A Comparison of a Fixed vs. Stratified Random Sampling Design for Electrofishing Largemouth Bass in Oklahoma

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Abstract: Two sampling designs were compared to evaluate Oklahoma's standardized sampling procedures for electrofishing largemouth bass (*Micropterus salmoides*) in reservoirs. Historical subjectively-chosen fixed sites were sampled along with random sites stratified by habitat category (good, fair, and poor) at four reservoirs in central Oklahoma. The stratified categories were determined by a composite of the shape/structure of the bottom, substrate type, and type of cover available in 0.5-km transects. Using the stratified random design, three of the four reservoirs showed significantly different ($P \leq 0.05$) catch per unit effort (CPUE, fish h^{-1}) between the habitat categories. Good habitat at those three lakes exhibited the highest CPUE while poor habitat was the lowest. CPUE was significantly lower ($P \leq 0.05$) at the stratified random sites than the fixed sites at two of the four reservoirs. Furthermore, Kolmogorov-Smirnov tests and visual observations indicated length frequencies between the two sampling designs were similar. Although CPUE results were mixed between the two designs, the stratified random sampling design was recommended for largemouth bass electrofishing. This design strengthens standardized sampling procedures over the fixed site design by meeting the assumption of random samples in probability statistics which allows comparisons among reservoirs and years to be made. It also likely provides more representative estimates of the population without jeopardizing precision when compared to the fixed site design.

Keywords: reservoir, catch rate, size structure, *Micropterus salmoides*

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Standardized sampling procedures are used by most fisheries management agencies to evaluate fish populations over time and between reservoirs in a region or state. Effective comparisons of fisheries data not only require identical gear types fished in a similar manner, but also a sampling design that allows such comparisons (Bonar et al. 2009). In 1977 the Oklahoma Department of Wildlife Conservation (ODWC) developed "Standardized Sampling Procedures (SSP) for Lake and Reservoir Management Recommendations" (Erickson 1978). Since that time, standardization of gear and methods has been modified through periodic revision to obtain more accurate and precise estimates of population data.

Oklahoma has historically used subjectively-chosen fixed site sampling in their SSP. Fixed sites are typically used to monitor changes in those sites over time but may be more biased than random sites (Bonar et al. 2009). These sites are generally used as an index of the population although biases in abundance and length frequencies can occur (Wilde and Fisher 1996, Larsen et al. 2001, Dauwalter et al. 2004). Additionally, characteristics of fixed sites may change at a disproportional rate to the rest of the reservoir (Noble et al. 2007). In contrast, a sampling design with a random component alleviates many of these biases, allows for comparisons to be made between reservoirs, and meets the assumptions of a probability statistics (Bonar et al. 2009).

Although random sampling designs are thought to be more robust and less biased, they can be more labor intensive. Due to the higher variability associated with random sites, these designs often require more effort to obtain precise estimates (Quist et al. 2006). To improve precision, stratified random designs perform better than simple random designs in nearly all cases (Hansen et al. 2007). Consequently use of a stratified random design was evaluated for ODWC's largemouth bass electrofishing SSP. The objectives of this study were to compare the mean catch per unit effort (CPUE, fish h^{-1}) estimates and variability, as well as size structure, associated with a fixed site versus a stratified random sampling design for electrofishing largemouth bass.

Methods

Study Area

This project was conducted at four reservoirs in central Oklahoma. Two of the reservoirs, Arcadia and Wes Watkins, had historically low largemouth bass mean CPUE (<25 fish h^{-1}), while mean CPUE at the other two, Konawa and Dripping Springs, has been historically high >100 fish h^{-1}. The four reservoirs were 462 to 679 ha and included a wide variety of habitat types typically found in Oklahoma, ranging from bare sand flats to timbered, rocky dropoffs (Table 1). The most common types of aquatic vegetation found in the four reservoirs included cattails (*Typha* spp.), common reed (*Phragmites australis*), water willow, (*Justicia americana*), long-leaf pondweed (*Potamongeton nodosus*), coontail (*Ceratophyllum demersum*), and smartweed (*Polygonum* spp.).

Table 1. Area (ha), shoreline length (km), mean depth (m), trophic state, historic CPUE (fish h^{-1}), and habitat category for four reservoirs sampled from 2009–2011 in Oklahoma.

Reservoir	Area	Shoreline length	Mean depth	Trophic state	Historic CPUE	Habitat category		
						Good	Fair	Poor
Arcadia	679	42	5.37	Eutrophic	20.7	19%	42%	39%
Wes Watkins	462	27	3.75	Eutrophic	23.7	30%	48%	22%
Dripping Springs	546	32	5.19	Hypereutrophic	114.0	43%	48%	9%
Konawa	465	35	4.29	Mesotrophic	159.4	40%	41%	19%

Field Sampling and Habitat Evaluation

The four reservoirs were electrofished during the spring 2009, 2010, and 2011. Samples were collected with a double-boomed electrofishing boat equipped with a 5.0 Smith-Root GPP set at 60 pulses sec^{-1} of direct current with voltage and amperage set for optimal output (watts) depending on conductivity. Sampling coincided with the pre-spawning and spawning periods for largemouth bass, which typically occurs in Oklahoma between the end of March and beginning of May when water temperature range from 15 to 23 C. Electrofishing was conducted during the day at 18 fixed sites that had been traditionally sampled by ODWC biologists; these sites had been chosen to obtain high catch rates. In addition, 18 random sites that were stratified in proportion to the habitat types at each reservoir were also sampled. All electrofishing transects were 15 min long, and largemouth bass collected from each site were counted, measured (total length, mm), and weighed (g) before being released.

In the stratified random sampling design, the number of sites sampled in each habitat category (good, fair, and poor) was proportional to the percent of each category available at each reservoir. It was previously determined that a 15-min unit of effort traversed approximately 0.5 km of shoreline. Therefore, the entire shoreline of each reservoir was surveyed prior to sampling in 2009 and a habitat category was assigned to each 0.5-km segment. In an attempt to objectively classify the habitats, habitat types were defined by three criteria: shape/structure of the bottom, substrate type, and type of cover. Shape/structure was determined by sonar, while substrate samples were collected or determined with a probe. Cover was determined by visual observation and sonar. Aquatic vegetation was generalized and treated as one type of cover regardless of type or density. If several different habitat types within the three criteria were encountered in a given segment or transect, the most prevalent type determined the classification. A point value based on largemouth bass spawning habitat preference was then assigned to the specific type within each of the three habitat criteria (Table 2; Stuber et al. 1982, Nack et al. 1993, Lyons 1995, Waters and Noble 2004, Sammons and Maceina 2005). The points from the three criteria within each transect were then added together to determine habitat category (0 to 7 points — poor, 8 to 11 points — fair, 12 to 15 points — good). These total point values used to determine the category were arbitrarily determined based on input from ODWC biologists on their experience with all possible combinations of the three criteria.

The CPUE was calculated by reservoir for each habitat category and analyzed with a two-way mixed model analysis of variance (ANOVA) to determine differences in catch rates between habitat categories. All data were log transformed ($y = \log_{10}[x+1]$) to correct for departures from normality. The yr effect was blocked to account for differences between yrs and treated as a random variable. If results were significant ($P \leq 0.05$), Tukey-Kramer tests were then performed to identify which catch rates in the three habitat categories differed at each reservoir.

At each reservoir, mean CPUE at fixed and stratified random sites were compared using a two-way mixed model ANOVA. All data was $\log_{10}$– transformed to normalize data and yr was blocked to account for differences between yrs. Tests were performed at a significance level of $P \leq 0.05$. To measure the precision of catch rates at fixed versus random sites, the coefficient of variation of the mean ($CV\bar{x} = SE\bar{x}^{-1}$), where SE and $\bar{x}$ are the sample standard error and sample mean, respectively, was calculated at each reservoir (Cyr et al. 1992). The ODWC has two target levels of precision as indicated by the $CV\bar{x}$. The first target is a $CV\bar{x} = 0.25$ which is adequate to make most management decisions while a $CV\bar{x} = 0.125$ is used in intensive or research studies. In addition, the mean number of samples needed to achieve these targets was calculated for fixed and random sites at each reservoir (Wilde and Fisher 1996).

Table 2. Criteria used to stratify habitat for electrofishing largemouth bass in Oklahoma. Points from each criteria are added to give a composite score for each transect. Good habitat equals 12 to 15 points, fair equals 8 to 11 points, and poor equals 7 points or less.

Shape/Structure	Point value	Substrate	Point value	Cover	Point value
Flat in a cove	5	Gravel (<75 mm)	5	Aquatic vegetation	5
Points	4	Clay	4	Timber/brush	4
Moderate slope (≈30° to 45°)	3	Sand	3	Rock (>610 mm)	3
Mainlake flat	2	Rock	2	None	0
Steep slope (≈45° to 60°)	1	Bedrock	1		
Cliff	0	Silt/mud	0		
Unknown	0	Unknown	0		

Length frequencies for largemouth bass were also compared between fixed and random sites each yr at lakes with adequate sample sizes (Miranda 2007). A Kolmogorov-Smirnov Test was used to determine differences in size structure ($P \leq 0.05$). Length-frequency histograms were also visually inspected as recommended by Neumann and Allan (2007) to confirm differences detected by Kolmogorov-Smirnov tests since it becomes sensitive to large sample sizes.

Results

Habitat Effects on Catch Rates

Dripping Springs and Konawa reservoirs, the high-catch reservoirs, were classified with 43% and 40% good habitat, respectively, while the low-catch reservoirs, Arcadia and Wes Watkins reservoirs, had 19% and 33% good habitat, respectively. Fair habitat comprised 41%–45% of total habitat among all reservoirs. Consequently, the low-catch reservoirs had a higher proportion of poor habitat as compared to the high-catch reservoirs (Table 1). Mean CPUE was highest in good habitat and lowest in poor habitat for all reservoirs ($F \geq 13.18$, df = 2,103, $P < 0.001$), except Drippings Springs Reservoir, where mean CPUE was similar among habitat types ($F = 1.21$, df = 2,103, $P = 0.302$, Figure 1). Mixed results were observed for the fair habitat category. For example, catch rates in fair habitat were different from other habitats at Konawa and Wes Watkins reservoirs but were similar to those in good habitat at Arcadia Reservoir (Figure 1).

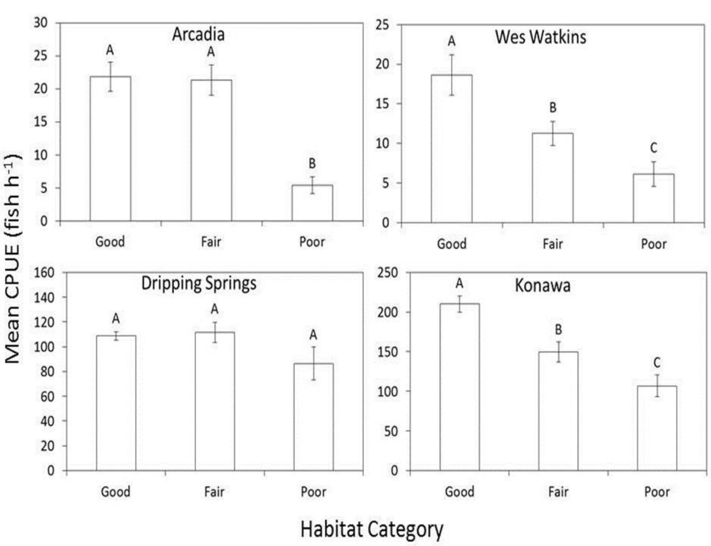

Figure 1. Mean CPUE (fish h^{-1}) at good, fair, and poor habitat for four Oklahoma reservoirs in 2009, 2010, and 2011. Error bars indicate 1 standard error. CPUE within habitat categories in each reservoir that share a letter were similar (Tukey-Kramer, $P \leq 0.05$).

Table 3. CPUE (standard error), coefficient of variation of the mean ($CV_{\bar{x}}$), number of samples needed to obtain a $CV_{\bar{x}} = 0.25$ and $CV_{\bar{x}} = 0.125$, F value, and P for fixed (F) and stratified random (SR) sampling designs at four reservoirs in Oklahoma from 2009–2011 (ANOVA, $P \leq 0.05$).

							Number of samples	
	Design	*n*	CPUE (SE)	$CV_{\bar{x}}$	*F*	*P*	$CV_{\bar{x}}$ 0.25	$CV_{\bar{x}}$ 0.125
Arcadia	F	54	20.22 (1.84)	0.09	7.80	0.006	7	29
	SR	54	13.41 (1.77)	0.13			15	60
Wes Watkins	F	54	14.74 (1.42)	0.10	1.26	0.264	8	32
	SR	54	14.44 (1.88)	0.13			15	58
Dripping Springs	F	54	113.11 (4.85)	0.04	1.53	0.220	2	6
	SR	54	105.19 (4.80)	0.05			2	7
Konawa	F	54	202.74 (9.96)	0.05	13.06	<0.001	2	8
	SR	54	156.81 (10.03)	0.06			4	14

Effect of Sample Design on Catch Rates

Mean CPUE was significantly lower at stratified random sites than fixed sites at Arcadia ($F = 7.80$, df = 1,104, $P = 0.006$) and Konawa ($F = 13.06$, df = 1,104, $P < 0.001$) reservoirs. Although CPUE was similar among habitats in the other two reservoirs, it ranked lower at the stratified random sites (Table 3). In Arcadia and Konawa reservoirs, mean CPUE at random sites was 66% and 77%, respectively, of that at fixed sites, while in Dripping Springs and Wes Watkins reservoirs, it was 93% and 98%, respectively, of the fixed site mean.

Data collected from the stratified random sites were similar to, although less precise than, the fixed sites as the $CV_{\bar{x}}$ was 20%–44% greater than that from fixed sites (Table 3). Under current ODWC sampling protocol (18 samples based on reservoir size) a $CV_{\bar{x}} = 0.25$, as indicated by mean CPUE of largemouth bass, could be achieved using either fixed sites or stratified random sites at all four reservoirs. This level of precision was easily met at the high-catch reservoirs, Dripping Springs and Konawa, where a maximum of 4 samples was needed for stratified random sites. The low-catch reservoirs required 7 samples for fixed sites at Arcadia Reservoir and 8 samples for fixed sites at Wes Watkins Reservoir while 15 samples were needed to reach this target level of precision for stratified random sites at both reservoirs. Data from the high-catch reservoirs were also precise enough to achieve a precision target of $CV_{\bar{x}} = 0.125$ using both fixed and stratified random sites, although neither design was precise enough at the low-catch reservoirs. At least 29 samples were required to achieve a $CV_{\bar{x}} = 0.125$ using fixed sites at Arcadia Reservoir, while 32 were needed at Wes Watkins Reservoir; approximately twice as many were needed to achieve this goal at stratified random sites.

Kolmogorov-Smirnov tests indicated that estimated size structure of the population was similar between fixed and random sites in almost every yr at the high-catch reservoirs although a significant difference ($P < 0.001$) was detected between fixed and random sites at Dripping Springs Reservoir in 2009. However, visual inspection of the length frequency histograms suggested the difference in size structure of largemouth bass collected at fixed and random sites was insignificant.

DISCUSSION

Habitat Evaluation

The stratified random design that was developed for electrofishing largemouth bass in Oklahoma has the potential to be an effective design utilizing habitat preference when fish are in a prespawn or spawning state. A stratified random design in Oklahoma may also be advantageous because the number of samples required for largemouth bass sampling (24) in large reservoirs (i.e., >4047 ha) by the SSP is likely too few to allow an adequate number of samples to be taken in less-common habit types using a simple random design. Under-sampling could cause a high proportion of samples to be taken in one habitat category which would consequently lead to an inaccurate estimate. Higher variability would also be expected, not only within a yr, but also among yrs. A random design stratified by habitat will ensure samples are taken from a wide range of habitats that may influence CPUE. However, catch rates were similar among habitat types in one of the four study reservoirs; therefore, stratification may not be necessary at all reservoirs as a simple random design should produce similar results and should be considered.

In order for the stratified habitat design to be effective, correct identification of habitat types is critical. The habitat classification criteria design employed in this study allows for some error as several habitat types were grouped together as good, fair, or poor. Misidentification of one of the three criteria in a segment would likely still result in correct classification unless point totals are near the breaks that separated the three habitat types.

Although a stratified random design may produce more accurate and precise samples, there are issues that must be considered when evaluating habitat. First, water-level fluctuations can greatly influence habitat availability (and thus quality) within electrofishing transects (Irwin and Noble 1996). Thus, electrofishing sampling should be conducted at similar water levels as those present during habitat evaluation to ensure that water levels do not decrease the validity of the habitat classification. Second, it may be impractical to evaluate habitat of the entire shoreline of a large reservoir due to manpower and funding constraints. However, lately GIS and side-scan sonar techniques have been successfully used to classify habitat in large lotic systems (Kaeser and Litts 2010, Kaeser et al. 2013), and these methods may have promise to measure habitat quickly and cheaply, even in large reservoirs. Obviously, habitat evaluation requires more time and resources prior to sampling. However, in many cases reservoir habitat does not change through time very rapidly; thus, habitat evaluation may be used to stratify electrofishing surveys for many years before needing to be redone.

Fixed vs. Stratified Random Design

Results were mixed when comparing fixed and stratified random designs. Differences and similarities were found at both high- and low-catch reservoirs, indicating that relative abundance had little or no impact on the effectiveness of the two designs. The two reservoirs that had similar mean CPUE between the two designs still provided lower estimates of relative abundance at random sites than fixed sites, which is similar to other studies (Hubbard and Miranda 1986, Quist et al. 2006, and McClelland and Sass 2012). Furthermore, studies have been mixed in their findings when comparing fixed and random designs. King et al. (1981) and Bonvechio et al. (2008) found no significant differences between fixed and random sites while electrofishing for largemouth bass while Hubbard and Miranda (1986) concluded random sites had significantly lower catch.

Fixed and stratified random sites at all reservoirs achieved a target $CV\bar{x}$ of 0.25 with 18 annual samples, which was enough precision to determine a drastic change in the population. In contrast, only the high-catch reservoirs were able to achieve a target $CV\bar{x}$ of 0.125 using either sampling design with 18 samples. Neither fixed site nor stratified random sampling designs met this target at low catch reservoirs. Presumably samples in reservoirs characterized by largemouth bass CPUE between 25–100 fish h^{-1} may be unable to achieve a target $CV\bar{x}$ of 0.125 with stratified random sites, but could using fixed sites.

The size structure in both the fixed and stratified random designs was similar in virtually all lakes and yrs. These results are similar to Bonvechio et al. (2008) although Hubbard and Miranda (1986) found PSD and RSD-38 values to be significantly higher at fixed sites. The results from this study suggest that both sampling designs provided representative estimates of the size structure for the largemouth bass populations at the four reservoirs in Oklahoma.

Although results in this study were mixed, the stratified random design was recommended from a theoretical standpoint because the estimates are likely less biased (Wilde and Fisher 1996, Larsen et al. 2001, Dauwalter et al. 2004) and provide a more representative relative abundance estimate of the population. This project demonstrated that a stratified random sampling design may improve abundance estimates without jeopardizing precision as compared to a fixed site design. In addition, it strengthens standardized sampling procedures by allowing for comparisons, both among yrs and among reservoirs, to be made and a wider range of statistical analysis to be performed, as it meets the assumptions of probability statistics. Periodic and continued evaluation of sampling designs used by state fish and wildlife agencies is important to assess statistical rigor, sampling effectiveness, and efficient use of manpower.

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