Influence of Environmental Variables on Flathead Catfish Electrofishing Catch[1]

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Abstract: Electrofishing was conducted twice monthly from June to October 1995 on Lake Ponca Reservoir and May to October 1996 on Fort Gibson Reservoir to evaluate how temporal and environmental factors such as time of sampling, water temperature, water depth, and differing habitat types affect sampling efficiency for flathead catfish (*Pylodictis olivaris*). Relationships among catch data and concurrent temporal and environmental data were determined by multiple regression analysis. For each reservoir, models were generated for *O/f* (numbers of individuals netted/3 minutes of electrofishing), *C/f* (numbers of individuals netted/3 minutes of electrofishing), C/f_H (numbers of individuals ≥510 mm total length netted/3 minutes of electrofishing), and C/f_R (numbers of individuals <200 mm total length netted/3 minutes of electrofishing) which were statistically significant. Sampling was most effective over areas where bank inclines were moderate to steep and bottom substrates were composed of riprap or natural rock, or where submerged structure was evident. Sampling was less effective during the later portions of the study period and as water temperatures decreased.

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Interest and concerns regarding Oklahoma's flathead catfish sport fisheries have steadily increased in recent years (Summers 1986). Sampling of flathead catfish in Oklahoma reservoirs has traditionally been limited to incidental catches in standardized gill-net sets (Erickson 1978). However, resulting catch rates are typically low. In recent years, electrofishing has been used effectively to collect flathead catfish (Weeks and Combs 1981, Gilliland 1988). The Oklahoma Department of Wildlife Conservation (ODWC) began using electrofishing in 1991 to assess flathead catfish populations in reservoirs. While electrofishing is extremely effective in sampling this species, it is not clear how temporal and environmental factors such as time of sampling, water temperature, water depth, and different habitat types might affect sampling efficiency.

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Current ODWC electrofishing procedures include sampling during summer months (Jun–Aug) after water temperatures reach 16 C. Sampling locations include typical flathead catfish habitat (rocky points, riprap, log piles, undercut banks, and timbered creek channels). The majority of flathead catfish sampling in Oklahoma takes place during June. However, flathead catfish appear to be more susceptible to electrofishing during July–October (Quinn 1988), and this may be temperature related. While electrofishing is ineffective for sampling flathead catfish at temperatures below 16 C, increases in effectiveness can usually be correlated with increases in water temperatures above 16 C (Morris and Novak 1968, Gilliland 1988).

Other environmental variables affecting flathead catfish abundance include structure and depth. Flathead catfish are usually structurally oriented (Hart and Summerfelt 1974, Coon and Dames 1991), and can be particularly abundant in both rocky and woody habitats (Layher and Boles 1979, 1980; Cunningham 1995; Weller 1996). However, the effects of these habitat types on flathead catfish abundance have not been described mathematically. While water depth is an important environmental variable affecting flathead catfish abundance in rivers (Coon and Dames 1991), its effect on reservoir populations is unknown. Therefore, a need existed to determine possible effects of temporal and environmental variables on electrofishing samples of flathead catfish as a method of improving ODWC's standardized electrofishing procedures.

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Methods

Lake Ponca Reservoir impounds Turkey and Little Turkey creeks, 8.1 km east of Ponca City in Kay County, Oklahoma. It was impounded in 1935 and covers 340 ha. It has a mean depth of 4.3 m, a maximum depth of 15 m, and a water exchange rate of 0.5. The reservoir is moderately turbid with mid-summer secchi disk readings averaging 70 cm; turbidity is primarily from plankton. Major forage fish species include gizzard shad (*Dorosoma cepedianum*) and bluegill (*Lepomis macrochirus*). Sport species include flathead catfish, largemouth bass (*Micropterus salmoides*), white bass (*Morone chrysops*), white crappie (*Pomoxis annularis*), channel catfish (*Ictalurus punctatus*), and palmetto bass (*M. chrysops* ♀ × *M. saxatilis* ♂).

Fort Gibson Reservoir is located along the Grand (Neosho) River in northeastern Oklahoma. This 8,053-ha impoundment located 19.3 km northeast of Muskogee is bordered by Wagoner County to the west and Cherokee County to the east; the upper reaches extend into southern Mayes County. It is a U.S. Army Corps of Engineers reservoir impounded in 1953 for hydropower, flood control, water supply, and recreational purposes. It also stores water, in conjunction with 4 other eastern Oklahoma reservoirs, during periods of high flow to assure adequate water for year-round operation of the McClellan-Kerr Arkansas River Navigation System. Fort Gibson Reservoir has a mean depth of 6 m, a maximum depth of 23.3 m, and a water exchange rate of 16.3. The reservoir is moderately turbid with mid-summer secchi disk readings averaging 79 cm; turbidity is primarily from plankton and sediment. Major forage fish species include gizzard shad and bluegill. Sport species include flathead catfish, largemouth bass, white bass, white crappie, black crappie (*P. nigromaculatus*), blue catfish (*I. furcatus*), and channel catfish.

Lake Ponca and Fort Gibson reservoirs were electrofished for flathead catfish during daylight hours twice monthly. Sampling was conducted on Lake Ponca Reservoir from June through October 1995 and on Fort Gibson Reservoir from May through October 1996. Sampling was conducted at 20 sites per reservoir systematically selected from a pool of sites sampled during previous flathead catfish surveys. These sites represented a broad range of catch rate values and the majority represented habitats which typically harbor flathead catfish, such as rocky points, riprap and steep undercut banks (Hale et al. 1987). An electrofishing boat outfitted with a Smith-Root GPP[2] (Smith-Root, Inc., Vancouver, Wash.) set at low direct current pulse rates (7.5–30 pulses/sec) was held stationary 2–10 m offshore (Gilliland 1988, Quinn 1988, Cunningham 1995) for 3 minutes at each site. A second boat was used to locate and net surfacing flathead catfish. The number of flathead catfish observed and the number and total lengths of flathead catfish netted were recorded.

Catch rates were expressed as the number of individuals netted plus those observed but not netted at each site per 3 minutes of electrofishing (*O/f*) and as the number of individuals netted at each site per 3 minutes of electrofishing (*C/f*). In addition to monitoring overall population density, objectives of ODWC sampling procedures for flathead catfish are also to monitor numbers of harvestable-sized individuals (Oklahoma has a 510-mm statewide minimum length limit on flathead catfish) and recruitment to age 1. Thus, catch rates were also expressed as the number of individuals ≥510 mm long (C/f_H) and <200 mm long (C/f_R) netted per 3 minutes. The 200-mm ceiling was used for the second length interval because age-1 flathead catfish are typically 160–200 mm long in Oklahoma (Jenkins 1952, Weeks and Combs 1981).

Conductivity (microsiemens), secchi disk visibility (cm), water depth (m), and water temperature (C) were collected in conjunction with electrofishing samples. At the beginning of the study, each site was categorized by presence or absence of obvious submerged structure, type of substrate, and degree of bank incline. Substrate was characterized by visually inspecting the shoreline and was categorized as either riprap, natural rock, or other substrate types. Bank incline was charted using a Lowrance X25B depth finder[3] (Lowrance, Inc., Tulsa, Oklahoma) and was categorized as steep (>45 degrees), moderate (10–45 degrees), or flat (<10 degrees). Because the data describing submerged timber, substrate, and bank incline were categorical rather than numeric, indicator variables were used to describe these variables (Table 1).

Multiple regression procedures were used to generate a model for each reservoir describing the effects of temporal and environmental variables on each catch statistic. Temporal data was included in the analysis by converting the month and day each sample was collected to Julian day. Residual analysis was performed on the models to test for normality, linearity, and homogeneity of variances. Models were also

2. Does not imply endorsement of this product by the ODWC.
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Table 1. Summary of indicator variables used to describe the differences in flathead catfish electrofishing catch rates due to bank incline (flat vs. moderate, moderate vs. steep, and flat vs. steep), bottom substrate (other substrate types vs. natural rock, natural rock vs. riprap, and other substrate types vs. riprap), or presence or absence of flooded structure characterizing each sampling site. Numeric values for the indicator variables are also included.

Habitat characteristics	Indicator variable 1	Indicator variable 2	Indicator variable 3
Bank incline			
Flat	−1	0	−1
Moderate	1	−1	0
Steep	0	1	1
Bottom substrate	Indicator variable 4	Indicator variable 5	Indicator variable 6
Other types	−1	0	−1
Natural rock	1	−1	0
Riprap	0	1	1
Flooded structure	Indicator variable 7		
Presence	−1		
Absence	1		

tested for multicollinearity (Montgomery and Peck 1982, Zar 1984). The data were $Log_{10}(Y+1)$ transformed because results of the residual analysis indicated that the variance was not homogenous for any of the models. The lowest mean square error value was used as the criterion for choosing the best model (Montgomery and Peck 1982). Standardized partial regression coefficients were used to determine the importance of the environmental variables (Montgomery and Peck 1982, Zar 1984). Statistical significance was assessed at the $P = 0.05$ level.

Results

Conductivity trends for both reservoirs were similar and, except for a drastic decline on Lake Ponca Reservoir during October, remained fairly stable during the study (Fig. 1). Secchi disk visibility trends were variable for both reservoirs and showed no distinct seasonal trends (Fig. 1). Secchi disk visibility was lowest on Lake Ponca Reservoir during June and July, but then increased and remained fairly stable for the remainder of the study. Conversely, secchi disk visibility on Fort Gibson Reservoir was highest from May through July. Sampling was conducted at fairly constant water depths for both reservoirs, although slightly deeper water was sampled on Fort Gibson Reservoir (Fig. 1). Water temperatures for both reservoirs were similar and typically highest from July through September (Fig. 1).

A total of 585 flathead catfish were observed on Lake Ponca Reservoir during 9 hours of electrofishing. Of those individuals observed, 420 ranging in length from 67 to 917 mm were netted. A total 509 flathead catfish were observed on Fort Gibson Reservoir during 10 hours of electrofishing. Of those individuals observed, 295 ranging in length from 128 to 1,060 mm were netted. Mean O/f, C/f, and C/f_R for Lake

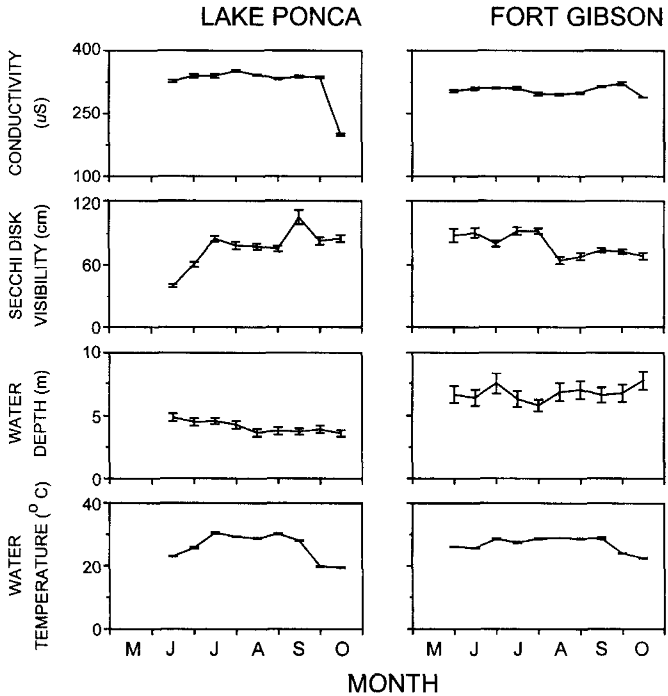

Figure 1. Mean bi-monthly conductivity, secchi disk visibility, water depth, and water temperature measurements for Lake Ponca Reservoir, June–October 1995, and Fort Gibson Reservoir, May–October 1996. Error bars represent 1 SE.

Ponca Reservoir were fairly constant from June through the first half of September (Fig. 2). However, catch rates decreased during the latter half of September and further decreased during October. Mean C/f_H for Lake Ponca Reservoir were low throughout the study. Mean O/f, C/f, and C/f_H for Fort Gibson Reservoir were greatest in May, declined through June and into July, and then remained fairly constant with some fluctuations from July through October (Fig. 2). Mean C/f_R for Fort Gibson Reservoir were low throughout the study.

The multiple-regression models describing O/f, C/f, C/f_H, and C/f_R for Lake Ponca Reservoir accounted for 40%, 31%, 6%, and 11% of the variance for each catch statistic, respectively. All models were significant ($P \leq 0.01$, Table 2). Julian day was included in all of the models as a negative variable, while secchi disk visibility and water temperature were included in at least 1 of the models as positive variables. All of the indicator variables contrasting bank incline (indicator variables 1–3) were included in at least 1 of the models as positive variables, indicating a general increase in electrofishing effectiveness as slopes became steeper. Similarly, all of the indicator variables contrasting bottom substrate (indicator variables 4–6) were included in at least 1 of the models as positive variables, indicating an increase in electrofishing effectiveness at sites with riprap substrate. The indicator variable contrasting the

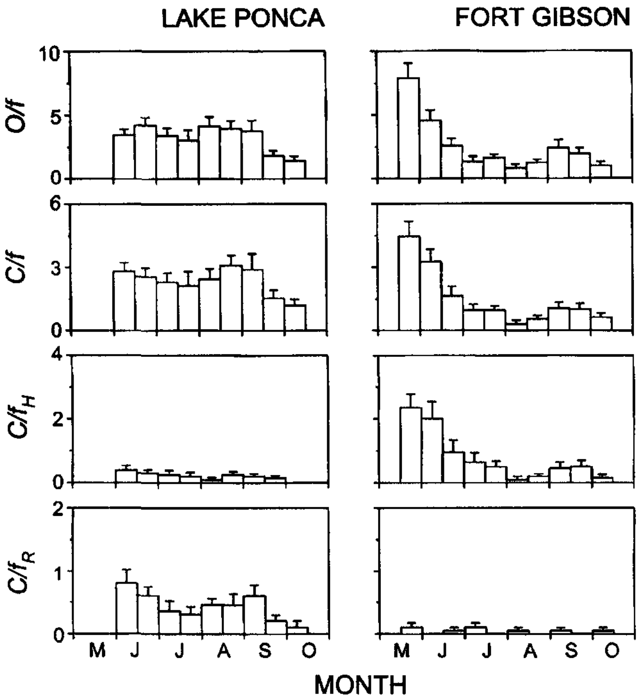

Figure 2. Mean catch rates for flathead catfish collected with electrofishing from Lake Ponca Reservoir, June–October 1995, and Fort Gibson Reservoir, May–October 1996, in Oklahoma. Catch rates are expressed as mean number of individuals observed per 3 minutes of electrofishing (O/f) mean number of individuals collected per 3 minutes of electrofishing (C/f), mean number of harvestable-sized (≥510 mm) individuals collected per 3 minutes of electrofishing (C/f_H) and mean number of age-1 (<200 mm) individuals collected per 3 minutes of electrofishing (C/f_R). Error bars represent 1 SE.

presence or absence of flooded structure (indicator variable 7) was included in the model describing *O/f* as a negative variable, indicating an increase in electrofishing effectiveness at those sites with flooded structure. Standardized partial regression coefficients indicated that Julian day, indicator variable 5 (contrasting natural rock and riprap substrates), and indicator variable 6 (contrasting other substrate types with riprap substrate) were the most important variables affecting flathead catfish electrofishing effectiveness on Lake Ponca Reservoir.

The multiple-regression models describing *O/f*, *C/f*, C/f_H, and C/f_R for Fort Gibson Reservoir accounted for 33%, 35%, 28%, and 9% of the variance for each catch statistic, respectively. All models were significant ($P < 0.01$, Table 2). Julian day and water temperature were included in all of the models except the one for C/f_R as a negative variable, while water depth was included in the model for *C/f* as a positive variable. Secchi disk visibility was included in the model for C/f_H as a negative variable but was included as a positive variable in the model for C/f_R. The indicator variable contrasting moderate

Table 2. Multiple-regression models describing flathead catfish electrofishing effectiveness (*O/f*, number of individuals observed per 3 minutes of electrofishing; *C/f*, number of individuals collected per 3 minutes of electrofishing; C/f_H, number of harvestable-sized individuals [≥510 mm] collected per 3 minutes of electrofishing; and C/f_R, number of age-1 individuals [<200 mm] collected per 3 minutes of electrofishing on Lake Ponca Reservoir, 1995 and Fort Gibson Reservoir, 1996. The model variable abbreviations are: I1 = indicator variable 1; I2 = indicator variable 2, I3 = indicator variable 3; I4 = indicator variable 4; I5 = indicator variable 5; I6 = indicator variable 6; I7 = indicator variable 7, JD = Julian day; WD = water depth (m); WT = water temperature (C); and SD = secchi disk visibility (cm). Partial regression coefficients b'_1, b'_2, b'_3, b'_4, b'_5, b'_6, and b'_7 refer to the first, second, third, fourth, fifth, sixth, and seventh variable terms, respectively.

	Partial regression coefficients								
Model	b'_1	b'_2	b'_3	b'_4	b'_5	b'_6	b'_7	R^2	P
Lake Ponca									
Log10(*O/f*+1) = 0.5820+0.1252(I6)−0.0024(JD)+0.0788(I3)+0.0020(SD)+0.0088(WT)+0.0350(I5)−0.0612(I7)	0.29	0.29	0.17	0.15	0.12	0.10	0.09	0.40	<0.01
Log10(*C/f*+1) = 0.6817+0.1300(I5)−0.0021(JD)+0.1043(I3)+0.0738(I4)+0.0022(SD)	0.38	0.27	0.24	0.21	0.17			0.31	<0.01
Log10(C/f_H+1) = 0.2053−0.0007(JD)+0.0217(I5)+0.0268(I1)	0.19	0.14	0.11					0.06	0.01
Log10(C/f_R+1) = 0.3214−0.0010(J)+0.0346(I2)+0.0333(I6)	0.21	0.16	0.14					0.11	<0.01
Fort Gibson									
Log10(O/*f*+1) = 2.0663+0.3200(I3)−0.0039(JD)+0.1697(I5)−0.0947(I2)−0.0333(WT)−0.0689(I7)	0.61	0.46	0.27	0.23	0.22	0.14		0.33	<0.01
Log10(*C/f*+1) = 1.9352−0.0038(JD)−0.0335(WT)+0.1245(I6)+0.0866(I3)+0.0779(I5)+0.0102(WD)	0.51	0.26	0.20	0.19	0.14	0.10		0.35	<0.01
Log10(C/f_H+1) = 1.4631−0.0032(JD)+0.1174(13)−0.0221(WT)−0.0014(SD)−0.0538(I6)	0.50	0.31	0.20	0.11	0.10			0.28	<0.01
Log10(C/f_R+1) = −0.0065+0.0260(I6)−0.0140(I2)+0.0004(SD)	0.21	0.20	0.12					0.09	<0.01

and steep slopes (indicator variable 2) was included in 2 of the models as a negative variable, while the indicator variable contrasting flat and steep slopes (indicator variable 3) was included in 3 of the models as a positive variable. These results together indicate a general increase in electrofishing effectiveness from sites with flat slopes, to sites with steep slopes, and finally to sites with moderate slopes. Two of the indicator variables contrasting bottom substrate (indicator variables 5 and 6) were included in at least 2 of the models as positive variables, indicating an increase in electrofishing effectiveness at sites with riprap substrate. However, the indicator variable contrasting other substrate types with riprap was included as a negative variable in the model describing C/f_H, indicating electrofishing for flathead catfish ≥510 mm was more effective over other substrate types. The indicator variable contrasting the presence or absence of flooded structure (indicator variable 7) was included in the model describing *O/f* as a negative variable, indicating an increase in electrofishing effectiveness at those sites with flooded structure. Standardized partial regression coefficients indicated that Julian day, indicator variable 3 (contrasting flat and steep slopes), and indicator variable 6 (contrasting other substrate types with riprap substrate) were the most important variables affecting flathead catfish electrofishing effectiveness on Fort Gibson Reservoir.

Discussion

The models describing *O/f* and *C/f* for both reservoirs were similar, with the exception that the *O/f* model explained more variance than the *C/f* model for Lake Ponca Reservoir. Generally, stunned flathead catfish surfaced within 45 sec after sampling was initiated and remained on the surface for 60–90 sec either lying motionless or swimming erratically. These responses are similar to those reported by Hale et al. (1987), Gilliland (1988), and Cunningham (1995). Because of the unpredictable responses of flathead catfish to being shocked, capture of stunned individuals is often difficult. Mean capture efficiencies (number of individuals observed that were also netted) for Lake Ponca and Fort Gibson reservoirs were 73.4% and 55.6%, respectively; values ranged from 59% to 84% and from 38% to 71%. This variability in catch efficiency may in part explain why the *O/f* model explained more variance than the *C/f* model for Lake Ponca Reservoir.

Julian day was included in 7 of the 8 models describing flathead catfish catch rates as a negative variable, indicating catch rates were highest during the early part of the study period. Although flathead catfish move into near-shore areas during late spring as water temperatures warm (Turner and Summerfelt 1971, Layher and Boles 1979), they often prefer deeper, cooler waters during summer months (Weller 1996). Perhaps this behavior explains the decrease in flathead catfish catch rates. My findings contradict those of Quinn (1988) who found catch rates for flathead catfish peaked in September and October. However, he attributed at least some of the increases in observed catch rates to improvements in electrofishing equipment and techniques.

Flathead catfish are usually structurally oriented (Hart and Summerfelt 1974, Coon and Dames 1991), and are particularly attracted to riprap habitat where they often spawn and are attracted to forage fish (Layher and Boles 1979, 1980; Cunningham 1995; Weller 1996). In general, the models indicated that sites with other substrates were the least productive in terms of catch rates. Furthermore, sites with riprap substrate were more productive in a majority of the models when contrasted with the other sites. The exception was C/f_H for Fort Gibson Reservoir, where sites with other substrates were the most productive. Two of the models also included the variable contrasting the presence or absence of underwater structure, indicating that flathead catfish will use other types of structure besides riprap and rock.

Steep banks seem to attract flathead catfish, especially during spawning (Fontaine 1944). In general, the models indicated that sites with flat bank inclines were the least productive in terms of catch rates. Furthermore, sites with steep banks were more productive in a majority of the models when contrasted with other sites. The exceptions were O/f and C/f_R for Fort Gibson Reservoir, where sites with moderate bank inclines were the most productive.

Secchi disk visibility was included in 4 of the models. However, partial regression coefficients indicated that this variable was relatively unimportant to the models. Mean bi-monthly values ranged from 68 to 92 cm for Lake Ponca Reservoir and 40–105 cm for Fort Gibson Reservoir. However, it is doubtful that these variations in secchi disk visibility would affect catch rates. Electrofishing catch rates for flathead catfish collected on several Oklahoma reservoirs from 1991 to 1996 were compared with corresponding secchi disk visibility readings representing a range of values. No significant correlations existed (ODWC, unpubl. data), indicating that secchi disk values at the ranges collected on Lake Ponca and Fort Gibson reservoirs have little or no effect on electrofishing catch rates for flathead catfish.

Water temperature was included in 4 of the models, O/f for Lake Ponca Reservoir and O/f, C/f, and C/f_H for Fort Gibson Reservoir. The O/f model for Lake Ponca Reservoir indicated that catch rates increased as water temperature increased. Mean bi-monthly water temperature for Lake Ponca Reservoir ranged from 23 to 30 C from June into September. However, water temperatures declined below 20 C between the 2 September sampling dates along with a corresponding decrease in catch rates. This sudden decrease in both water temperatures and O/f probably accounts for the significance of this variable in the model. Conversely, the models for Fort Gibson Reservoir indicated that catch rates decreased as water temperature increased. Mean bi-monthly water temperature for Fort Gibson Reservoir ranged from 22 to 29 C over the entire 1996 study period. Catch rates for Fort Gibson Reservoir steadily declined during this same period. Several studies have indicated that electrofishing for flathead catfish is less effective at water temperatures of 16–20 C (Morris and Novak 1968, Gilliland 1988, Quinn 1988) and ineffective at temperatures <16 C (Weeks and Combs 1981). These results would suggest that although sampling at temperatures >16 C may be effective, maximum sampling effectiveness can only be maintained at temperatures >20 C. However, as water temperatures continue to rise, catch rates may decline because flathead catfish eventually move into cooler, deeper waters after spawning (Weller 1996).

Weller (1996) found flathead catfish preferred water depths >2 m except during spring months. I found a similar relationship during this study. However, water depth was only included in 1 of the models, indicating that it is not as important to predicting sampling effectiveness as some of the other variables investigated.

Based on these results, sampling effectiveness (as measured by O/f, C/f, C/f_H, and C/f_R) for flathead catfish in reservoirs seems to be related to pre-spawning migrations of individuals into near-shore areas followed by post-spawn migrations to deeper areas as water temperatures increase. If maximizing catch-related population indices is the goal, then late May and early June are better times to sample flathead catfish, as opposed to later months (Jun–Oct) when water temperatures are warmer. Furthermore, sampling sites should be located in areas of reservoirs where bank inclines are moderate to steep and bottom substrates are composed of riprap or natural rock or where submerged structure is evident.

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