Articles

Environment Affects Sucker Catch Rate, Size Structure, Species Composition, and Precision in Boat Electrofishing Samples

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Abstract

Catostomidae (catostomids) are suckers of the order Cypriniformes, and the majority of species are native to North America; however, species in this group are understudied and rarely managed. The popularity in bowfishing and gigging for suckers in the United States has increased concerns related to overfishing. Little information exists about the relative gear effectiveness for sampling catostomids. We sought to evaluate the relative effectiveness of boat electrofishing for sampling Black Redhorse *Moxostoma duquesnei*, Golden Redhorse *M. erythrurum*, Northern Hogsucker *Hypentelium nigricans*, White Sucker *Catostomus commersonii*, and Spotted Sucker *Minytrema melanops* populations in Lake Eucha, Oklahoma. We used an information theoretic approach to determine the abiotic variables related to sucker catch per effort (*C/f*). Our analysis indicated that sucker *C/f* was highest during the night and decreased with increasing water temperature. Sucker size structure was significantly different between daytime and nighttime samples; however, effect size estimates for size structure comparisons indicated that size distributions exhibited moderate overlap. Distributional comparisons indicated that daytime and nighttime samples were similar for fish greater than 180 mm in total length. Effect size estimates also indicated little association between the proportion of each species captured and time of day or water temperature. Night electrofishing in reservoirs at water temperatures from 16 to 25°C yielded the most precise *C/f* estimates, with the highest numbers of suckers collected at water temperatures from 6 to 15°C. Further study of the relationship between abiotic variables and catostomid catchability using various gears will be beneficial to agencies interested in these populations.

Keywords: sucker sampling; electrofishing; size structure

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Introduction

Most fishes in the family Catostomidae (hereafter catostomids) are endemic to North America, with the only exceptions being the Chinese Sucker *Myxocyprinus asiaticus* and Longnose Sucker *Catostomus catostomus* (Harris and Mayden 2001; Page and Burr 2011; Bagley et al. 2018). In total, there are an estimated 76 extant catostomid species, with 75 species within North America (Harris and Mayden 2001; Cooke et al. 2005; Page and Burr 2011; Bagley et al. 2018). However, detailed investigation of catostomid morphology and genetics over the last three to four decades revealed additional species (e.g., Apalachicola Redhorse *Moxostoma* sp. [Gilbert 1992; Mettee et al. 1996], Southeastern Blue Sucker *Cycleptus meridionalis* [Burr and Mayden 1999]), and other new species have been proposed (e.g., *Pantosteus virescens*, *P. jordani*, *P. lahontan*; Unmack et al. 2014). Despite their prevalence across North America, catostomids are rarely managed and are understudied in the United States (Holey et al. 1979; Cooke et al. 2005). The few studies that have researched catostomids focus on imperiled species (e.g., Razorback Sucker *Xyrauchen texanus*) or species with more cosmopolitan distributions across North America (e.g., White Sucker *C. commersonii*; sensu Cooke et al. 2005). Catostomids are especially understudied relative to other common families or economically important families in North America, such as Centrarchidae or Salmonidae (Cooke et al. 2005; Rypel et al. 2021). However, catostomids may be vulnerable to overfishing (Matheney and Rabeni 1995; Begley et al. 2017, 2018; Radford et al. 2021; Lackmann et al. 2019, 2021, 2022), making them important focal species for current research efforts.

The vulnerability of catostomid populations to overfishing is concerning given the general imperilment of freshwater fishes in North America. For example, Williams (1989) estimated that 21.3% of freshwater fishes in North America are imperiled, and extinction rates appear to be increasing (sensu Ricciardi and Rasmussen 1999). This is especially concerning for catostomids, as many of their populations are already threatened by habitat degradation arising from human alterations (Cooke et al. 2005). In fact, more than half (>55%) of all catostomid species are already classified as imperiled (Harris et al. 2014), and many other species have not been conservation assessed using modern biological data considering recent (i.e., after Harris et al. 2014) paradigm-shifting life history information (e.g., Lackmann et al. 2019). Catostomids, as a group, are primarily thought of as underused by anglers across much of North America; however, commercial (e.g., Moyle 2002), bait (e.g., Brandt and Schreck 1975; Begley et al. 2017), and specialized sport fisheries have long existed (e.g., Matheney and Rabeni 1995; Markle and Cooperman 2002). For example, upward of 20 million pounds of catostomids were harvested annually from the Great Lakes from the late 1800s to the early 1900s, and populations showed signs of decrease as early as 1917, although no harvest regulation occurred (Koelz 1926).

A recent increase in bowfishing popularity across the United States (Scarnecchia and Schooley 2020) has added substantial concern regarding the potential for catostomid overharvest (e.g., Radford et al. 2021; Lackmann et al. 2019, 2022). Although initially assumed as targeting invasive fishes, such as Common Carp *Cyprinus carpio*, bowfishing harvest varies greatly by location (Quinn 2010; Scarnecchia and Schooley 2020), with native species being the most harvested (Rypel et al. 2021). Quinn (2010) found that catostomid harvest, specifically Spotted Sucker *Minytrema melanops*, made up most of the catch at two Arkansas bowfishing tournaments. Scarnecchia and Schooley (2020) found that Smallmouth Buffalo *Ictiobus bubalus* and Bigmouth Buffalo *I. cyprinellus* constituted most of the harvest during the 2018 U.S. Open Bowfishing Championship and included harvest of Blue Sucker *Cycleptus elongatus*, a species of conservation concern in Oklahoma. Monitoring catostomid populations is necessary to determine their vulnerability to growth-and-recruitment overfishing, and management actions may be beneficial where overfishing is occurring (Holey et al. 1979; Begley et al. 2017, 2018; Lackmann et al. 2019, 2021, 2022).

To properly monitor fish species, it is necessary for managers and researchers to understand sampling technique effectiveness. Sampling technique studies often take the form of gear comparisons (e.g., gillnetting vs. electrofishing; Van Den Avyle et al. 1995), catchability (q) estimates (e.g., q of electrofishing; Speas et al. 2004), or comparisons of the relative effectiveness of a gear under different abiotic conditions (e.g., daytime vs. nighttime electrofishing; Paragamian 1989). We are unaware of any studies that use the aforementioned techniques on reservoir catostomid populations. However, gear comparisons (Pugh and Schramm 1998; Paukert 2004) and studies estimating the relative effectiveness of electrofishing (McInerny and Cross 2004; Hine 2019) for catostomids were conducted in river and lake systems. We sought to determine the relationship between abiotic variables and catch per effort (C/f), precision, size distribution, and observed species composition of reservoir catostomid populations sampled by boat-mounted electrofishing so that we can provide recommendations for those interested in using boat-mounted electrofishing to monitor select populations. We selected electrofishing because it is commonly used (sensu Bonar et al. 2009; Reynolds and Kolz 2012) and is an effective gear for capturing more common (e.g., White Sucker; McInerny and Cross 2004) and imperiled (e.g., Razorback Sucker; Tyus and Karp 1990) catostomids. We focus our study on Black Redhorse *Moxostoma duquesnei*, Golden Redhorse *M. erythrurum*, Northern Hogsucker *Hypentelium nigricans*, White Sucker, and Spotted Sucker (hereafter suckers). We sought to 1) determine the relationship between selected abiotic variables and the catch rate, size distribution, and proportion of catostomids captured with boat-mounted electrofishing and 2) determine the precision of catch rates along with the number of samples that would be required to estimate relative catch at various levels of precision.

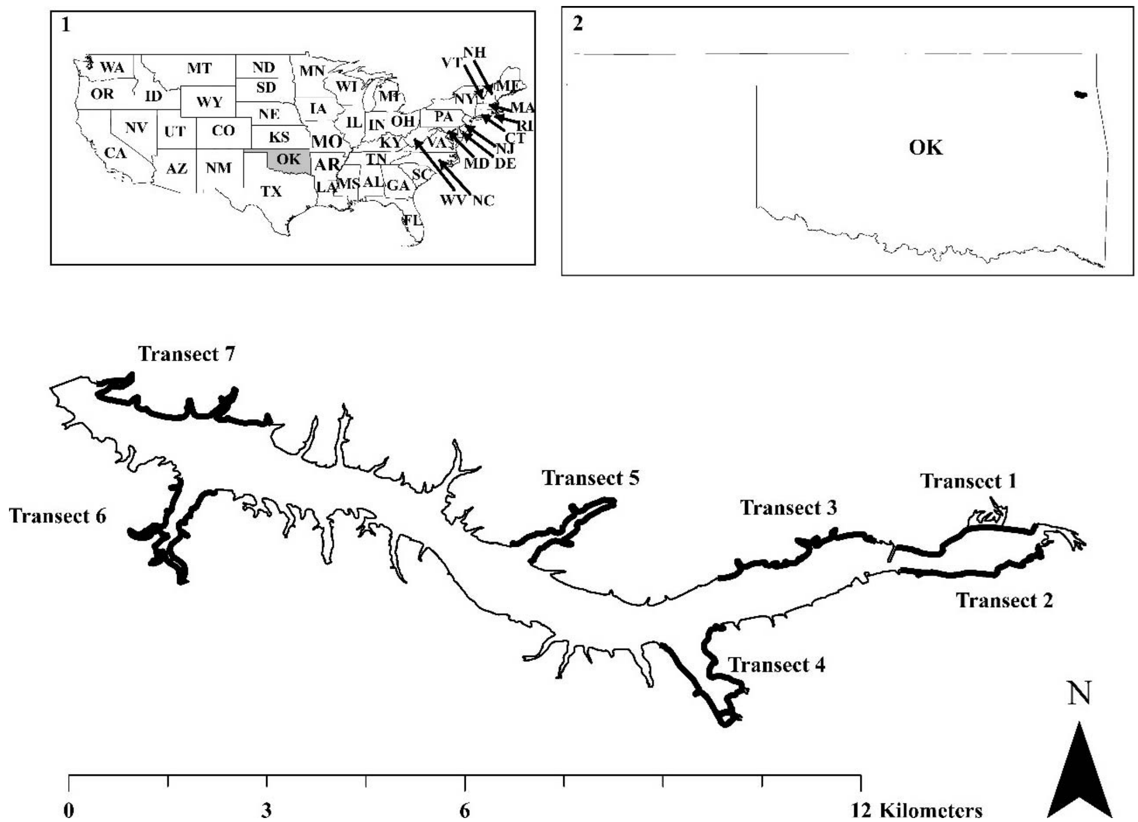

Figure 1. Electrofishing transect locations (bold lines) for boat-mounted electrofishing sampling that we conducted on Lake Eucha, Oklahoma. Inset maps indicate 1) the location of Oklahoma (gray fill) within the contiguous United States and 2) the location of Lake Eucha (black fill) within the state of Oklahoma. We conducted electrofishing sampling on Lake Eucha, Oklahoma, from 2019 to 2020 as part of a study to provide sampling recommendations for reservoir sucker populations (*Moxostoma duquesnei, M. erythrurum, Hypentelium nigricans, Catostomus commersonii,* and *Minytrema melanops*) using boat-mounted electrofishing based on catch rate, size distribution, proportion of suckers captured, and precision of catch rates.

Study Site

Our sampling took place in Lake Eucha, Oklahoma (Figure 1). Lake Eucha is a ~902-ha reservoir (when at spillway level) that was created by damming Spavinaw Creek in 1952 (Jackson 1957). An Oklahoma Water Resources Board survey conducted in December of 1999 reported that the reservoir had a mean depth of 8.2 m and a maximum depth of 25.6 m; however, the surface area of the reservoir was 1136 ha at the time, indicating that it was above the spillway level (i.e., depths may not be representative of average conditions; Oklahoma Water Resources Board 2002). The reservoir has a median secchi depth of 1.5 m (range = 0.9–3.8 m), median chlorophyll-a concentration of 14.8 μg/L (range = 0.6–39.2 μg/L), median pH of 7.9 (range = 6.8–8.6), and mean turbidity of 3.9 mg/L (range = 1.2–9.1 mg/L; Oklahoma Water Resources Board 2002). The reservoir is in northeastern Oklahoma within the Ozark Highlands ecoregion (Figure 1; Woods et al. 2005). The Ozark Highlands has a moderate climate with average high temperatures of 9°C in January and 33°C in July and an average annual rainfall of ~120 cm (Woods et al. 2005). This area is primarily forest, woodland, and pasture and is characterized by its karst topography and numerous springs (Nigh and Schroeder 2002). The western portion of the ecoregion where Lake Eucha, Oklahoma, is located contains cherty clay soils (Woods et al. 2005).

Methods

Sampling procedure and data collection

We sampled using pulsed direct current electrofishing regulated via either a Smith Root 5.0 generator-powered pulsator or a Midwest Lake Electrofishing Systems (MLES) infinity electrofishing system. We used two Smith-Root SAA-6 boom-mounted anodes when we sampled with the Smith Root 5.0 generator-powered pulsator, and we used one MLES collapsible boom-mounted anode when we sampled with the MLES Infinity electrofishing system. The aluminum hull of the boat acted as the cathode for both systems, and we always used a pulse frequency of 60 Hz. When operating both systems, we standardized peak power applied to the fish by adjusting the system output according to the measured ambient conductivity (obtained by adjusting the specific conductivity using water temperature) based on tables present within Miranda (2009).

We collected 30 samples in a haphazard manner, attempting to maximize spatial interspersion (based on transect location) across Lake Eucha, Oklahoma, between March 18, 2019, and October 6, 2020, during routine electrofishing for a mark–recapture study. We sampled a total of seven transects (Figure 1). We varied total distance of each transect haphazardly between 1.0 and 5.5 km to investigate the relationship between distance sampled and electrofishing catch. We took daytime (~30 min after sunrise and before sunset) and nighttime (~30 min after astronomical twilight and before sunrise) samples less than 24 h apart along the same section of each transect to limit any temporal or spatial effects. Although we selected sample location and distance haphazardly, we randomly determined if we would conduct daytime or nighttime electrofishing first. We sampled throughout each year, specifically between March 18 and September 27 in 2019 and between January 24 and October 6 in 2020, allowing us to investigate the potential relationship between water temperature and level and the number of fish captured. We sampled by maneuvering the electrofishing boat toward and away from the shoreline, taking special care to sample submerged structures (e.g., large woody habitat, emergent macrophytes, and boulders). We recorded the amount of time electrofishing during each sample event (i.e., the amount of time that power was applied to the electrodes in hours). We identified all captured fishes to species based on criteria from Page and Burr (2011) and measured them to the nearest 1 mm in total length (TL). We did not observe any post-electrofishing morality for suckers during the study.

Numerical comparison of catch

To estimate the average effectiveness of electrofishing across species, we pooled the number of suckers captured during each electrofishing event. We divided the pooled number of suckers captured by time spent electrofishing (hours) to obtain an effort-standardized estimate of catch (*C/f*; Pope et al. 2010) that we used as our response variable. We used surface water temperature (water temperature; °C), ambient conductivity (μS/cm^3), reservoir gauge height (gauge height; m), reservoir storage (m^3), electrofishing site (i.e., site 1 to site 7), distance electrofished (m), and electrofishing boat (i.e., Smith Root vs. MLES) as exploratory variables in our analysis, as we hypothesized that there may be a relationship between these variables and our observed *C/f* for suckers. We estimated water temperature from a handheld conductivity meter (ORAPXI international model number 9908) and converted it to ambient conductivity to use in selecting a power goal before we began electrofishing. We obtained gauge height and reservoir storage from the U.S. Geological Survey gauging station (station 07191285, Lake Eucha, Oklahoma). For each sampling event, we averaged gauge height and water level from 15-min measurements for the entire daytime or nighttime period. We recorded electrofishing boat, site name, time of day, and length of the electrofishing transect at each site (Figure 1).

We used generalized linear modeling (GLM; McCullagh and Nelder 1989) with an information theoretic model selection approach to determine if sucker *C/f* varied based on our predictor variables. Before candidate model set construction, we used Spearman's ρ (Spearman 1904) to estimate the correlation between all ordinal predictor variables, but we could not analyze time of day and electrofishing boat in this way given their binary nature. Instead, we measured the potential correlation of time of day and electrofishing boat variables relative to ordinal variables using point-biserial correlation (Glass and Hopkins 1996). We used Pearson's χ^2 test (Pearson 1900) to determine the strength of association between our time of day and electrofishing boat variables. We determined significant correlations ($\alpha = 0.05$) via the "cor.test()" or "chisq.test()" functions in program R version 3.6.3 (R Core Team 2020) and estimated *P* values from the asymptotic *t* approximation via Spearman's ρ or from Pearson's cumulative χ^2, respectively. We observed significant correlations between gauge height, reservoir storage, ambient conductivity, distance electrofished, and electrofishing site, along with water temperature and ambient conductivity (Table 1). We never included significantly correlated predictors in the same candidate model to minimize potential multicollinearity within our GLM. Our candidate model set contained an intercept-only model, all possible additive combinations of variables with insignificant correlations, and models that contained main effects and a two-way interaction between uncorrelated variables (Table 2; Table S1, *Supplemental Material*).

We used a gamma distribution with a log link to fit all our GLMs. We selected the gamma distribution because data were all above 0 and positively skewed (McCullagh and Nelder 1989). We fit GLMs in program R version 3.6.3 using the "glm()" function (R Core Team 2020), which automatically estimated the dispersion parameter (ϕ) for each model. We ranked candidate models via Akaike information criterion corrected for small sample size (AIC$_c$; Hurvich and Tsai 1989) and estimated AIC$_c$ weights (w_i). We considered models within 2ΔAICc of the top candidate model to have similar likelihoods (Burnham and Anderson 2002). We determined evidence ratios (estimated using w_i) via Kullback–Leibler information theory (Royall 1997; Burnham and Anderson 2002) relative to the top-ranked model (based on lowest AIC$_c$). We used McFadden's pseudo-R^2 (ρ^2; McFadden 1974) estimates to estimate the strength of each the relationship. A ρ^2 of 0.20 indicated "excellent" model fit (McFadden 1979).

Comparing size distributions and species proportions

To determine if variables that exhibited a relationship with sucker *C/f* also exhibited a relationship with the size distribution of suckers, we compared length frequency distributions between day and night samples

Table 1. Correlation matrix for explanatory variables that we used to explain variations in sucker catch per effort (*C/f* [sucker spp./hour]) from Lake Eucha, Oklahoma. Variables include time of day (daytime vs. nighttime), gauge height (estimate of reservoir water level), reservoir storage (estimate of reservoir fullness), water temperature, ambient conductivity, distance electrofished, site electrofished, and electrofishing boat used (boat; i.e., Smith Root and Midwest Lake Electrofishing Systems). Significant correlations ($\alpha = 0.05$) from Spearman's ρ (Spearman 1904) that we obtained from an asymptotic *t* approximation or Pearson's cumulative χ^2 (Pearson 1900) are bold. We collected data on Lake Eucha, Oklahoma, from 2019 to 2020 as part of a study to provide sampling recommendations for reservoir sucker populations (*Moxostoma duquesnei, M. erythrurum, Hypentelium nigricans, Catostomus commersonii,* and *Minytrema melanops*) using boat-mounted electrofishing based on catch rate, size distribution, proportion of suckers captured, and precision of catch rates.

	Gauge height	Reservoir storage	Water temperature	Ambient conductivity	Distance	Site	Boat
Time of day	<−0.01[a]	<−0.01[a]	0.08[a]	0.13[a]	<0.01[a]	<0.01[a]	0.00[b]
Gauge height		>**0.99**	0.27	**0.39**	**−0.51**	**−0.49**	−0.36[a]
Reservoir storage			0.27	**0.39**	**−0.51**	**−0.49**	−0.36[a]
Water temperature				**0.46**	0.23	0.18	−0.26[a]
Ambient conductivity					**−0.46**	**−0.42**	−0.28[a]
Distance						**0.91**	0.05[a]
Site							0.15[a]

[a] We used the point-biserial method to estimate categorical by continuous variable correlations.
[b] We used a χ^2 test to estimate categorical by categorical variable correlations.

($\alpha = 0.05$) and pairwise combinations of samples taken within three temperature groups using two-sample Kolmogorov–Smirnov (K–S) tests (Kolmogorov 1933; Smirnov 1939) with Bonferroni adjustments ($\alpha = 0.01$ Bonferroni 1936). We initially assessed groupings of 5, 10, 15, and 20°C. The 5°C grouping resulted in low sample sizes (i.e., $n = 3$), and groupings of 15 or 20°C resulted in poor resolution due to the increased size of the temperature groups. Therefore, we used the following 10°C groups: 6–15°C, 16–25°C, and 26–35°C (hereafter >25°C). To determine the amount of similarity between length frequency distributions obtained from either time of day or temperature groups, we also estimated the amount of distributional overlap ($\hat{\eta}$; Pastore and Calcagnì 2019) between samples using the "boot.overlap()" function from the overlapping package (Pastore 2020). We selected $\hat{\eta}$ for comparison as it is a distribution-free metric (i.e., it makes no assumptions regarding symmetry, unimodality, normality, etc.). We bootstrapped each distributional compar-

Table 2. Candidate model rankings for all gamma-distributed generalized linear models with Akaike weights (w_i) $\geq$ 0.01 that we used to explain variations in sucker catch per effort (*C/f* [sucker spp./hour]) from Lake Eucha, Oklahoma. Included are McFadden's pseudo-R^2 (ρ^2; McFadden 1974), Akaike information criterion corrected for small sample size (AIC_c; Hurvich and Tsai 1989) estimates, and evidence ratios (ERs) relative to the top model. The intercept-only model is represented by (—). We collected data on Lake Eucha, Oklahoma, from 2019 to 2020 as part of a study to provide sampling recommendations for reservoir sucker populations (*Moxostoma duquesnei, M. erythrurum, Hypentelium nigricans, Catostomus commersonii,* and *Minytrema melanops*) using boat-mounted electrofishing based on catch rate, size distribution, proportion of suckers captured, and precision of catch rates. Additional (lower-ranked) models are given in Table S1, *Supplemental Material*.

Exploratory variables	ρ^2	AIC_c	ΔAIC_c	w_i	ER
Time of day + water temperature	0.07	260.64	0.00	0.32	1.00
Time of day + water temperature + distance electrofished	0.07	263.29	2.65	0.09	3.74
Time of day + gauge height + water temperature	0.07	263.43	2.79	0.08	4.03
Time of day + reservoir storage + water temperature	0.07	263.46	2.81	0.08	4.08
Time of day + water temperature + electrofishing site	0.07	263.46	2.81	0.08	4.08
Time of day + water temperature + time of day × water temperature	0.07	263.52	2.87	0.08	4.24
Time of day + water temperature + electrofishing boat	0.07	263.54	2.90	0.08	4.24
—	0.01	264.97	4.33	0.04	8.70
Time of day	0.04	264.97	4.33	0.04	8.70
Time of day + distance electrofished	0.04	266.71	6.07	0.02	21.47
Time of day + electrofishing site	0.04	266.97	6.32	0.01	23.00
Time of day + ambient conductivity	0.04	267.15	6.51	0.01	26.83
Time of day + reservoir storage	0.04	267.34	6.70	0.01	29.27
Time of day + gauge height	0.04	267.38	6.74	0.01	29.27
Time of day + electrofishing boat	0.04	267.61	6.96	0.01	32.20
Time of day + electrofishing boat + electrofishing boat × time of day	0.05	268.52	7.87	0.01	53.67
Time of day + reservoir storage + time of day × reservoir storage	0.05	269.03	8.39	0.01	64.40
Time of day + distance electrofished + time of day × distance electrofished	0.05	269.04	8.40	0.01	64.40
Time of day + gauge height + time of day × gauge height	0.05	269.06	8.42	0.01	64.40

ison 10,000 times so that we could derive mean and 95% confidence intervals (CIs) for $\hat{\eta}$. We interpreted $\hat{\eta}$ in a similar manner as Cohen's *d* (Cohen 1988), as suggested by Pastore (2020), meaning that $\hat{\eta} = 0.20$ would indicate a small distributional overlap, $\hat{\eta} = 0.50$ would indicate a moderate distributional overlap, and $\hat{\eta} = 0.80$ would indicate a large distributional overlap.

We iteratively compared TLs from each time of day ($\alpha = 0.05$) and temperature group (Bonferroni-adjusted $\alpha = 0.01$) to determine if there was a minimum size threshold (i.e., a minimum TL) at which there was no significant difference (based on K–S tests) and high overlap (based on $\hat{\eta}$). To do this, we iteratively removed samples one group at a time in 10-mm TL groups, starting with the minimum size group captured until we included up to half of the cumulative size distribution. We conducted significance and overlap testing on the remaining data after each removal step. We started at the lower end of the size distribution because boat-mounted electrofishing is biased against smaller individuals (Dolan and Miranda 2003). We obtained mean and 95% CI for $\hat{\eta}$ for each iteration to determine if overlap between sample distributions changed. Once all iterations were conducted, we plotted categorical significance from our K–S tests and $\hat{\eta}$ estimates against the minimum size group of fish retained to determine if there was a threshold length at which either time of day or temperature group differences were insignificant (K–S tests) or exhibited a high amount of overlap ($\hat{\eta}$).

To determine if the environmental variables that exhibited a relationship with sucker *C/f* were also related to the proportion of each species we observed, we counted the number of each species captured during either the daytime or nighttime or when water temperatures were between 6 and 15°C, 16 and 25°C, and >25°C and compared them ($\alpha = 0.05$) using a Fisher's exact test (Fisher 1934; Freeman and Halton 1951). Fisher's exact test was selected because values that were ≤5 occurred when using both our grouping schemes. After we estimated significance levels, we used Cramér's *V* test (Acock and Stavig, 1979) to estimate the strength of association between the number of each species captured within diel period and temperature groups. We interpreted Cramér's *V* based on its relationship to the *w* statistic when a table has five rows, as suggested by Cohen (1988). Briefly, $V = 0.05$ indicates low association between categories, $V = 0.15$ indicates moderate association between categories, and $V = 0.25$ indicates strong association between categories.

Precision of catch estimates

We estimated the precision of samples obtained from each time of day and temperature group separately to determine the variation in catch rates for variables related to sucker *C/f*. We obtained precision estimates using the following formula to estimate residual standard error (RSE; sensu Evans et al. 2011):

$$\mathrm{RSE} = \frac{\left(\sigma_{C/f} \big/ \sqrt{n}\right)}{\mu_{C/f}} \times 100,$$

where $\sigma_{C/f}$ is the standard deviation estimate for effort-standardized catch from each group obtained via

$$\sigma_{C/f} = \sqrt{\frac{\sum_{i=1}^{n} e^2_{C/f_i} = (C/f_1 - \mu_{C/f})^2 + \ldots + (C/f_n - \mu_{C/f})^2}{(n-1)}},$$

and $\mu_{C/f}$ is the mean estimate of effort-standardized catch for each group obtained via

$$\mu_{C/f} = \frac{\sum_{i=1}^{n} C/f_i = C/f_1 + \ldots + C/f_n}{n},$$

where $e^2_{C/fi}$ represents the squared residual of each *i*th effort-standardized estimate of catch, C/f_i represents the *i*th effort-standardized estimate of catch, and *n* represents the total number of *C/f* observations from each sample group.

To determine the minimum number of samples needed to achieve a target level of precision of *C/f* for our time of day and temperature groupings, we used a Monte Carlo bootstrapping approach, as recommended by Dumont and Schlechte (2004). This approach estimates *s*, the number of samples required to obtain a target level of precision from a cumulative frequency distribution of *C/f* estimates obtained via resampling. We used RSE = 25 (RSE_{25}) and RSE = 15 (RSE_{15}) as our target levels of precision (Robson and Regier 1964; Hardin and Conner 1992; Dumont and Schlechte 2004). The Monte Carlo bootstrapping approach also allowed us to estimate the total number of suckers that would be captured based on the number of surveys required to obtain RSE_{25} or RSE_{15}. The estimated number of captured individuals was included as it is of interest when additional fisheries metrics are desired (e.g., growth curves and length–weight regressions). We used 10,000 Monte Carlo simulations to better estimate the "tails" of our cumulative frequency distribution to allow more robust predictions given our sample sizes of *C/f* within each time of day and temperature group (i.e., 8–15 samples). We estimated RSE_{25} and RSE_{15} and estimated number of captured individuals based on number of surveys using the empirical 80th and 95th percentiles of our *C/f* cumulative frequency distributions. These percentiles correspond to the likelihood of obtaining the desired level of RSE and obtaining the target number of fish in either 4 of 5 (80th percentile) or 19 of 20 (95th percentile) survey attempts.

Results

Numerical comparison of catch

Our most likely model for predicting variation in sucker *C/f* was the additive combination of time of day and water temperature (Table 2; Data S1, *Supplemental*

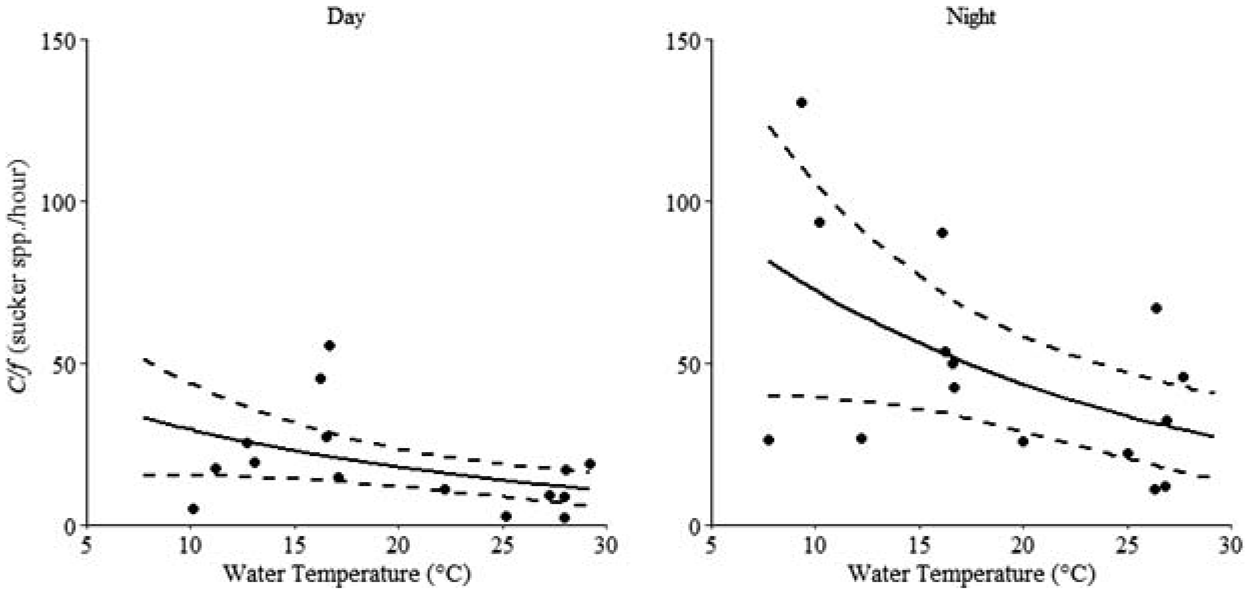

Figure 2. Observed catch per effort (*C/f* [sucker spp./hour]) in Lake Eucha, Oklahoma, at various water temperatures during the day and night (points). We included the mean (solid lines) and 95% confidence intervals (dotted lines) of predicted *C/f* from the top-ranked model based on Akaike information criterion corrected for small sample size (AIC_c; Hurvich and Tsai 1989). We collected data on Lake Eucha, Oklahoma, from 2019 to 2020 as part of a study to provide sampling recommendations for reservoir sucker populations (*Moxostoma duquesnei, M. erythrurum, Hypentelium nigricans, Catostomus commersonii,* and *Minytrema melanops*) using boat-mounted electrofishing based on catch rate, size distribution, proportion of suckers captured, and precision of catch rates. The plot above is not an interaction but is instead the additive effect of the two variables.

Material). This model indicated that sucker *C/f* decreased as temperature increased, and daytime electrofishing had lower sucker *C/f* than nighttime electrofishing (Figure 2). Evidence ratios indicated that our top model was approximately four times more likely than the next best model. Values of ρ^2 indicated that our most likely model described variation in sucker *C/f* similar to the next seven most likely models. However, all seven of these models included time of day and water temperature and additional explanatory variables or an interaction between time of day and water temperature. This may indicate that the addition of distance electrofished, gauge height, reservoir storage, electrofishing site, electrofishing boat, or an interaction between time of day and water temperature would not improve our ability to describe variation in sucker *C/f* (based on ρ^2).

No other models were within $2\Delta AIC_c$ of our most likely model, indicating that they did not have similar relative likelihoods (Table 2). However, estimates of w_i and evidence ratios indicated that our top model did not clearly outperform models two to nine. To determine if any model selection bias occurred when using $2\Delta AIC_c$ as our cutoff value, we used an exploratory model averaging approach (Burnham and Anderson 2002; Lukacs et al. 2010) to determine if any other additional variables had a discernable (i.e., different from 0) relationship with estimates of sucker *C/f* (Data S2, *Supplemental Material*). This additional analysis confirmed our initial findings that time of day and water temperature were the only exploratory variables that had a discernable relationship with estimates of sucker *C/f*. This may indicate that no model selection bias occurred when using $2\Delta AIC_c$ as our cutoff.

Comparing size distributions and species proportions

Our observations of sucker TLs that we captured during the day ranged from 86 to 442 mm and had a mean of 255mm (95% CI = 105–392 mm), whereas TLs for suckers that we captured during the night ranged from 71 to 481 mm with a mean of 281 mm (95% CI = 110–395; Data S3, *Supplemental Material*). Our distributional overlap test indicated that length distributions of both groups had strong overlap (mean $\hat{\eta} = 0.69$ and 95% CI $\hat{\eta}$ = 0.63–0.75; Figure 3). The most apparent dissimilarity occurred between ~100 and 250 mm TL, although moderate dissimilarity was apparent throughout the distributions (Figure 3). Our K–S tests indicated that TLs of suckers that we sampled during the night (transect samples = 15 and suckers = 1,236) were significantly different ($D = 0.19$ and $P < 0.05$) from suckers that we sampled during the day (transect samples = 15 and suckers = 490; Figure 3). However, the significant difference in our K–S test is likely the result of large sample size given the results of our overlap test.

Our K–S tests indicated that TLs of suckers that we sampled between 6 and 15°C were significantly different from suckers that we sampled between 16 and 25°C ($D = 0.24$ and $P < 0.01$) but statistically similar to fish that we sampled at >25°C ($D = 0.08$ and $P = 0.08$; Figure 3). The TLs of suckers that we sampled between 16 and 25°C were significantly different from suckers that we sampled

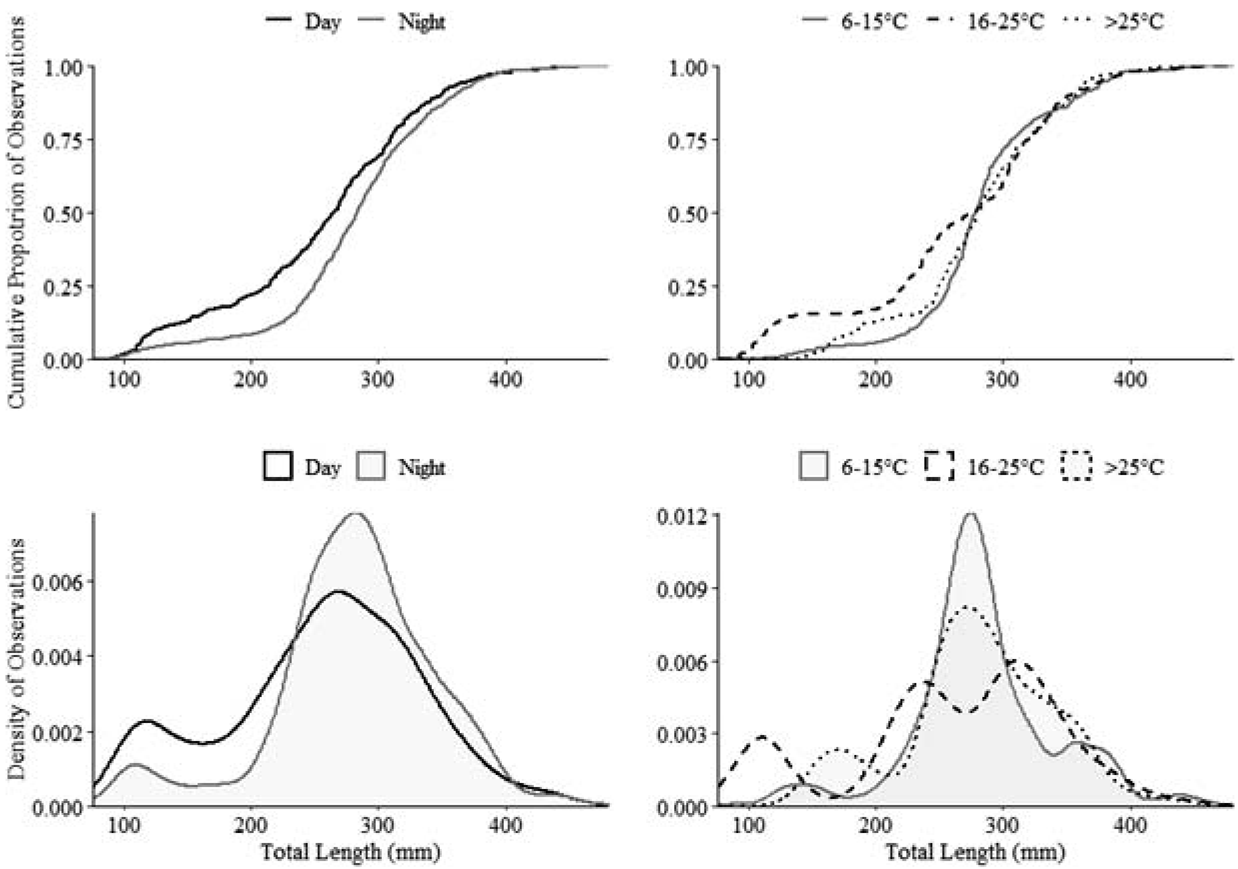

Figure 3. Cumulative empirical distributions and density of observations of total lengths for all suckers that we sampled via electrofishing on Lake Eucha, Oklahoma, during the daytime or nighttime and within three temperature groupings (6–15°C, 16–25°C, and >25°C). We collected data on Lake Eucha, Oklahoma, from 2019 to 2020 as part of a study to provide sampling recommendations for reservoir sucker populations (*Moxostoma duquesnei, M. erythrurum, Hypentelium nigricans, Catostomus commersonii,* and *Minytrema melanops*) using boat-mounted electrofishing based on catch rate, size distribution, proportion of suckers captured, and precision of catch rates. Cumulative empirical and density distributions of total lengths are specific to either the time of day or temperature group comparisons (i.e., they present the same data in a different grouping scheme).

at >25°C (D = 0.20 and P < 0.01). Suckers that we captured between 6 and 15°C (transect samples = 8 and suckers = 556) had TLs from 90 to 458 mm (mean = 283 mm and 95% CI = 142–392 mm), whereas suckers that we captured between 16 and 25°C (transect samples = 11 and suckers = 719) had TLs from 76 to 481 mm (mean = 262 mm and 95% CI = 99–397 mm). Suckers that we captured when water temperatures were >25°C (transect samples = 11 and suckers = 451) had TLs of 139–442 mm (mean = 280 mm and 95% CI = 155–387 mm). The distribution of sucker TLs that we captured between 6 and 15°C had moderate overlap with suckers that we captured between 16 and 25°C (mean $\hat{\eta}$ = 0.53 and 95% CI $\hat{\eta}$ = 0.48–0.57) and moderate to strong overlap with suckers that we captured at >25°C (mean $\hat{\eta}$ = 0.70 and 95% CI $\hat{\eta}$ = 0.63–0.76). Likewise, the distribution of sucker TLs that we captured between 16 and 25°C had moderate to strong overlap with suckers that we captured between 20 and 29°C (mean $\hat{\eta}$ = 0.60 and 95% CI $\hat{\eta}$ = 0.56–0.64). Density curves indicated that dissimilarity occurred between all three temperature groups across all lengths; however, the 6–15°C temperature group had some similarity with the >25°C group for fish from 220 to 260 mm in TL (Figure 3).

Our iterative removals of fish below TL groups ranging from 80 to 280 mm yielded mixed results. Comparing daytime and nighttime samples, we found that the distributions were statistically similar for all suckers from 210 to 270 mm; however, if we only retained suckers of ≥280 mm, distributions became statistically different (Figure 4). Similarly, we obtained high $\hat{\eta}$ estimates for retention of suckers of ≥180 mm. Our iterative removals comparing TLs of suckers that we sampled between 6 and 15°C with those that we sampled between 16 and 25°C and those that we sampled between 16 and 25°C with those sampled at >25°C showed no change in $\hat{\eta}$ and were always significantly different (Figure 4). Our iterative removals comparing TLs of suckers that we sampled between 6 and 15°C with those that we sampled at >25°C indicated that significance varied depending on the minimum size of fish that we retained. Interestingly, consecutive moderate to high $\hat{\eta}$ estimates

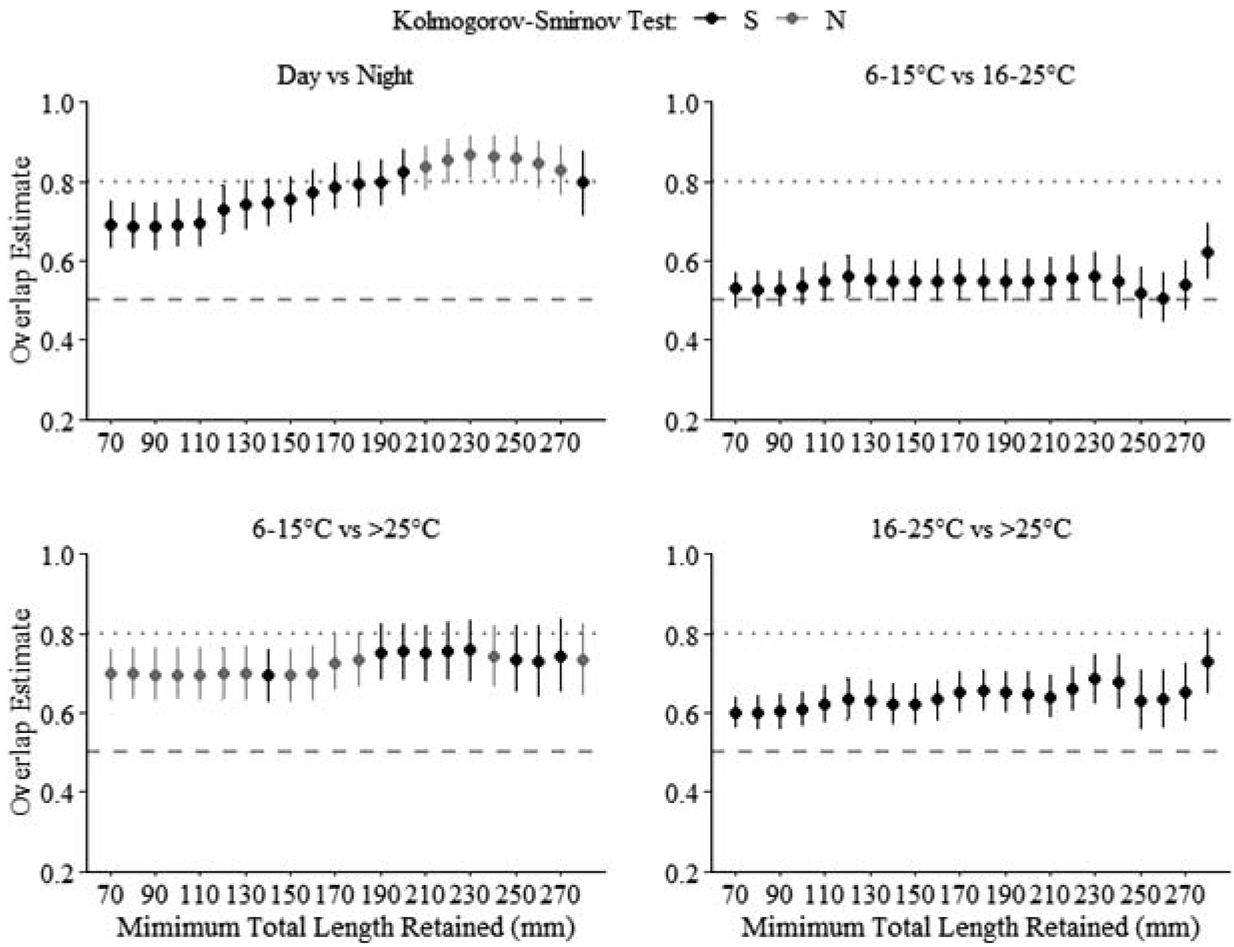

Figure 4. Mean and 95% confidence intervals for overlap estimates ($\hat{\eta}$) for total length distributions of suckers that we sampled via electrofishing on Lake Eucha, Oklahoma, during time of day (day and night) and temperature (6–15°C, 16–25°C, and >25°C) groupings after removing fish below a threshold size (i.e., minimum total length retained [mm] indicates the smallest length group included in the overlap estimate). Included are results of a Kolmogorov–Smirnov test determining if the total lengths between distributions are significantly different ("S," black circles and error bars) or not ("N," gray circles and error bars) at $\alpha = 0.05$ (time of day groups) or $\alpha = 0.01$ (temperature groupings using Bonferroni adjustment). The dotted and dashed horizontal lines represent high ($\hat{\eta} = 0.8$) and moderate ($\hat{\eta} = 0.5$) overlap between distributions, respectively. Low overlap ($\hat{\eta} = 0.2$) is represented by the bottom of the *y*-axis scale. We collected data on Lake Eucha, Oklahoma, from 2019 to 2020 as part of a study to provide sampling recommendations for reservoir sucker populations (*Moxostoma duquesnei, M. erythrurum, Hypentelium nigricans, Catostomus commersonii,* and *Minytrema melanops*) using boat-mounted electrofishing based on catch rate, size distribution, proportion of suckers captured, and precision of catch rates.

indicate that the size distribution of suckers from the 16–25°C and >25°C groups was more similar for fish >190 mm in TL.

We found a weak association between the proportion of species that we captured during the diel sampling periods. Although there was a significant difference between the proportion of species that we captured during the diel period ($P < 0.05$; Table 3) and the proportion of species that we captured among our three temperature groupings ($P < 0.05$; Table 4), the effect size estimates were weak (Cramér's $V = 0.10$ and $V = 0.07$, respectively). Because of the weak effect sizes, these relationships are likely not particularly meaningful to researchers or managers (Cohen 1988; Rea and Parker 1992).

Precision of catch estimates

Our estimated RSE for samples that we took during the night was lower than for those taken during the day (Table 4). Our Monte Carlo simulations indicated that night sampling would also achieve RSE_{25} and RSE_{15} with fewer samples and capture more suckers than day electrofishing. Sampling from 16 to 25°C yielded the lowest RSE, and sampling from 6 to 15°C yielded the highest RSE (Table 4). Electrofishing from 16 to 25°C would also achieve RSE_{25} and RSE_{15} with fewer samples but would capture fewer suckers than when taken from 6 to 15°C or in >25°C. The same number of samples would be required to achieve RSE_{25} when electrofishing from 6 to 15°C and in >25°C, but fewer samples would be needed to achieve RSE_{15} when electrofishing in

Table 3. Number and percentage of total catch of each sucker species (*Moxostoma duquesnei, M. erythrurum, Hypentelium nigricans, Catostomus commersonii,* and *Minytrema melanops*) that we captured via electrofishing on Lake Eucha, Oklahoma, based on time of day or temperature groupings (temperature group). We collected data on Lake Eucha, Oklahoma, from 2019 to 2020 as part of a study to provide sampling recommendations for reservoir sucker populations using boat-mounted electrofishing based on catch rate, size distribution, proportion of suckers captured, and precision of catch rates. Numbers and percentages of total catch are specific to either the time of day or temperature group comparisons (i.e., they present the same data in a different grouping scheme).

	Time of day, no. (%)		Temperature group, no. (%)		
Species	**Day**	**Night**	**6–15°C**	**16–25°C**	**>25°C**
Black Redhorse	38 (2)	49 (3)	42 (2)	32 (2)	13 (1)
Golden Redhorse	1 (<1)	1 (<1)	0 (0)	2 (<1)	0 (0)
Northern Hogsucker	7 (<1)	8 (<1)	5 (<1)	7 (<1)	3 (<1)
Spotted Sucker	445 (26)	1,179 (68)	511 (30)	678 (39)	435 (25)
White Sucker	1 (<1)	0 (0)	0 (0)	1 (<1)	0 (0)

>25°C. However, the most suckers would be captured when electrofishing from 6 to 15°C.

Discussion

We found that time of day (i.e., day vs. night) and water temperature were the strongest predictors associated with sucker *C/f* in reservoirs. Higher catostomid catch rates occur at night from lakes (Sanders 1992; McInerny and Cross 2004) and rivers (Pierce et al. 2001; Hine 2019); however, in-depth statistical tests were not conducted. Higher nighttime electrofishing *C/f* also occurs for prominent North American traditional gamefish families, such as Centrarchidae (Paragamian 1989; McInerny and Cross 2000) and Percidae (Pierce et al. 2001; McInerny and Cross 2004). The exact mechanisms behind higher nighttime *C/f* when electrofishing are not clear. We hypothesize that it is likely the result of differential use of nearshore areas, reduced avoidance behavior, or a combination, increasing both the probability of encounter and immobilization during nighttime (Anderson 1995). We are unaware of any publications that measure the relationship between water temperature and sucker *C/f*. McInerny and Cross (2000) found the highest catch rates for White Sucker less than 150 mm in TL during nighttime in the spring on Minnesota lakes. However, daytime and nighttime electrofishing samples collected in the early summer, late summer, and autumn were statistically similar (McInerny and Cross 2000). Hine (2019) found statistically lower catostomid *C/f* during winter than during spring, summer, and autumn in the Wabash River in Illinois. Hine (2019) did not report temperature ranges for each season; however, anecdotally, these results indicate that catostomid *C/f* may increase with temperature. These contradictory findings are likely the result of water temperature having differential effects on *q* in lotic vs. lentic systems, species-specific differences (i.e., Golden Redhorse were the only species that both we and Hine [2019] sampled), or incomparable explanatory variables (i.e., seasonal differences are not directly comparable with water temperature variations). Of these possibilities, species- and system-specific differences are the most likely as fish responses to thermal stimuli vary by species (Reynolds and Casterlin 1977; Leuven et al. 2011), and the same species in different systems may exhibit different responses to environmental phenomena (sensu Pope and Willis 1996).

We found that sucker *C/f* was related to both time of day and water temperature. Specifically, only candidate

Table 4. The number of samples (*n*) and precision (residual standard error; $RSE_{C/f}$) of sucker catch per effort (*C/f* [sucker spp./hour]) from electrofishing on Lake Eucha, Oklahoma, for time of day (day, night) and temperature (6–15°C, 16–25°C, and >25°C) groups (sample group). We include the estimated number of electrofishing samples required to obtain an RSE of 25 (RSE_{25}) or 15 (RSE_{15}) based on the empirical 80th and 95th percentiles obtained from 10,000 Monte Carlo simulations. We provide the estimated total number of suckers that would be captured based on the estimated number of surveys needed to obtain the target level of precision at each percentile for each sample group in parentheses. We collected data on Lake Eucha, Oklahoma, from 2019 to 2020 as part of a study to provide sampling recommendations for reservoir sucker populations (*Moxostoma duquesnei, M. erythrurum, Hypentelium nigricans, Catostomus commersonii,* and *Minytrema melanops*) using boat-mounted electrofishing based on catch rate, size distribution, proportion of suckers captured, and precision of catch rates. Note that *n*, $RSE_{C/f}$, RSE_{25}, and RSE_{15} are specific to either the time of day or temperature group comparisons (i.e., they present the same data in a different grouping scheme).

			RSE_{25}		RSE_{15}	
Sample group	***n***	$RSE_{C/f}$	**80th**	**95th**	**80th**	**95th**
Day	15	21	13 (197)	16 (207)	30 (492)	35 (516)
Night	15	18	10 (397)	12 (405)	23 (983)	27 (1,040)
6–15°C	8	36	17 (584)	20 (574)	44 (1,658)	48 (1,603)
16–25°C	11	17	7 (230)	9 (256)	17 (600)	20 (645)
>25°C	11	29	17 (280)	20 (278)	42 (761)	47 (758)

models with their additive effect were ranked above the intercept-only model (i.e., they were stronger predictors than the null model), and they exhibited the highest relative fit to our data (based on ρ^2). A simple mechanistic explanation for the additive effect is reduced metabolic function at lower water temperatures, resulting in suckers with lower activity and mobility (Johnston and Dunn 1987; Bartolini et al. 2015). Reduced nighttime avoidance behavior has the constant effect of making suckers easier to capture during nighttime samples (Reynolds and Kolz 2012). Reduced mobility due to lower metabolic activity caused by colder water temperatures is well documented in poikilothermic fishes (Guderly 2004). It is assumed that fish are easier to capture during nighttime due to their impaired ability to visually detect the boat; however, this theory is extrapolated from the effect of turbidity on daytime electrofishing *C/f* (McInerny and Cross 2000; Pierce et al. 2001). Conversely, the ability of the dip netter to see fish may improve during the nighttime, as suggested for bowfishers due to reduced water disturbance from wind or boats and less glare (Scarnecchia and Schooley 2020). Alternatively, sucker abundance may vary temporally based on water temperature and diurnally based on light levels such that more fish were present and could be captured during cooler nighttime samples. This alternate hypothesis is supported by the strong influence of temperature on the metabolism and spatial use of habitat by fishes (Coutant 2006) and the increased use of shallow water by White Suckers at nighttime relative to daytime (Carlander and Cleary 1949). However, it is unclear if all catostomids vary their use of nearshore shallow water habitats based on light levels. Furthermore, the use of nearshore areas by catostomids, especially White Suckers, may be a system-specific phenomenon (Reighard 1913; Tremblay and Magnan 1991; Bureau of Reclamation and Colorado State University 1993). Based on the literature available, our observed decreased *C/f* is likely due to the combination of differential nearshore habitat use, lower mobility resulting from metabolic processes, easier detection by the dip netter, and reduced avoidance behavior due to visual impairment. Further study is needed to determine the relationship between these variables and *q*, and by extension *C/f*, of catostomids.

Including reservoir storage, gauge height, distance electrofished, site electrofished, and electrofishing boat did not improve our GLM model fit or predictive potential (based on ρ^2 and AIC_c), and our model-averaged parameter estimates indicated that they were not related to our observations of sucker *C/f* (Data S2, *Supplemental Material*). Our findings for reservoir storage and gauge height indicated that suckers do not vary their use of littoral habitats in reservoirs based on water availability. Although we did not conduct species-based statistical comparisons, this agrees with descriptive statistics (means and derived 95% CIs) for catostomids captured via electrofishing in the lower Mississippi River at various water levels (Pugh and Schramm 1998). We found it surprising that distance electrofished and electrofishing boat were not related to sucker *C/f* given information presented by Bayley and Austen (2002) and Reynolds and Kolz (2012), respectively. Given the correlated nature of distance and time spent electrofishing (McInerny and Cross 2000), we hypothesize that most of the distance effect was accounted for when we standardized catch to *C/f* (hours of power applied to the water). It is also possible that our operational procedures (i.e., maneuvering the electrofishing boat toward and away from the shoreline) or the variation in habitat types within a transect reduced the strength of the relationship between distance sampled and sucker *C/f*. We theorize that standardizing power output based on power transfer theory (i.e., adjusting for changes in water conductivity; Kolz 1989; Miranda 2009) was the main reason that the electrofishing boat did not have a discernable relationship with sucker *C/f*. This theory is further supported because ambient conductivity was not included as an exploratory predictor in any of the candidate models with a similar likelihood as the top-ranked model. It is most likely that electrofishing site was not related to sucker *C/f* because each site contained heterogeneous habitats (e.g., bluff walls, macrophyte beds, shoreline slopes, and substrates), indicating that *q* may vary within each site (sensu Hangsleben et al. 2013).

Although we observed strong trends (i.e., increased sucker *C/f* during nighttime and during cooler water temperatures), our data exhibited a large amount of variation (based on ρ^2), indicating that other variables not measured in this study could reduce variation in sucker *C/f* and improve model fit. A measure of water clarity may help explain additional variation observed during daytime (McInerny and Cross 2000; Pierce et al. 2001) and potentially nighttime samples. Likewise, separating electrofishing sites by habitat type and recording sucker *C/f* for each habitat separately might either increase model fit or reduce variation in *C/f* (Buynak and Mitchell 1993; Hangsleben et al. 2013). The effects of seasonal variation (e.g., spring, summer, autumn, and winter) or important life history periods (e.g., spawning vs. not spawning) may also be worth investigating, as they may be related to sucker *C/f* (Pope and Willis 1996). Additional observations regarding the effect of season or period on sucker *C/f* should help determine if hypothesized disagreement between our results and those of Hine (2019) are due to species- or system-specific environmental variations or if season and water temperature were incomparable explanatory variables. Although we included time of day as a binary variable (i.e., nighttime and daytime), differences in nearshore habitat use may occur at finer temporal scales. We used multiple dip netters while collecting these data, which may also relate to increased variation in sucker *C/f*, as Hardin and Conner (1992) showed that electrofishing catch may vary by crew. Unfortunately, we did not collect data in a manner that allowed dip netter to be included as a fixed or random effect in our model. Electrofishing boat was not related to sucker catch; however, electrofishing field size likely varied based on boom configurations (i.e., one vs. two booms; Miranda 2009; Reynolds and Kolz 2012). If electrofishing field size was related to sucker *C/f*, then we would expect electrofishing boat to have exhibited a relationship with sucker *C/f*. Our results may indicate that field size was not strongly related to our observations of sucker *C/f*. Despite our findings, the relationship between electrofishing field sizes and *q* is poorly understood, and researchers and managers should know that there is still potential that electrofishing field size is related to *q* and by extension observations of *C/f* for other catostomids or suckers in other systems.

Daytime electrofishing appeared to capture similar-sized fish as nighttime electrofishing. The weak effect size associated with differences in size distributions from daytime and nighttime samples is more likely the result of large sample size than strong dissimilarity between the length frequency distributions (Jennions and Møller 2003; Nakagawa and Cuthill 2007). This agrees with Hine (2019) who found no significant difference in size distributions of catostomids captured during daytime or nighttime in the Wabash River in Illinois. Iterative removals of fish below various TL thresholds further support the hypothesis that the K–S test result may be due to sample size, as removal of fish of $<$180 mm in TL resulted in strong overlap estimates (based on $\hat{\eta}$), and removal of fish of $<$210 mm in TL resulted in statistical insignificance between fish size that we collected during day or night. Reexamining the results with various estimates of $\hat{\eta}$, we concluded that nighttime electrofishing captures similar-sized fish as daytime electrofishing; however, nighttime electrofishing did capture more fish less than 280 mm in TL. We know of no other publications that compared sucker sizes between daytime and nighttime samples. However, time of day affects electrofishing size bias for other fishes, including Smallmouth Bass *Micropterus dolomieu*, Largemouth Bass *M. salmoides*, Gizzard Shad *Dorosoma cepedianum*, and Bluegill *Lepomis macrochirus* (Paragamian 1989; Dumont and Dennis 1997).

Our study is the first that we know of to investigate the relationship between temperature and sucker size captured via electrofishing, although Hine (2019) captured different sizes of catostomids during spring and autumn than during summer or winter seasons. Sucker TLs were most dissimilar between our moderate temperature group (16–25°C) and our coldest (6–15°C) and warmest ($>$25°C) groups. However, sucker TLs from all groups were moderately similar. These minor differences between sucker TLs may be due to seasonal variations in sucker size distributions in shallow habitats, where electrofishing is effective. Seasonal variations in size distributions for littoral zone fish populations is not surprising (Pope and Willis 1996), and seasonal variations in size structure of sampled fish occur for other species (e.g., Largemouth Bass; Dumont and Dennis 1997).

Although electrofishing during the nighttime captured a significantly different proportion of sucker species than daytime electrofishing, there appeared to be little association between species proportions and time of day (based on *V*). Night electrofishing captured more of every species except White Sucker; we only sampled one White Sucker, and we caught it during the day. This may indicate that encountering a White Sucker in Lake Eucha, Oklahoma, is a rare event, and the fact that we captured the one White Sucker during the day may be a coincidence. We captured all other species during both daytime and nighttime. This agrees with Hine (2019), who caught the same species in both day and night electrofishing samples. It is unknown if sucker species proportions from electrofishing are indicative of the proportions within a system, as *q* is unknown for the majority of catostomids. Furthermore, it is unknown if *q* of electrofishing varies diurnally for the majority of catostomids. Data present in Pierce et al. (2001) indicate that electrofishing *q* varies diurnally for Quillback *Carpiodes Cyprinus* and Bigmouth Buffalo, which may indicate that electrofishing *q* changes diurnally for other sucker species. A mixed gear approach (e.g., seining and electrofishing) may help determine if diurnal differences in sucker species proportions are due to differences in nearshore habitat use or diurnal differences in *q* of electrofishing. For example, electrofishing data from East and West Okoboji Lakes, Iowa–Minnesota, indicated that White Sucker is only available for capture at night (Pierce et al. 2001). However, seining data from the same systems showed that White Sucker is available for capture in the nearshore area during the day and night, suggesting that the difference was due to a diurnal change in *q* of electrofishing (Pierce et al. 2001). However, a mixed gear approach may not solve all sampling issues, as it does not guarantee a suitable number of captures for each species (McInerny and Cross 2004). Like time of day, the proportions of sucker species that we captured varied with temperature; however, this association was weak (based on *V*). We are unaware of any study that evaluated how temperature affects species composition from electrofishing, but seasonal effects exist. Data from lotic systems suggest that River Redhorse *Moxostoma carinatum* and Silver Redhorse are only available for capture during the spring and summer, whereas White Sucker is only available for capture during the winter (Hine 2019). Conversely, data from lentic systems suggest that White Sucker is the most available for capture during the spring, although early summer data were statistically similar (McInerny and Cross 2004). Our data suggest that all species except Black Redhorse had higher counts when water temperatures were 16–25°C. However, when we compare proportions of catch across our temperature groups, there was little variation for any species but Spotted Sucker (based on percentage of catch). It is unclear, based on the published literature, if electrofishing *q* always changes based on temperature, although it is possible given the strong influence of temperature on fish metabolic rates (Coutant 2006) and water density (Wetzel 2001).

Our results indicate that electrofishing is an effective sampling method for suckers. This is important because little information was available regarding the precision of *C/f* estimates for suckers including catostomids. We theorize that this is likely due to the lack of management focus on the family (sensu Holey et al. 1979; Begley et al. 2018; Lackmann et al. 2021). Data that are available indicate that precision estimates (coefficient of variation = standard deviation/mean × 100) for electrofishing and netting, specifically trammel and hoop netting, are imprecise (Pugh and Schramm 1998; Paukert 2004). Data presented in Pugh and Schramm (1998) indicate that hoop netting is less precise than electrofishing for catostomids on the lower Mississippi River. Paukert (2004) was unable to attain estimates of the number of samples (*n*) needed to obtain recommended levels of precision for Flannelmouth Sucker *Catostomus latipinnis* and Bluehead Sucker *C/f* in the Colorado River in Arizona by using electrofishing (estimated $n = 500$) or trammel netting (estimated $n = 304–489$). Unlike Paukert (2004), the samples that we took during the day and night and from temperatures between 16 and 25°C had RSE estimates below 25. Likewise, we estimated that a maximum of 20 samples was all that was needed to obtain RSE_{25} for all times of day and temperature groups. Furthermore, we estimated that a maximum of 20 samples was all that was needed to obtain RSE_{15} when electrofishing from 16 to 25°C, and a maximum of 27 samples was all that was needed to obtain RSE_{15} when electrofishing at night. Interestingly, our simulations indicated that the estimated number of captured individuals would be highest when electrofishing at night or from 6 to 15°C, instead of from 16 to 25°C. These findings agree with our GLM results, which indicate that sucker *C/f* is higher at cooler water temperatures. These estimates indicate that boat electrofishing during the night at water temperatures from 16 to 25°C would be best for monitoring trends in sucker *C/f*, but electrofishing at water temperatures from 6 to 15°C would be better if the study or management objective(s) require greater numbers of suckers.

Based on our results, we suggest sampling suckers using electrofishing in similar reservoirs during the night at water temperatures from 16 to 25°C, but samples can be taken between 6 and 15°C if capturing the greatest number of suckers is desired. More or longer sampling events may also be used if sampling between 16 and 25°C to capture more individuals, as water temperatures and sucker *C/f* are inversely related. Sampling across all times of day and temperature groups resulted in similar estimates of sucker species composition (based on *V*). Furthermore, sampling during the night resulted in statistically different size distribution estimates based on K–S but not based on $\hat{\eta}$. Interestingly, size distribution estimates when we sampled at water temperatures from 16 to 25°C were only statistically different from those that we obtained at water temperatures >25°C (based on K–S); yet, samples that we obtained at water temperatures from 6 to 15°C were still moderately dissimilar (based on $\hat{\eta}$). Our sampling recommendations are adequate for those interested in obtaining relative size structure or age structure information or for those conducting mark–recapture work as long as they account for seasonal fluctuations due to recruitment (Pope and Willis 1996). Other gear comparisons including suckers were generally inconclusive because they compared catostomids in aggregate with other families (Cvetkovic et al. 2012) or only compared specific habitat conditions (e.g., Pugh and Schramm 1998). Future studies focused on gear comparisons for suckers and other catostomids would be beneficial, especially given data indicating that electrofishing *q* for suckers may vary between systems or seasons (Pierce et al. 2001; Hangsleben et al. 2013). Future work examining how time of day, water temperature, season, water clarity, sampling personnel, and electrofishing field size affect *q* or *C/f* of suckers and other catostomids when electrofishing would help provide more detailed management options. This is especially important given the general imperilment of catostomids (>55% of species; Harris et al. 2014) and concerns over increasing harvest (Lackmann et al. 2019, 2022; Radford et al. 2021). Along with studies of electrofishing, additional gear comparisons would be helpful to better understand the biases associated with various methods of monitoring catostomid populations. We believe additional focus on understanding how to best sample each of the morphological catostomid ecotypes (Moyle 2002) would be beneficial to management. It is likely that differences in *q* and *C/f* exist for each ecotype, as they exhibit differences in habitat preferences and body morphology.

Supplemental Material

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Data S1. This supplement includes data that we used for the effort-standardized catch analysis. Included are the pooled number of suckers captured divided by the amount of pedal-down time (hours) needed to collect each sample to obtain an effort-standardized estimate of catch (*C/f*) that we used as our response variable. Predictor variables were time of day, reservoir gauge height (gauge height; m), reservoir storage (m^3), ambient conductivity ($\mu S/cm^3$), surface water temperature (water temperature; °C), electrofishing site (e.g., site 1 and site 2), distance electrofished (m), and electrofishing boat (i.e., Smith Root vs. Midwest Lake Electrofishing Systems). We collected data on Lake Eucha, Oklahoma, from 2019 to 2020 as part of a study meant to provide sampling recommendations for reservoir sucker populations (*Moxostoma duquesnei, M. erythrurum, Hypentelium nigricans, Catostomus commersonii,* and *Minytrema melanops*) using boat-mounted electrofishing based on catch rate, size distribution, proportion of suckers captured, and precision of catch rates.

Available: https://doi.org/10.3996/JFWM-22-052.S1 (17 KB XLSX)

Data S2. Methods and results that we obtained using an exploratory model averaging approach based on likelihood ratios to determine if there is a discernable relationship (based on 95% confidence intervals) between our predictor variables and effort-standardized sucker catch (*C/f* [sucker spp./hour]) from Lake Eucha, Oklahoma. We collected the data used in this supplement on Lake Eucha, Oklahoma, from 2019 to 2020 as part of a study meant to provide sampling recommendations for reservoir sucker populations (*Moxostoma duquesnei, M. erythrurum, Hypentelium nigricans, Catostomus commersonii,* and *Minytrema melanops*) using boat-mounted electrofishing based on catch rate, size distribution, proportion of suckers captured, and precision of catch rates.

Available: https://doi.org/10.3996/JFWM-22-052.S2 (58 KB DOCX)

Data S3. This supplement includes data that we used for length-based analyses. Included is the species of fish captured (not used for any analysis), TL of each fish captured, surface water temperature (water temperature; °C), and time of day. Blank cells indicate missing observations. We collected data on Lake Eucha, Oklahoma, from 2019 to 2020 as part of a study meant to provide sampling recommendations for reservoir sucker populations (*Moxostoma duquesnei, M. erythrurum, Hypentelium nigricans, Catostomus commersonii,* and *Minytrema melanops*) using boat-mounted electrofishing based on catch rate, size distribution, proportion of suckers captured, and precision of catch rates.

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Table S1. Candidate model rankings for all gamma-distributed generalized linear models with Akaike weights (w_i) of <0.01 used to explain variations in sucker catch per effort (*C/f* [sucker spp./hour]) from Lake Eucha, Oklahoma. Included are McFadden's pseudo-R^2 (ρ^2; McFadden 1974), Akaike information criterion corrected for small sample size (AIC_c; Hurvich and Tsai 1989) estimates, and evidence ratios (ERs) relative to the top model. The intercept-only model is represented by (–). We collected data used for this table on Lake Eucha, Oklahoma, from 2019 to 2020 as part of a study meant to provide sampling recommendations for reservoir sucker populations (*Moxostoma duquesnei, M. erythrurum, Hypentelium nigricans, Catostomus commersonii,* and *Minytrema melanops*) using boat-mounted electrofishing based on catch rate, size distribution, proportion of suckers captured, and precision of catch rates.

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