Commonwealth Environmental Water Office

Long Term Intervention Monitoring

Basin Matter – Vegetation–revision 2019

Prepared by: Sam Capon, Cherie Campbell and Ben Stewart-Koster

Final Report- revision 2019

La Trobe Publication 211/2018

Basin-Matter Vegetation - revision 2019

Report prepared for the Commonwealth Environmental Water Office by La Trobe University

For further information contact:

Nick Bond

La Trobe University
PO Box 991
Wodonga VIC 3689

Ph: (02) 6024 9650

Email: N.Bond@latrobe.edu.au
Web: www.latrobe.edu.au
Enquiries: cfe@latrobe.edu.au

This monitoring project was commissioned and funded by Commonwealth Environmental Water Office.

Copyright

Disclaimer

Document history and status

Version	Date Issued	Reviewed by	Approved by	Revision type
Final	16/11/2018	Sam Capon	Nicole Thurgate	Internal
Final	17/05/2019	CEWO	Irene Wegener	External
Final	10/05/2021	Rachel Gorman	Nick Bond	Internal

Distribution of copies

Version	Quantity	Issued to
Draft	1 x Word	CEWO
Final	1 x PDF 1 x Word	Irene Wegener

Contents

Basin Matter - Vegetation Diversity foundation report

1   Why?

Vegetation diversity refers to the diversity of plants, including populations of plant species and the vegetation communities which they form. Both composition (e.g. species richness) and structure (e.g. height) are important components of vegetation diversity. With respect to the LTIM project, vegetation diversity is considered through all phases of the flow regime relevant to a particular riparian, wetland or floodplain ecosystem (i.e. dry, base flow, fresh, bank-full, overbank).

Vegetation diversity was included in the suite of matters for evaluation at the Basin scale because it:

- aligns well with Basin Plan objectives;
- is known to be flow-sensitive;
- provides a good short-term response to environmental watering; and
- is easily communicated to and valued by the broader community.

Vegetation diversity is also highly significant ecologically, supporting and regulating many of the other components and processes targeted by the Basin Plan and Basin Matters (e.g. provision of habitat to waterbirds).

The presence and abundance of wetland, riparian and floodplain plants and vegetation communities are strongly influenced by hydrology (Brock & Casanova 1997; Capon *et al.* 2012; Casanova & Brock 2000; Roberts & Marston 2011). Patterns of wetting and drying have an overriding influence on the composition and structure of vegetation communities in such habitats as well as their spatial and temporal dynamics across the landscape (Capon & Dowe 2007; Alexander *et al.* 2008). Hydrologic characteristics of individual flow or flood pusles (e.g. timing, depth, duration, rate of drawdown) influence the responses of individual plants (e.g. growth or reproduction) and the occurrence and/or outcome of population processes (e.g. dispersal or establishment). Over longer time periods, therefore, the structure of plant populations and vegetation communities are strongly shaped by flow history (e.g. flood frequency, duration of dry spells etc.)

Changes in flow regimes can significantly affect vegetation diversity across multiple spatial scales both in the short term and over longer periods of time. In the short term, even minor changes to the timing, depth, duration or rate of drawdown of flow and floods can result in considerable differences in the composition and structure of wetland vegetation communities at a fine scale (e.g. Webb *et al.* 2006). At an ecosystem scale, changes to individual flood pulses can affect the presence, distribution and abundance of individual plant species and, therefore, the diversity of vegetation communities across a riverine landscape. Over time, changes to the flow regime can consequently result in the local extirpation of some species and the invasion of others as well as shifts in the distribution and abundance of species and vegetation communities across the landscape. Such changes have significant implications for ecosystem function (e.g. provision of habitat, patterns of primary production) and the ecosystem goods and services provided (e.g. water quality regulation).

2   What?

This component of the Basin Evaluation will address the following short-term (one-year) and long-term (five-year) Basin-scale evaluation questions:

- What did Commonwealth environmental water contribute to vegetation species diversity?
  - i.e. How did Commonwealth environmental water affect the presence, distribution and abundance of individual plant species?
-
- What did Commonwealth environmental water contribute to vegetation community diversity?
  - i.e. How did Commonwealth environmental water affect the composition and structure of particular vegetation communities?
  - How did Commonwealth environmental water affect the presence, distribution and abundance of particular vegetation communities?

Monitoring of vegetation diversity at Selected Areas will occur across a range of wetland, floodplain and riverine sites, mostly on an event basis (i.e. before and after environmental water delivery) but in some cases more frequently. Data collection will include records of vegetation diversity (i.e. presence, cover and height of plant species) and observations of vegetation structure (e.g. canopy cover, litter cover, bare ground). A summary of vegetation diversity sampling at Selected Areas is presented in Table 1.

Data collected by M&E Providers at the Selected Areas will be collated and analysed by the Basin Matter team to evaluate the effects of Commonwealth environmental water on the diversity of plants and vegetation communities with respect to:

1. *species level responses*: responses to environmental water of individual plant species across Selected Areas including changes to species presence, distribution and abundance;
2. *community level responses*: responses to environmental water of particular vegetation communities within specific habitat types (e.g. ANAE vegetation types) across Selected Areas including changes in species diversity, composition and structure; and
3. *landscape level responses*: responses to environmental water of vegetation communities across the Selected Areas including changes in the presence, distribution and diversity of particular vegetation communities.

These will be delivered annually

The Basin-scale evaluation will build on the following assessments:

1. *Aggregated Area scale, annual evaluation*. Across the selected areas, this will identify vegetation outcomes to water actions by comparing observed outcomes to the outcomes predicted to occur in the absence of the environmental flow. In particular, this evaluation will be used to assess the consistency of responses to watering at species and community levels. To be delivered in years 4 and 5 after enough data is curated in the MDMS.

2. *Basin-scale, annual evaluation*. For un-monitored sites, a multiple lines of evidence approach will be used to describe the likely outcomes of annual water actions. To be delivered in year 4 and 5 after enough data is curated in the MDMS.

3. *Area scale, 1-5 year evaluation*. For selected areas, this will assess the cumulative outcomes from water actions over the relevant time-frame. It is possible that the models may be able to identify the influence of antecedent conditions, in which case the counterfactual

scenario(s) will include consideration of the annual outcome without antecedent water actions. To be delivered in year 5.

4. *Basin-scale, 1-5 year evaluation*. This assessment will build on the annual basin-scale evaluation and area scale 1-5 year evaluations to describe the likely cumulative outcomes of water actions over the relevant time-frame compared with the counterfactual scenarios(s). To be delivered in year 5.

To support these evaluation processes the Basin Matter will develop:

1. preliminary and updated databases of:

   a. plant species responses to watering; and

   b. vegetation community responses to watering.

2. predictive tool(s) to estimate Commonwealth environmental water contributions to vegetation species diversity across the Basin both in the short-term and long-term (and vegetation responses to watering more generally)

The relationship between data collection, analysis, evaluation and reporting is illustrated in Figure 1.
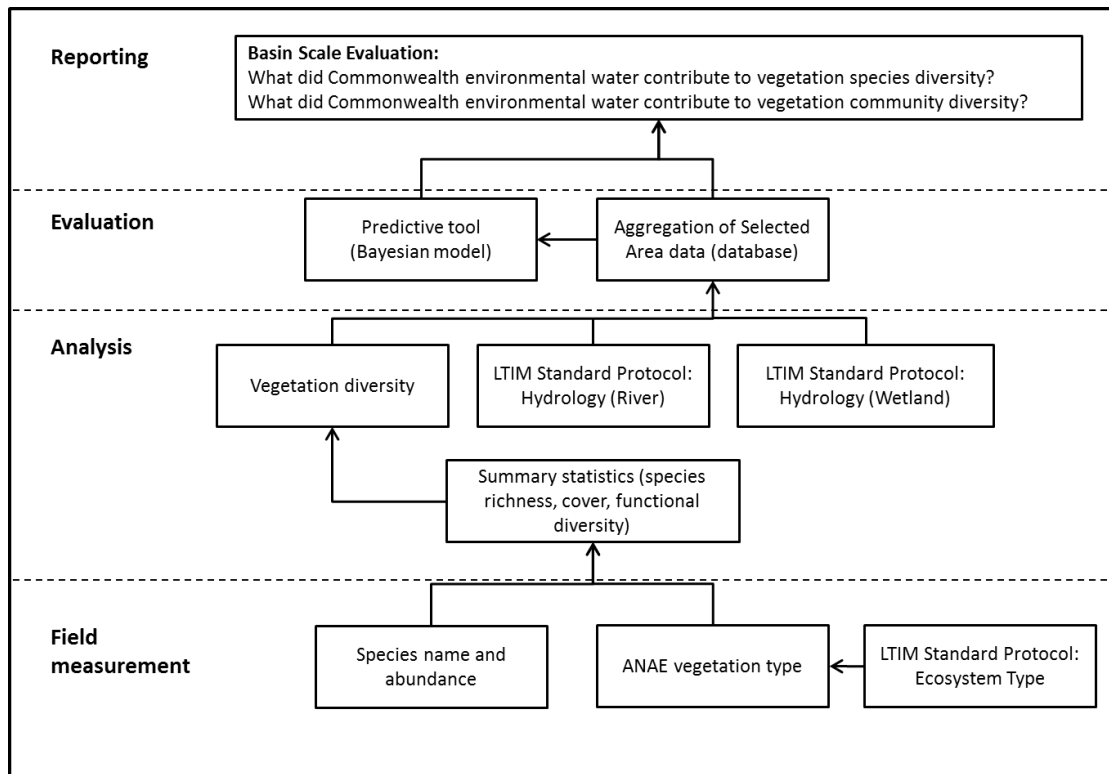
Figure 1. Schematic of key elements in the LTIM Project Standard Protocol: Vegetation Diversity

Table 1. Summary of vegetation diversity and vegetation community structure data to be collected at each Selected Area

Selected Area	Veg type[1]	Timing of sampling	# Zones[2]	# Sites per zone	# Quadrats /Transects per site	Quadrat / Transect description	Sampling unit description	VEGETATION DIVERSITY METRICS		COMMUNITY STRUCTURE METRICS					
								% Cover by species	# Tree seedlings/saplings 3 classes (20-50cm; 50-130cm; 1.3-3m)	% Canopy cover (>5 m tall)	% Understorey cover (1-5 m tall)	% Groundcover (<1 m tall)	% Litter cover	% Wood cover	% Bare ground
Goulburn	Fr	before & after Oct Spring Fresh	1	4	16	transects perpendicular to channel, sampling every 1m along 2m lengths, points every 10cm. (point-intercept method)	% cover values calculated for each elevation on each transect (point-intercept method)	✓	✓ (in 3 1m x 1m quadrats at top, middle and bottom of bank)	✓	✓	✓	✓	✓	✓
Edward-Wakool	Fr	bi-monthly between Sept & Mar (monthly for non-id metrics)	4	5	1	transects perpendicular to channel, sampling from 5 permanent markers along 25m transects parallel to water, points every 50 cm along	% cover values calculated for each elevation on each transect (point-intercept method)	✓		✓	✓	✓	✓	✓	✓
Warrego	Fl	before & after CEW (Aug/Oct & Mar/Jun)	1	8	3	0.04ha (20m x 20m) quadrats	% cover values for 0.04ha quadrat	✓	✓	✓	✓	✓	✓	✓	✓
Murrum-bidgee	Fr	Sept, Nov, Jan & Mar	1	4	3	1 x 20m transects, sampling in 1m quadrats	% cover values for each 1m quadrat	✓	✓	✓	✓	✓	✓		✓
Murrum-bidgee	Fl		2	4	2-3	1 x 10m quadrats	% cover values for each 10m quadrat	✓	✓	✓	✓	✓	✓		✓

Selected Area	Veg type[1]	Timing of sampling	# Zones[2]	# Sites per zone	# Quadrats /Transects per site	Quadrat / Transect description	Sampling unit description	% Cover by species	# Tree seedlings/saplings 3 classes (20-50cm; 50-130cm; 1.3-3m)	% Canopy cover (>5 m tall)	% Understorey cover (1-5 m tall)	% Groundcover (<1 m tall)	% Litter cover	% Wood cover	% Bare ground
								VEGETATION DIVERSITY METRICS		**COMMUNITY STRUCTURE METRICS**					
Lachlan	Fr	before & after CEW (Mar/April and 3 months after 1st fill)	5	1-4	2-3	100m transects with observations recorded every 1m	% cover values for each 1m x 1m quadrat	✓▢					✓	Length of fallen timber >10 cm	✓
Lachlan	Fl		5	2-5	2-4	0.04ha plots nested within 0.1ha plots	% cover values for 0.04ha plot (N.B. Canopy cover recorded for 0.1ha plot)	✓	✓	✓	✓	✓	✓	✓	✓
Gwydir	Fr	before & after CEW (Aug/Oct & Mar/Apr)	1	1	2	transects with observations recorded every 1m	% cover values for each 1m x 1m quadrat	✓	✓				✓		✓
Gwydir	Fl	before & after CEW (Aug/Oct and Mar/Apr)	2	13	3	0.04ha plots nested within 0.1ha plots	% cover values for 0.04ha plot (N.B. Canopy cover recorded for 0.1ha plot)	✓	✓	✓	✓	✓	✓	Length of fallen timber >10 cm	✓

1 – Fr: fringing vegetation (i.e. riverbanks or wetland gradients), Fl – floodplain vegetation (i.e. assumed to be homogenous unit)

2 – refers to wetland complexes in Lachlan

3   How?

3.1   Data

The LTIM Project standard methods for vegetation have been designed to provide data appropriate for the evaluation of vegetation outcomes at the Basin scale. This data may be complemented by a range of existing data sets including those collected under previous environmental watering monitoring programs such as The Living Murray (TLM), the Integrated Monitoring of Environmental Flows (IMEF), the Victorian Environmental Flows Monitoring and Assessment Program (VEFMAP) and the Narran Lakes monitoring programs.

In addition to vegetation diversity data (Table 1), it is anticipated that the M&E Service Providers will provide Site and Area scale hydrological information, including antecedent flow conditions for sample sites as well as hydrologic metrics relevant to the time of sampling (e.g. water depths, discharge, soil moisture). This data will be supplemented with further information on potential non-flow drivers of vegetation diversity (e.g. soil type) supplied by M&E Service Providers or collated by the Basin Matters Vegetation Diversity team (Table 2).

Predictions of vegetation diversity responses to Commonwealth environmental watering at the Basin scale will also depend on hydrologic data provided by the Basin Matters Hydrology team for both Selected Areas and at the Basin scale. Information concerning the extent, timing, duration and depth of inundation in relation to discharge, and associated antecedent flow conditions, will be particularly critical to enable the prediction of counterfactual outcomes.

3.2   Developing the evaluation approach

There are three steps to developing the capacity to undertake the Basin scale evaluation of vegetation diversity: 1) foundational review, 2) identification of the transferability of responses through aggregation and analysis of Selected Area and existing data; and 3) development of predictive models to qualitatively and quantitatively evaluate the contribution of Commonwealth environmental water to vegetation diversity in other areas and at the Basin scale.

3.2.1   Foundational review

An initial task will be to compile preliminary databases of 1.) plant species responses to watering and 2.) vegetation community responses to watering. Plant species responses will include changes in the presence, distribution and cover of particular species with respect to specific hydrological and other conditions (e.g. ANAE type). Vegetation community responses will include species richness, species diversity, species evenness, dominance etc. (delivered in year 5). Plant species and vegetation community watering response databases will be updated with data from Selected Areas (and elsewhere if possible) over the program's duration. This review will inform the subsequent aggregated analysis and model development

3.2.2   Aggregated analysis

A key issue in predicting the vegetation response to flow is to understand the extent to which responses are consistent through time and our capacity to apply information developed in one area to other areas in the Basin. These issues will be assessed by combining (aggregating) and analysing all the LTIM vegetation data. Aggregated data will be analysed annually and over the long-term to determine consistency of plant species and vegetation community responses to watering within and between Selected Areas over time. Effects of key non-flow drivers (e.g. geographic location, canopy cover etc.) in determining vegetation diversity responses to watering will also be investigated. A functional group approach (Brock & Casanova 1997) will be used to assess community level responses as previous work indicates that this is more conducive to conducting comparisons between wetlands at a landscape scale (Alexander *et al.* 2008; Campbell *et al.* 2014). Aggregated data will be evaluated, for example, to determine if species within functional groups respond similarly across Selected Areas to similar conditions. Functional groups will also be used to characterise and assess community level responses (e.g. within group species richness, functional diversity).

3.2.3   Predictive models

The evaluation process requires prediction of vegetation responses to flow in order to predict both counterfactual and expected outcomes. As a consequence the Basin Evaluation of vegetation diversity will develop quantitative models to enable predictions of vegetation diversity responses to environmental water delivery. Preliminary models of ecohydrological relationships between flow and the responses of individual plant species and particular vegetation communities will be constructed using the aggregated data from Selected Areas and other available sources. Model response variables will include the presence and abundance of selected species (e.g. key representatives of each functional group) and a range of metrics used to characterise vegetation community responses in the aggregated analysis (i.e. species richness, total cover, functional diversity etc.).

The different approaches to data collection across the selected areas provide a set of constraints and opportunities that necessitate a flexible framework to predictive model development.   The sampling design of the program will result in data collected at multiple scales across the selected areas from different sources. As a resul,t we anticipate predictor variables to come from quadrat and site scale (e.g. soil characteristics, distance from stream channel), as well as the reach/zone scale (e.g. recent and long term hydrology). These constraints require tailored statistical model development, to ensure the estimated ecohydrological relationships are robust and transferable to areas beyond the monitoring locations. We anticipate using Bayesian hierarchical models for this purpose.

Bayesian hierarchical models are being used increasingly for ecohydrological models (e.g. Webb *et al.* 2010; Stewart-Koster *et al.* 2011; 2013). The Bayesian approach offers a flexible framework to develop models that account for relationships across spatial and temporal scales and account for multiple ecological processes that determine species distribution and abundance (Stewart-Koster *et al.* 2013). This approach will facilitate the inclusion of predictor variables collected at multiple scales, across the selected areas. Of particular

importance, is the capacity to develop models that account for relationships between response variables and predictor variables, at the finest unit of observation at each selected area (e.g. quadrat or transect), that can be scaled up to levels that are useful for management decision making (e.g. river reaches, sub-catchments or even catchments). A hierarchical approach to modelling, will facilitate the development of cross scale models, while the Bayesian framework provides a framework to predict outside the sampling domain while accounting for predictive uncertainty. This should provide the capacity to develop ecohydrological relationships that can be applied at larger scales than the initial units of observation, thereby addressing the needs of basin management.

The full predictive models discussed here are likely to require several years of data and will mainly be used for long-term evaluation. Simpler models will be developed to provide short-term predictions. All statistical models will be updated and refined over the five-year monitoring period as more data becomes available for calibration and validation.

3.3 Synthesis

The vegetation response databases and models will be used in conjunction with Basin scale hydrological data to conduct annual and longer-term assessments of vegetation diversity responses to Commonwealth Environmental Water at species, community and landscape scales within Selected Areas and across the Basin. Models will seek to provide estimates, for instance, of the number of species that have benefited from Commonwealth environmental water at the Basin scale. Similarly, predictions of landscape scale responses may include, for example, the area of particular ANAE vegetation types that have benefitted from Commonwealth environmental water across the Basin. Models will also be used to explore counterfactual outcomes within and across Selected Areas as well as at a Basin scale.

3.4 Links to other Basin Matters

As well as having clear links with the Basin Matters hydrology team, the vegetation diversity Basin matter may in turn inform other Basin matters, including fish, stream metabolism and generic fauna, by providing data on potentially relevant drivers relating to riparian vegetation condition and structure. The vegetation diversity analyses will also involve considerable collaboration with the Ecosystem Diversity Basin matter analyses so that results can be integrated and interpreted in conjunction.

Table 2. List of likely predictor variables to be used in the Basin Scale analyses

(N.B. some vegetation diversity metrics will also be used as predictors in some models, e.g. canopy cover, litter cover etc.)

VARIABLE	DESCRIPTION	SPATIAL CONTEXT	TEMPORAL CONTEXT	TEMPORALLY VARYING?	DATA SOURCE
Hydrologic variables					
% area inundated	Of quadrats (not fringing veg)	Within sampling unit	At time of vegetation surveys	Y	Selected Area M&E providers
Water depth	Mean	Within sampling unit	At time of vegetation surveys	Y	Selected Area M&E providers
Soil moisture	Submerged / waterlogged / damp / dry	Within sampling unit	At time of vegetation surveys	Y	Selected Area M&E providers
Time since last inundated	Days	Within sampling unit	At time of vegetation surveys	Y	Selected Area M&E providers
Duration inundated in last year	Days	Within sampling unit	At time of vegetation surveys	Y	Selected Area M&E providers
Timing of last inundation	Month	Within sampling unit	At time of vegetation surveys	Y	Selected Area M&E providers
Depth of last inundation	Mean	Within sampling unit	At time of vegetation surveys	Y	Selected Area M&E providers
Antecedent flow conditions	Discharge, timing of peak, rate of rise and drawdown, etc.	Within Selected Area / zone	Recent flow / flood pulse and longer time periods	Y	Selected Area M&E providers
Weather / climate variables					
Antecedent rainfall	Means, Totals	Within Selected Area / zone	1 month preceding, 3 months preceding, year preceding	Y	Bureau of Meteorology
Antecedent temperature	Means, Max / Min	Within Selected Area / zone	1 month preceding, 3 months preceding, year preceding	Y	Bureau of Meteorology
Long-term precipitation	Annual mean, seasonal means	Within Selected Area / zone	Long-term record	N	Bureau of Meteorology
Long-term temperature	Annual mean, seasonal means/max/min	Within Selected Area / zone	Long-term record	N	Bureau of Meteorology
Other non-flow variables					
Canopy composition	Woody species present	Of site	During LTIM project	N	Selected Area M&E providers
Soil type	Broad classes	Of site	N.A.	N	Existing mapping
Current land use	Broad classes (e.g. heavily grazed, lightly grazed etc.)	Of site	During LTIM project	N	Anecdotal, Selected Area M&E providers
Historic land use	As above	Of site	As per records	N	Anecdotal, Selected Area M&E providers
Elevation	Height above sea level	Of site	N.A.	N	LiDAR or other mapping
Geographic coordinates	Latitude, longitude	Of site	N.A.	N	Mapping

4   Risks

The main risks associated with the Basin Scale evaluation of vegetation diversity concern the availability of sufficient and appropriate data.

First, there may be difficulties in collecting consistent and thorough vegetation diversity data from Selected Areas at the times proposed due to changes in conditions (e.g. large-scale flooding). Quality of vegetation diversity data is also a potential concern as there may be discrepancies in species identification, the use of scientific names, allocation of species to functional groups or estimates of cover between researchers within and/or between Selected Areas. Some of these issues may be mitigated by conducting analyses using aggregate indices, e.g. plant functional groups, cover classes, based on consistent data standards (e.g. using the Australian Plant Name Index). Deviations from standard (or proposed) methods may present problems for Basin matter evaluation where alignment of different data standards in the data management system becomes difficult, e.g. incompatible Category III variables.

Second, the suitability of available complementary data, particularly hydrological data, may present a challenge to the proposed evaluation approach. Depending on the outcomes of preliminary analyses and model development, for instance, different hydrological variables or variables with different spatial and/ or temporal characteristics from those available may be required. This may necessitate additional collection of processing of complementary data.

Finally, there is a small possibility that the variability of vegetation diversity data collected from Selected Areas is too great to enable the detection of clear patterns in relation to hydrology or other available environmental variables at the desired scales. Should this occur, adjustments to monitoring approaches may be required.

An additional risk to the project relates to the continuity of personnel involved, both in the Selected Area M&E teams as well as the Basin Matter evaluation team. With respect to the latter, the risk will be mitigated through clear and thorough documentation of all data collection, processing, analysis and evaluation conducted.

References

Alexander P, Nielsen D and Nias D (2008) Response of wetland plant communities to inundation within floodplain landscapes. *Ecological Management and Restoration,* 9, 187-195.

Brock MA and Casanova MT (1997) Plant life at the edge of wetlands: ecological responses to wetting and drying patterns. *Frontiers in Ecology*, 181-192.

Campbell CJ, Johns CV and Nielsen DL (2014) The value of plant functional groups in demonstrating and communicating vegetation responses to environmental flows. *Freshwater Biology*, *59*(4), 858-869.

Capon SJ and Dowe JL (2007) Diversity and dynamics of riparian vegetation. *Principles for riparian lands management. Land & Water, Australia.[Links]*, 3-33.

Casanova MT and Brock MA (2000) How do depth, duration and frequency of flooding influence the establishment of wetland plant communities? *Plant Ecology*, *147*(2), 237-250.

Roberts J and Marston F (2011) *Water regime for wetland and floodplain plants: a source book for the Murray-Darling Basin*. Canberra: National Water Commission.

Stewart-Koster B, Olden JD, Kennard MJ, Pusey BJ, Boone EL, Douglas M and Jackson S (2011) Fish response to the temporal hierarchy of the natural flow regime in the Daly River, northern Australia. *Journal of Fish Biology* 79:1525–1544.

Stewart-Koster B, Boone EL, Kennard MJ, Sheldon F, Bunn SE and Olden JD (2013) Incorporating ecological principles into statistical models for the prediction of species' distribution and abundance. *Ecography* 36:342–353.

Webb, JA, Stewardson MJ and Koster WM (2010) Detecting ecological responses to flow variation using Bayesian hierarchical models. *Freshwater Biology* 55:108–126.

Webb M, Reid M, Capon S, Thoms M, Rayburg S and James C (2006) Are flood plain-wetland plant communities determined by seed bank composition or inundation periods? *IAHS PUBLICATION*, *306*, 241.