ASSESSING URBAN–RURAL DIFFERENCES IN LARGEMOUTH BASS ABUNDANCE IN MINNESOTA

Jonathan Gates
Aquatic Biology Program
Bemidji State University
Bemidji, MN, USA
gatesjonathan716@gmail.com
Faculty Sponsor: Dr. Andrew W. Hafs (andrew.hafs@bemidjistate.edu)

***Abstract*—Urbanization can significantly alter freshwater ecosystems and influence sport fish populations. This study examined differences in largemouth bass *Micropterus nigricans* catch-per-unit-effort (CPUE) between urban and rural lakes in Minnesota and evaluated temporal changes between 2000–2010 and 2011–2021. Forty lakes (20 urban, 20 rural) were selected using Minnesota Department of Natural Resources fisheries survey data. Lakes were classified using NLCD 2019 land cover data, with ≥10% developed land designated as urban. Nonparametric analyses (Wilcoxon rank-sum and signed-rank tests) were used to assess spatial and temporal differences in CPUE. Results showed that rural lakes had consistently higher median CPUE than urban lakes in both periods. In the early period, median CPUE was 3.22 (0.99–39.30 IQR) in rural lakes and 1.00 (0.65–1.69 IQR) in urban lakes. In the late period, values were 2.63 (0.58–54.40 IQR) and 0.54 (0.21–1.44 IQR), respectively. Differences between urban and rural lakes were statistically significant in both periods ($p < 0.05$), while temporal differences within lake types were limited. These findings indicate that urbanization is associated with reduced largemouth bass abundance and that these effects have persisted over time. Protecting shoreline habitat and reducing nutrient inputs may help maintain sustainable bass populations in developed lake systems.**

INTRODUCTION

Largemouth bass *Micropterus nigricans* are an important sport fish in Minnesota, and their abundance is commonly measured using catch-per-unit-effort (CPUE) through standardized gillnetting and electrofishing programs conducted by the Minnesota Department of Natural Resources. Ecological differences between urban and rural environments, including shoreline development, fishing pressure, nutrient loading, boat traffic, shoreline vegetation removal, and stormwater runoff, have been shown to influence fish populations and aquatic population structure. These factors have been shown to influence fish populations and aquatic population structure (Jennings et al. 1999; Wang et al. 2003). These environmental pressures are typically more common near urban centers and may lead to reduced abundance or altered size structure and recruitment in sportfish populations. Because largemouth bass are sensitive to habitat modification, they are a useful bioindicator species for assessing how urbanization influences lake ecosystems.

Eutrophication is a common consequence of increased nutrient input into freshwater systems, particularly nitrogen and phosphorus from agricultural runoff, urban stormwater, and wastewater discharge (Likens 2013; Mitsch and Gosselink 2015). This nutrient enrichment stimulates excessive algal growth, which can lead to harmful algal blooms, reduced water quality, and oxygen depletion as decomposing plant and animal matter consumes dissolved oxygen. In severe cases, eutrophication results in hypoxic conditions that disrupt aquatic food webs and cause fish kills, particularly in urban lakes where anthropogenic impacts are more concentrated. Often leading to these factors becoming increasingly common amongst urban systems. Largemouth bass serve as effective bioindicator species in these environments due to their ecological role as top predators, broad geographic distribution across the U.S, and sensitivity to habitat and water quality changes. Their abundance, growth and condition can reflect ecosystem health, making them valuable for assessing the biological impacts of eutrophication and other environmental stressors common in urban systems. For example, studies have shown that largemouth bass in eutrophic, urban lakes often exhibit slower growth rates, lower condition factors, and altered age structures compared to those in less impacted rural systems, showing that urbanization and increased nutrient levels can have measurable effects on fish development and population dynamics (Johnson and Davis 1997).

Minnesota's geography provides an ideal natural gradient across the landscape for examining how different landscapes influence nutrient loading into lakes. To the west, the tallgrass prairie region, characterized by deep, nutrient rich soils and extensive agricultural development create conditions where runoff can carry elevated levels of nitrogen and phosphorus into nearby waters, likely due to increased agricultural pressures. Moving eastward, this transitions sharply into a variety of mixed hardwood forests, conifer forests, as well as wetlands, peatlands, and a lake rich, glacial landscape. Each of these landcovers interacts with nutrients differently. Forests typically slow runoff and filter nutrients with their extensive root systems, while wetlands and swamps can act as nutrient sinks or sources and lake rich areas provide a variety of pathways for nutrient transport and retention (Likens 2013; Mitsch and Gosselink 2015). This variety of ecosystems makes Minnesota especially valuable for examining how contrasting soils, vegetation, and land use contribute to the differing nutrient loads observed across its lakes, that could ultimately affect fish populations over time.

Minnesota presents an excellent study region because it contains a blend of lakes near growing cities, such as Bemidji, Duluth, Hibbing, St. Cloud, Minneapolis- St. Paul and Grand Rapids, as well as lakes in remote forested settings with minimal human disturbance. The Minnesota Department of Natural Resources maintains a long-term fisheries database with consistent sampling methods across thousands of lakes, allowing for a spatial and temporal analysis of bass CPUE. By comparing CPUE across urban and rural lakes and across two time periods (2000–2010 vs. 2011–2021), this project aims to determine whether the patterns of largemouth bass abundance reflect known effects of urbanization and whether those patterns have changed over time within these 40 systems.

METHODS

Sample selection. — Largemouth bass CPUE data was compiled from the Minnesota Department of Natural Resources LakeFinder survey database (MNDNR 2026). To ensure full temporal coverage, the lake selection process identified lakes that were surveyed at least once during 2000–2010 and at least once during 2011–2021. Among all qualifying lakes, a final sample of 20 urban lakes and 20 rural lakes were selected, resulting in a total of 40 lakes used consistently in both periods. This fixed lake design ensures that comparisons reflect true changes within the same set of systems rather than differences in sampling coverage from different lakes. For each lake, the CPUE value from the survey closest to the midpoint of each period will be used to maintain consistency and prevent overrepresentation of heavily sampled lakes. For example, if a lake was surveyed six times over the span of six years, the third sample year will be selected, closest to the midpoint of that sampling period (early or late).

Urban and rural designations were determined using percent developed shoreline buffers. Lakes were derived from Minnesota Geospatial Commons lake polygon data (Minnesota Geospatial Commons 2021). Urban/rural designations were based on the percentage of developed land surrounding each lake using NLCD 2019 land cover data (USGS 2019). Lakes with ≥10% urban land were classified as urban, and those below 10% as rural. Once classified, only lakes that met both the spatial criteria and the temporal survey requirements (one survey per period) were retained for the final sample of 20 urban and 20 rural lakes.

The analysis compared largemouth bass CPUE across two distinct time periods, 2000–2010 (early period) and 2011–2021 (late period), using the same lakes in both periods. Because the same lakes appeared in both datasets, the temporal comparison used paired statistical approaches, such as the Wilcoxon signed-rank test, to assess whether CPUE has increased, decreased, or remained stable over time within each lake category. Spatial differences between urban and rural lakes were assessed within each time period using nonparametric comparisons (Wilcoxon rank-sum tests). A two-factor statistical test was applied, treating urbanization category (urban vs. rural) and survey period (early vs. late) as factors, allowing the assessment of both main effects and potential interactions that would indicate different rates of change between the two lake types. CPUE distributions were compared and examined for skew, outliers, and irregularities.

To visualize spatial patterns and verify classification decisions, lake locations were plotted on regional basemaps showing city major watersheds and their urban/rural designation.

RESULTS

Largemouth bass CPUE differed substantially between rural and urban lakes across both study periods (2000–2010 and 2011–2021). Rural lakes consistently exhibited higher median CPUE values than urban lakes (Table 1). During the early period, rural lakes had a median CPUE of 3.22 (IQR: 0.99–39.30), whereas urban lakes had a median CPUE of 1.00 (IQR: 0.65–1.69). In the late period, rural lakes again showed higher abundance with a median CPUE of 2.63 (IQR: 0.58–54.40), while urban lakes declined to 0.54 (IQR: 0.21–1.44). The mean CPUE values exceeded medians in all categories, indicating a right-skewed distribution, which means that the skew is driven by a small number of very highly productive lakes, particularly within rural systems (Figure 1).

There were significant differences between CPUE in rural and urban lakes during both study periods. In the early period, rural lakes showed significantly greater CPUE than urban lakes ($W = 276.5$, $p = 0.04$). Similarly, during the late period, rural lakes maintained significantly higher CPUE values than urban lakes ($W = 285.5$, $p = 0.02$).

Temporal comparisons between periods showed no significant change in CPUE within either classification. Urban lakes showed a decline in median CPUE from 1.00 during the early period to 0.54 during

Table 1. Summary statistics table including urbanization classification, study period, and mean, median and standard deviation CPUE values. Note: CPUE values reflect the number of fish caught per unit effort (gillnet, electrofishing or trapnet). Skewed distributions are shown, as mean CPUE values exceed medians due to a small number of lakes with very high catches.

Urban/Rural	Period	#	Mean CPUE	SD CPUE	Q1	Median CPUE	Q3	IQR
Rural	Early	20	20.6	25.2	1.0	3.2	39.3	38.3
Rural	Late	20	33.1	45.8	0.6	2.6	54.4	53.8
Urban	Early	20	5.7	20.6	0.7	1.0	1.7	1.0
Urban	Late	20	7.8	29.0	0.2	0.5	1.4	1.2

the late period, though this difference was not statistically significant (W = 249, p = 0.19). Rural lakes maintained relatively stable CPUE across periods (W = 187, p = 0.74). Boxplots further illustrated the broader interquartile ranges and greater variability observed in rural lakes, whereas urban lakes remained consistently clustered near low CPUE values (Figure 2).

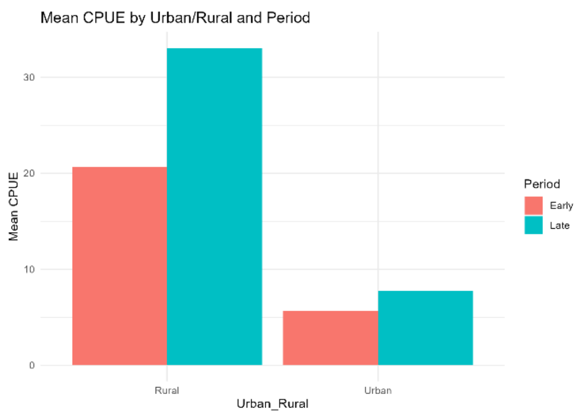

Figure 1. Comparison of mean largemouth bass catch-per-unit-effort (CPUE) between rural and urban lakes across two decades. Rural lakes exhibited a substantial increase in mean abundance from the Early (20.64) to Late (33.06) period, while urban systems remained comparatively lower.

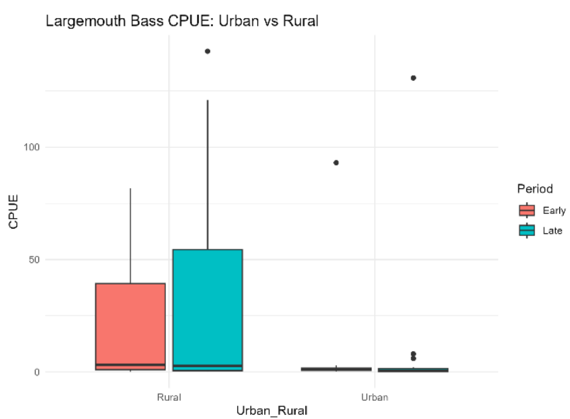

Figure 2. Boxplots illustrating the distribution of CPUE for rural (red) and urban (teal) lakes across the Early (2000–2010) and Late (2011–2021) study periods. Horizontal lines represent medians, boxes indicate the interquartile range (IQR), and individual points denote outliers. Increased variance and higher maximum catch rates are evident in rural systems over time.

Spatial patterns further supported these findings, with higher CPUE values concentrated in less-developed northern and forested regions of Minnesota, while lakes near urban centers such as Minneapolis, Duluth, Grand Rapids, and Bemidji generally exhibited lower largemouth bass abundance. The spatial distribution of lakes revealed that urban systems were concentrated around major population centers and developed corridors, whereas rural lakes were more common throughout northern forested regions of the state (Figure 3). These results suggest that urbanization and associated anthropogenic stressors may negatively influence largemouth bass populations in Minnesota lakes.

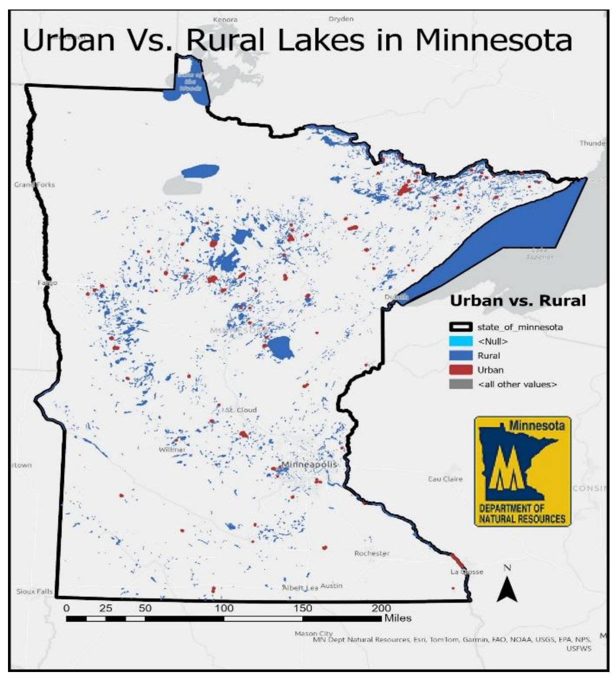

Figure 3. Geographic distribution of lakes classified as urban (red) and rural (blue) across the state of Minnesota. Urban designations are clustered primarily around major population centers, including the Twin Cities metropolitan area, Duluth, St. Cloud, and the Iron Range communities, while rural lakes dominate the north-central and northeastern forested regions.

DISCUSSION

Urban lakes exhibited consistently lower Largemouth bass abundance than rural lakes across both study periods. Median CPUE values were substantially lower in urban systems during both the early (2000–2010) and late (2011–2021) periods, and statistical tests confirmed these differences were statistically significant. Similar patterns have been documented in previous studies examining the effects of shoreline development and urbanization on freshwater fish populations. For example, shoreline modification and increased residential development have been linked to reductions in habitat complexity and declines in fish abundance across many North American lake systems (Jennings et al. 1999; Schmieder et al. 2001). Additionally, research conducted in Minnesota has shown that urbanization can alter fish community structure and reduce the abundance of sensitive species (Radomski and Goeman 2001). The consistency of these findings with the present study suggests that even medium levels of surrounding development may lead to measurable effects on largemouth bass populations in Minnesota lakes.

Habitat alteration associated with shoreline development likely represents one of the primary mechanisms driving reduced CPUE in urban lakes. Residential development often leads to the removal of coarse woody habitat, aquatic vegetation, riparian buffers and other structural features in the littoral zone. These structures provide important refuge and feeding habitat for largemouth bass, their fry and their prey. Studies have shown that the removal of coarse woody structure can significantly alter fish communities and food web dynamics in lake ecosystems (Sass et al. 2006). Similarly, studies examining shoreline development have documented declines in woody debris and other structural habitat in developed lakes (Francis and Schindler 2006). Because largemouth bass rely heavily on structurally complex littoral environments for spawning, foraging, and juvenile survival. Reductions in habitat availability may lower recruitment success and ultimately decrease overall abundance in well developed systems.

Water quality changes associated with urban watersheds may further contribute to the reduced bass abundance seen in urban lakes. Impervious surfaces such as roads, parking lots and residential buildings increase stormwater runoff and nutrient loading into nearby water bodies (Arnold and Gibbons 1996). Increased nutrient inputs often accelerate eutrophication, which can increase turbidity, alter prey communities, and even create seasonal hypoxic conditions that stress fish populations (Likens 2013). Previous research has shown that largemouth bass populations in eutrophic lakes can exhibit altered growth patterns and population dynamics under lower water quality conditions (Johnson and Davis 1997). In urban systems where nutrient loading is more common, these water quality issues may add to the habitat alterations associated with shoreline development, limiting bass abundance even more.

Comparisons between study periods indicate that rural lakes generally maintained stable or slightly increasing CPUE values, while several urban lakes exhibited moderate declines. Even though variability existed among individual lakes, the urban rural CPUE disparity suggests that anthropogenic pressures in developed watersheds have remained consistent or may be intensifying over time. Similar long-term patterns have been reported in studies examining the compounding effects of land usage change on aquatic ecosystems (Wang et al. 2003). Continued lakeshore development has increased recreational pressure and expanded impervious surface coverage therefore contributing to long term constraints on fish populations in urban lake systems.

The strongly skewed distribution of CPUE abundance values observed in this study also provides insight into variability between lake systems. A small number of lakes exhibited exceptionally high catch rates, producing mean CPUE values that were substantially higher than the medians. It also suggests that lake specific factors such as habitat quality, productivity, or management history can strongly influence bass abundance. While several rural lakes supported very high CPUE values, these highly productive systems were comparatively rare among urban lakes, further emphasizing the ecological constraints imposed by urban development. Rural lakes also showed substantially wider IQRs than urban lakes, hinting at greater variability and the presence of highly productive systems, whereas urban lakes showed consistently narrow IQRs centered around low CPUE values.

Several limitations should be considered when interpreting these results. First, CPUE represents a relative abundance rather than an absolute population estimate and may be influenced by variation in sampling efficiency or environmental conditions during surveys. As mentioned before, they can also vary by specific system history with habitat quality, productivity, or management history influencing CPUE values. However, the standardized sampling protocols used by the Minnesota Department of Natural Resources help minimize methodological variability between lakes and time periods (MNDNR 2021). Second, each lake was represented by a single survey within each time period to maintain consistent sampling effort and may not capture short term population changes. Future research into additional variables such as water chemistry, angling pressure, forward facing sonar and invasive species presence could further clarify the mechanisms driving reduced bass abundance in urban lake systems.

Despite these limitations, the consistent pattern observed across two decades strengthens the conclusion that urbanization is linked to reduced largemouth bass abundance in Minnesota lakes. From a management perspective, these results highlight the importance of maintaining riparian shoreline habitat and protecting littoral structure in developed watersheds. Conservation practices such as preserving vegetated shoreline buffers, limiting nutrient runoff, and retaining woody habitat may help slow the ecological impacts of lakeshore development. Because many urban lakes provide accessible recreational fisheries for nearby populations, targeted habitat restoration and proactive management strategies could play an important role in sustaining largemouth bass populations and maintaining angling opportunities in the future.

Overall, this study demonstrates that landscape development patterns are closely linked to sport fish abundance in northern Minnesota lakes. Long term fisheries monitoring datasets, when combined with geospatial land cover analysis, provide a powerful framework for seeing just how human land use influences freshwater fisheries ecosystems. Continued monitoring and spatial analysis will be essential for guiding science based fisheries management and conservation strategies across Minnesota's historic lake systems, so generations after us can enjoy these same opportunities.

References

Arnold, C.L. and C.J. Gibbons. 1996. Impervious surface coverage: The emergence of a key environmental indicator. Journal of the American Planning Association 62:243–258.

Francis, T.B. and D.E. Schindler. 2006. Degradation of littoral habitats by residential development: Woody debris in lakes of the Pacific Northwest and Midwest, USA. Ambio 35:274–280.

Jennings, M.J., D.E. Schindler, and R.A. Ryder. 1999. Effects of shoreline development on freshwater fish populations. Ecological Applications 9:143–158.

Johnson, B.M. and J.C. Davis. 1997. Population dynamics and growth of largemouth bass in eutrophic lakes. North American Journal of Fisheries Management 17:123–134.

Likens, G.E. 2013. Lake Ecosystem Ecology: A Scientific Approach to Lake Management. Springer, New York, New York.

MNDNR (Minnesota Department of Natural Resources). 2026. LakeFinder: Fisheries Survey Data. Accessed February 2026. https://www.dnr.state.mn.us/lakefind/index.html.

MNDNR (Minnesota Department of Natural Resources). 2021. Minnesota Water Resources Data Portal. Accessed February 2026. https://www.dnr.state.mn.us/waters/index.html.

Minnesota Geospatial Commons. 2021. Minnesota Lake Polygon Data. Accessed February 2026. https://gisdata.mn.gov/dataset/minnesota-lake-polygons.

Mitsch, W.J. and J.G. Gosselink. 2015. Wetlands. 5th Edition. John Wiley & Sons, Hoboken, New Jersey.

Radomski, P.J. and T.J. Goeman. 2001. Effects of urbanization on freshwater fish communities in Minnesota. Fisheries 26:6–12.

Sass, G.G., J.F. Kitchell, J.N. Carpenter, T.R. Hrabik, J.J. Marburg, and M.G. Turner. 2006. Fish community and food web responses to a whole-lake removal of coarse woody habitat. Fisheries 31:321–330.

Schmieder, P.K., J.R. Post, and D.P. Krueger. 2001. Shoreline modification and its impacts on game fish populations. Transactions of the American Fisheries Society 130:107–115.

USGS (U.S. Geological Survey). 2019. National Land Cover Database (NLCD 2019). Accessed February 2026. https://www.mrlc.gov/data.

Wang, L., J. Lyons, P. Kanehl, and R. Bannerman. 2003. Impacts of urbanization on stream habitat and fish. Environmental Management 31:738–749.

Wright, H.E. 1972. Quaternary history of Minnesota. Pages 515–547 in P.K. Sims and G.B. Morey, editors. Geology of Minnesota: A Centennial Volume. Minnesota Geological Survey, St. Paul.

Zar, J.H. 1999. Biostatistical Analysis. 4th Edition. Prentice Hall, Upper Saddle River, New Jersey.

Zumberge, J.H. 1952. The Lakes of Minnesota: Their Origin and Classification. Minnesota Geological Survey Bulletin 35. University of Minnesota Press, Minneapolis.