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Effect of Sample Duration on Catch Rate and Size Structure Data for Blue Catfish Collected by Low-Frequency Electrofishing

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Abstract
Although low-frequency, pulsed-DC electrofishing is considered the most effective method for sampling Blue Catfish *Ictalurus furcatus* in reservoirs, efforts to improve sampling efficiency have not been fully explored. Optimizing sampling duration can reduce cost and effort if shorter sample times still produce precision similar to that of longer samples. We compared several catch rate and size structure metrics from the first and second 5-min intervals of 10-min low-frequency electrofishing samples for Blue Catfish in three Oklahoma reservoirs ($N = 40$ sites total). The total Blue Catfish CPUE ($CPUE_{Total}$), CPUE of preferred-length fish (>760 mm; $CPUE_{760}$), mean TL, proportional size distribution (PSD), and PSD of preferred-length fish did not significantly differ between sampling intervals. One reservoir had a higher proportion of 200–299-mm fish in the second 5-min interval; however, no other differences in length frequency or other size metrics were detected between the first and second 5-min intervals in any reservoir. Sampling precision met the target level (relative standard error = 20) for $CPUE_{Total}$ but not $CPUE_{760}$ during both the first 5 min and the full 10-min sample at all reservoirs. Monte Carlo simulation indicated that 10 samples would be needed to achieve the target precision (relative standard error ≤ 20) for $CPUE_{Total}$ and 38–65 samples would be needed for precise $CPUE_{760}$ metrics regardless of sample duration. In fisheries with moderate catch rates like those we observed (150–500 fish/h), we recommend short-duration (i.e., 5-min) sampling because data of the same quality can be collected with reduced cost and effort. For situations in which sampling precision is low (e.g., $CPUE_{760}$), we recommend increasing the number of replicate 5-min samples. Using shorter sample durations provides a method for managers to obtain quality population data more efficiently, allowing time for other worthwhile management activities that would otherwise not be possible.

Proper management of fish hinges on the ability to accurately and precisely measure population characteristics (Zale et al. 2012). Sampling efficiency is also paramount because natural resource agencies typically have limited resources (i.e., time and money) to effectively sample and manage waterbodies. Although sampling accuracy and precision are typically most important for effective management, quality sampling methods may not be practical if they require more time and effort than are available (Bodine et al. 2013). Given these requirements and limitations, practitioners often explore strategies that improve the efficiency of accurate and precise sampling gears. Such a strategy can potentially free up available resources that could then be applied to managing other

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fisheries, effectively improving the ability to manage all resources.

Management of Blue Catfish *Ictalurus furcatus* populations has historically been challenging because the most accurate and precise sampling gears are also labor intensive. Low-frequency electrofishing (LFE) is often regarded as the best option for sampling Blue Catfish because it produces higher catch rates and lower size bias than any other available sampling gear (Buckmeier and Schlechte 2009; Bodine and Shoup 2010; Evans et al. 2011). Bodine et al. (2011) reported that a simple random sampling design with 10–20 independent replicate samples is sufficient for accurately estimating population metrics. Despite these attributes, LFE also requires more labor (i.e., person-hours) to conduct a typical sample than most other available gears. A typical LFE sample is conducted in pelagic habitats where fish can surface up to 100 m from the electrofisher, requiring additional "chase boats" and staff to collect surfaced fish (Bodine and Shoup 2010). Most investigators use 10–15-min samples (Cailteux and Strickland 2007; Bodine and Shoup 2010), which can be costly when sampling numerous stations (i.e., up to 20; Bodine et al. 2011) with a six- to nine-person crew and two to three boats. In fact, a day of electrofishing easily requires two to three times the effort of most fish sampling events. Shorter-duration samples could save significant time and money if the same quality of work can be accomplished in less time. Although reducing sample time by 5 or 10 min does not sound extensive, it must be considered that shorter samples also reduce the time spent handling fish (which often takes longer than the sample duration), and these time savings are multiplied by the large number of crew members to achieve a substantial savings of person-hours (e.g., completing one site 15 min faster with 9 people saves 2.25 person-hours/site, a savings that is realized across every site sampled). Furthermore, shortening of samples may allow sufficient sites to be sampled such that one less trip to the lake is possible, adding considerable travel cost savings (i.e., 3 vehicles typically required on each trip to the lake). However, it is unknown whether shorter-duration samples would lead to increased variability in catch rate or size structure because fewer fish are captured or because the length of time before fish begin to surface varies. In addition, shorter-duration samples could also lead to a size bias if different sizes of fish surface at different rates. Therefore, we conducted the present study to determine whether shorter-duration (5-min) samples provide data quality similar to that attained with long-duration (10-min) samples.

METHODS

The LFE trials were conducted in three eutrophic, main-stem impoundments (Kaw, Keystone, and Oologah reservoirs) in north-central Oklahoma to examine the effects of 5- versus 10-min sample durations on catch rate and size structure data for Blue Catfish. Kaw Reservoir is 6,896 ha, with an average depth of 7.6 m; Keystone Reservoir is 9,555 ha, with an average depth of 7.0 m; and Oologah Reservoir is 11,922 ha, with an average depth of 5.8 m. Each reservoir was electrofished with common LFE methods following the procedures of Bodine and Shoup (2010). In short, samples were taken during summer with a Smith-Root Model SR-16EB boat equipped with a Model 5.0 generator-powered pulsator and two Model SAA-6 anode arrays (Smith-Root, Inc., Vancouver, Washington). Direct current at 15 pulses/s was used at the high-voltage setting of the generator-powered pulsator. Two chase boats, each with two dipnetters, were used to collect fish. No netters were used on the electrofishing boat. Sampling sites were randomly selected from Kaw and Keystone reservoirs (12 sites each) and the larger Oologah Reservoir (16 sites) for a total of 40 paired samples. Sample sizes were chosen to ensure collection of an unbiased size structure and provide adequate precision for catch rate data (relative standard error [RSE] < 20; Bodine and Shoup 2010; Bodine et al. 2011). Electrofishing was performed for 10 continuous minutes, and fish that were caught during the first 5 min and the second 5 min were placed in separate live wells.

We chose to sample a given site for 10 min, with fish captured in the first and second 5-min intervals recorded separately. Size structure is usually more similar within sites than among sites, presumably because Blue Catfish schools are composed of similar-sized fish (Bodine et al. 2011). Therefore, our approach is a better direct comparison of sample duration than an approach sampling for different durations at different locations. Furthermore, comparing the quality of data from the first 5 min with that from the second 5 min (or the full 10 min) from the same school is the most direct approach given the research question (i.e., "Does data quality change if sampling at a given location continues for 10 min, or is a 5-min sample sufficient to accurately and precisely quantify fish in that location?"). Although our approach was most directly related to the context of the sampling process, it produced an analysis tradeoff in that fish caught during the first 5 min would clearly be autocorrelated with those caught over the full 10-min sample (i.e., fish sampled in the first 5 min would be counted in both samples). To address this, we statistically compared catch rate and fish size metrics from the first 5-min interval with metrics from the second 5-min interval using an analysis that accounted for correlatedness of the two intervals at the same site (i.e., repeated-measures design). This approach assumes that if no difference is detected between the first and second 5-min samples, then the overall 10-min sample would provide information similar to that provided by a 5-min sample (but with more fish). However, because precision is heavily influenced by the number of data points included in an analysis, the RSE (i.e., coefficient of variation of the mean) from the 5-min sample was compared to the RSE from the full 10-min sample to more precisely account for how sample duration affects precision (i.e., the full 10-min sample should capture more fish, potentially resulting in a lower RSE). Relative standard error was calculated as $RSE = 100 \times (SE/mean)$.

Separate repeated-measures ANOVA tests were used to assess differences between the first and second 5-min sampling intervals for the CPUE (number/h of electrofishing) of all Blue Catfish ($CPUE_{Total}$), CPUE of preferred-length fish (>760 mm TL; $CPUE_{760}$; Gabelhouse 1984), mean TL ($\log_{10}[x+1]$ transformed), proportional size distribution (PSD; arcsine[$\sqrt{x}$] transformed), and PSD of preferred-length fish (PSD-P; arcsine[$\sqrt{x}$] transformed). Transformations were used as needed to normalize residuals in the analysis. Sites nested within reservoirs were treated as random subjects that were repeatedly measured, and reservoirs were treated as a random blocking variable. The number of samples needed to achieve a target level of precision (i.e., $RSE \leq 20$) was calculated from the 80th percentile of 1,000 resampled events as described by Dumont and Schlechte (2004). This procedure was performed for the RSE of $CPUE_{Total}$ and the RSE of $CPUE_{760}$. Length frequency distributions of Blue Catfish from each sampling duration (pooled across sites) were compared separately for each reservoir by using two-sample Kolmogorov–Smirnov (KS) asymptotic tests. The ANOVAs were performed using the MIXED procedure in SAS (SAS Institute 2013), KS asymptotic tests were performed with the NPAR1WAY procedure in SAS, and RSE analyses were conducted in Microsoft Excel using a Visual Basic script. Significance of all tests was evaluated as $\alpha \leq 0.05$.

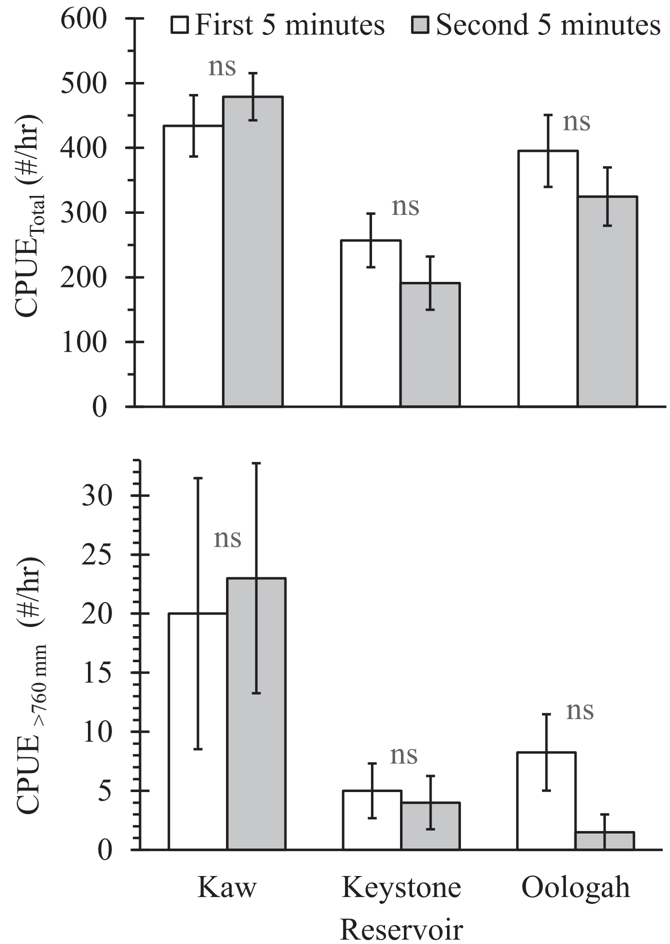

FIGURE 1. Total Blue Catfish CPUE ($CPUE_{Total}$) and the CPUE of preferred-length fish (>760 mm TL; $CPUE_{760}$) from the first 5 min or second 5 min of 10-min samples from low-frequency (15-pulses/s), pulsed-DC electrofishing in Kaw, Keystone, and Oologah reservoirs, Oklahoma (vertical bars represent ± 1 SE; ns = indicates no significant difference between sampling intervals).

RESULTS

Overall, 2,321 Blue Catfish were collected; 1,218 fish were collected in the first 5 min, and 1,103 were collected in the second 5 min. Mean CPUE (number/h of electrofishing) was not significantly different between the first and second 5 min for $CPUE_{Total}$ ($F_{1,\ 76} = 2.22$, $P = 0.14$) or $CPUE_{760}$ ($F_{1,\ 76} = 0.98$, $P = 0.33$; Figure 1). Sampling precision met target RSE levels for $CPUE_{Total}$ during all sampling intervals at all reservoirs, and no clear increase in precision occurred from longer-duration samples (Table 1). Both sampling durations required 10 or fewer samples to achieve an RSE of 20 for $CPUE_{Total}$. However, precision of $CPUE_{760}$ was poor, with RSE values ranging from 39 to 57, and both 5-min samples and the combined (10-min) samples failed to achieve the target RSE of 20 in all reservoirs (Table 1). The average number of samples required to achieve the target RSE for $CPUE_{760}$ ranged from 38 to 65, with no consistent pattern between 5- and 10-min sampling intervals.

Mean TL ($F_{1,\ 76} = 0.23$, $P = 0.63$; Figure 2), PSD ($F_{1,\ 76} = 0.02$, $P = 0.88$; Figure 3), and PSD-P ($F_{1,\ 76} = 0.05$, $P = 0.82$; Figure 3) all varied among reservoirs and between the 5-min sampling intervals, but overall there was no significant difference for any metric between the first and second 5-min intervals. Length frequency distributions were also similar between sampling intervals for Kaw (KS asymptotic test: KSa = 0.39, $P = 0.99$) and Keystone (KSa = 0.43, $P = 0.99$) reservoirs (Figure 4). At Oologah Reservoir, the second 5-min sample had a higher proportion of 200–299-mm fish relative to the first 5-min sample (KSa = 1.97, $P < 0.01$), but length frequencies otherwise had a similar shape (Figure 4).

TABLE 1. Relative standard error (RSE) and the number of samples needed to achieve the target level of precision (i.e., RSE = 20; N_{RSE20}) for the catch rate (fish/h of electrofishing) of all Blue Catfish sizes ($CPUE_{Total}$) and the catch rate of only preferred-length fish (>760 mm TL; $CPUE_{760}$) from the first 5 min and the full 10-min sample obtained by low-frequency (15-pulses/s), pulsed-DC electrofishing in three Oklahoma reservoirs (N = number of samples actually taken at the reservoir).

		$CPUE_{Total}$				$CPUE_{760}$			
		First 5 min		Full 10 min		First 5 min		Full 10 min	
Reservoir	N	RSE	N_{RSE20}	RSE	N_{RSE20}	RSE	N_{RSE20}	RSE	N_{RSE20}
Kaw	12	10.9	5	7.9	3	57.4	65	45.2	52
Keystone	12	16.1	10	16.5	10	46.3	46	46.8	46
Oologah	16	14.1	10	13.2	9	39.2	38	46.6	45

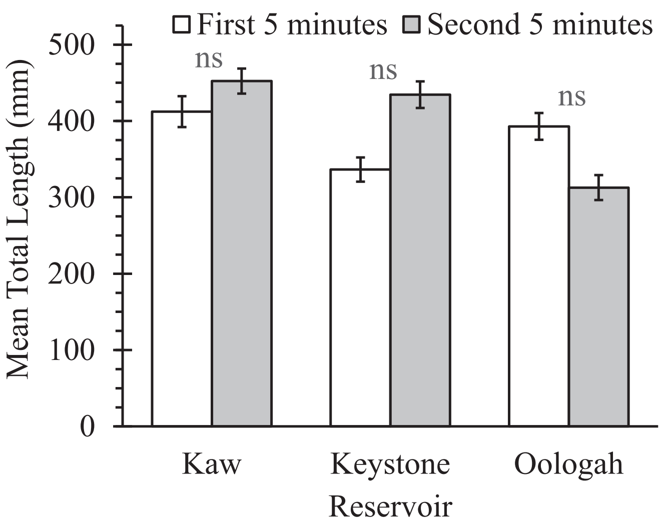

FIGURE 2. Mean TL of Blue Catfish sampled by low-frequency (15-pulses/s), pulsed-DC electrofishing during the first 5 min or second 5 min of 10-min samples from Kaw, Keystone, and Oologah reservoirs (vertical bars represent ± 1 SE; ns = no significant difference between sampling intervals).

DISCUSSION

Blue Catfish LFE requires significant labor; thus, identifying strategies that can reduce labor while still producing comparable data quality is important to resource managers. Sampling of Blue Catfish with LFE usually involves three boats (and therefore 3× the travel cost of other sampling methods) and a crew of six to nine people (which is 2–3× more people than most other fish sampling events). Although typical LFE samples often range from 10 to 15 min (Cailteux and Strickland 2007; Bodine and Shoup 2010), we found that 5-min samples produced data that were similar to those generated by 10-min samples (i.e., similarly accurate and precise). This study produced no compelling evidence that reducing sample duration to 5 min would significantly alter the precision or accuracy of abundance or size-based metrics; thus, the 5-min duration appeared to produce representative estimates. Although

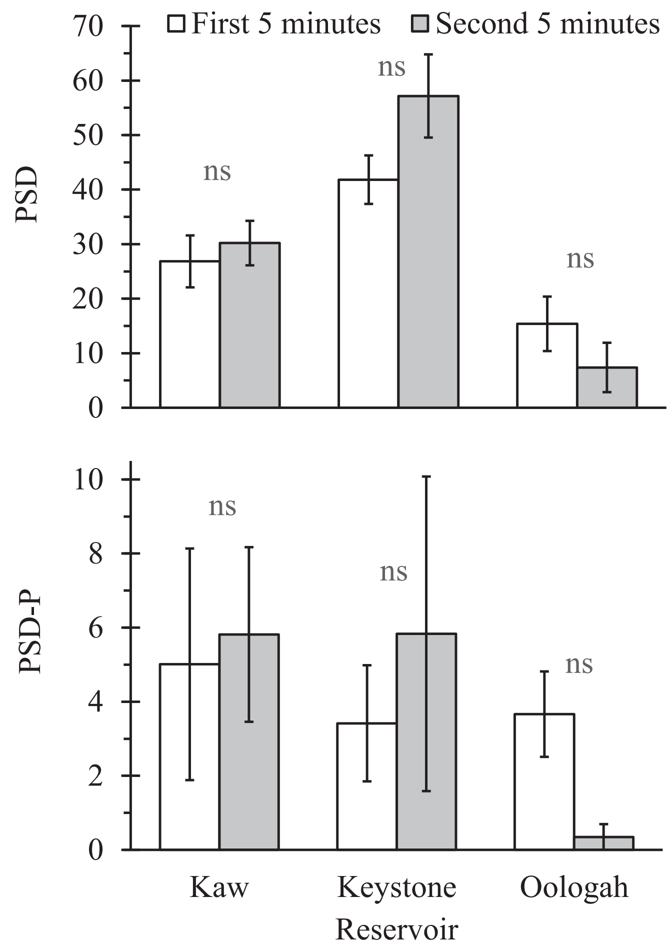

FIGURE 3. Size structure metrics (proportional size distribution [PSD] and the PSD of preferred-length fish [PSD-P]) for Blue Catfish sampled by low-frequency (15-pulses/s), pulsed-DC electrofishing during the first 5 min or second 5 min of 10-min samples from Kaw, Keystone, and Oologah reservoirs (vertical bars represent ± 1 SE; ns = indicates no significant difference between sampling intervals).

one slight difference in length frequency was observed, we believe that this difference was not large enough to alter management decisions. In most situations, the 5-min

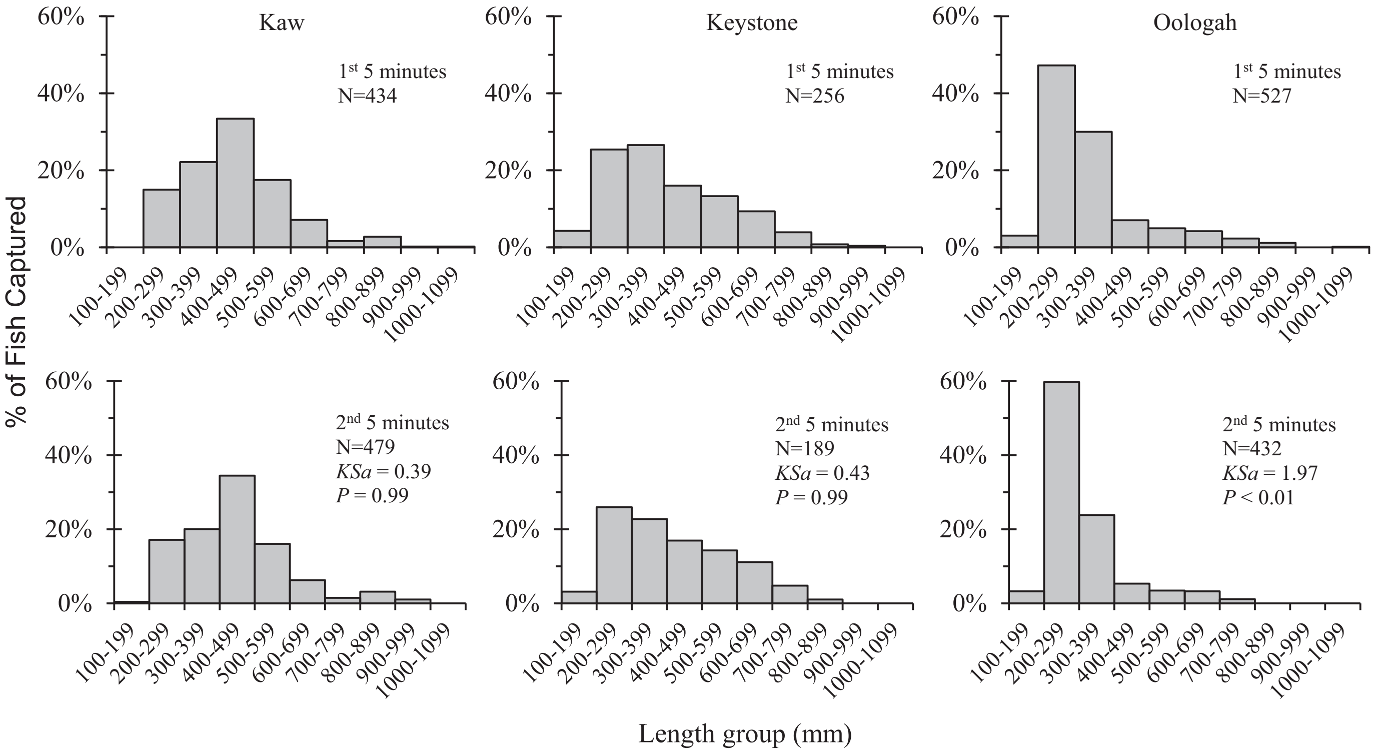

FIGURE 4. Length frequency histograms of Blue Catfish sampled by low-frequency (15-pulses/s), pulsed-DC electrofishing during the first 5 min or second 5 min of 10-min samples from Kaw, Keystone, and Oologah reservoirs. Kolmogorov–Smirnov asymptotic test statistics (KSa) and *P*-values in the bottom panels compare cumulative frequency distributions from the first 5 min and second 5 min within the same reservoir.

duration should be adequate for estimating most metrics and provides better sampling efficiency when sampling reservoirs, but the total number of fish required to meet sampling objectives should still be considered (Miranda 2007; Bodine et al. 2011; Coggins et al. 2013) and additional sites should be sampled if needed. This shorter sampling interval could lead to substantial savings, not only through reducing the electrofishing time by 5–10 min/sample but also through the time saved in working up the smaller sample of fish and perhaps by allowing enough sites to be sampled per day to shorten the number of days required to achieve the desired replication.

Biologists should be mindful of tradeoffs when selecting a sample duration. Shorter-duration samples often allow for more replicates within a sampling event, which can allow for a broader spatial representation, such as the design recommended by Bodine et al. (2011). However, short-duration samples could increase variability if both catch rates and population density are lower than those in the current study. Blue Catfish can take up to 90 s to begin surfacing (Bodine and Shoup 2010), which effectively reduces the actual capture time. This, coupled with low population densities, could produce an insufficient number of fish during 5-min samples to reliably estimate size-based metrics. Such a concern is particularly relevant for contexts in which biologists are interested in quantifying the abundance of rare, large fish (e.g., preferred- or trophy-sized fish). In these situations, biologists should consider using the longer, more traditional durations to minimize the zero-inflation and distributional problems that are common in these types of samples. It is unknown how low catch rates can be before longer-duration samples would be advisable; biologist discretion is advised until further study is conducted.

Our study provides guidance on the optimal sample duration for LFE of Blue Catfish in reservoirs, but these results should not be applied out of context. For example, the effect of current in lotic habitats could alter the timing or location at which fish surface, so our conclusions should not be extrapolated to riverine environments without additional study. Our results might also seem applicable to LFE sampling for Flathead Catfish *Pylodictis olivaris*, but this species is considerably less abundant than Blue Catfish, so the present results should not be applied to Flathead Catfish without further research. However, our study approach could easily be used by researchers to address optimal sampling for these related questions and even for less-related sampling scenarios (e.g., optimal soak time for gill nets or trap nets, optimal duration of high-frequency electrofishing, etc.). Unfortunately, there is no one-size-fits-all sampling design. Nevertheless, the more efficient 5-min sample duration is recommended for sampling Blue Catfish in reservoir habitat when practical (e.g., when large fish are not the main sampling target and when catch rates are similar to those in our study lakes), as this saves time that can be allocated to other important management efforts.

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