Flood Exposure and Plant Community Characteristics in Restored Floodplain Wetlands

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Introduction

- Two main objectives of wetland restoration are to establish plant communities that 1) are characteristic of wetlands (i.e., hydrophytic) and 2) have desired compositional quality.
- Hydrologic factors such as depth, duration and frequency of flooding are generally considered important influences on wetland plant community characteristics. However, the degree of influence that flooding has on particular community characteristics in restored wetlands is not well established.
- Restoration strategies may be improved by developing more systematic approaches for evaluating flood disturbance regimes and their influence on wetland plant communities.
- We evaluate the influence of flooding on the plant communities at floodplain wetland restoration sites along a flood exposure gradient. The goal of this research is to provide an understanding of the development of restored wetland plant communities in a hydrologic context, particularly in the context of the flood disturbance regime.

Quantifying Flood Exposure Gradient

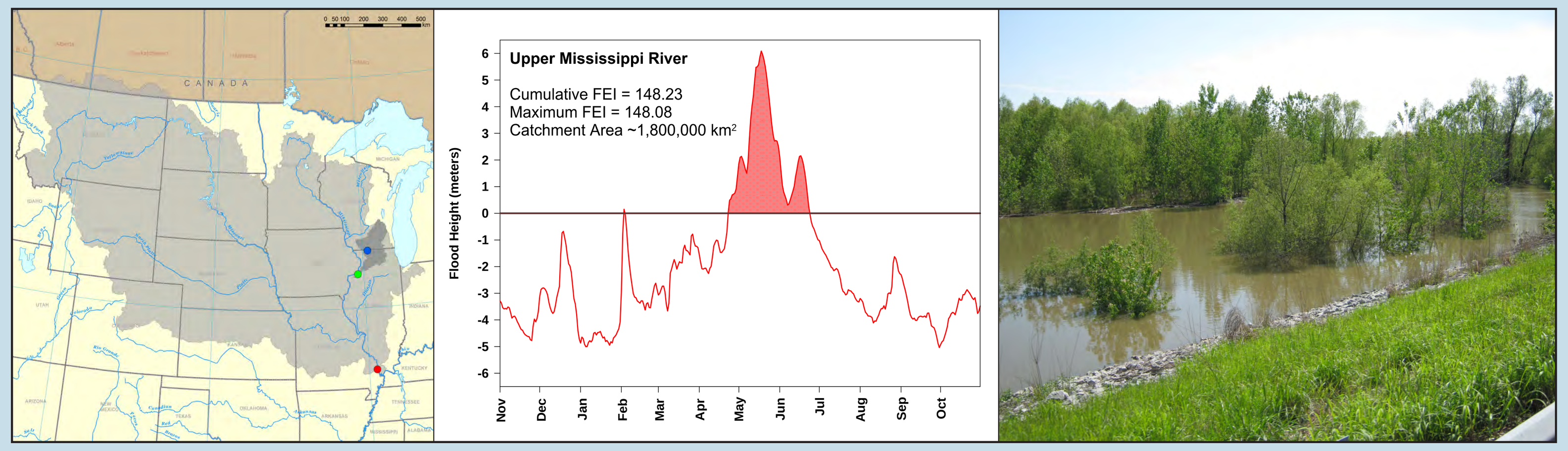
A variety of approaches have been developed for evaluating the hydrologic regime of aquatic habitats (e.g., Richter et al. 1996). These generally focus on river-channel systems and are based on stream discharge. In this study, we use a stage-based flood exposure index (FEI) to account for the depth and duration of direct inundation of floodplain wetland plant communities that are only periodically flooded. FEI is defined here as:

$$FEI = D_{avg}(R)$$

where D_{avg} is the average depth above a specified elevation threshold and R is the duration of the flood above the threshold. The unit of flood exposure is meter-days.

Shown below are examples of floodplain wetland restoration sites from the A) Upper Mississippi River, B) Rock River and C) Richland Creek, IL. Each triptych below shows contributing watershed, an annual hydrograph with corresponding FEI values, and photographs from each site. Red, green and blue dots in the maps indicate the locations of corresponding wetland restoration sites, respectively.

A



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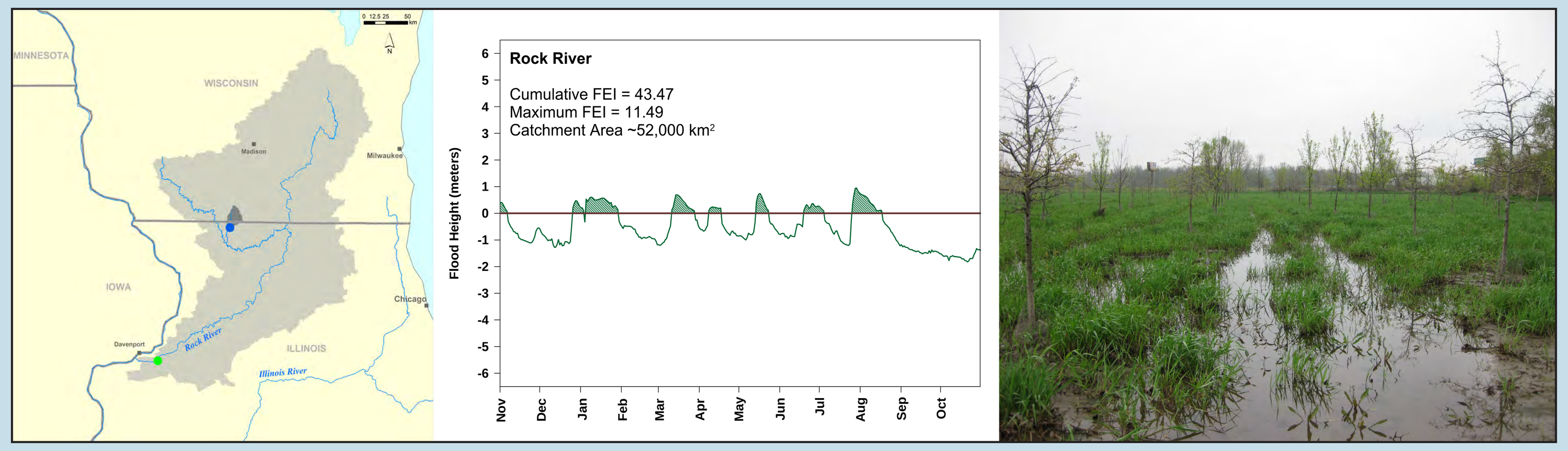

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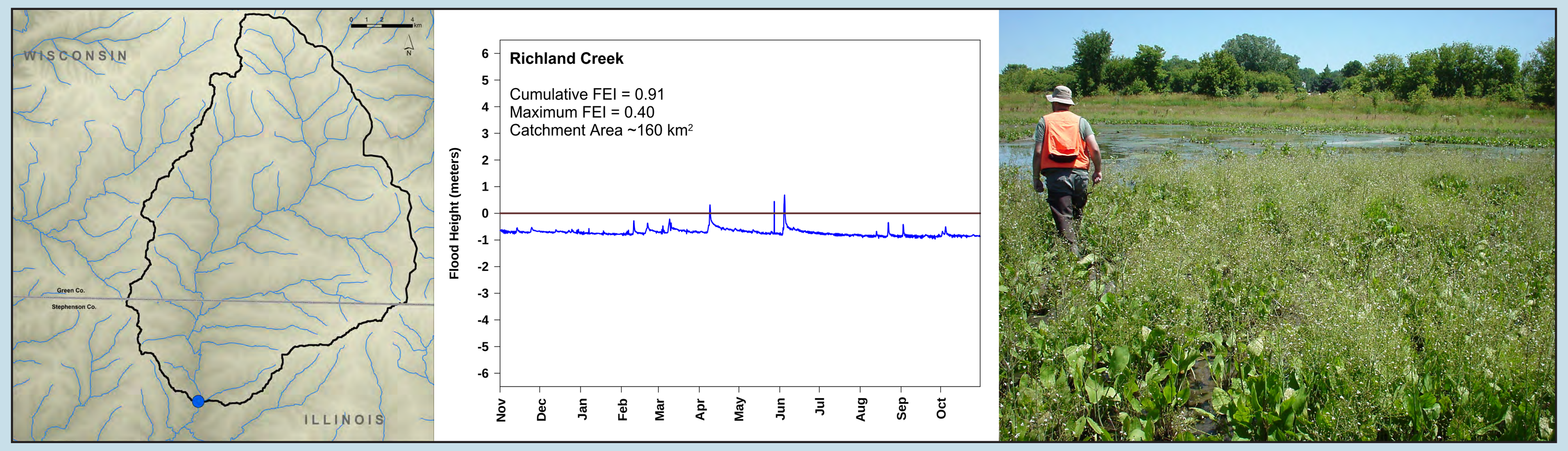


Methods

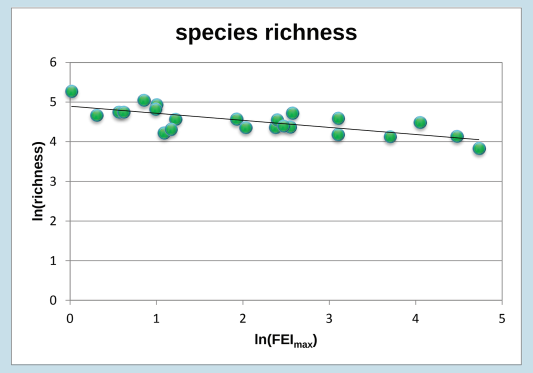
Red dots indicate locations of 23 floodplain wetland restoration sites evaluated in this study.

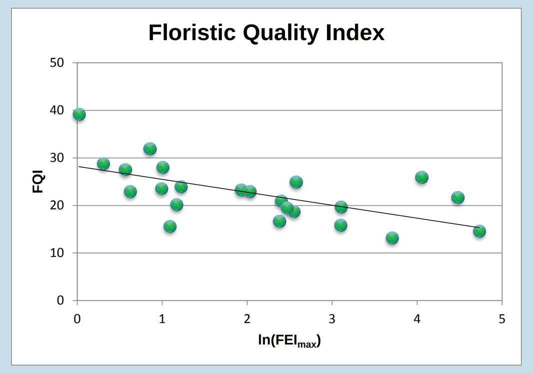
- Hydrology and vegetation were monitored at 23 floodplain wetland restoration sites in Illinois, USA. Contributing drainage areas for sites range from 4 to ~1.8 million km².
- For each site, FEI was calculated for each flood event for each year of the monitoring period.
- Maximum annual FEI (FEI_{max}) and each vegetation metric was averaged over the monitoring period at each site. Duration of monitoring ranged from 3 to 8 years.
- Simple linear regression was used to model relationships and determine statistical significance between FEI_{max} and each plant community metric.

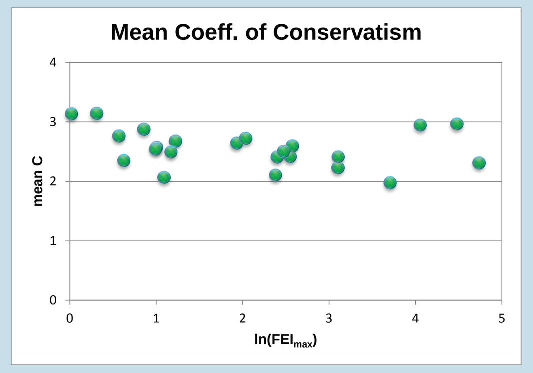
Results

The graphs below show distributions between each of ten vegetation metrics and FEI_{max}. Species richness and FEI_{max} were log-transformed prior to applying the regression model. Results of the simple linear regressions on FEI_{max} (Table 1) show significant inverse correlations between species richness, floristic quality index (FQI) and proportion perennials. Best-fit lines are shown in graphs for the three metrics that have statistically significant relationships.

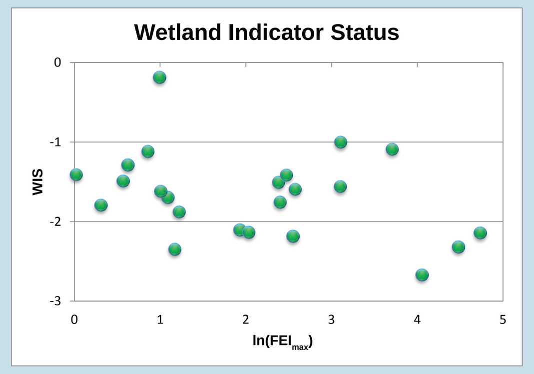
Richness and FQI

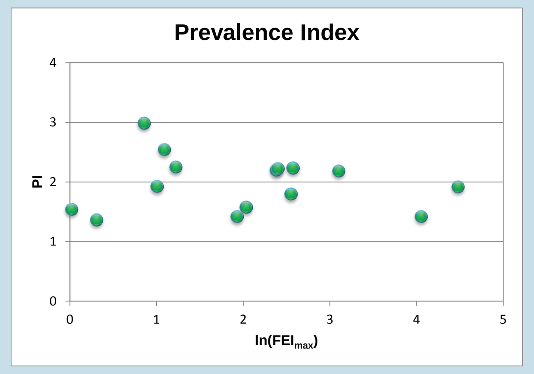


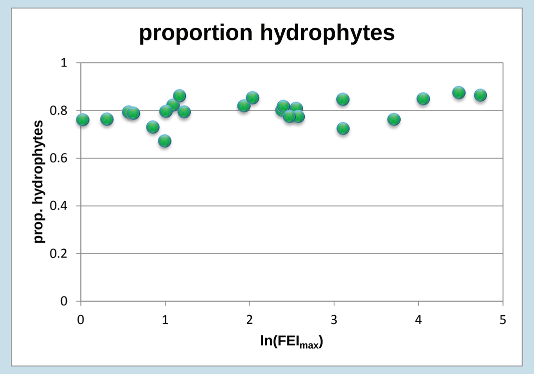




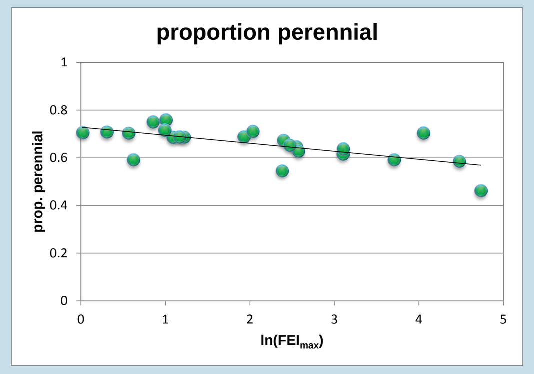
Hydrophytes

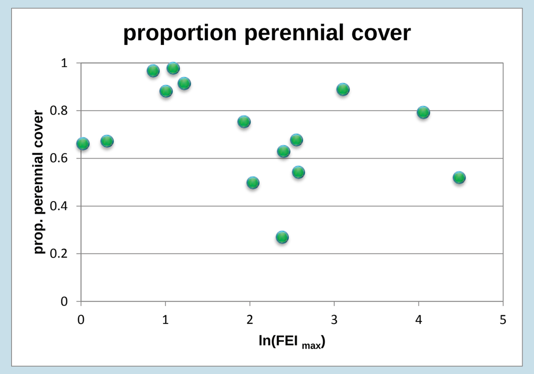




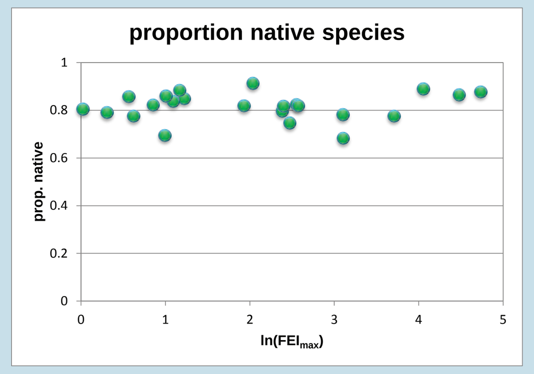


Perennials





Natives



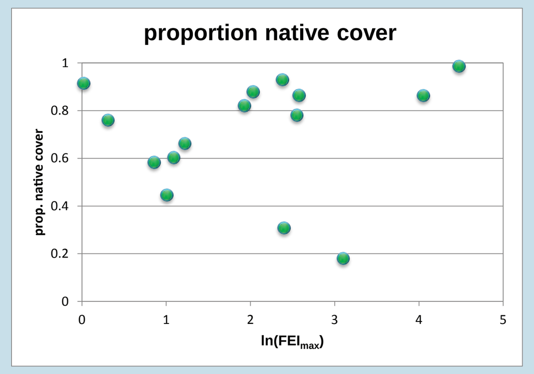


Table 1. Results of the linear regression of various plant community metrics on ln(FEI_{max}). Bold values indicate significant correlation at Bonferroni-adjusted α = 0.005.

Dependent Variable	n	slope	intercept	F	R^2	PR>F
ln (richness)	23	-0.1763	4.9021	24.63	0.540	**<.0001**
ln (richness)+area*	23	-0.1860	4.8364	14.34	0.589	**0.0001**
mean C	23	-0.0686	2.7024	1.94	0.085	0.1783
FQI	23	-2.7224	28.2126	12.61	0.375	**0.0019**
WIS	23	-0.1412	-1.3709	2.98	0.124	0.0991
prop. hydrophytes	23	0.0163	0.7655	5.15	0.197	0.0339
Prevalence Index	15	-0.0316	2.0395	0.10	0.008	0.7567
prop. perennial	23	-0.0335	0.7280	15.82	0.430	**0.0007**
prop. native	23	0.0047	0.8081	0.26	0.012	0.6181
% perennial cover	15	-0.0494	0.8094	1.44	0.100	0.2519
% native cover	15	0.0225	0.6614	0.19	0.015	0.6693

*The influence of area is minimal as compared with the model with ln(FEI_{max}) alone.

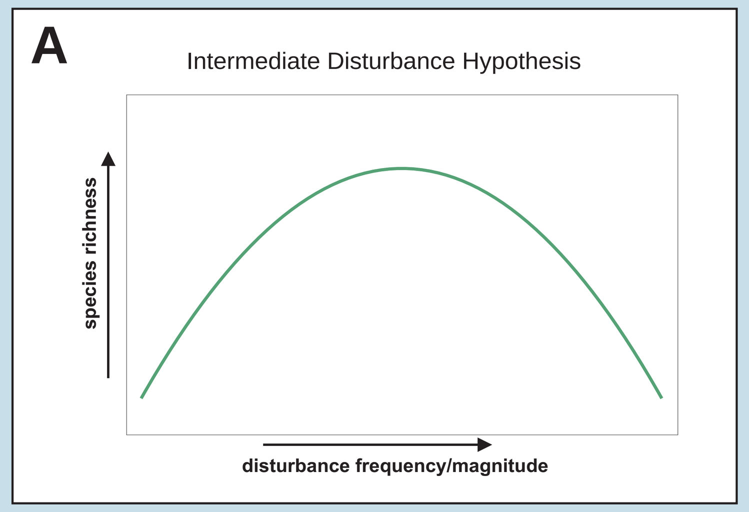
Discussion

Species Richness and FQI

- Strong correlation of species richness and FQI with FEI_{max} confirmed our assumption that flood regime is a principal factor for determining species diversity. For species richness, flood exposure accounts for over half of the variability. Mean C did not show a trend with FEI_{max} suggesting that flooding does not significantly influence community conservatism.
- Following from the intermediate disturbance hypothesis (Connell 1978, Bendix 1997), we expected to find the highest species richness at intermediate values of flood exposure. Instead, high species richness was associated with low flood exposure and low species richness was associated with high flood exposure. The resulting distribution of species richness across the disturbance gradient fits a logarithmic rather than a parabolic form (see panel below).

Flood Disturbance and Species Richness

A



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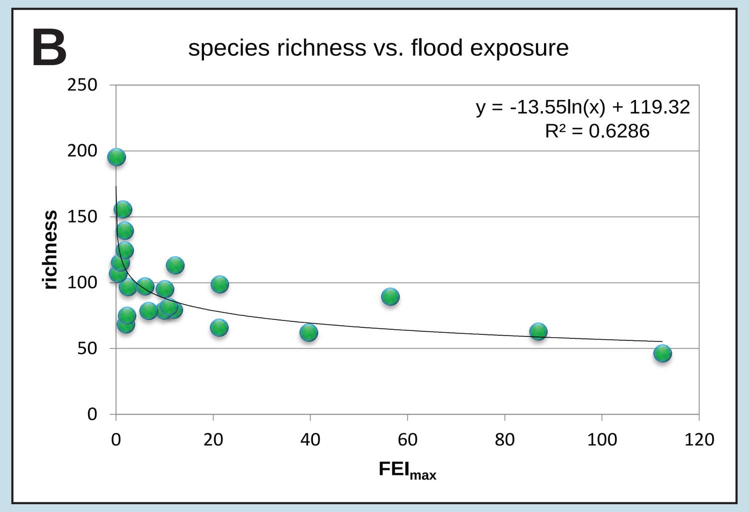

The graphs above show the contrast between A) the intermediate disturbance hypothesis (adapted from Bendix 1997) and B) the observed distribution of species richness versus flood exposure in restored floodplain wetlands. The intermediate disturbance hypothesis (Connell 1978) predicts that maximum biodiversity will develop at intermediate disturbance frequencies or magnitudes. This idea provides a useful context for evaluating the distribution of plant community diversity in riparian areas (Bendix 1997) including floodplain wetlands, which are exposed to varying degrees of flood disturbance.

Hydrophytes

- Contrary to expectation, Wetland Indicator Status (WIS), Prevalence Index (PI) and proportion hydrophytes were not significantly correlated with FEI_{max}. However, WIS and proportion hydrophytes did show weak trends of increasing "wetness" of the overall plant community with increasing FEI_{max}. PI showed no trend with FEI_{max}.
- The lack of significant relationships of WIS, PI and proportion hydrophytes with FEI_{max} suggests that sites with higher magnitude flood exposure do not neccesarily have "wetter" plant communities.

Perennials and Natives

- Proportion of perennial species showed a strong inverse correlation with FEI_{max}. This is consistent with the expectation that high magnitudes of flood exposure cause disturbances that kill perennial species and allow more annual and biennial species to colonize. Proportion perennial cover also shows an inverse trend but the relationship is not significant.
- Proportion native species and proportion native cover showed no significant correlation suggesting that flooding does not have an effect on the occurrence of native species within restoration sites.

Conclusions

- For this analysis, the general assumption that flood regime has a strong influence on restored floodplain wetland plant communities is met for community quality but not for conservatism, affinity for wetness and nativity.
- Evaluation of the relationships between plant community characterstics and the flood exposure gradient provides a useful context to aid understanding of flood disturbance in floodplain wetlands.
- Evaluation of regional wetland plant community-flood exposure relationships could aid future wetland restoration planning and monitoring.

References: Bendix, J. 1997. Flood disturbance and the distribution of riparian species diversity. Geogr. Rev. 87, 468–483.

Connell, J.H. 1978. Diversity in Tropical Rain Forests and Coral Reefs. Science 199 (4335), 1302-1310.

Richter, B.D. Baumgartner, J.V., Powel J. and Braun, D.P. 1996. A method for assessing hydrologic alteration within ecosystems. Conserv. Biol. 10, 1163-1174.

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