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[Article]

Capture Efficiency of Blue Catfish Electrofishing and the Effects of Temperature, Habitat, and Reservoir Location on Electrofishing-Derived Length Structure Indices and Relative Abundance

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Abstract.—Current sampling methods for blue catfish *Ictalurus furcatus* are suspected of being strongly biased against preferred-length fish ($\geq$762 mm in total length [TL]), making it difficult to accurately determine the species' population density and size structure. To understand this potential bias with respect to electrofishing, we conducted seasonal and habitat-specific sampling on three Oklahoma reservoirs using 15-pulse/s DC at the 100–1,000 V setting (the percent of range being adjusted to achieve 4-A output). Temperature, habitat, and reservoir section were analyzed to determine which variables were associated with the highest total catch per unit effort ($\mathrm{CPUE}_{\mathrm{Total}}$), the CPUE of preferred-length blue catfish (CPUE_{762}), and the relative stock density of preferred-length fish (RSD_{762}). Total CPUE and CPUE_{762} were significantly higher when the water temperature was 18°C or more, but the variability increased as the temperature exceeded 28°C. Catch rates were significantly higher in the upper reservoir section for all length-groups, and no differences in $\mathrm{CPUE}_{\mathrm{Total}}$ were detected among habitats (channels, points, or flats). Both CPUE_{762} and RSD_{762} were highest in channel habitats, but the high variability and low catch rates of these larger fish limit the utility of habitat-specific sampling based on these findings. Additionally, we evaluated the capture efficiency of electrofishing by creating a population with a known length-frequency distribution. This population was sampled on three separate dates to determine which length-groups were more vulnerable to electrofishing. No significant differences in catch rate were detected among the length-groups, and the mean total catch from each sample was always less than 10% of the total population. Our results indicate that low-frequency electrofishing is not size selective and provides representative samples of blue catfish between 200 and 1,000 mm TL. We recommend that sampling be conducted at temperatures between 18°C and 28°C and that standard sampling protocols adopt a stratified design that incorporates reservoir section.

Blue catfish *Ictalurus furcatus* are one of the catfish species most sought after by anglers in North America (Vokoun and Rabeni 1999). Because of their potential to produce trophy-size fish, blue catfish fisheries have been considered highly important by anglers in more than 30 U.S. states (Michaletz and Dillard 1999). As a result, the harvest pressure on larger fish can be high (Arterburn et al. 2002) and overharvest of preferred-size fish (fish $>$762 mm in total length [TL]) is suspected (Kuklinski and Boxrucker 2010). Because catfish anglers are more harvest oriented than anglers targeting other warmwater species (Wilde and Ditton 1999; Arterburn et al. 2002), enhanced management strategies may be needed to sustain quality fisheries. However, the evaluation of blue catfish populations that is needed to implement and evaluate these management strategies is difficult because current standardized sampling protocols are still in the early stages of development (Brown 2009). The inadequacy of sampling methods is consistently listed as one of the most commonly encountered management constraints in surveys of catfish managers (Michaletz and Dillard 1999; Brown 2009).

Of particular concern is the ability of fisheries managers to accurately assess population density and length structure. Many gears have been tested for their effectiveness in sampling blue catfish but have been found either to be ineffective or to result in extreme length bias (Gale et al. 1999; Vokoun and Rabeni 1999). Gill nets can be effective for blue catfish in some habitats, but they typically underrepresent fish less than 250 mm long and overrepresent those more than 350 mm long (Buckmeier and Schlechte 2009) and often yield low catch rates from which substantial effort is required to estimate population characteristics (Dumont and Schlechte 2004; Buckmeier and Schlechte 2009). Many other catfish sampling methods (e.g., slat traps, wire baskets, trap nets, fyke nets, and hoop nets) are selective for channel catfish *Ictalurus*

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punctatus but ineffective for blue catfish (Holland and Peters 1992; Sullivan and Gale 1999; Vokoun and Rabeni 1999; Buckmeier and Schlechte 2009). Low-frequency, pulsed-DC electrofishing (15 pulses/s) is the most effective approach to sampling blue catfish in reservoir and riverine environments (Justus 1996; Jons 1999; Boxrucker and Kuklinski 2008; Buckmeier and Schlechte 2009; Cailteux and Strickland 2009) and is the one most commonly used by fisheries managers (Brown 2009). Boxrucker and Kuklinski (2008) reported that electrofishing was highly efficient in sampling blue catfish (with catch rates up to 700 fish/h) and adequate for comparing annual trends in relative abundance but that further modifications to electrofishing protocols were needed to decrease the variability in catch data, evaluate the potential size bias, and determine capture efficiency.

For there to be reliable comparisons among years and lakes, the standardization of blue catfish electrofishing is essential; yet little information on the factors that should be included in such a protocol is available. Many factors are known to affect catch rates in riverine habitats; these include water temperature, depth, conductivity, fish size, and the use of chase boats (Justus 1996). However, the available information on sampling in lakes and reservoirs, especially season- and habitat-specific sampling, is limited (Vokoun and Rabeni 1999).

To properly interpret the sampling data obtained from a given gear, the capture efficiency of that gear should first be quantified using a known density and size structure of fish (Hamley 1975; Vokoun and Rabeni 1999). For most species, electrofishing is biased toward larger fish (Dolan and Miranda 2003). However, anecdotal evidence suggests that in the case of blue catfish low-frequency electrofishing is biased toward smaller ones (<762 mm; Boxrucker and Kuklinski 2008). The inability to accurately sample larger fish is particularly problematic for fisheries managers because biased size-structure estimates can create problems in evaluating population characteristics.

To provide the information needed to standardize low-frequency, pulsed-DC electrofishing for blue catfish, we conducted a study to determine (1) the effect of temperature, habitat (points, channels, flats, and standing timber), and reservoir section (upper versus lower) on total CPUE ($\mathrm{CPUE}_{\mathrm{Total}}$), the CPUE of preferred-length fish (CPUE_{762}), and length structure (i.e., the relative stock density of preferred-size fish [RSD_{762}]); (2) the precision (as indicated by the coefficient of variation) of these measurements; and (3) the capture efficiency of electrofishing for a blue catfish population with a known density and length structure.

Methods

Seasonal Sampling

Three reservoirs (Kaw, Keystone, and Oologah) in north-central Oklahoma were selected for this study based on the high abundance of moderate- and large-size blue catfish in them. The reservoirs ranged from 6,779 to 12,561 ha in size. From June 2006 through February 2007, each reservoir was electrofished twice each season (summer, fall, winter, and spring, each season consisting of three calendar months with June being the first summer month) during daylight hours. However, catch rates declined precipitously in the fall and no fish were collected from December to February, suggesting that electrofishing would not be efficient enough for standardized sampling during these months. Therefore, from March 2007 through May 2008 each reservoir was sampled only once during late spring, early fall, and winter and twice during summer.

Electrofishing was standardized using low-frequency (15-pulse/s) pulsed DC (Corcoran 1979; Quinn 1988; Justus 1996; Reynolds 1996). Ten-minute samples were taken using a 4.9 m Smith-Root aluminum boat (SR-16EB) equipped with a Smith-Root 5.0 generator powered pulsator (GPP) and two boom-mounted Smith-Root SAA-6 anode arrays. The hull of the boat served as the cathode. The 100–1,000-V range was selected on the GPP and percent-of-range adjustments were made to standardize the output at 4 ± 0.5 A (typically 60–100% of the range). In areas of very high conductivity, the electrodes were raised to reduce the amperage and meet this target output. As described by Boxrucker and Kuklinski (2008), two chase boats with two dipnetters on the bow of each were used to collect fish that surfaced away from the boats. No dipnetters were used on the electrofishing boat. As electrofishing began, the boat remained motionless until fish began to surface (typically 60–90 s). Because blue catfish schools tend to move, once fish began surfacing the electrofishing boat was slowly moved in the direction of the highest density of surfaced fish in an attempt to follow the school. If the rate of fish surfacing decreased, the boat was slowly moved again in an effort to locate more fish in areas within the sampling site that had not yet been sampled.

Each reservoir was stratified into two sections, upper and lower, that were sampled separately. The lower section began at the dam and extended 40% of the length of the reservoir. The next 20% was treated as a buffer to clearly separate the two sections. The remaining 40% of the reservoir was designated the upper section. At normal conservation pool, the

TABLE 1.—Physical and chemical characteristics of three study reservoirs in north-central Oklahoma in May 2008.

			Mean depth (m)	
Reservoir	Surface area (ha)	Conductivity (μs/cm)	Upper section	Lower section
Kaw	6,779	410.1	6.4	10.6
Keystone	9,073	989.2	6.7	10.6
Oologah	12,561	288.7	6.7	9.7

average depth in the upper section of all three reservoirs ranged from 6.4 to 6.7 m and the average maximum depth was 10.1 m. The average depth in the lower section ranged from 9.7 to 10.6 m, with an average maximum depth of 19.5 m (Table 1). The samples within each reservoir section included four replicates of three specific habitat types: points, flats, and creek channels, along with standing timber when it was available. Because timber was not present throughout the reservoir, these samples were surveyed without respect to reservoir section and were tested in a separate analysis. Each section was sampled for 10 min at each of 12 randomly selected sites (i.e., 4 points, 4 flats, and 4 creek channels, for a total of 24 sites in each reservoir). Six additional randomly selected timbered sites were sampled at Kaw and Oologah reservoirs. As Keystone Reservoir had limited timber habitat, the timber there was sampled in its entirety (three distinct sites). Because fish surfaced in locations outside of the habitat sampled, all fish were categorized as having been captured in the habitat where the sampling began. Sampling sites were spaced far enough apart that fish never surfaced in adjacent sample sites. Sampling all of the sites in a reservoir required a minimum of two full days to complete. On each sampling day, the reservoir, reservoir section, and starting location were selected at random to minimize possible temporal bias.

Analysis

All captured fish were measured (TL [mm]) and released. The temperature, habitat, and reservoir section were recorded at each site. Total CPUE, CPUE_{762}, and RSD_{762} were calculated as response variables for each sample. Temperature was categorized in 5°C groups beginning with the highest temperature recorded (32°C) and analyzed by means of a repeated-measures analysis of variance (ANOVA; i.e., sites nested within lakes were treated as subjects). Because the overall CPUE of coldwater samples (<18°C) was significantly lower than that of warmwater samples ($F_{4,\ 601} = 208.25$, $P < 0.001$; Tukey P for all comparisons < 0.001) and too low to include in a standardized sampling protocol (<30 fish/h), these samples were omitted from further analysis.

Habitat and reservoir section were analyzed by means of a two-way (habitat × section) repeated-measures ANOVA (sites nested within lakes were treated as subjects). The CPUE from timber sites was analyzed by means of a one-way repeated-measures ANOVA. Six additional sites from each reservoir were randomly selected for comparison with timber sites. All analyses were performed with the PROC MIXED procedure in SAS (SAS Institute 2004); the CPUE data were $\log_{10} + 1$ transformed to adjust for their nonnormal distribution and heteroscedasticity. For significant ANOVA effects ($P < 0.05$), subsequent pairwise comparisons of the means were made by means of Tukey's test.

The effects of temperature, habitat, and reservoir section on sample precision were evaluated for $\text{CPUE}_{\text{Total}}$ and CPUE_{762} using the coefficients of variation (CV = SE/mean) from the untransformed data. From these estimates, the number of samples needed to achieve a target CV of 0.20 was calculated as

$$N = [\text{SD}/(0.20\,\text{mean})]^2.$$

The numbers of samples needed to achieve secondary CV targets of 0.30 and 0.40 were calculated analogously.

Sampling from a Known Population (Capture Efficiency)

Study area.—Dahlgren Lake, located 18 km northeast of Lexington, Oklahoma, is a 12-ha impoundment owned and operated by the Oklahoma Department of Wildlife Conservation. At normal conservation pool, the reservoir has a maximum depth of 8 m. The lake is a closed system that had no blue catfish before the experiment. This lake was selected primarily because it had a maximum depth (>4 m) and surface area (>10 ha) that closely resembled the coves in the test reservoirs (Kaw, Keystone, and Oologah).

Sampling.—Blue catfish ($N = 281$) were collected by electrofishing at Waurika Lake and transported to Dahlgren Lake. An attempt was made to collect 40 fish per 100-mm length-group from 200 to 1,000 mm TL (seasonal sampling results suggested that fish <200 mm do not fully recruit to electrofishing gear). As fish

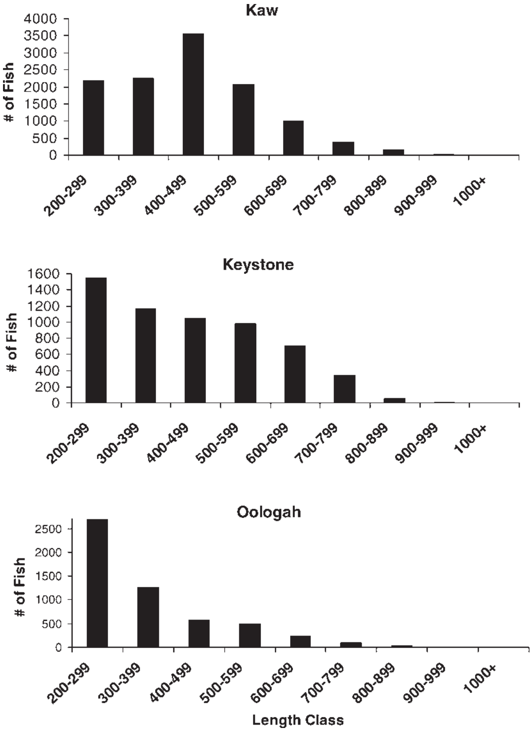

FIGURE 1.—Overall length frequencies of blue catfish captured by electrofishing at Kaw, Keystone, and Oologah reservoirs from June 2006 to May 2008. Samples were collected during spring, summer, winter, and fall.

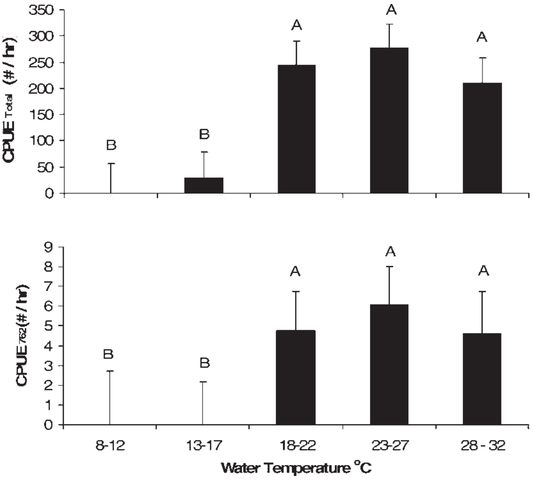

FIGURE 2.—Total catch per unit effort ($\text{CPUE}_{\text{Total}}$) and CPUE of blue catfish 762 mm or longer (CPUE_{762}) obtained by electrofishing in Kaw, Keystone, and Oologah reservoirs at different water temperatures from June 2006 to May 2008. The error bars are SEs; within panels, different letters indicate significant ($P < 0.05$) differences.

in the larger length-groups (700–1,000 mm) were less abundant in Waurika Lake, only 22–25 fish were used for each of these length-groups. Fourteen fish were used for the length-group of fish greater than 1,000 mm. Collected fish were immediately placed in hauling tanks equipped with agitators, oxygen diffusers, and water treated with NaCl to produce a 1% solution. They were then transported to Dahlgren Lake and allowed to acclimate to the temperature before being released. Before releasing the fish, we visually observed them for signs of stress (i.e., discoloration, abnormal gill ventilation rate, loss of equilibrium, etc.). Only fish that did not appear to be stressed were released into the lake. No dead fish were observed during the experiment.

Sampling began 3 d after stocking to ensure that the fish had time to recover from handling stress and to disperse throughout the lake. Dahlgren Lake was then electrofished (using the same electrofishing settings as in the seasonal reservoir sampling) in its entirety (10 min of effort) on three occasions from June 2 to June 4. Fish were given a minimum 24-h recovery period between the replicate samples. As in our seasonal sampling, each collection included two chase boats and a crew of seven people. All of the fish captured were measured and returned to the lake. The mean arcsine-transformed capture efficiencies (percentages of fish captured in each 100-mm length-group) were compared among length-groups by means of a one-way ANOVA. All analyses were performed with the PROC MIXED procedure in SAS ($P < 0.05$; SAS Institute 2004). Pairwise comparisons between length-groups were subsequently tested by means of Tukey's test.

Results

Seasonal Sampling

We sampled approximately 25,000 blue catfish during the 2-year project. Most fish were less than 700 mm (Figure 1). Total CPUE was significantly higher at water temperatures of 18°C or more than at colder temperatures ($F_{4,\ 601} = 208.25$, $P = < 0.001$; Tukey P for all comparisons < 0.001). The mean catch rates among water temperatures of 18°C or more were not significantly different (Tukey P for all comparisons ≥ 0.156), ranging from 209 to 277 fish/h (Figure 2). Below 18°C the mean catch rates were always less than 30 fish/h, and no fish were ever captured at water temperatures below 10°C. The catch rates for fish 762 mm or longer were low at all temperatures, ranging from 0 to 6.1 fish/h, but they were significantly higher at temperatures of 18°C or more ($F_{4,\ 601} = 15.32$, $P < 0.001$; Tukey P for all comparisons < 0.001; Figure 2). No differences in CPUE_{762} were detected among

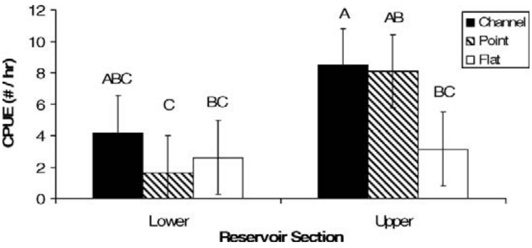

FIGURE 3.—Mean CPUE of blue catfish 762 mm or longer obtained by electrofishing in different habitats and sections of Kaw, Keystone, and Oologah reservoirs from June 2006 to May 2008. The error bars are SEs; different letters indicate significant ($P < 0.05$) differences.

temperatures of 18°C or more (Tukey P for all comparisons $\geq$ 0.928), the catch rates ranging from 4.6 to 6.1 fish/h.

Upper-reservoir sites had significantly higher $\text{CPUE}_{\text{Total}}$ (327 ± 55.8 [mean ± SE]) than lower reservoir sites (180 ± 55.8) ($F_{1,\ 497} = 28.54$, $P < 0.001$), but no differences were detected among habitats (points, flats, and creek channels). There was a significant interaction between habitat and reservoir section for CPUE_{762} ($F_{2,\ 571} = 3.04$, $P = 0.048$), indicating that the way in which habitat related to CPUE differed between the upper and lower portions of the reservoir. Upper-reservoir points and channels had significantly higher catch rates than lower-reservoir points (Tukey $P < 0.02$ for all comparisons), and upper-reservoir channels had significantly higher catch rates than upper- and lower-reservoir flats (all Tukey $P < 0.01$; Figure 3). No significant differences were detected between timber and nontimber sites for $\text{CPUE}_{\text{Total}}$ ($F_{1,\ 2} = 2.51$, $P = 0.25$) or CPUE_{762} ($F_{1,\ 2} = 0.17$, $P = 0.72$).

The precision of total CPUE (CV_{Total}) was least at temperatures of 28°C or more, but all values were near or below the target level of 0.20 (Table 2). Mean CV_{Total} ranged from 0.09 to 0.16, and the average number of samples needed to achieve the target level of 0.20 ranged from 15 to 20 for all temperatures. The coefficients of variation for fish 762 mm or longer were considerably larger than those for CV_{Total}, and there were no clear trends among reservoirs or temperatures (Table 2). All CV_{762} values were greater than 0.20 and they were typically greater than 0.40. The average number of samples needed to achieve a target level of 0.20 ranged from 104 to 366, and the number needed for a target level of 0.40 ranged from 26.0 to 91.5.

The precision of the catch rates varied widely among habitats and reservoir sections. The CVs for $\text{CPUE}_{\text{Total}}$ and CPUE_{762} were twice as high in lower-reservoir sections (Table 2). The value of CV_{762} was much lower in channels than in flats, points being intermediate. However, all habitats had similar values for CV_{Total} (Table 2). Timber sites had higher CV_{762} values than nontimber sites. The presence of timber did not appear to affect CV_{Total}, however; approximately four additional sites were needed to achieve a CV_{Total} target level of 0.20 (Table 2).

No significant differences in RSD_{762} were detected

TABLE 2.—Average precision estimates (CV; $N = 3$, 95% confidence intervals in parentheses) and the number of 10-min samples needed to achieve target CV levels for total catch per unit effort (CPUE) and CPUE of fish 762 mm or longer from seasonal blue catfish electrofishing (June 2006–May 2008) on Kaw, Keystone, and Oologah Reservoirs.

			Number of samples for		
CPUE metric	Temperature or habitat	Mean CV	CV = 0.20	CV = 0.30	CV = 0.40
Total	18–22°C	0.10 (0.08–0.12)	15.9	7.0	4.0
	23–27°C	0.09 (0.06–0.12)	15.3	6.7	3.8
	28–32°C	0.16 (0.12–0.20)	20.5	9.1	5.1
762	18–22°C	0.71 (0.24–1.18)	366.1	162.7	91.5
	23–27°C	0.49 (0.09–0.89)	104.1	46.3	26.0
	28–32°C	0.60 (0.28–0.92)	187.7	83.5	46.9
Total	Upper	0.06 (0.05–0.07)	8.5	3.8	2.1
	Lower	0.11 (0.10–0.12)	26.9	12.0	6.7
762	Upper	0.29 (0.17–0.41)	111.8	49.7	27.9
	Lower	0.73 (0.18–1.28)	998.3	443.7	249.6
Total	Channel	0.10 (0.09–0.11)	15.9	7.1	4.0
	Flat	0.11 (0.08–0.14)	20.0	8.9	5.0
	Point	0.09 (0.07–0.11)	12.2	5.4	3.1
	Timber	0.15 (0.09–0.21)	24.6	11.0	6.2
	No timber	0.16 (0.09–0.21)	20.9	8.9	5.0
762	Channel	0.20 (0.12–0.28)	71.0	31.6	17.7
	Flat	1.65 (0–4.07)	9,711.6	4,316.3	2,427.9
	Point	0.51 (0.14–0.88)	546.1	242.7	136.5
	Timber	0.67 (0.14–1.20)	325.3	144.6	81.3
	No timber	0.39 (0.35–0.43)	127.5	56.7	31.9

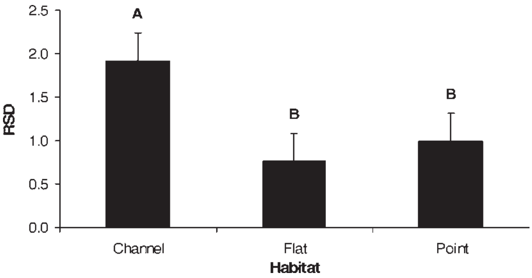

FIGURE 4.—Mean relative stock density (RSD) of preferred-size blue catfish (≥762 mm TL) obtained by electrofishing in different habitats at Kaw, Keystone, and Oologah reservoirs from June 2006 to May 2008. The error bars are SEs; different letters indicate significant ($P < 0.05$) differences.

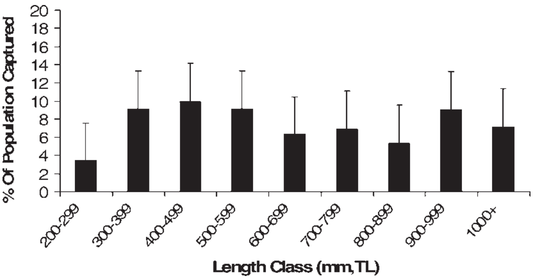

FIGURE 5.—Mean capture efficiency (percent of the actual population captured) by length-group of blue catfish captured by electrofishing at Lake Dahlgren in July 2008 after the lake was stocked with a known number of fish. The error bars are SEs.

among water temperatures of 18°C or more ($F_{2,\ 4} = 1.90$, $P = 0.26$) or reservoir section ($F_{1,\ 1002} = 1.02$, $P = 0.31$). However, channel habitats had higher RSD_{762} values than points and flats ($F_{3,\ 1002} = 8.72$, $P < 0.001$; Tukey P for all comparisons ≤ 0.01; Figure 4). No significant effects of timber were detected ($F_{1,\ 187} = 0.75$, $P = 0.39$).

Sampling from a Known Population Length Distribution

We detected no significant differences in the proportion of the population captured by electrofishing according to length-groups in Dahlgren Lake ($F_{8,\ 16} = 0.27$, $P = 0.96$, Figure 5). The average percent captured ranged from 3.4% to 10% for all length-groups. The overall capture rate was low, averaging 21 fish/sample. The total percentage of the population caught for the composite of all length-groups averaged 6.7%. No length bias against large fish was detected; the average percentage return for fish less than 700 mm was 7.6%, that for fish greater than 700 mm 7.1%.

Discussion

Standardization is a critical component of any sampling regime (Murphy and Willis 1996; Cailteux and Strickland 2009). Unbiased, consistent sampling methods allow comparisons among years within lakes and among different lakes. Skewed or poorly representative data may also lead to incorrect estimates of relative population size, growth, or mortality and could ultimately result in poor management decisions (Bayley and Austen 2002). Many factors, such as season, temperature, habitat, reservoir section, and depth are known to influence CPUE and the variance in the data for other species, such as centrarchids (Harden and Connor 1992), flathead catfish *Pylodictis olivaris* (Cunningham 2000), and river populations of blue catfish, flathead catfish, and channel catfish (Justus 1996). Our results indicate that this is also true for blue catfish in reservoirs. We found that electrofishing was consistently effective in sampling blue catfish at all temperatures over 18°C with no length bias. Because catch rates declined precipitously at lower temperatures, we recommend that sampling for this species only be conducted at warmer temperatures when CPUE comparisons are to be made. Further, we recommend that blue catfish sampling protocols be standardized, at least with respect to season (temperature) and reservoir section.

Temperature and Habitat

Water temperature appeared to be the primary factor influencing CPUE in our study, accounting for a difference of two orders of magnitude in catch rates. Justus (1996) reported that electrofishing for blue catfish in river systems was effective only at water temperatures above 22°C. Similarly, electrofishing catch rates for flathead catfish are low at temperatures below 16°C (Quinn 1988; Cunningham 2000) and increase as temperature increases (Justus 1996; Cunningham 2000). In our study, catch rates were similarly high at all temperatures of 18°C or more but declined rapidly at temperatures less than 18°C and no fish were captured at temperatures below 10°C. The variance in catch rates was slightly higher at temperatures of 28°C or more. Therefore, to achieve higher precision and sampling efficiency, we recommend that blue catfish sampling be conducted at temperatures between 18°C and 28°C.

Our results suggest that temperature does not disproportionately affect the catch rate of any length-group. However, even after approximately 120 electrofishing hours, the overall variability of CPUE_{762} was still high, leaving little statistical power to detect changes in catch. Average CV_{762} values ranged from 0.49 to 0.71 for all temperatures, suggesting that our data can at best detect a 50% change in the population of fish 762 mm or longer. These results, combined with those of Boxrucker and Kuklinski (2008), indicate the impracticality of obtaining large enough samples to precisely estimate CPUE_{762}. However, our capture efficiency data (the Dahlgren Lake data) suggest that this is caused by the low abundance of blue catfish rather than the inefficiency of the gear.

Lower variability and higher catch rates were observed for $\mathrm{CPUE}_{\mathrm{Total}}$ and CPUE_{762} in the upper reservoir. It is unclear whether this was caused by biological or behavioral phenomena or the electrofisher was ineffective in portions of the lower reservoir. The depth in the lower sections of our reservoirs ranged from 4 to 21 m with an average of 11 m, while that in the upper sections ranged from 4 to 18 m with an average of 7 m. When sampling the lower sections, we observed that CPUE continued to decline as we approached the dam. Samples collected at or near the dam (usually at depths exceeding 15 m) contained few or no fish, while those collected away from the dam were much larger. In other fish species, tetany is known to decline with water depth and distance from the electrode, thereby influencing catch rates (Fisher and Brown 1993); we suspect that this is also true for blue catfish. However, we were unable to analyze the effect of depth on CPUE because the vertical distribution of the fish was unknown. Because we could not identify the exact depth of the fish within the water column, the results from a depth analysis would be speculative. Further, our sample sites were randomly selected and therefore not distributed among depths in a way that would be appropriate for examining this relationship. A more detailed evaluation of the effects of depth on estimates of relative abundance is needed.

Seasonal depth selection by blue catfish could, however, explain why electrofishing was ineffective at low water temperatures ($<18°$C). Blue catfish move upstream during the spring (Pugh and Schramm 1999) and use primarily deeper portions (e.g., 14 m) of the lower reservoir during winter (Fischer et al. 1999). They select depths of approximately 5 m during spring and summer (Grist 2002) and areas near the thermocline during periods of stratification (Fischer et al. 1999). Buckmeier and Schlechte (2009) also suggested that blue catfish are more vulnerable to electrofishing in late summer because they are forced to occupy the upper portions of the water column. These documented seasonal patterns of depth selection are consistent with our observed decline in catch (i.e., we obtained lower catch rates in periods when previous research suggests that blue catfish are in deeper water). Further research is warranted to test this hypothesis.

Unlike reservoir section, the CPUE of large fish and its variability were only slightly affected by habitat. Although previous studies have found that catfish, including blue catfish, prefer specific habitat types (Driscoll et al. 1999; Weller and Winter 2001; Edds et al. 2002; Grist 2002), our results suggest that habitat selection by blue catfish in large reservoirs is limited. We found no difference in CPUE or CV among habitats for fish less than 762 mm. Although significant habitat effects (or habitat × section interaction) were detected for CPUE_{762} and RSD_{762}, the extremely low catch rates of fish in this size-group make these findings trivial when applied to data sets with more moderate replication than that in our study. In general, the sample size needed for the precise determination of CPUE for these fish ($\geq$71 samples to achieve a CV $\leq$0.20) is too high for practical implementation in sampling protocols. Further, the difference in RSD_{762} that we detected, while statistically significant, only amounted to a 1% difference in the abundance of large fish, an amount that arguably would not be meaningful to angler catch rates in the fishery (and probably would not be detected with the lower replication that is typical in sampling this species). Given the high variability in the catch rates for large blue catfish, specialized, habitat-specific sampling regimes may not be warranted for them. We suggest that standardized sampling protocols be tailored to meet the sampling requirements for fish less than 762 mm.

Sampling from a Known Population Length Selectivity

Although in certain species electrofishing can be biased toward large fish (Bayley and Austen 2002; Dolan and Miranda 2003; Dauwalter and Fisher 2007), our results indicate that all length-groups of blue catfish from 200 to 1,000 mm were equally vulnerable to low-frequency electrofishing. Similarly, Buckmeier and Schlechte (2009) determined that blue catfish 250–855 mm were equally vulnerable. Therefore, we suggest that the low catch rate of large blue catfish in typical electrofishing samples (Figure 1) is a product of low abundance rather than gear bias.

We found that less than 10% of the total population was collected during each sampling event. This was slightly lower than the electrofishing catchability of other species, such as largemouth bass *Micropterus salmoides* (22%; Woodrum 1979). For each of the electrofishing samples, few fish surfaced and most (approximately 95%) were successfully netted; catchability in dense reservoir populations may be even lower when more fish surface at once than can be readily dipnetted. As with the reservoir sampling, we observed that the majority of the fish that surfaced were in the uppermost portion of the lake (where the average depth was less than 3 m) and few fish surfaced at or near the dam (where the average depth was approximately 5 m).

Further research on blue catfish electrofishing using known populations in bodies of water with different chemistry and depth structure is needed to confirm our results. Additionally, the vertical distribution of blue catfish within the water column may affect their catchability, and this has yet to be investigated. Our results suggest that low-frequency electrofishing is effective at sampling blue catfish 200–1,000 mm long and can be used to compare CPUE data for the purpose of tracking changes in population size or length distribution. We suggest that standard sampling protocols adopt a stratified design that incorporates a higher number of samples in the upper reservoir to improve precision. The number of samples required to precisely estimate relative abundance should be based on the estimates of variability obtained during sampling.

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