Spatiotemporal drivers of suitable overwintering habitat for centrarchids in the Upper Mississippi River System

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Backwater habitats in the UMRS

- The Upper Mississippi River System (UMRS) stretches from St. Paul, MN to Cairo, IL and includes the Illinois River
- Consists of 26 pools separated by locks and dams
- The UMRS is a large floodplain river that contains plentiful off-channel habitat that provides habitat for fish communities

Fig. 1. Pools of the UMRS (J. Houser)

Suitable overwintering habitat

- Overwintering conditions play a central role in the survival of fishes, and populations can often be bottlenecked by lack of habitat availability
- Suitable habitat for centrarchids is often defined by depth (≥ 1m), flow (≤ 0.01 m/s), temperature (≥ 1 °C) and dissolved oxygen (≥ 5 mg/L) (Sheehan et al. 1990)

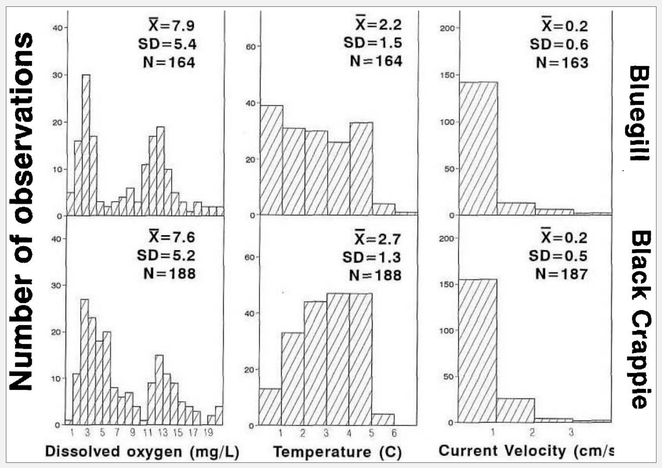

Figure 2. Number of individuals observed occupying habitats of varying conditions (Knights et al. 1995). Individuals prioritized suitable dissolved oxygen concentrations, even if other habitat metrics weren't ideal

- Despite the importance of maintaining overwintering habitat, there remains uncertainty in the spatiotemporal drivers of midwinter conditions

LTRM and Aquatic Areas databases

Long term resource monitoring (LTRM) database

- Mid-winter water quality and environmental condition data for backwaters across 14 pools
  - Parameters to assess suitability (dissolved oxygen, temp., flow)
  - Snow depth and ice thickness

Aquatic Areas database (De Jager et al. 2018)

- Detailed spatial polygon data for all backwaters in the UMRS
- Polygons include metrics of size and connectivity
  - Effective connections (measure of flow through a water body)
  - Percent of perimeter adjacent to aquatic systems
  - Area (hectares), maximum depth

Objectives: To determine frequency of suitable overwintering habitat within backwaters of the UMRS and the spatiotemporal drivers of suitability

Methods

Merging LTRM and Aquatic Areas spatial database

- All individual sampling points within an aquatic area polygon were merged to determine presence of suitable habitat, snow depth, and ice thickness for individual backwaters between 1994 and 2019
- A backwater was considered to have suitable winter habitat in a year if it had at least 1 sampling point that met all of the criteria for centrarchids

Statistical analysis

- Generalized linear mixed effects model (GLME) to determine how two metrics of backwater connectivity (**effective connections** and **percent of a perimeter that is adjacent to an aquatic area**), **area, maximum depth**, **snow depth**, and **ice thickness** influenced the probability of a backwater being suitable
- **Year** was used as a random effect to focus on fixed effects of snow depth and ice thickness each winter

Fig. 3. Bluegill (top) and black crappie (bottom) – 2 prominent centrarchids in the UMRS (L. Merry)

Frequency of suitable overwintering habitat in backwaters

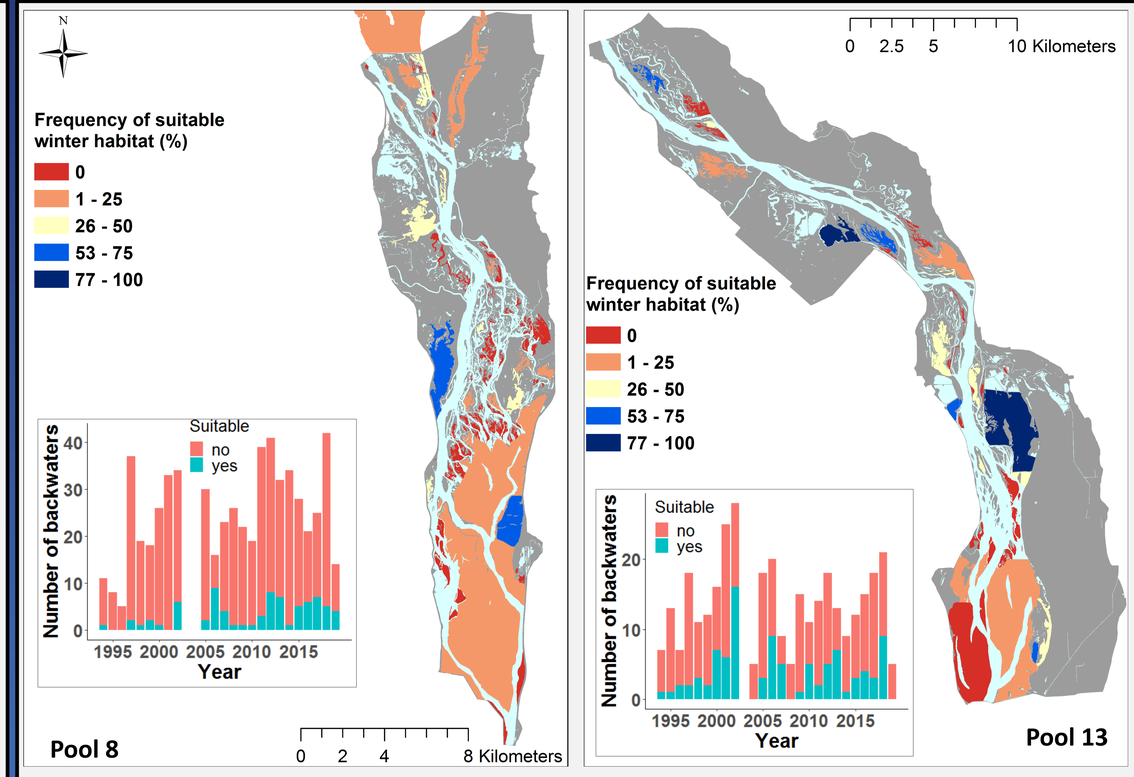

Figure 4. Percent of years that sampled backwaters had suitable habitat in pools 8 and 13. All included backwaters had at least 2 years of midwinter data collected between 1994 and 2019. Follow link (https://bit.ly/2Qhyou2) for additional pools. Insets represent the number of individual backwaters for pools 8 and 13 that had suitable habitat (1994 - 2019)

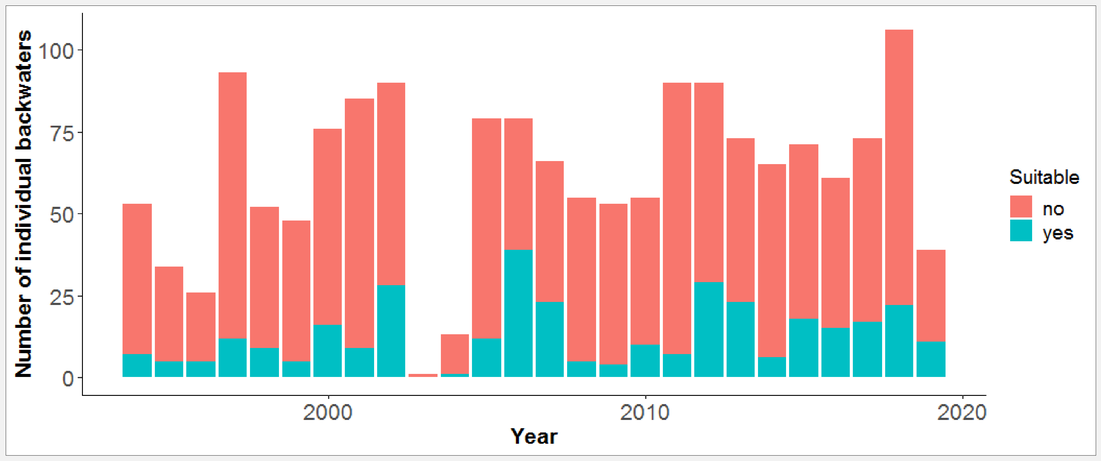

Figure 5. Number of sampled backwaters across LTRM pools that had suitable or non-suitable habitat from 1994-2019.

Spatiotemporal drivers of habitat suitability

Table 1. GLME output for the effects of fixed parameters on the probability of a backwater area being suitable

Parameter	Estimate	SE	p
Intercept	**-1.826**	**0.275**	**<0.001**
Effective connections	**-0.025**	**0.004**	**<0.001**
Aquatic perimeter (%)	**-0.045**	**0.005**	**<0.001**
Mean ice thickness (cm)	-0.009	0.007	0.217
Mean snow depth (cm)	**-0.137**	**0.024**	**<0.001**
Log10 Area (hectares)	**0.867**	**0.136**	**<0.001**
Log10 Max depth (m)	**2.140**	**0.251**	**<0.001**

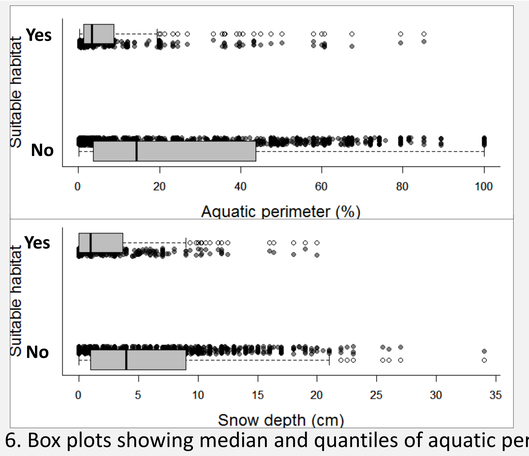

Figure 6. Box plots showing median and quantiles of aquatic perimeter and snow depth for suitable and non-suitable backwaters

- Increases in backwater connectivity and snow depth resulted in a decreased probability of a backwater being suitable
- Increases in depth and area increased the probability of backwater suitability
- When accounting for snow, ice thickness did not have a significant effect on backwater suitability

Initial conclusions

- Connectivity and snow depth reduce suitability of backwater habitat throughout the UMRS
- Suitable habitat for limnophelic fishes is already scarce throughout the UMRS due to connectivity, and prolonged winters with increased snowfall could further reduce habitat availability

Next steps

- Detailed modeling of factors that determine suitability
- Incorporate habitat suitability indices (e.g., Laaker 2020)
- Extend models beyond LTRM pools and backwaters
- Work with on-the-ground managers to prioritize backwaters for modification to promote suitability

Acknowledgements

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References

- Knights, B.C., B.L. Johnson, and M.B. Sandheinrich. 1995. Responses of Bluegills and Black Crappies to Dissolved Oxygen, Temperature, and Current in Backwater Lakes of the Upper Mississippi River during Winter. North American Journal of Fisheries Management 15: 390–99.
- De Jager, N.R., J.T. Rogala, J.J. Rohweder, M. Van Appledorn, K. L. Bouska, J.N. Houser, and K.J. Jankowski. 2018. Indicators of ecosystem structure and function for the Upper Mississippi River System. U.S. Geological Survey Open-File Report 2018–1143
- Sheehan, R. J., W. M. Lewis, and L. R. Bodensteiner. 1990. Winter habitat requirements and overwintering of riverine fishes. Illinois Department of Conservation, Federal Aid in Sport Fish Restoration, Project F-79-R, Final Report, Springfield.
- Laaker, D. 2020. Bluegill Overwintering Model. Technical Report, USACE