THE INFLUENCE OF COARSE WOODY HABITAT ON *MICROPTERUS SALMOIDES* SIZE STRUCTURE AND CATCH-PER-UNIT-EFFORT IN NORTHERN TEMPERATE LAKES

JULIA BARRON
Smith College, Northampton, MA 01063 USA

MENTOR SCIENTISTS: DR. CHRIS SOLOMON AND ALEX ROSS
Cary Institute of Ecosystem Studies, Millbrook, NY 12545 USA

Abstract. There is an ongoing debate on the role of coarse woody habitat (CWH) and its effects on fish populations in north temperate lake ecosystems. The struggle to study CWH and observe its direct influence on fish life history prolongs this issue. In order to understand the function of CWH for fish populations, we caught largemouth bass on a gradient of lakes with differing CWH abundances and shoreline building densities. We determined largemouth bass size structure and catch per unit effort (CPUE) by both angling and electrofishing methods on 12 lakes. There was no relationship found between the presence of CWH and largemouth bass size structure and CPUE. However, there was a noticeable difference in size structure and CPUE relative to shoreline density between the two different fishing methods. While angling CPUE declined as building density increased, the amount of fish caught by electrofishing increased. No relationship was found in size structure for fish caught through angling, but as the building density increased in lakes, the mean length of fish caught through electrofishing decreased. Our findings suggest that shoreline building density and CWH may have an impact on the CPUE and size structure of largemouth bass populations caught using different methods of fishing, and this should be taken into account for fisheries managers, and in future lake conservation efforts.

INTRODUCTION

The density of coarse woody habitat (CWH) in north-temperate lake ecosystems may influence the abundance and size structure of their fish populations. There is continued debate on the role of natural CWH within the littoral zones of lake ecosystems and how it influences fish communities. Sass et al. (2006) found that through the removal of CWH in lakes, predator species such as largemouth bass (*Micropterus salmoides*) growth was negatively affected relative to the decreased population of yellow perch. However, it was found in another study that largemouth bass young of year mortality was unrelated to the presence and density of CWH (Ziegler et al. in press). The role of littoral CWH in ecosystems is still largely misunderstood, however understanding its role in aquatic ecosystems will be important for lake conservation and fisheries management efforts.

Largemouth bass behavior and life history is largely determined and tailored to the ecological community in which they live; CWH has the ability to play a crucial role in the life history of largemouth bass. This type of habitat can be defined as large or small trees, branches, roots, or logs that are submerged within a lake or other body of water (Czarnecka 2016). It was found to be one of the most prominent influencers of largemouth bass recruitment and survivorship (Ahrenstorff et al. 2009). CWH also serves as a fish aggregating structure and refuge from other predators (DeBoom and Wahl 2013). Other fish species that are prey to Largemouth bass such as yellow perch (*Perca flavescens*) and bluegill (*Lepomis macrochirus*) commonly use CWH as a refuge (Ramirez 2017). Due to this aggregating role, the abundance of CWH may have a limiting effect on largemouth bass growth and predator-prey interactions. In low CWH conditions, bass adopted a foraging way of actively hunting for prey, while in higher CWH conditions, the main hunting strategy transformed into one that required less movement (DeBoom and Wahl 2013). This could suggest that with less CWH, largemouth bass growth and size structures may be affected due the role CWH has on their hunting and diets. According to the Wisconsin Department of Natural Resources Bureau of Fisheries

Management, this fish species is known to prefer aggregating structures in their habitat, specifically objects located in calm and shallow water such as grass, weeds, and trees (Mecozzi 2008). The ability of largemouth bass to capture prey increases as CWH becomes more complex (DeBoom and Wahl 2013). Another study found increased bass catchability in sites within a lake that included a high percentage of CWH (Wildenhain 2016). Also when lake levels decline and CWH becomes more inaccessible to fish, largemouth bass populations are reduced as a result of the decreased growth of their prey (Gaeta et al. 2014). Because of the nature of CWH and its ability to aggregate different types of fish species, studying its complexity and abundance may be able to indicate fish abundance as well. Knowing this, it is still unclear how CWH may be affecting fish population dynamics within a lake ecosystem. A higher abundance of CWH may have a positive effect on aggregation, and lead to a higher rate of catchability in those specific areas of the lake (Wildenhain 2016), however if this high rate of catchability is looked at in exclusion to fisheries independent data, it may lead to a false prediction of fish abundance and eventual collapse of the population.

Lakeshore development has negatively affected lake ecosystems and littoral habitat in particular, as logs and macrophyte cover are removed to account for building structures and residential docks. In general, lakes with highly developed shorelines contain less CWH (Francis and Schindler 2006). Human-caused disruptions of littoral habitat due to residential development alter lake ecosystems, so much that fish production capacities can be affected (Schindler et. al 2000). Higher amounts of lakeshore development and housing density could indicate a lower CWH abundance. This can negatively affect fish populations through the loss of overall habitat (Gaeta et al. 2014). The potential effects of diminishing predation refuges due to lakeshore development might also alter the ability for ecosystems to support larger-sized fish and hold a higher population capacity.

The presence of aggregating structures like CWH may influence angler behavior. In turn, high catchability of fish near CWH may steady or increase catch-per-unit-effort, or CPUE, however decreases the actual lake population. In a case like this, the population may exhibit hyperstability; if there is a higher rate of catchability (or higher CPUE) near aggregating structures such as CWH, this may mask the accurate population dynamics. CWH is known to present an easy opportunity to anglers, as larger amounts of fish can be harvested faster and with less effort (Erisman et al. 2011). When anglers target specific aggregating locations in fisheries, an illusion of a stable population is apparent, potentially masking the actual population downfall (Erisman et al. 2011). A hyperstable population can occur as a result of overfishing these aggregating locations, and often lead to an eventual population collapse, therefore putting the overall ecosystem at risk. In order to account for hyperstability, managers tend to use a combination of largely accessible fisheries dependent data (i.e. angler catch rates) as well as less common fisheries independent data (i.e. electrofishing) in order to make management decisions.

Because of the ongoing changes to shoreline development in north temperate lake ecosystems, we wanted to look at the role of CWH and how increased housing density specifically affects largemouth bass populations. We surveyed a gradient of lakes with differing housing densities and CWH abundance within Vilas County, Northern Wisconsin. Multiple angling and electrofishing events took place on each lake to calculate catch per unit effort (CPUE) which was used to estimate the catchability and relative abundance of largemouth bass in each lake. Each fish caught during both fishing events were measured to determine population size structure and how they compare to lakes with varying abundances of CWH.

METHODS AND MATERIALS

Study Area

To investigate population size structure of largemouth bass across a gradient of CWH and shoreline building density we sampled twelve lakes (Figure 1). Each lake had a specific value for building density (100m from shoreline), explained later in this section (Table 1). Largemouth bass were the focal species for our study, however each lake had distinct fish communities common of north temperate lakes.

Estimating Relative Abundance

To estimate relative abundance, we calculated catch per unit effort (CPUE) of largemouth bass for each of our study lakes. CPUE was calculated for both angling and electrofishing. Each lake has an average CPUE value based on the hours and number of fish caught throughout the course of the summer season. CPUE is defined as the number of hours fished divided by the number of fish caught. An important formula for "catch" was used in this study:

$$C = qEB$$

Where catch (C) equals catchability (q) multiplied by unit effort (E) and biomass (or abundance) of fish (B). The equation for CPUE can be derived from this formula, and is C/E. This can also be described as catchability (q) multiplied by fish abundance (B).

In addition to calculating CPUE, the size structure (or length) of each largemouth bass we captured was recorded. Data was collected through a minimum of two electrofishing and three daytime angling events per lake.

Field Protocol

Electrofishing took place in the evening hours. This was done so as to not disturb residential units and users of the lake while also to catch the population of fish off-guard during a time of day when feeding takes place nearshore and anglers are usually inactive. The lakes chosen in our specific study area are precipitation-fed and generally have low conductivity. Because the process of electrofishing is limited by the conductivity of the water itself, we used a 480V AC electrofishing box. At night, the boat was driven parallel to the shoreline in the littoral zone, mostly in locations where CWH is known to exist. Two researchers net fish from the bow of the boat as they are shocked and measured each one regardless of species.

Our angling procedure took place during the day and mimicked the way anglers typically fish on lakes. Each lake endured a morning and evening angling event in order to prevent bias for the time of day. This method of fishing is catch-and-release, and its purpose is to place minimal disturbance on target and non-target species within the lake. Large hooks with YUM Dinger lures were used on all lakes.

Using electrofishing data to calculate CPUE can provide a fisheries independent abundance index that is less sensitive to hyperstability than angling. As electrofishing captures fish less selectively and more independent from angling, this capture method allows for a more realistic view of fish populations. However, angling data can provide a CPUE that could differ drastically to electrofishing, due to time spent angling, angler skill, size bias, and method used for fishing. This CPUE value is also more representative of catchability from anglers each day. Both electrofishing and angling CPUE values were compared and evaluated for all studied lakes.

Shoreline Building Density

Due to time constraints, we were unable to calculate the density of CWH per km of shoreline for each lake studied. A comparison was made in Sass et al. (2006) that found a significant relationship between CWH density and shoreline building density within north temperate lakes. Using our data for lakes studied this summer and soon to be studied in years to come, we compared CWH density and shoreline building density and also found a significant relationship ($p = 0.0002$, $R^2 = 0.4$) (Figure 2). Because of how density of CWH is negatively correlated with high levels of shoreline development, housing density and density of CWH are used interchangeably within this study.

Data Analysis

The relationship between fish length and shoreline housing density was tested using a linear mixed model regression. Profile confidence intervals were also made at 2.5% and 97.5%. A log transformation was performed in order to normalize data. Comparing method of fishing to fish length and building density required the use of another linear mixed model, again with profile confidence intervals. A linear regression was utilized to compare CPUE values with building density separated by fishing method.

RESULTS

Across all 12 lakes and both fishing methods, we caught over 2,500 largemouth bass. Length of these fish ranged from 40mm to 530mm. CPUE values ranged from .25 to 12.0 (angler hour)$^{-1}$ in angling and 2.0 to 204.0 (electrofishing hour)$^{-1}$ in electrofishing. The average length of bass caught through angling was higher than that of electrofishing. Building density varied across study lakes, with four out of the 12 lakes having no buildings around their shoreline, while the remaining eight lakes ranged from 6.6 to 43.2 buildings within 100m of their shoreline. A few lakes were removed from analysis due to the low amount of largemouth bass caught and/or time constraints.

Size Structure

Although size structure of fish captured by angling did not change along the shoreline building gradient, it was found that size structure of fish captured by electrofishing did. Overall, CWH did not affect length when gear is not treated independently, as shown in a confidence interval for the slope of the relationship between fish length and CWH density (2.5%=-2.05, 97.5%=0.40). Results did not qualitatively differ when we log-transformed building density before analysis 2.5%=-12.6, 97.5%=9.3). When treated independently, however, gear influences size structure (Figure 3). The confidence interval for electrofishing did not include 0 (2.5%=-20, 97.5%=-5.5) and shows that unlike angling, electrofishing has a significant relationship to building density and fish length. This was still true when log-transformed (2.5%=-20.1, 97.5%=-5.6).

Catch per Unit Effort

We predicted that CPUE would decrease as the building density increased in lakes, since a lower amount of CWH would therefore be present. However, we observed CPUE responding differently to CWH depending on how we captured fish (Figure 4). When comparing angling and electrofishing CPUE vs. building density in a linear regression, electrofishing CPUE increases in lakes as building density increases ($p < .001$). In addition, angling was shown to have an inverse relationship ($p < .001$). This indicates that there are differences between method of fishing that changes CPUE depending on building density and presence of CWH.

DISCUSSION

Although shoreline building density (or CWH density) was not shown to influence with largemouth bass fish lengths for both angling and electrofishing combined, electrofishing had a significant decreasing pattern as shoreline building density increased in lakes. No pattern was found through angling lengths, as the mean length of fish did not change across our development gradient. However, this negative correlation between electrofishing fish lengths and residential development does not imply that this gradient is affecting fish length. The reason for this result could be due to the nature of electrofishing compared to angling. Angler selectivity is known to bias the sizes and numbers of largemouth bass caught due to intention and fishing technique (Gabelhouse and Willis 1986). This is a possibility as to why a statistically significant relationship did not exist between largemouth bass length caught through angling and CWH abundance. Because the angling procedure involved using the same YUM Dinger lure and large hook size, anglers fishing on these lakes could have been unknowingly size-selective. Electrofishing is known to be less size-selective than angling, as most fish of differing sizes are able to be shocked and collected. Results of electrofishing showed that this method had a significant relationship to building density and fish length. This could simply be the result of less size-selectivity, or a relationship between fish length and CWH abundance. It is also worth noting that largemouth bass living in high development lakes take longer to achieve trophy lengths in the fishery compared to bass living in undeveloped lakes, as the growth rates of small largemouth bass are positively correlated with a higher presence of CWH due to higher predation (Gaeta et al. 2011).

This negative relationship between electrofishing fish lengths and building density is called further into question when observing the CPUE trends (Figure 5). As building density increased, the CPUE for electrofishing also increased significantly. The reason for this could be a change in fish community structure in lakes with more residential presence. Lakes with higher angler pressure due to high building density could change the lake fish community from one once dominated by the now largely harvested walleye (*Sander vitreus*), for example, to one now dominated by largemouth bass (Hansen et al. 2015). It would be helpful in a future study to see how fish communities are made up in lakes with high building density. Another influencer of high electrofishing CPUE values are docks acting as aggregating structures. It has been known that although they do not play an ecological role in lakes, docks and piers may provide a type of structure to fish communities (Sass 2009). Another possibility for a high CPUE in electrofishing were that the two lakes with the highest building density, Johnson and Arrowhead Lake, were the smallest lakes studied. The fish population may have had less littoral habitat available to them, and therefore were more likely to be immobilized by currents put out by the electrofishing boat.

Hyperstability could also be coming into play as electrofishing CPUE rises due to increased residential development. It is possible that CWH does not have a significant role in the formation of a hyperstable population. It was predicted that a high CPUE may indicate a higher presence of CWH. This is true in the case of angling, but not in electrofishing (Figure 4). However, hyperstability is related to areas of high aggregation (Erisman et al. 2011). If lakes with high building density have low CWH abundance, CWH is not the cause of the high electrofishing CPUE observed. There may be other forces at play other than CWH that influenced these high catch rates. The differing protocols behind angling and electrofishing may have had a role in differing CPUE values as well.

These opposite results found in CPUE values when comparing angling to electrofishing could have implications in determining management decisions of these north temperate fisheries. The nature of electrofishing often limits catchability compared to angling. Such problems with range limitations (the distance in which fish can respond to electricity), water conductivity/temperature and difficulty in reaching the correct currents to produce an immobilizing response, water visibility and clarity, and the lower likelihood of netting fish located at lower depths make electrofishing much different from angling tactics (Wisconsin Department of Natural Resources 1974). Because of this, often angling data has been used for management decisions due to its accessibility and less-limiting nature. Carefully screened angling data has been shown to represent size structure data observed through electrofishing, and it has been documented in the past that positive correlations exist between angling and electrofishing catch rates (Isaak 1992). However, our results showing disparity between size structure and CPUE due to capture methods shows that managers should also consider fisheries independent data (i.e. electrofishing) when deciding population management tactics. It might be necessary to take these extra steps in order to compare angling and electrofishing data in order to better understand and manage north temperate lake fisheries.

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APPENDIX

TABLE 1. Location of the twelve study lakes in 2018 including their CWH density (previously measured in Sass et al. (2009)) and shoreline building density.

Lake ID	Lake Name	Latitude	Longitude	Total CWH Logs per km of Shoreline	Building Density 100m from Shoreline
CP	Camp Lake (Pen Basin)	45.9979203	-89.7332605	85	0
CS	Camp Lake (Small Basin)	45.9979203	-89.7332605	85	0
LK	Little Rock Lake	45.9957442	-89.7024859	343	0
WS	Wabasso Lake	45.9748566	-90.002212	–	0
WC	Wildcat Lake	46.1729139	-89.6169457	–	6.583782429
LC	Little Crooked Lake	46.1508532	-89.6951094	80	10.43926107
LH	Lake of the Hills	45.9839078	-89.2447399	–	16.17612086
FD	Found Lake	45.9505119	-89.4531966	92.5	24.36329363
TO	Towanda Lake	45.9385442	-89.7077093	154.2857143	26.14759985
LR	Little Spider Lake	45.9711465	-89.7084172	82.5	33.67430914
JS	Johnson Lake	45.89974	-89.72062	2.5	36.0974511
AR	Arrowhead Lake	45.9063386	-89.6902355	17.5	43.18095508

FIGURE 1. Map of study lakes in Vilas County, Wisconsin, USA.

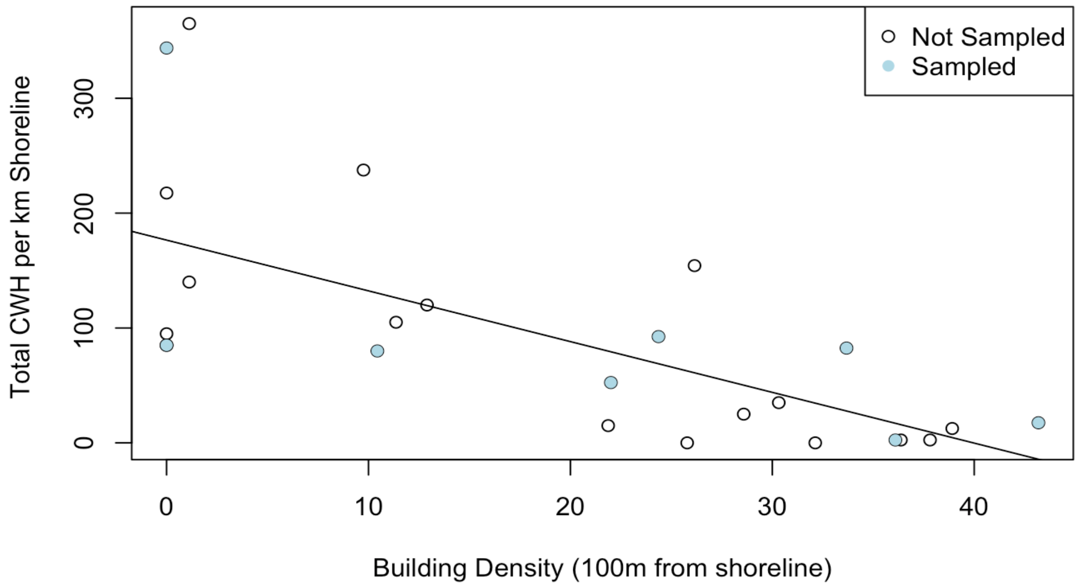

FIGURE 2. Relationship between residential development and CWH abundance in both the lakes sampled in 2018 (closed circles) as well as those being sampled in coming years (open circles; $p = 0.000185$, $R^2 = 0.4249$).

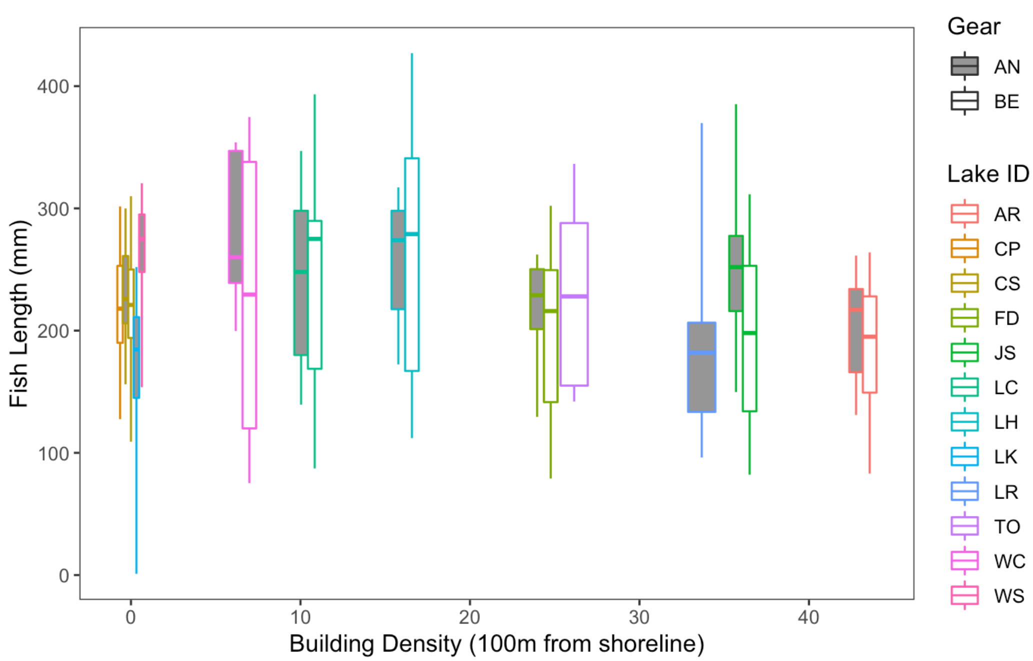

FIGURE 3. Largemouth bass length measurements along a gradient of shoreline building density. Boxplots are sorted by gear type as well as gradient of building density in the lakes studied. Length of boxplot is determined by a 95% confidence interval quantile.

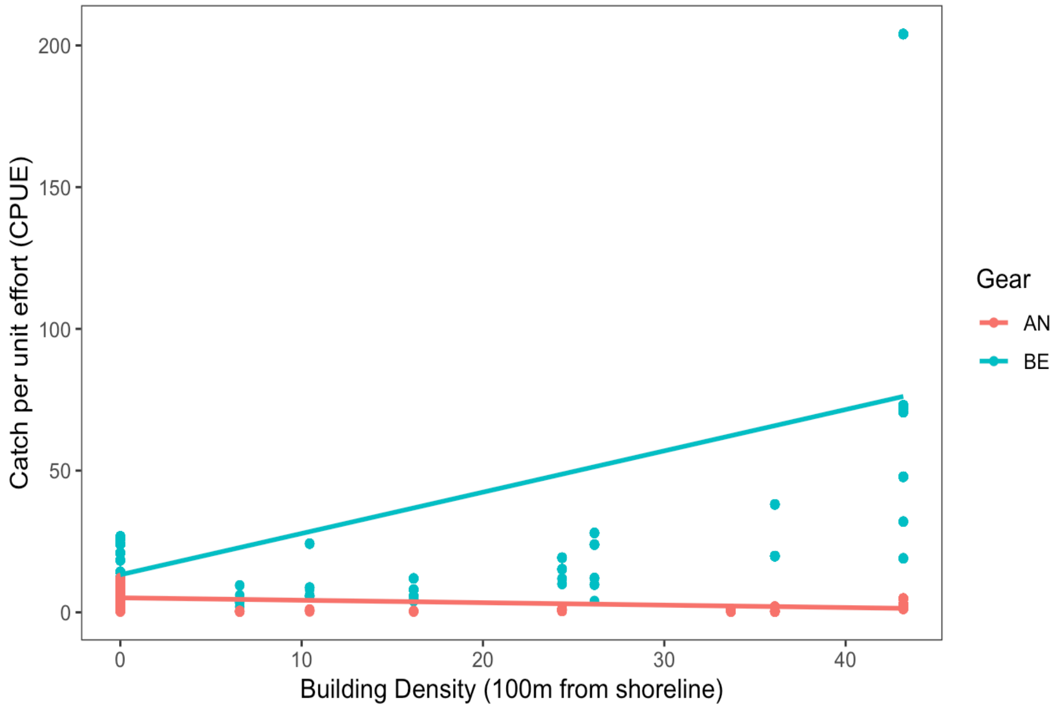

FIGURE 4. Comparison between angling and electrofishing with CPUE and shoreline building density with linear trend lines.

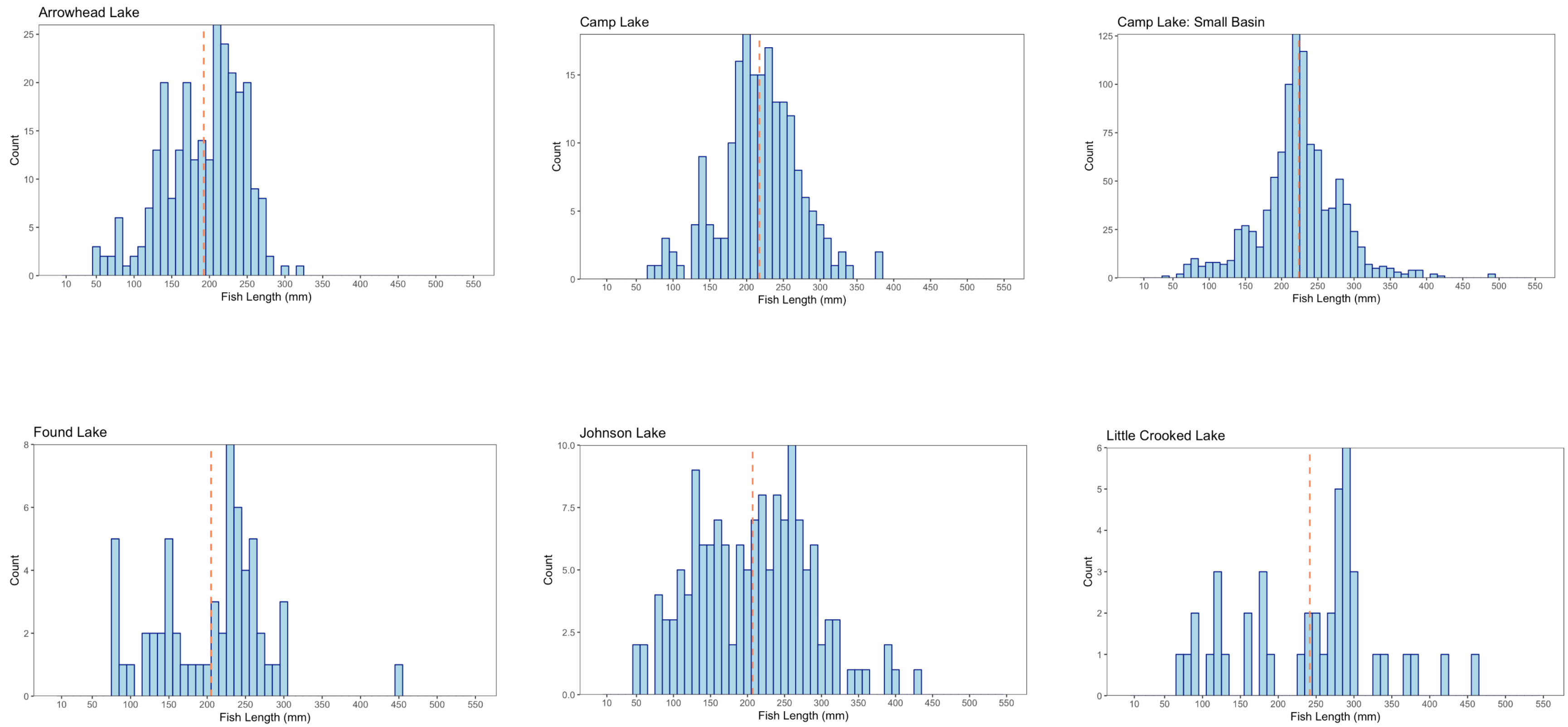

FIGURE 5. Histograms for each lake studied determining the size structure of largemouth bass caught through both electrofishing and angling. Means are noted by a vertical dotted line.

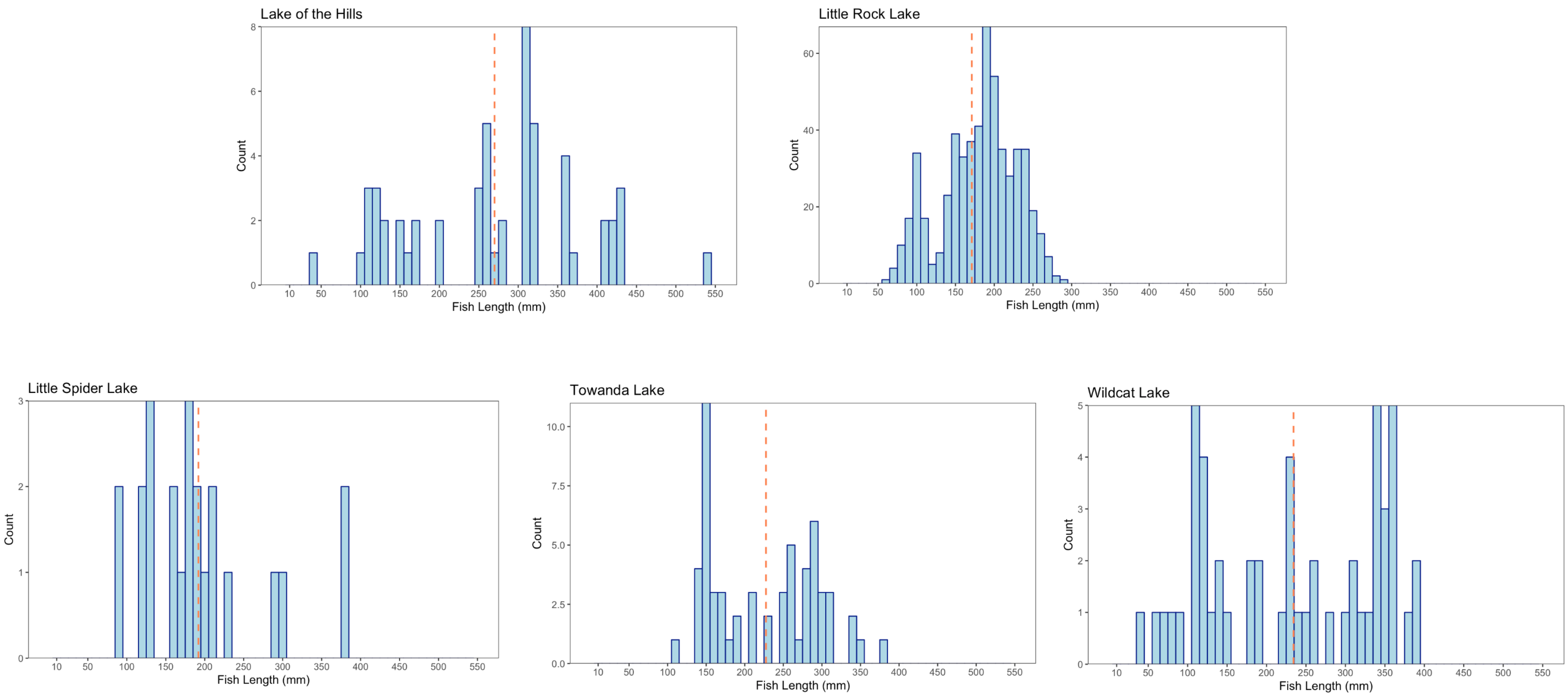

FIGURE 5 (CONTINUED). Histograms for each lake studied determining the size structure of largemouth bass caught through both electrofishing and angling. Means are noted by a vertical dotted line.