RELATIONSHIP BETWEEN RATIO OF HYBRID SUNFISH TO THEIR PARENT SPECIES AND LATITUDE

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***Abstract*—Hybrid sunfish of the *Lepomis* genus make up a generally small but notable portion of the population of sunfish in Minnesota lakes. Hybrid sunfish play a significant role in freshwater ecosystems across the United States. They are both morphologically and behaviorally distinct in some ways and similar in other ways to their parent species, causing them to both fill and compete with their parent species for niches occupied by multiple *Lepomis* species. Despite this, the ratio of hybrid sunfish to their parent species has never been properly explored. This study observed if the ratio of hybrid sunfish to their parent species in over 900 lakes changed with latitude. The study gathered information from standard and targeted surveys performed by the Minnesota Department of Natural Resources. Multiple regression tests were performed to determine a best model. AIC scores provided evidence to suggest that the relationship between latitude and hybrid ratio was quadratic. Peak hybrid ratios occurred between 44.6 and 47.1 degrees latitude. Potential causes could be more spawning temperature overlaps or more suitable topography for hybridization in lakes between those latitudes.**

INTRODUCTION

Sunfish hybridization is widespread across centrarchids, particularly among members of the *Lepomis* genus. The many species of sunfish are important parts of American wetland ecosystems, often with multiple species inhabiting the same ecosystem. Hybrid sunfish are often composed of a combination of their parents' morphological and behavioral characteristics, allowing them to occupy the same niches as either of their parents. They are commonly used in stocking bodies of water, as they do not have the tendency of other commonly stocked sunfish to overcrowd due to their lower reproductive capability. They even occasionally make up most of the sunfish in a body of water (Hubbs 1955).

There are 22 different natural hybridizations between various Centrarchids, with several of them being fertile (Bolnik 2009). Hybrid sunfish differ from their parents in notable ways, such as the presence of hybrid vigor (Hubbs 1955) and distinctly skewed sex ratios (Childers 1965) in certain hybrids, differing courtship (Clarke 1984), and generally a lower but not absent fertility. Within lakes that contain multiple parent species causes of hybridization may include crowded spawning grounds (Hubbs 1955), scarcity of partners of the same species (Hubbs 1955), and similar spawning temperature requirements. In Minnesota, the primary species involved in hybridization across most of the state are the Bluegill *Lepomis macrochirus*, the Pumpkinseed *Lepomis gibbosus*, and the Green Sunfish *Lepomis cyanellus*, with the Warmouth *Lepomis gulosus* being limited to the southeastern edge of the state along the Wisconsin border.

The objective of this study is to draw a detailed comparison between the ratio of hybrid sunfish to their parent species and how it trends across changing latitudes. This will allow a better understanding of the influence of hybrid sunfish in lakes across North America.

METHODS

The lakes were found through consulting the Minnesota Department of Natural Resources (MNDNR) who provided a list of lakes that were found to contain hybrid sunfish by their Lake Index of Biological Integrity Surveys. Data for quantities of hybrid sunfish and parent species were found using a MNDNR program they offer known as "LakeFinder" (MNDNR 2025). LakeFinder provided a list of surveys that were done on a given lake, as well as the numbers of fish found in each survey. In total, 933 lakes were found to contain hybrid sunfish.

Surveys were divided between targeted and standard surveys, with standard samples primarily using gill nets and trap nets while targeted samples primarily used electrofishing and seine nets. Only the most recent year of surveys that contained Hybrid Sunfish were used for information, so in many lakes either a targeted or a standard survey were used for data while in others both were used.

The latitude of the lake was found through LakeFinder, as each lake also includes its location on Google Maps. The approximate center of the lake was found, and the latitude was taken from it in decimal degrees.

The hybrid ratio for a lake was calculated for targeted and standard surveys through recording all hybrid sunfish and parent species found in a survey, before dividing the hybrid sunfish by all sunfish to find what portion of the population hybrid sunfish make up. In the following equation H=hybrid, B=bluegill, P=pumpkinseed, and G=green sunfish.

$$Hybrid\ Ratio = \frac{H}{H + B + P + G}$$

This was done similarly for the total hybrid ratio for a lake, however, the hybrids in the standard survey and targeted survey were added together and then divided by the total sunfish in both surveys. In the following equation Hs=hybrid totals from standard surveys, Ht= hybrid totals from targeted surveys, Ts=total sunfish from standard surveys, and Tt=total sunfish from targeted surveys.

$$Hybrid\ Ratio = \frac{Hs + Ht}{Ts + Tt}$$

A scatter plot was then created for standard surveys and targeted surveys, as well as the two combined, showcasing the ratio and latitudes of the lakes. To test if hybrid ratio changed by latitude, ratios were log transformed to account for the unusual spread in the data. Then linear, quadratic, and intercept only models were compared using AIC scores (Akaike 1973). This was done for standard, targeted, and total surveys individually.

RESULTS

The lakes were all between 43.6 and 48.1 degrees in latitude. In total, there were 555,591 sunfish recorded in the surveys, with 30,319 of them being hybrids. The total hybrid ratio across the lakes ranged between 0.00038 and 1, with most falling under 0.4.

The best fit model for explaining hybrid ratio across Minnesota surveyed lakes was log(Hybrid Ratio) ~ Latitude + I(Latitude^2) which for the total surveys had an AIC score of 3273.645. The second-best fit model for total surveys was log(Hybrid Ratio) ~ 1 which had an AIC score of 3286.816 (Figure 1). Standard surveys had an AIC score of 2206.963 for log(Hybrid Ratio) ~ Latitude + I(Latitude^2) and a second-best fit AIC score of 2216.414 for log(Hybrid Ratio) ~ 1 (Figure 2). Targeted surveys had an AIC score of 1603.472 for log(Hybrid Ratio) ~ Latitude + I(Latitude^2) and a second-best fit AIC score of 1604.57 for log(Hybrid Ratio) ~ 1 (Figure 3). Since the AIC score for the null model was not more than 2 units higher, there is not strong support for a relationship between hybrid ratio and latitude for sunfish captured in targeted surveys.

In summary, both the standard and total survey data demonstrated a relationship between latitude and the hybrid ratio, while the targeted did not. The ratio of hybrid sunfish rose starting at 44.6 degrees latitude before plateauing and eventually gradually decreasing starting at 47.1 degrees latitude. Over the range of latitude, the ratio of hybrid sunfish would change by about three percent.

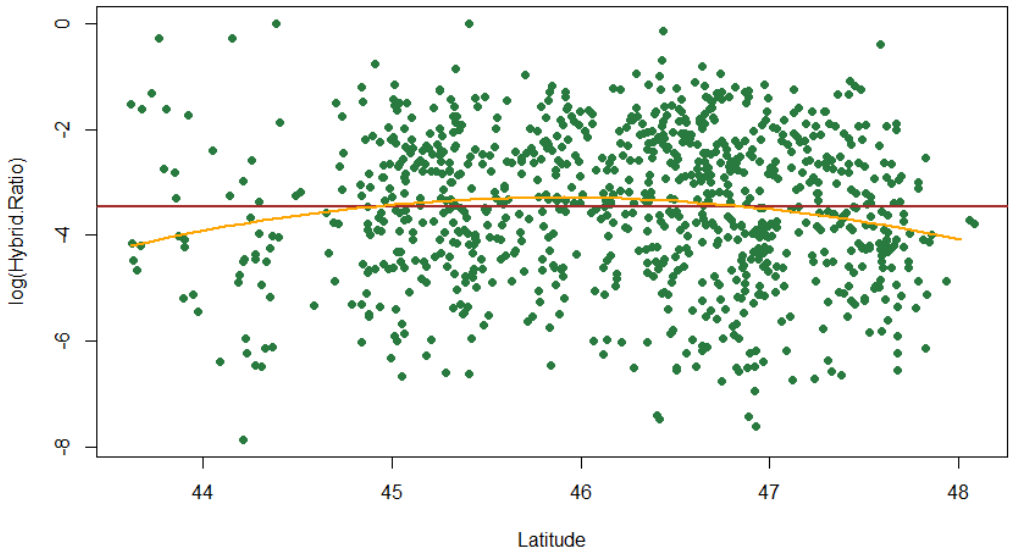

Figure 1. Scatterplot depicting the relationship between hybrid ratio and latitude across all Minnesota Lakes. There is a distinct rise and fall in the ratio of hybrid sunfish between 44.6 and 47.1 as shown by the graph.

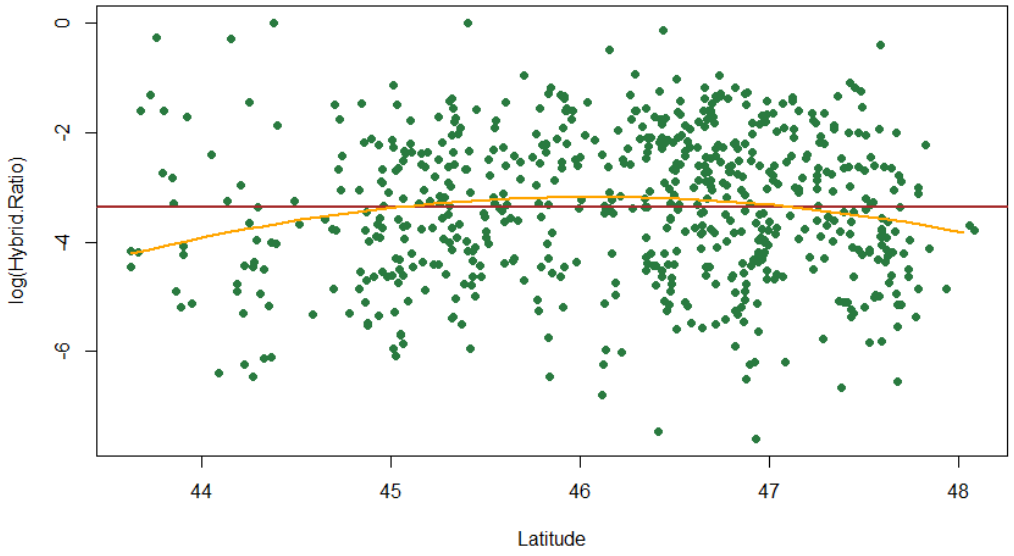

Figure 2. Scatterplot showcasing the hybrid ratio and latitude for standard surveys. There was once again a distinct rise in the hybrid sunfish ratio began around 44.6 as well as a taper that began at around 47.1.

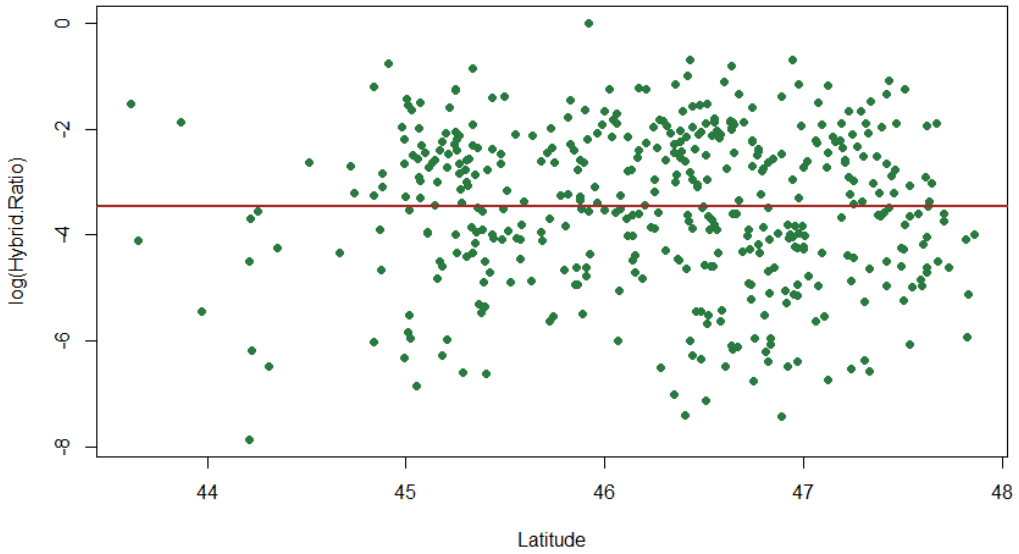

Figure 3. Scatterplot showcasing the hybrid ratio and latitude for targeted surveys. As the p-value was too high (p=0.079), there was no relationship found for the data and there is no quadratic line present.

DISCUSSION

This study provides evidence to suggest the ratio of hybrid sunfish is highest between the latitudes of 44.6 and 47.1 within the state of Minnesota. There are multiple potential causes for this. The most likely cause is spawning temperature overlap. Pumpkinseed spawning temperatures begin at 17 °C and continue to 26 °C, though the peak is between 20 and 22 °C. Green Sunfish begin peak spawning at 20 °C and continue till 28 °C, at which point they taper down. Bluegills start spawning at 20 °C as well and continue until 31 °C (Warren 2009) and while ideal spawning temperatures for bluegills could not be found, it would be surprising if they don't overlap with at least the green sunfish if not the pumpkinseed as well. Latitudes between 44.6 and 47.1 degrees likely have suitable water temperatures for peak spawning in multiple parent species (likely green and pumpkinseed) for the longest, giving them more time to hybridize and by extension increasing the ratio of hybrid sunfish in lakes at those latitudes, especially if combined with other known factors such as limited breeding ground or lack of partners of the same species (Hubbs 1955).

The study found that there was a significant relationship between latitude and hybrid ratio within standardized survey data as well as the total survey data for each lake. This was not the case for targeted survey data, likely because there were much fewer targeted surveys that produced hybrid sunfish than standard. There are a few potential causes for this. The most important may very well be misidentification. Targeted surveys rely on electrofishing and seining in shallow water, while standard surveys rely on trap and gill nets used in deeper water. The mesh size in the seines used in targeted surveys is much smaller than the mesh size in trap nets, which causes them to capture significantly more small fish including juvenile or even young-of-year (YOY). Juvenile and particularly YOY are notoriously hard to identify between related species of species of fish, even beyond sunfish (Baumsteiger 2005). This is made worse by hybrids which possess overlapping characteristics with the already difficult to differentiate juveniles of their parent species.

Due to this, there is a good chance many young-of-year or even juvenile hybrid sunfish were misidentified as similarly aged bluegill or pumpkinseeds which would decrease the number of hybrids identified as such in the surveys. If more hybrids were correctly identified, it's very possible that the hybrid ratio for targeted surveys would more closely resemble that of standard and total surveys.

Overall, the study provides clear evidence of the relationship between hybrid ratio and latitude for centrarchids, with an ideal range of latitudes for the hybrids of the three surveyed parent species. This is important as not only does it give us a better understanding of the distribution of hybrid sunfish but will also work as a benchmark to analyze how these ratios change with the encroachment of climate change impacting the spawning temperatures and ranges of the parent species.

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