 20 year ARI flood magnitude \*\* | Magnitude of 20 year Average Return Interval flood, as calculated from the fitted Log-Pearson III distribution of flood magnitudes. Flood independence criterion = 7 days between peaks. |  |  |  |
| CV of all years’ mean high spell magnitude\*\*\* | Inter-annual variation in mean high spell magnitude. |  |  |  |
| CV of all years’ number of high spells | Inter-annual variation in high spell frequency. |  |  |  |
| Mean rate of rise \* | The mean rate of positive changes in mean daily flow. Rapid rise rates are associated with greater hydraulic shear stress. |  |  |  |
| Mean rate of fall \* | The mean rate of negative changes in mean daily flow. Flood fall rates are typically related to flood rise rates and also partly determine the duration that flooded areas are inundated. |  |  |  |
| Mean of all years’ number of high spells | Average yearly frequency of flows above the 95th percentile. |  |  |  |
|  |  |  |  |  |
| CV of all years Baseflow Index | Coefficient of variation in baseflow index across years. |  |  |  |
| Predictability based on monthly mean daily flow (P) |  |  |  |  |
| Constancy based on monthly mean daily flow ( C) | |  |  |  | | --- | --- | --- | |  | *Constancy* is a measure of how uniform the event occurs through all seasons. It is maximized when the time series value is the same for all seasons, for example a desert river with many zero flows will have a high constancy value. |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | |  |  |  |  |  |  |  |  | | --- | --- | |  |  | |  |  |  |
| Contingency based on monthly mean daily flow (M) | *Contingency* a measure of how uniform the event occurs through all seasons. It is maximized when the pattern of time series values is the same from year to year, for example, high flows occur every winter of the record. |  |  |  |
| Contingency based on monthly minimum daily flow (M) |  |  |  |  |
| Mean magnitude of low spell troughs \* | Mean magnitude of flows below the 5th percentile. Flood independence criterion = 7 days between peaks. |  |  |  |
| Baseflow index | Ratio of baseflow to total flow, averaged across all years in the time series. |  |  |  |
| Moving average 7 day minimum mean \* | The average flow of the driest week of every year in the time series. |  |  |  |
| Predictability based on monthly minimum daily flow (P) |  |  |  |  |
| Mean of all years number of low spells | Average yearly frequency of flows below the 5th percentile. |  |  |  |
| CV of all years mean of low spell magnitude |  |  |  |  |
| Mean duration of low spells | Mean duration of flows which remain below the 5th percentile of flows |  |  |  |
| CV of all years’ number of low spells | Coefficient of variation of low spell frequency across years |  |  |  |
| Constancy based on monthly mimimum daily flow ( C) |  |  |  |  |
| Mean days per year under 0.1ML/day flow | Mean number of days per year having flow under 0.1mL/day. |  |  |  |
| Mean zero flow days per year | Mean number of days per year having zero flow. |  |  |  |
| CV of all years’ low spell mean duration | CV of low spell duration across years. |  |  |  |

\* normalised by mean daily flow, , \*\* thresholded at 95th percentile, \*\*\* thresholded at 5th percentile

Finally, we performed permutational multivariate analysis of variance using distance matrices (vegan package in R) across these chosen metrics to confirm that our field sites did indeed form three significantly different hydrological categories.

**Abundance weighted site means of wood density**

To investigate variation in wood density across hydrological gradients at the community level, abundance weighted means of wood density were generated for each site. Species abundance was compiled from records of % cover at the shrub (1-4m), subcanopy (4-8m) and canopy (8+) strata according to the following equation: sum(A1,shrub, A1,subcanopy, A1,canopy) / sum(A1-n,shrub, A1-n,subcanopy, A1-n,canopy) where A is % cover at a given stratum. Wood density values were then weighted according to species fractional abundance and then summed to produce the abundance weighted site mean. This method integrates particular trait values with their real world abundance as a measure of ‘performance’, while providing a useful reduction in data dimensionality. Wood density varies only over one order of magnitude, while exhibiting relatively high intra-species plasticity. As such, abundance weighted site means work well for environmental gradient studies because the focus is maintained on the functional characteristics of the community, rather than on species *per se*.

**Comparison of hydrological classes**

Raw species trait values were lumped according to the hydrological class membership and differences between classes tested for using a post-hoc Tukey’s HSD test. This test was repeated using class-lumped abundance weighted site means.

**Lm’s against hydro variables**

Ordinary least-squares regression models were generated for selected metrics to determine relationships between hydrological gradients and raw species wood density values. The same process was repeated using abundance weighted site mean values. Wood density data was normally distributed and did not require transformation.

* + Despite being from orthogonal groups according to Kennard et al. correlation analyses, hydro metrics are intercorrelated within this small dataset – “the correlation matrix exhibits positive dependency in this small dataset”
    - This makes statistics complicated: Bonferroni correction is out (independence assumption violated), and assumptions are not met for standard FWER (family-wise error rate) techniques either (independence assumption violated). We the have to move to FDR (false discovery rate) techniques. “The Benjamini and Hochberg (1995) false discover rate controlling procedure (BH procedure) is known to control the FDR for positively dependent test statistics (Benjamini andYekutieli, 2001).” – Yekutieli 2007 *Journal of Statistical Planning and Inference.*
    - BH procedure in R (stats package) used to adjust p values
      * BY procedure should also be appropriate. It gives different values and rejects every one of my models so fuck that. BH it is.

We identified the most ecologically relevant axes of variation in hydrological conditions by running a principal components analysis over hydrological metrics which showed significant relationships with site mean wood density values.

**Testing for specialisation in ecological strategy**

In this study we describe a novel method for identifying specialisation in ecological strategy along environmental gradients. The riparian environment provides an ideal context for such a test as hydrology is such a dominant driver of community assembly, meaning significant specialisation can be expected as disturbance intensity or fluctuation in water availability increase. We used Trait Gradient Analysis (*sensu* Ackerly & Cornwell, 2007) to decompose community-level interspecific trait variation into within-site (alpha) and across-landscape (beta) components. We were then able to identify where specialisation occurs within the landscape by quantifying changes in site-wise dispersion of beta trait components (across a hydrological gradient of choice).

*Trait Gradient Analysis*

Trait Gradient Analysis was performed on wood density data following Ackerly and Cornwell (2007). All calculations were made in R, using scripts provided as Supplementary Information to Ackerly and Cornwell (2007). The analysis is fed with a matrix describing the name, abundance and trait value of species found at each site and the following parameters are generated: 1.) abundance weighted mean trait values for each site (tp), 2.) an inter-site mean trait value for each species (ts), 3.) a niche breadth (Rs) for each species 4.) an alpha trait value (alphaT) for each species, 5.) a beta trait value (betaT), for each species.

In TGA, the trait gradient is a one dimensional ordination of sites according to their abundance-weighted site mean trait values. The betaT value integrates the site mean trait values of all sites at which that species occurs, and represents the characteristic position of a species along the trait gradient. For example, a high betaT for wood density indicates that a species is typically found at sites with high mean wood density – regardless of whether the species wood density value is low or high. AlphaT and betaT values are calculated by linear decomposition of a species mean trait value (ts), defined by: ts = alphaT + betaT. The alpha trait value, then, is calculated by subtracting betaT from the mean species trait value. It provides a metric of the difference between a species’ mean trait value and the trait values of other species with which it co-occurs, and can be positive or negative. For example, a high alphaT for wood density indicates that that a species typically has higher wood density than the species it co-occurs with. Finally each species is associated with a niche breadth, Rs, which corresponds to the range of site mean trait values across which a species occurs and is measured in units of wood density (g/cm3). Both Ackerly and Cornwell (2007) and Gallagher & Leishman (2012) have provided elegant descriptions of the mechanistics of TGA, and the reader is referred to these publications for more in-depth discussion.

*betaT dispersion as a measure of niche specialisation*

We can replace raw species trait values with betaT values, and run them in a linear model against an axis where the sites are ordered according to some environmental gradient. Now we have a model that describes relationship of species trait values to the environmental gradient with noise due to intra-site variability removed (remember ts = alphaT + betaT). This model includes abundance weightings but is no more instructive than a plot of raw species trait values against the environmental gradient. We can however look at dispersion of betaT (betaTdisp) across the gradient: as betaT values of species occurring at a site converge, the likelihood that they were found at the same sites increases, indicating specialisation in ecological strategy.

An issue arises here in that betaT is generated as a mean of ts values. To give an explicit example: 0.1 + 0.9 / 0.2 = 0.5, 0.4 + 0.6 / 0.2 = 0.5. The first equation would represent a species with high niche breadth whereas the second would represent a low niche breath species. Rs values can be used to confirm whether betaTdisp indicates that species are present at the same set of sites. If both Rs.mean and betaTdisp are low at a site, species are specialised to a narrow niche. Where site Rs.mean is high, species are cosmopolitan, so tight betaTdisp does not necessarily indicate ecological strategy specialisation. By assessing correlation of betaTdisp with Rs.mean across a dataset, it is possible to determine to what extent betaTdisp is a valid measure of specialisation. If a strong correlation is apparent, we can assert that if betaTdisp decreases in a predictable manner over the gradient, this indicates an increase in specialisation in species ecological strategy.

It is also useful to consider this approach in the context of patchy sampling. In this case, species with the same real niche ranges may be assigned different betaT values. As the ratio of Rs to the number of sites used to calculate betaT (Nplots) increases, so too does the potential error associated with betaT. Therefore for species found at more than one site, this ratio Rs /Nplots can be used as a metric of error. We can plot site mean Rs/Nplots ratios against an environmental variable for kicks. The model shouldn’t be significant. Where species are only found at one site, it is not possible to determine if this measurement is representative of their true range or if it is an artefact caused by patchy sampling. Sites such as Sportsmans Creek which have a completely unique assemblage with in the datasets, giving both Rs and Nplots of zero for all species, are essentially a statistical bummer. The fact that this site sits neatly within observed trends gives the value some credence at least.

Not all field data comes from big budget programmes with saturating sampling intensity, and we shouldn’t let patchiness in ecological sampling deter us too much. We simply need to be clear on what our tests are able to say about the data we have available.

*Testing betaT dispersion over hydrological gradients*

Site-wise ranges of species betaT values were calculated. Range was used as it provides a measure of dispersion that is directly comparable to Rs. Standard deviations and coefficients of variation of betaT were also tested and produced much the same results as ranges. Ordinary least-squares regression models were then generated over gradients of the hydrological parameters shown in *Table X*. Because betaT.range distributions were not normally distributed, so we compared these models against a null model of community assembly. This null model was generated by resampling the vector of site numbers without replacement, using the R script provided by **Ackerly and Cornwell (2007).** This approach maintained site-level distributions of species diversity, *the number of occurences per species, and the intraspecific distribution of both abundance and trait values within species.* One-way ANOVA was used to test for differences between betaT.range – environment and betaT.range.null – environment models. Models that were not significantly different from the null model were discarded. The BH method was again used to account for increased type 1 error associated with multiple comparisons.

We identified the most ecologically relevant axes of variation in hydrological conditions by running a principal components analysis across hydrological metrics which showed significant relationships with betatT.range.

To determine the significance of betaT calculation error, we can compare betaT.dispersion – environment relationships with Rs – environment relationships ??

Niche breadth / number of sites species occurred in or n/Rs as measure of betaT error? – most species will throw a NaN because they were only found in one site…

Rs on its own is not a useful measure of niche specialisation at the site level because it doesn’t indicate whether different species at a particular site come from a similar region of the gradient. Whereas betaT.dispersion on its own can’t tell you whether a particular species is present at similar or different regions of a gradient (because it’s a mean).

Assuming correlation of betaT with Rs (over the environmental gradient…) the degree of dispersion of betaT values at a given site, then, indicates whether the species are specialised to a particular site or set of sites, or

Can we can use the degree of correlation between betaT.disp and Rs.mean to check for the influence of ‘broken’ betaT values (i.e. high range, low n[sites])