



River connectivity promotes diversification of fish communities in gravel pit lakes

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Introduction

While human activity is often a source of degradation to freshwater ecosystems, humans can create artificial habitats that serve as substitutes for lost habitats. Gravel pits are one example of a manmade freshwater habitat that can host aquatic communities as well as serve recreational purposes (Zhao et al., 2016). Campbell Lakes are former gravel pits along Whitewater River (Harrison, OH) that have been stocked with Bluegill, Largemouth Bass, Yellow Perch, and other sportfish by Great Parks to promote recreational fishing but are no longer stocked due to increasing connectivity with Whitewater River.

► **Question:** How have the fish communities of Campbell Lakes changed with increasing connectivity to the Whitewater River?

► **Hypothesis:** Temporary flooding and permanent connections to Whitewater River through bank erosion are causing an increase in backwater lotic species.

Site

Campbell Lakes are located approximately eight kilometers up from the confluence of Whitewater River and the Great Miami River. Currently, there are four permanent channel connections in the Campbell Lakes system: Center West and East, Center West and Whitewater River, South and Whitewater River, and Center East and Northeast. Additionally, bank overflow during high river discharge can cause temporary connections between the lakes (Fig. 1b-c).

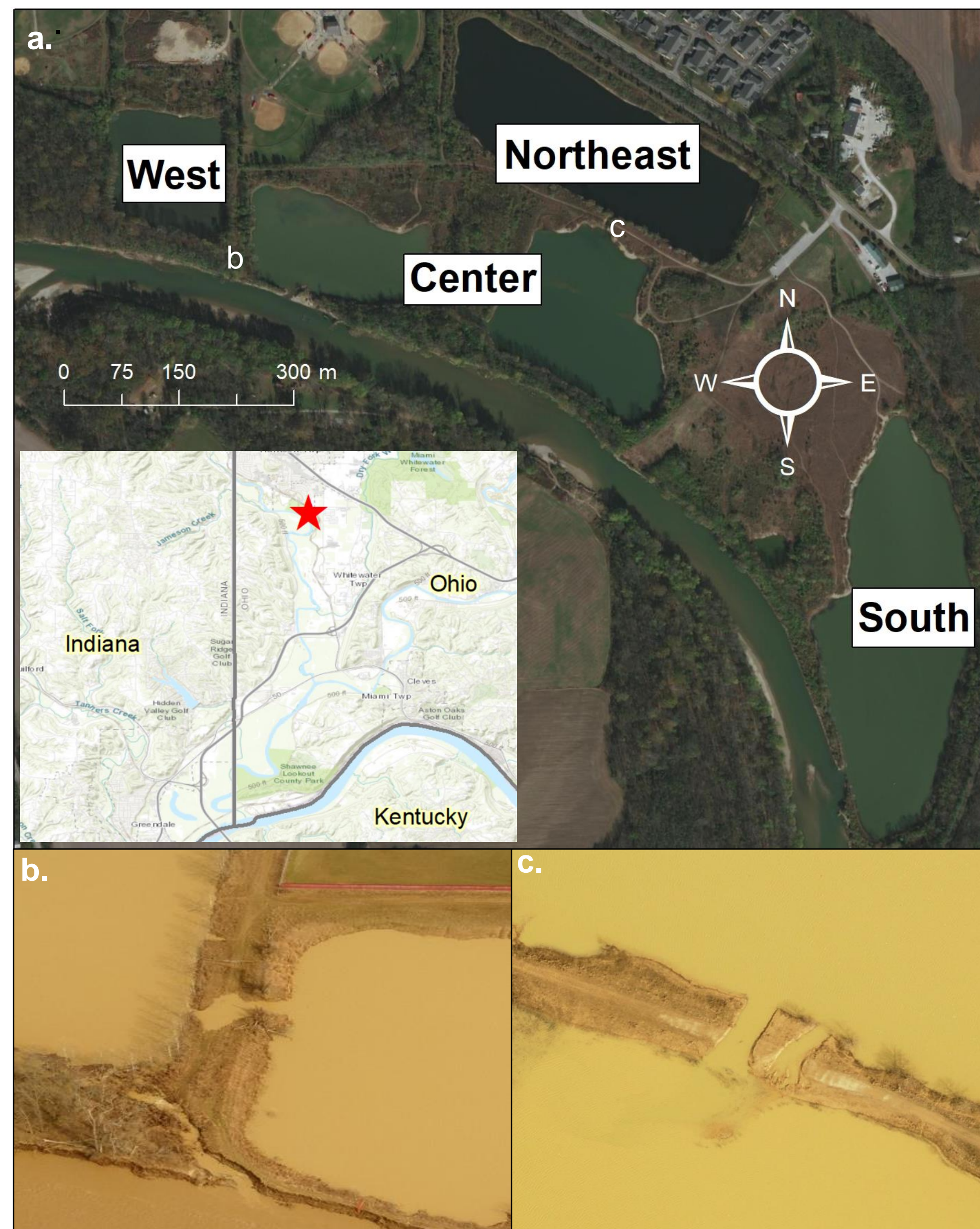


Figure 1. a) Aerial imagery of Campbell Lakes with map showing relative location within the region. The locations of b and c within the lake system are shown. b) Temporary connections between West Lake, Center Lake, and Whitewater River during high discharge, 3/21/2008. c) Temporary connection between Northeast and Center Lakes during the same event, 3/21/2008.

Materials and Methods

Surveys:

► The Booth lab collected and identified fish via boat electrofishing in July 2020. This data was compared to similar Campbell Lake surveys (Lorentz 2004, 2007, and 2012). Not all lakes were included in each survey, and effort was distinctly low in 2004. Fish data from Whitewater River and the Great Miami River were obtained from Midwest Biological Institute surveys (1995 and 2013).

Connectivity:

► Connectivity between the lakes and Whitewater River over time was explored through aerial imagery from Google Earth and the Hamilton County Auditor property search. River discharge data was obtained from USGS Gauge 03276500. High flow events were postulated by identifying dates with discharge values

of approximately 1,000 m³/s or greater, the discharge recorded on the date with photographed breaching between the lakes and rivers (Fig. 1b-c).



Statistical analysis:

► All analyses were carried out in R (v.3.6.2). Fish relative abundance, species richness, and Shannon-Wiener Diversity were calculated by lake for each survey year using all species. Shannon Diversity was calculated using *diversity* in the *vegan* package (Oksanen et al., 2020). We ran a nonmetric multidimensional scaling (NMDS) analysis and an analysis of similarity using *metaMDS* and *ANOSIM* in the *vegan* package to test for significant differences in community compositions across sites and years, for just Campbell Lakes and for Campbell Lakes, Whitewater River, and Great Miami River. Fish from the Atherinopsidae and Cyprinidae families (excluding Common Carp) for all years and fish under 50 mm in 2020 were excluded from the NMDS analysis.

Results

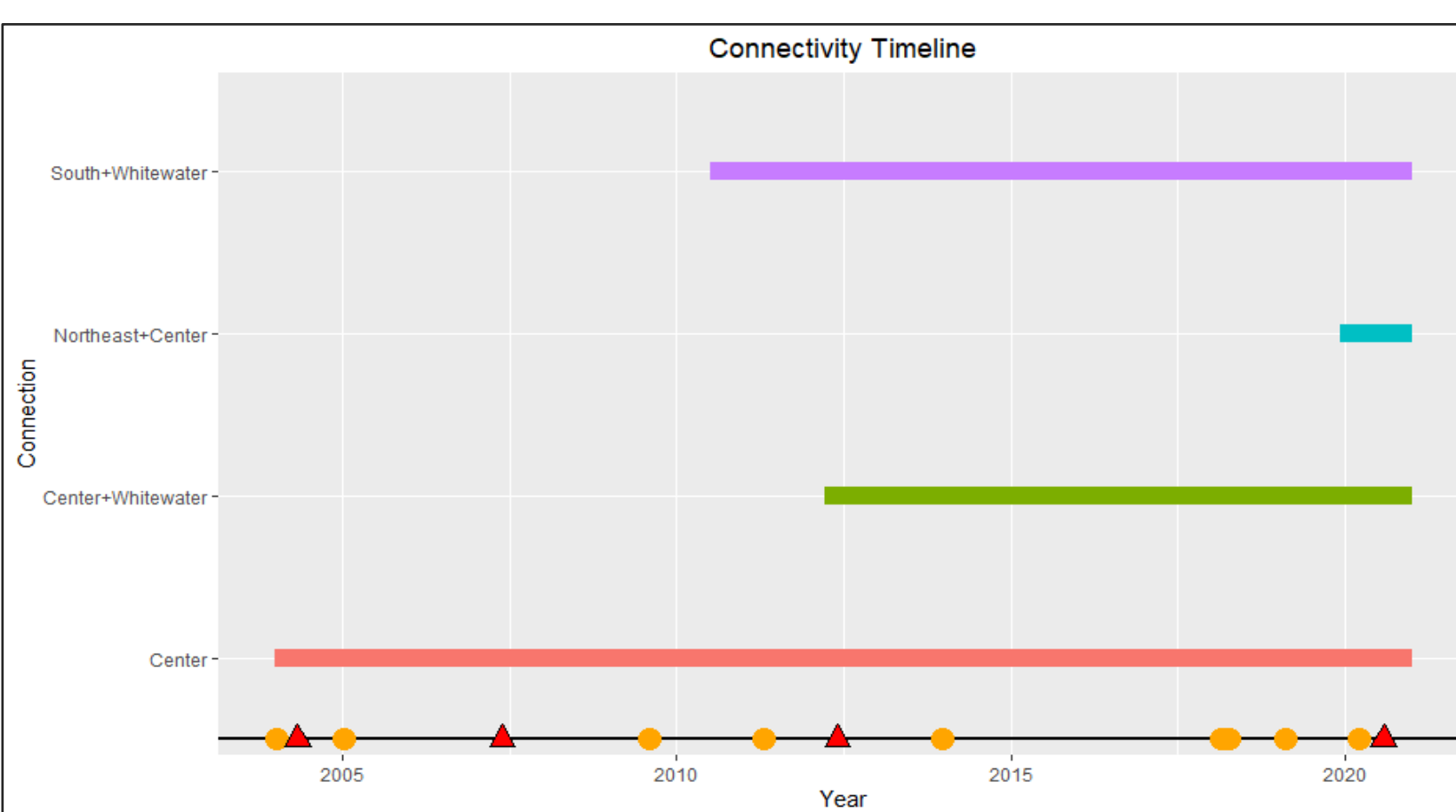


Figure 3. A timeline of permanent connections between the lakes and rivers as well as high-discharge events (orange circles) that may have caused temporary connections. Survey years are denoted by red triangles. By 2020, all lakes but West are connected to another body.

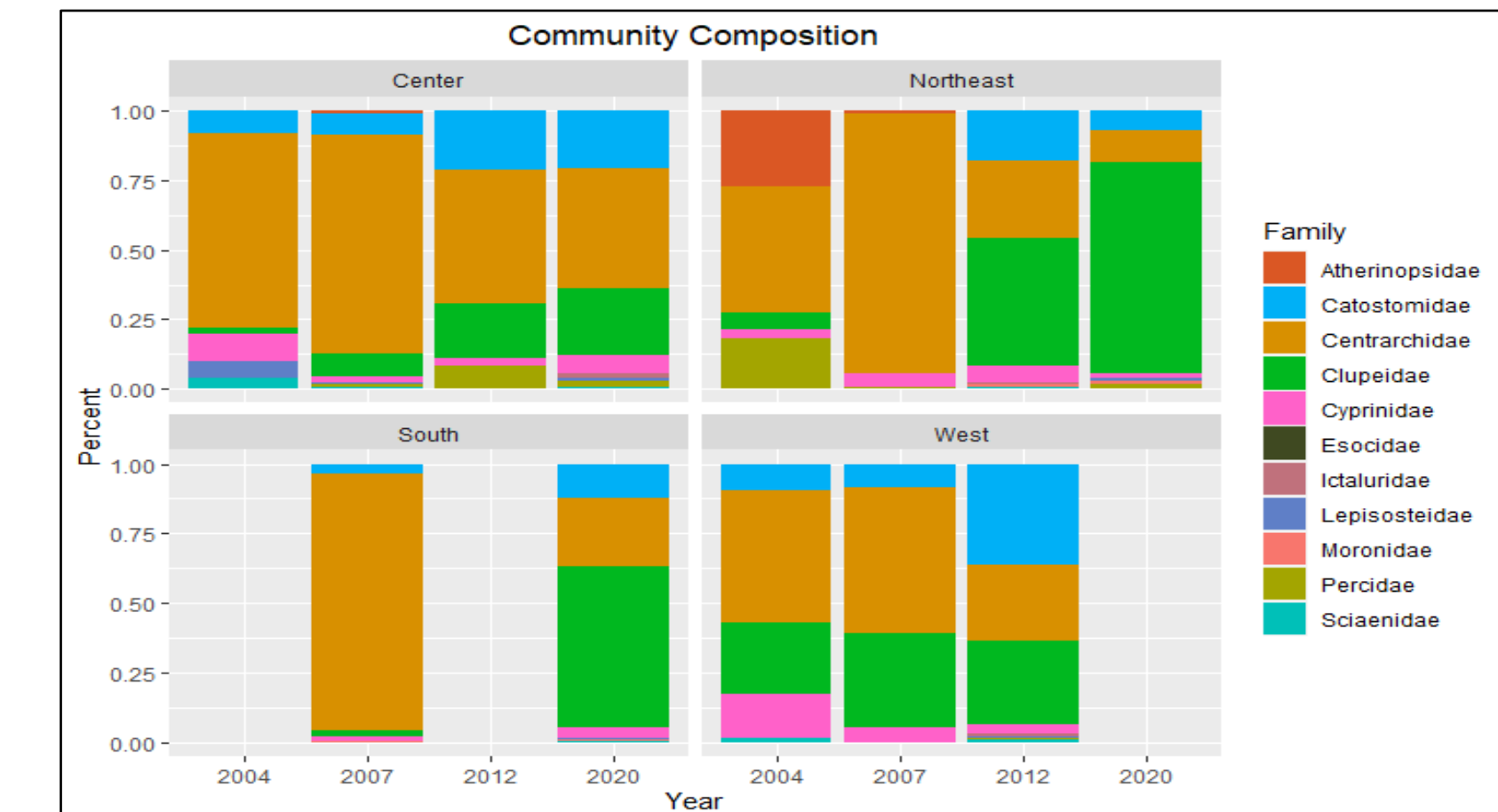


Figure 4. Fish community composition in each lake as a relative proportion of total count. Centrarchids dominate the lakes in early surveys but comprise lower relative abundance in 2012 and 2020.

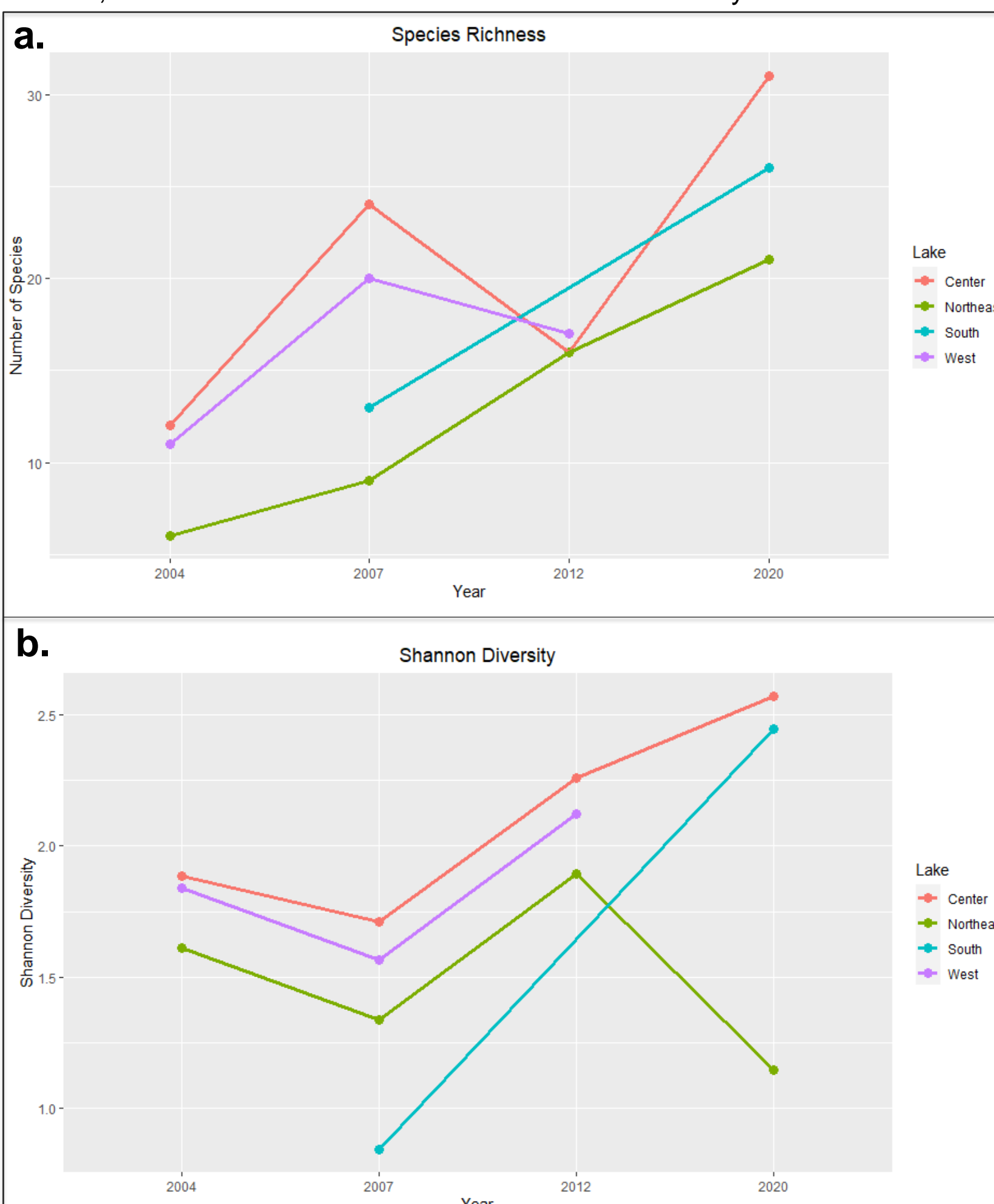


Figure 5. a) Number of species observed per lake in survey years. All lakes experience a net increase in species richness from 2004 to 2020. b) Shannon-Wiener diversity values based on fish counts per lake in survey years. The decline in Northeast 2020 is due to gizzard shad dominance rather than a reduction in species richness.

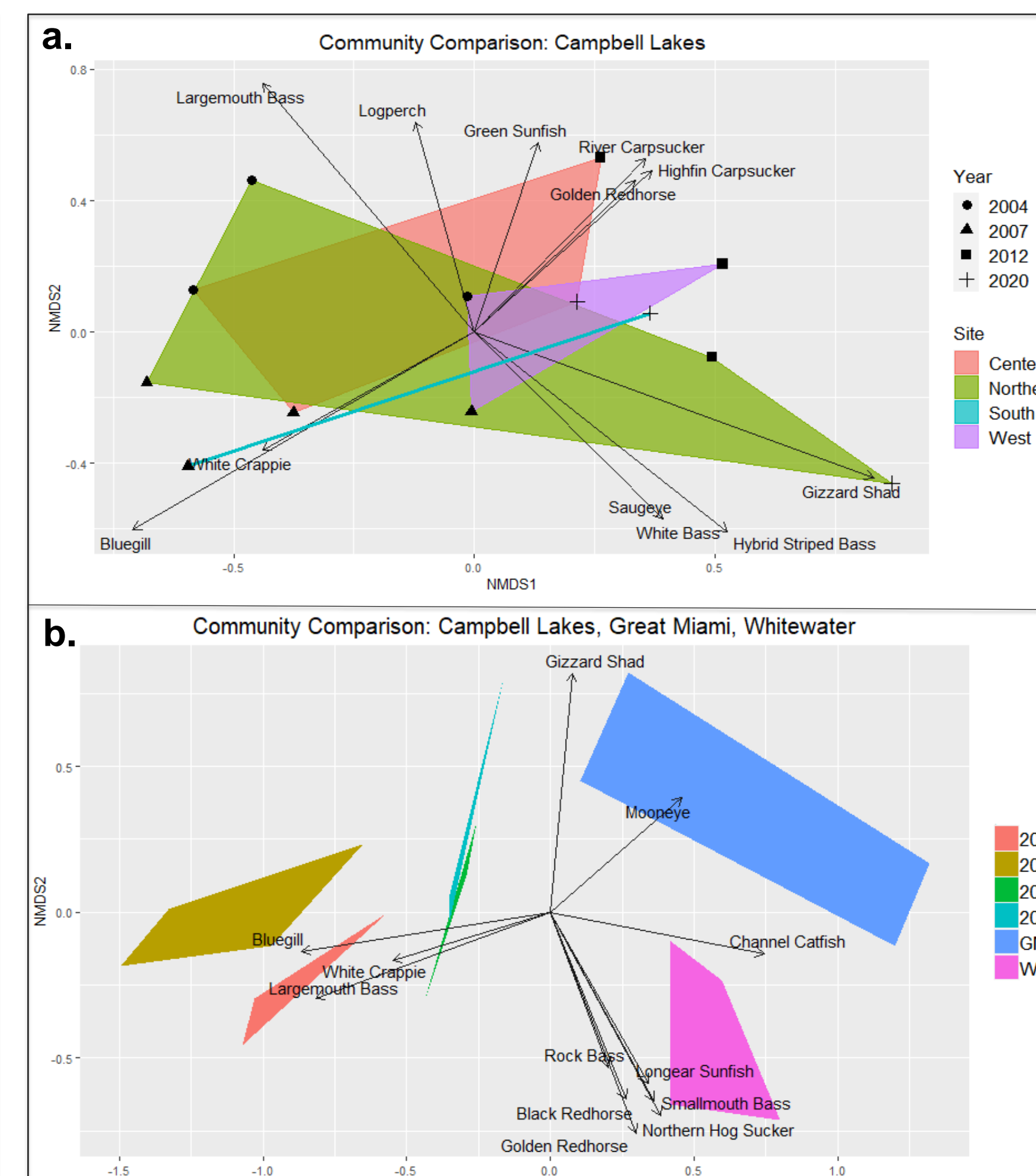


Figure 6. NMDS analysis of site similarity with 12 most influential species shown. a) Lakes are connected by convex hulls. Note the spread of Northeast Lake, indicating a dramatic change in community composition. b) Convex hulls are Campbell Lake sites of the same survey year, Great Miami (GM) sites, and Whitewater (WW) sites. Lake sites are dissimilar from river sites.

Results

Based on the analysis of similarity, fish community compositions in Campbell Lakes have differed significantly across survey years ($p=0.001$). The R statistic was 0.795; values close to 1 indicate community dissimilarity. Communities did not differ significantly across lakes. Centrarchids differed significantly in the lakes between years ($R=0.3354$, $p=0.008$), generally comprising lower proportions of communities (Fig. 4). Campbell Lake sites (all years), Great Miami sites (2013), and Whitewater River sites (2013) differed significantly from each other ($R=0.5578$, $p=0.001$).

Discussion

The Campbell Lakes fish communities appear to be diversifying, demonstrating a gradual shift from lentic to lotic species. Weakening centrarchid dominance coupled with increases in species richness and Shannon diversity suggest the lakes are no longer dominated by lentic sportfish species. Catostomid species that are associated with the 2012 and 2020 communities, such as Smallmouth Buffalo, Golden Redhorse, and Quillback Carpsucker, are suggestive of a riverine backwater community. The 2012 and 2020 lake sites are closer on the NMDS1 axis to the Great Miami and Whitewater sites than the 2004 and 2007 lake sites, further indicating the lake communities are becoming more lotic.

Based on the increase in connectivity between the lakes and Whitewater River, the diversification of the lakes is likely due to dispersal through either newly-established connections or temporary breaches in high flow periods. Northeast Lake, the lake most isolated from the river, particularly demonstrates the effects of increasing connectivity with species richness increasing from 6 species in 2004 to 21 species in 2020. Following the establishment of a permanent connection between Center and Northeast Lakes in 2020, 9 new species were observed in Northeast, with 4 of the 9 species previously seen in Center Lake. Interestingly, several species in Campbell Lakes such as Black Buffalo were observed in the Great Miami but not Whitewater, and species such as Bigmouth Buffalo and Spotted Sucker were not observed in either river but were found in the lakes in 2020.

Although the results are limited by differing survey efforts, particularly the low effort in 2004, the increase in lotic species in Campbell Lakes is supported by previous observations (Hamilton County Park District, 2012).

Conclusion

Connectivity between the lakes and Whitewater River seem to be influencing the fish communities by introducing novel species. The Campbell Lakes communities will continue to gradually shift from lentic to backwater riverine, providing new habitats for river species. The ecological implications of these interactions should be considered when managing stocked lakes that connect to rivers, such as Campbell Lakes.

References

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Acknowledgments

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