May 27, 2026

Biodiversity trends across urban and rural lakes in Ohio

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SUMMARY

Freshwater lakes supply local residents important culture and ecosystem services, yet freshwater lakes face many challenges from surrounding human activity that can affect local biodiversity. Nearby human activity can alter the biodiversity surrounding a lake by increasing risk of nutrient runoff, pollution, and species introduction or removal. In Ohio, few studies have explored how urban and rural lakes might differ in biodiversity trends, particularly trends within lakes surrounding fauna. The aim of this study was to compare the biodiversity of urban and rural lakes to determine how proximity to a large city might influence species presence and abundance. Six lakes were studied in the Southwest Ohio region and identified as urban or rural depending on their distance to the nearest major city of Cincinnati. The count of unique species and number of each species present outside lakes were used to calculate Shannon's Biodiversity Indices (i.e., abundance and evenness). My hypothesis was that biodiversity differs between urban and rural lakes, with rural lakes displaying a greater biodiversity. William H. Harsha Lake, an urban and the largest lake, exhibited the highest count of unique species (n=31) but there were no large differences in species abundance or species evenness between urban and rural lakes. My study shows the importance of tracking lake biodiversity in Southwest Ohio to better understand the unique influence different human activity has on lake quality.

INTRODUCTION

The lakes of Ohio provide drinking water for more than 11 million people and are critical habitats for approximately 170 species of fish, 200 species of birds, and 70 species of mollusks, making them important ecosystems to protect (1). William H. Harsha Lake, located in Southern Ohio, supplies drinking water for at least 40,000 people yet has been found to contain 42 pesticide compounds, mainly as a result of nearby urbanization (2). Ohio lakes face significant challenges, mainly from increased human activity that increase risk of eutrophication, runoff and erosion (3). These environmental impacts may indirectly affect local diversity and can directly increase mortality risk of aquatic species (4;5). However, the effects of these disturbances on biodiversity trends have been little studied in Ohio.

The biodiversity of a lake can serve as an indicator on the general health of the local ecosystem. One way researchers measure the quality of lakes is by counting the number of species present and measuring diversity indices (e.g., Shannon's H, Shannon's E, alpha). For example, a study conducted in India, collected fish across two lakes to investigate the correlation between water quality parameters and biodiversity (6). Researchers found that factors such as depth, conductivity and salinity had a significant impact on biodiversity, which suggests that these factors should be taken into consideration when designing infrastructure. Current studies may follow a similar methodology to better understand how urbanization influences diversity at the local scale.

This study explores the current biodiversity trends in rural and urban lakes in Ohio using Shannon's H and Shannon's E indices for comparison. I hypothesize that biodiversity indices differ between urban and rural lakes, with rural lakes having a greater number of species and more evenness. Given that a closer distance to urbanization may increase the risk of human pollution, urban lakes are assumed to be at higher risk of indirect effects that result in lower biodiversity indices compared to rural lakes. Contrary to my hypothesis, my study found that an urban lake displayed the highest Shannon's H and Shannon's Evenness, but the next highest biodiversity indices showed no relation amongst rural and urban lakes. Overall, no correlation was found between urban and rural lake biodiversity.

RESULTS

Species presence:

At each lake, any organism spotted was recorded, indicating both count and species type. When analyzing the results, I added up the number of species for each lake to gain an understanding of the species diversity. The total number of species was greatest for Rocky Fork Lake (n=33), followed by William H. Harsha Lake (n=31), Rush Run Lake (n=31), Lake Isabella (n=29), Paint Creek Lake (n=27), and Lake Barber (n=26; **Table 2**). The most sighted taxa were birds including vultures, gulls, double crested cormorants, and Canadian geese. Aquatic species like bluegill and catfish were only observed when fishermen would reveal their catch. Other rare species were the bald eagle and osprey that were observed in Rocky Fork Lake and Paint Creek Lake.

Of the species observed, three are considered invasive: Carp, spotted at Paint Creek Lake, European Starlings, spotted at Rocky Fork Lake, and House Sparrows, spotted at Lake Barber, Rocky Fork Lake, and Paint Creek Lake. This is important to consider because invasive species have been found to have a negative effect on the biodiversity of ecosystems, competing with native species (7).

Shannon's H

In addition to the number of species, the Shannon's H Index was calculated for each lake. This index signifies biodiversity, with a higher number correlated with higher diversity. Among rural lakes, the highest Shannon's H was for William H. Harsha Lake (0.77), followed by Lake Barber (0.55), and lowest for Lake Isabella (0.43; **Table 3**). For urban lakes, the highest was for Lake Paint Creek (0.72), followed by Rocky Fork (0.51), and Rush Run (0.38). When comparing urban and rural lakes, I found that the highest Shannon's H was for William H. Harsha Lake followed by Paint Creek Lake and lowest for Rush Run Lake. There was no relative difference in Shannon's H between rural and urban lakes (**Figure 2**).

Shannon's E

Shannon's E Index was also calculated for each lake. This index signifies how equally distributed individuals are across a species, with a higher value indicating greater evenness. Among rural lakes, the highest Shannon's E was for William H. Harsha Lake (0.23), followed by Lake Barber (0.17), and lowest for Lake Isabella (0.13; **Table 4**). For urban lakes, the highest was for Paint Creek Lake (0.22), followed by Rocky Fork (0.14), and Rush Run (0.11). When comparing urban and rural lakes, I found that the highest Shannon's E was for William H. Harsha Lake followed by Paint Creek Lake and lowest for Rush Run Lake. There was no relative difference in Shannon's E between rural and urban lakes (**Figure 2**).

DISCUSSION

This research did not find major differences in biodiversity indices between urban and rural lakes. William H. Harsha Lake contained the highest number of species, with no one dominant species occupying the surrounding lake. The lake with the lowest species count was Rush Run Lake, a rural lake that was dominated by swallows. A personal observation is that Rush Run Lake is surrounded by farms which support flying insects, the main food source for swallows. In a study that analyzed the biodiversity of urban versus rural ponds, urban ponds were found to support a lower number of species than rural and floodplain ponds (8). Likewise, this study shows that some rural lakes may better support only a selected number of species compared but lake size likely plays a role in this pattern.

Lake size could also influence biodiversity trends. William H. Harsha Lake was by far the largest lake at 2160 acres and had the highest number of surrounding species. Past studies have shown that many species are found in the littoral zones of lakes and thus lakes with a larger size will have more shoreline, likely increasing biodiversity presence (9). In addition, William H. Harsha Lake is the deepest lake at 113 feet. This could influence aquatic biodiversity as past studies have found that lake depth has a positive correlation with species presence (6). Further research could explore if lake size is related to species abundance and evenness.

Nearby agriculture may have influenced biodiversity trends in rural lakes and potentially reduced species abundance. All rural lakes are in close proximity to farms containing livestock. Past studies have found that agriculture poses a significant threat to biodiversity (10; 11). Converting ecosystems into farmland has been found time and time again to be a significant contributor to biodiversity loss (10; 11). This study did not directly measure aquatic biodiversity and acknowledges that aquatic species might also be affected by agricultural activities. For example, the use of pesticides by farmers to protect their crops inputs excess phosphorus and nitrogen into lakes, resulting in harmful algal blooms that directly increase fish mortality (12; 13). Future research should explore how agriculture practices may influence biodiversity and water quality of nearby lakes.

Given the increasing pressure of climate change, growing urbanization, and pollution runoff, lake studies should investigate current biodiversity trends in lakes. Ohio supports over 11.8 million residents that depend on lakes for many ecosystem services including provisioning (e.g., food, drinking water), regulation (e.g., local climate regulation), supporting (e.g., habitat for nursery), and cultural (e.g., cognitive and scientific development) (14). Measuring the conditions of local lakes through personal observations or with the help of citizen scientists can help sustain these and other services for future generations.

MATERIALS AND METHODS

Sites and Classification:

Six lakes including three rural and three urban were visited a total of three times each (**Figure 1**). Urban lakes were classified as being located 30 miles or less from a major city and rural lakes 50 miles or greater. In addition, lakes had to be 20 acres or greater (**Table 1**). The chosen urban lakes were: William H. Harsha Lake, Lake Isabella, and Lake Barber, and the chosen rural lakes were: Rush Run Lake, Rocky Fork Lake, and Paint Creek Lake. Out of the six lakes, all of them except for Lake Barber are regularly stocked with fish. William H. Harsha Lake, Rush Run Lake, Rocky Fork Lake, and Paint Creek are all located near farmland and livestock.

Data Collection

Lake visits occurred from July 20, 2025 to September 7, 2025 with one and a half hours spent at each lake, adding up to a total of 27 hours of observation. I spent 45 minutes walking around the rim of the lake, maintaining a maximum distance of 100 feet from the rim. Afterwards, 45 minutes of observation was spent in a sedentary position. All animals seen during the hour and a half period were recorded in a notebook, measuring time, species, and count. Animals recorded were those directly observed including birds, fish (fishing activity), and mammals. Species were identified using a bird book or Merlin Bird ID.

Other Parameters

Other parameters recorded included the weather at each site during the observation time (recorded in degrees), fishing activity (denoted as either yes or no), the number of fish caught by fishermen, and the species of fish caught. Fish that could be identified were included in our analysis.

Data Analysis

From the organism data collected, a Shannon biodiversity index was used to determine the biodiversity of each lake. Shannon's H index is a measure of abundance and evenness within a species population, where p_i is the proportion of a species relative to the total number of species (15):

$$H = -\sum_{i=1}^{S} p_i \ln p_i$$

A high value indicates the area contains a higher number of species. Shannon's evenness is a measure of how evenly a species is distributed in an environment, where S is the number of total species present in an ecosystem (15):

$$E_H = \frac{H}{\ln S}$$

Values range from 0 to 1, with 1 representing complete evenness. I estimated both for all lakes to determine species abundance and evenness. All analysis was completed using Google Sheets.

ACKNOWLEDGMENTS

The author would like to acknowledge the assistance of Chris Brown.

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Figures and Figure Captions

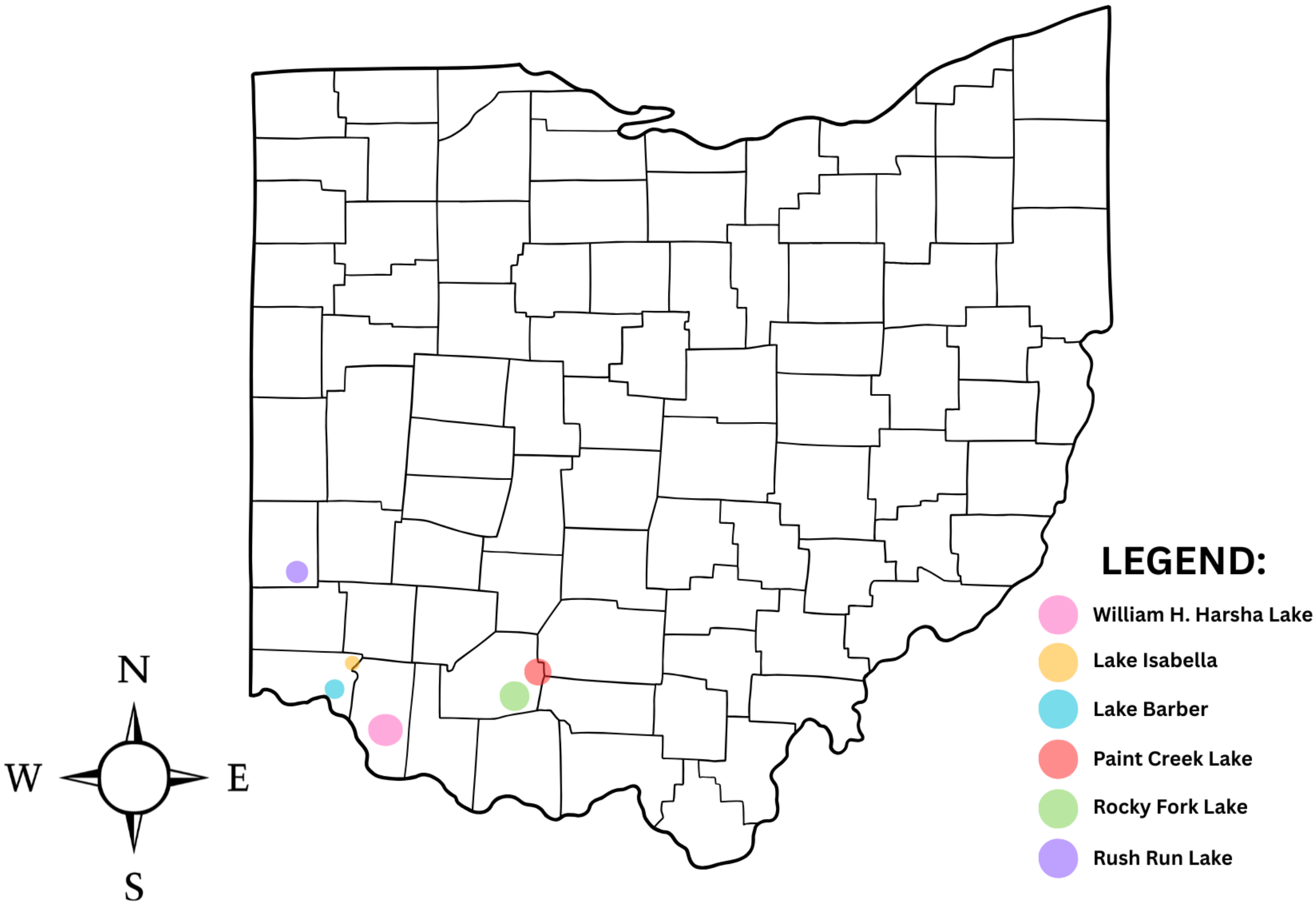

Figure 1. Geographic location of study sites in Ohio. The size of each point is determined by the relative size of each individual lake.

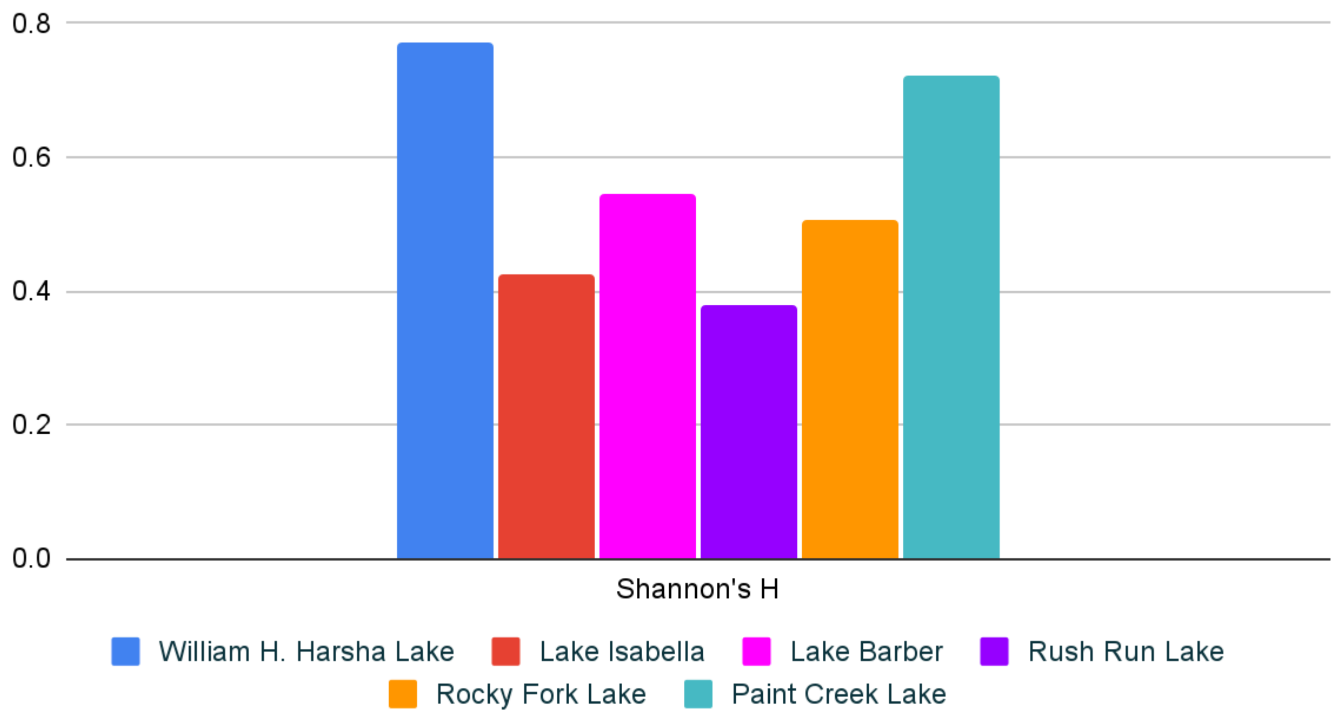

Figure 2. Shannon's H across the six lakes. Bar graph showing the values of Shannon's H for each lake. Shannon's H was calculated using the equation $H = -\sum_{i=1}^{S} p_i ln\, p_i$ and a higher value indicates greater species diversity.

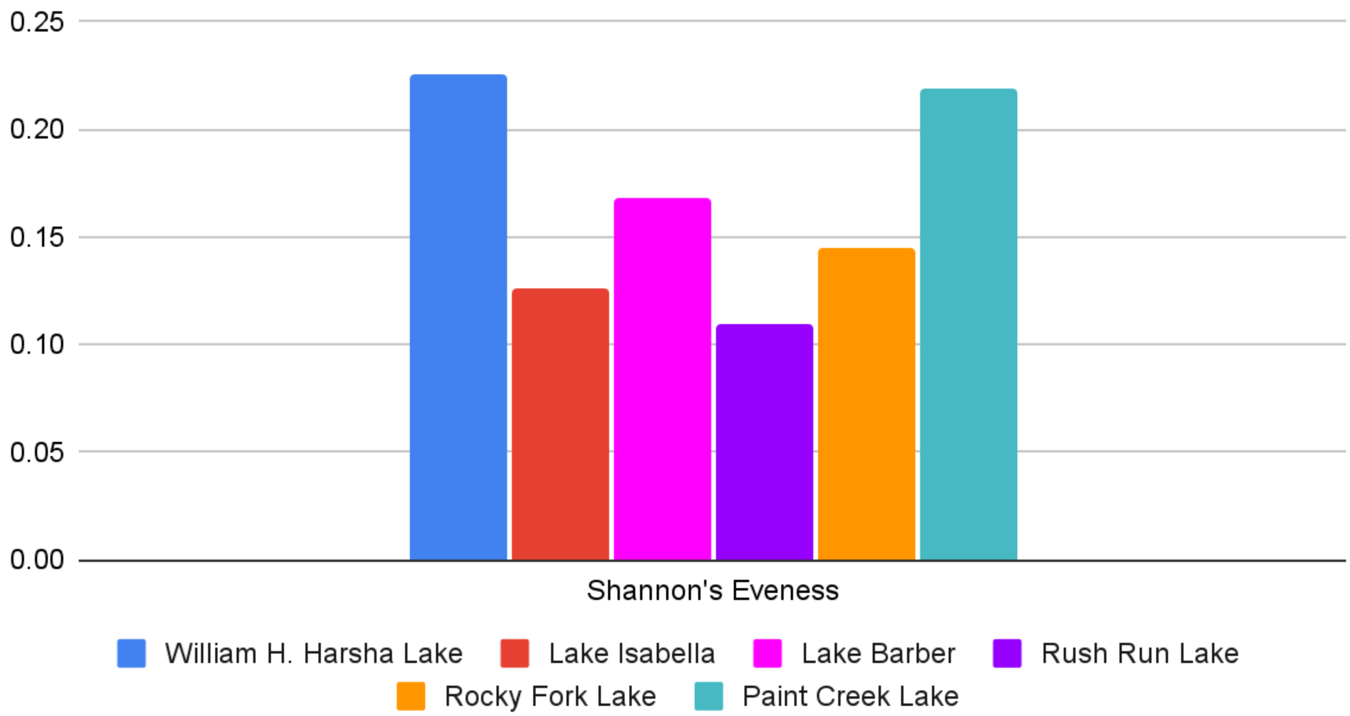

Figure 3. Shannon's E across the six lakes. Bar graph showing the values of Shannon's E for each lake. Shannon's E was calculated using the equation $E_H = \frac{H}{\ln S}$ and a higher value indicates greater species evenness.

Tables with Captions

Site:	Size (ha):	Distance from Cincinnati (mi):
William H. Harsha Lake	2160	27
Lake Isabella	28	17
Lake Barber	52	14
Rush Run Lake	54	50
Rocky Fork Lake	1992	64
Paint Creek Lake	1190	73

Table 1. Size, in acres, and distance, in miles, of each lake from the nearest major city, Cincinnati. The first three lakes were classified as urban lakes and the last three as rural.

Site:	Total organisms:	Total species:
William H. Harsha Lake	205	31
Lake Isabella	125	29
Lake Barber	193	26
Rush Run Lake	123	31
Rocky Fork Lake	339	33
Paint Creek Lake	260	27

Table 2. Organism and species totals. Complete count of the total organisms observed (i.e., total number of individuals) and total number of unique species observed.

Site:	Shannon's H:	Shannon's E:
William H. Harsha Lake	0.7730	0.2251
Lake Isabella	0.4257	0.1264
Lake Barber	0.5465	0.1677
Rush Run Lake	0.3774	0.1099
Rocky Fork Lake	0.5076	0.1452
Paint Creek Lake	0.7204	0.2186

Table 3. Shannon's H and E for each lake. Shannon's H was calculated using the equation $H = -\sum_{i=1}^{S} p_i \ln p_i$ and a higher value indicates greater species diversity. Shannon's E was calculated using the equation $E_H = \frac{H}{\ln S}$ and a higher value indicates greater species evenness.