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SEASONAL AND DIEL VARIATION IN ELECTROFISHING SIZE-SELECTIVITY AND CATCH-PER-HOUR OF LARGEMOUTH BASS IN MINNESOTA LAKES

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SEASONAL AND DIEL VARIATION IN ELECTROFISHING SIZE-SELECTIVITY AND CATCH-PER-HOUR OF LARGEMOUTH BASS IN MINNESOTA LAKES[1]

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Abstract. Seasonal and diel differences in electrofishing catch per hour (CPUE) and size-selectivity of largemouth bass *Micropterus salmoides* among 16 lakes in south central Minnesota were determined. Electrofishing CPUE of largemouth bass < 120 mm total length (TL) was usually highest during the day in fall, but CPUE of largemouth bass ≥ 200 mm TL was generally highest during spring at night. Day CPUE of largemouth bass < 200 mm TL usually exceeded night CPUE regardless of Secchi depth, but day CPUE of largemouth bass ≥ 200 mm TL never exceeded night CPUE when Secchi depths were greater than 2 m. Day and night CPUE in fall were better correlated with population density estimates of largemouth bass ≥ 200 mm TL than day and night CPUE in spring, but all correlations were weak ($r <$ 0.60). Each sampling period (fall day, fall night, spring day, and spring night) selected against largemouth bass < 200 mm TL, but larger length groups were sampled similarly. Secchi depth, season, and time of day must be considered when developing procedures to sample largemouth bass with electrofishing.

Introduction

Electrofishing is the best gear for capturing largemouth bass *Micropterus salmoides*, but diel and seasonal differences in electrofishing catches have been documented (Reynolds 1983; Carline et al. 1984; Gilliland 1985; Bettross and Willis 1988). Electrofishing is primarily done in fall or spring and usually at night, but daytime electrofishing is also successful (Houser and Rainwater 1975; Gilliland 1985; Bettross and Willis 1988; Kruse 1988; IDNR 1995). However, little information is available addressing whether electrofishing during any of these sampling periods provides representative samples of largemouth bass populations.

Spring electrofishing at night has provided useful data for monitoring trends in population density, but we do not know if fall or day electrofishing provides similar data. Night electrofishing catch-per-unit-effort (CPUE) in spring was significantly correlated with population density of largemouth bass ≥

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200 mm total length (TL) among years within a Wisconsin lake, among strata within two North and South Carolina reservoirs, and among South Dakota impoundments (Coble 1992; McInerny and Degan 1993; Hill and Willis 1994). Electrofishing CPUE was also significantly ($P < 0.05$) correlated with population density of largemouth bass ≥ 200 mm TL among Ohio impoundments; however, both fall and spring CPUE were included (Hall 1986). Seasonal differences in CPUE are expected because some portions of largemouth bass populations sampled in spring are not sampled in fall (Van den Avyle 1976; Minnesota Department of Natural Resources file data).

Electrofishing is also size selective, but seasonal or diel size selectivity of pulsed DC electrofishing has not been determined. Electrofishing with AC in late summer or fall in small Missouri impoundments showed a greater selection for largemouth bass of increasing length, but other sampling periods were not addressed (Reynolds and Simpson 1978). Furthermore, pulsed DC electrofishing is now commonly used for sampling largemouth bass.

Diel differences in electrofishing were associated with water clarity, but specific data on these relationships have not been reported. Gilliland (1985) found that more and larger largemouth bass in two Oklahoma impoundments were caught during the night than day, but differences were less when water clarity decreased. However, day and night CPUE in an Alabama-Georgia impoundment did not differ (Malvestuto and Sonski 1990). Reynolds (1983) suggested that fish in clear water detect and avoid electrofishing boats better during the day than at night, thus reducing day CPUE.

Standardized sampling procedures for Minnesota lake surveys recommend that electrofishing be done during day or night in either fall or spring as long as catch per hour is at least 15 largemouth bass ≥ 200 mm TL (Schlagenhaft 1993), but no data are available addressing whether any of these sampling periods provide samples representative of largemouth bass populations. Furthermore, sampling procedures are based mostly on observations from reservoirs in the midwest and south and may not be applicable to Minnesota where largemouth bass inhabit natural lakes. Our objectives were to determine size selectivity and accuracy of catch per hour to reflect density of largemouth bass for four sampling periods (fall day, fall night, spring day, and spring night), and to identify those sampling periods that provide representative samples. Furthermore, effects of water clarity on electrofishing catches were to be determined.

Methods

Largemouth bass in 16 lakes (18 to 329 hectares) in south central Minnesota were sampled with shoreline electrofishing. Each lake was electrofished during one fall (September and October) and the following spring (May and early June), 1992 to 1995, when water temperatures were 9° to 22° C. Two sets of day and night electrofishing runs were done within each season. Day electrofishing was followed by night electrofishing in one-half of the lakes with the order being reversed for the other half. Diel sampling orders of the second set of electrofishing runs were reversed. For each lake, except the largest, the entire shoreline, at depths ranging from 0.5 to 1.5 m, was electrofished. The 329 hectare lake was divided into 11 shoreline segments with 7 or 8 randomly selected segments sampled per day-night set.

The primary elecrofishing boat was equipped with a Coffelt® VVP 2E electrofisher powered by a 3.5 KW generator that supplied pulsed DC. The boat was the cathode with a single stainless steel sphere (28 cm in diameter) as the anode. A different boat with a Coffelt® VVP 15 electrofisher powered by a 5 KW generator was used during the second set of electrofishing runs on some lakes. This boat was also the cathode, but the anode consisted of four metal conduit (2.5 cm) droppers set parellel to the bow. On all samples, one netter attempted to capture all stunned largemouth bass. Electric power was continually supplied during electrofishing. Output power transferred from water to fish (Kolz 1989; based on volt and ampere meters on the electrofisher) was similar among lakes (3.2 KW; s.e. = 0.1 KW). Weather conditions varied among electrofishing runs. Lakes were not electrofished when raining or when winds exceeded 25 km per hour.

We measured (total length in mm) all largemouth bass and clipped the anal fin of all largemouth bass ≥ 120 mm TL captured in fall. Secchi disk depth (m) was measured before each day electrofishing run. Day and night electrofishing catch per hour was calculated for largemouth bass < 120 mm, 120 to 199 mm, 200 to 299 mm, and ≥ 300 mm TL in fall and spring. Effects of sample period, lake, and sample period * lake interaction on each length group were identified with two-way ANOVA. Catch per hour data were transformed into logarithms for this analysis. Associations between ratios of day to night catch per hour of each length group and Secchi depth were identified with Pearson correlations.

Population densities of largemouth bass ≥ 200 mm TL at each lake were estimated with the modified Schnabel method (Ricker 1975). All largemouth bass marked in fall were pooled and treated as a single marking run with each spring electrofishing run treated as separate recapture runs. Population size was not estimated unless at least four marked largemouth bass were recaptured (Ricker 1975). Population density was expressed as the number per hectare of lake surface area. Associations between day and night electrofishing CPUE within each season and population density of largemouth bass ≥ 200 mm TL among lakes were determined with Pearson correlations. Because population density in each lake was estimated in fall, overwinter mortality rates among lakes were assumed equal.

Length-frequency distributions (10 mm length groups) of largemouth bass ≥ 120 mm TL were calculated for each day-season sample period electrofished at each lake. Day and night samples within each season were pooled for these calculations. Kolmogorov-Smirnov tests were used to determine if length-frequency distributions within lakes differed dielly and seasonally. Bonferroni adjustments were done on all multiple tests to protect against Type I error (Trippel and Hubert 1990). Mean lengths of largemouth bass ≥ 120 mm TL were also calculated for each electrofishing sample. Sample period effects were determined with Kruskal-Wallis tests. Preliminary analyses indicated that catches of largemouth bass < 120 mm TL, primarily age 0, caused much of the day-season variation among sampling periods; therefore, this size group was eliminated from length-related analyses.

Size-selectivity for largemouth bass was estimated for each day-season sample period. Length groups from 120 to 199 mm TL and by 50-mm increments for largemouth bass ≥ 200 mm TL were established. For each sample period, the total number of largemouth bass captured, total number of fish marked in fall, total number of fish examined for marks in spring, and the number of marked fish recaptured in spring at all lakes were pooled by length group. Preliminary analysis showed that catch efficiencies (catch per hour / population density of largemouth bass ≥ 200 mmTL) within each sample period differed among lakes; therefore, only data from lakes with similar catch efficiencies (± 25%) were pooled. Petersen (Chapman modification) estimates of population size (with 95% confidence intervals) for each length group were calculated with pooled mark-recapture data (Ricker 1975). The total number of largemouth bass in each length group caught during each sampling period was divided by the population size estimate of the same length group. These ratios were then plotted against length groups of increasing length.

Results

Electrofishing catch per hour of each length group of largemouth bass differed among day-season sampling periods, but sample period effects were not consistent among lakes. Catch per hour of largemouth bass < 120 mm TL was usually highest during the day in fall, but catch per hour of larger fish was usually lowest during the day in spring, and highest at night in spring (Figure 1). Catch per hour differed significantly among sample periods and lakes (Table 1). However, significant sample period * lake interactions, observ-

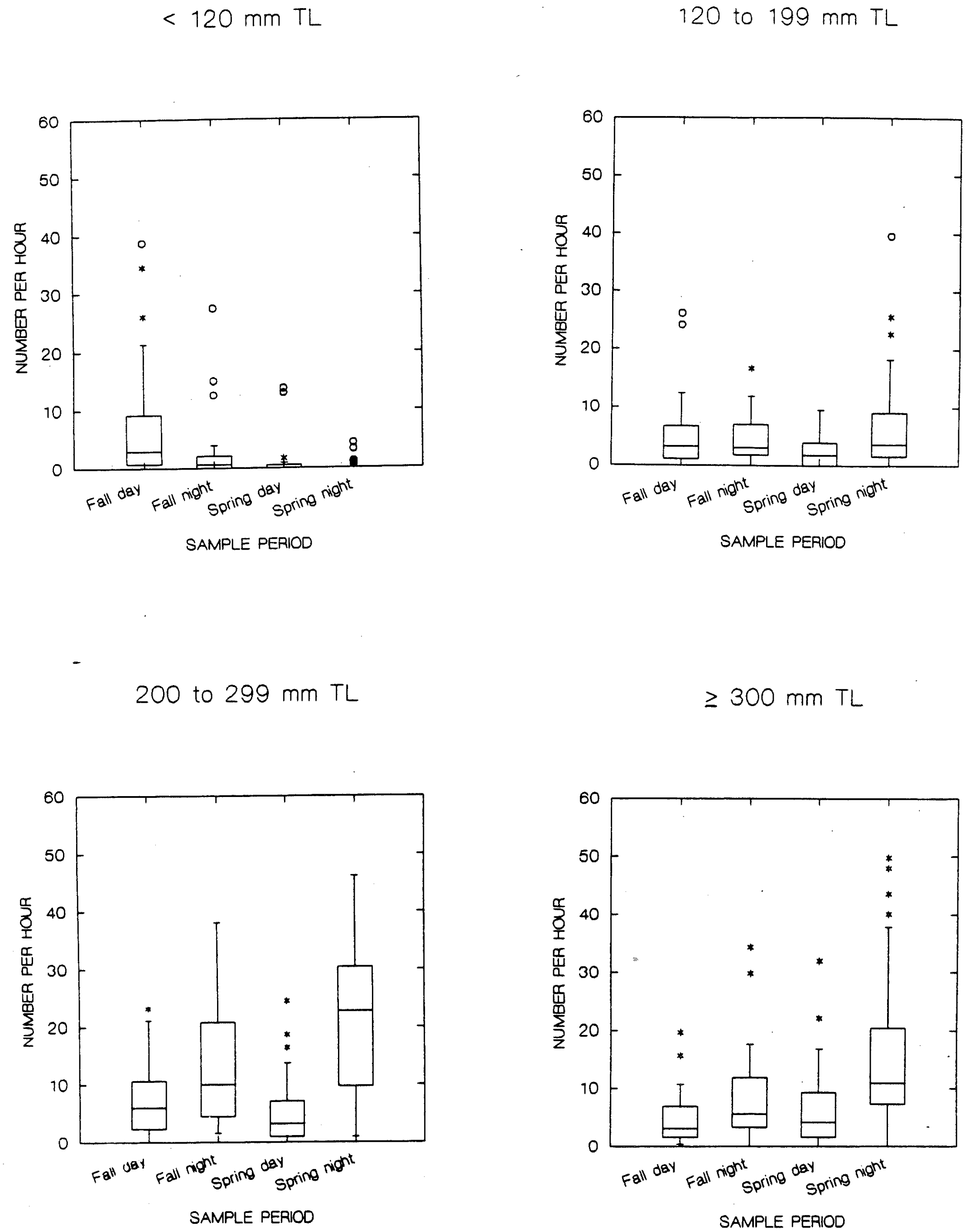


Figure 1. Box plots of electrofishing catch per hour of largemouth bass < 120 mm, 120 to 199, 200 to 299 mm, and ≥ 300 mm TL during day and night in fall and spring from 16 lakes in south central Minnesota (horizontal line within box is median, the lower and upper horizontal lines on boxes are the lower and upper quartiles, the vertical lines are the range of values that fall within 1.5 times the interquartile range, and asterisks and open circles are outliers.

ed in two of the length groups suggested that sample period effects were not consistent among lakes (Table 1).

Some diel and seasonal differences in catch per hour were associated with Secchi depth, which also differed among seasons and lakes. Day CPUE of largemouth bass < 120 mm TL usually exceeded night CPUE regardless of Secchi depth, whereas day and night CPUE of largemouth bass 120 to 199 mm TL were similar across all measured Secchi depths (Figure 2). Day CPUE of largemouth bass ≥ 200 mm TL exceeded night CPUE only when Secchi depths were less than 2 m (Figure 2). Ratios of day to night CPUE of all length groups were negatively correlated with Secchi depth, but only the correlations involving largemouth bass ≥ 200 mm TL differed significantly from zero (Figure 2). Diel differences in catch per hour of largemouth bass ≥ 200 mm within lakes were usually lower in fall than in spring, and Secchi depths were also usually lower in fall (mean = 2.0 m in fall, mean = 3.2 m in spring; $F = 63.31$; df = 1; $P < 0.0001$). Secchi depths also differed significantly among lakes ($F = 9.47$; df = 15; $P < 0.0001$), but did not change seasonally at all lakes ($F = 2.67$; df = 15; $P = 0.0096$ for season * lake interaction).

Population densities of largemouth bass ≥ 200 mm TL were estimated at 14 of the 16 lakes, but catch per hour was not strongly associated with population density during any sampling period. Correlations between electrofishing catch per hour and population density were better in fall than in spring, and when electrofishing was done at night (Figure 3). Correlation coefficients between fall catch

Table 1. Two way ANOVA tables showing probabilities for effects of sample period (fall day, fall night, spring day, and spring night), lake, and sample period * lake interaction on electrofishing catch per hour (CPUE) of largemouth bass < 120 mm, 120 to 199 mm, 200 to 299 mm, and ≥ 300 mm TL in 16 Minnesota lakes.

Dependent variable: Log CPUE of largemouth bass < 120 mm TL

Independent variable	df	SS	MS	*F*	*P*
Sample period	3	5.81	1.94	32.50	<0.0001
Lake	15	8.11	0.54	9.07	<0.0001
Sample period * Lake	45	3.95	0.09	1.47	0.0772

Dependent variable: Log CPUE of largemouth bass 120 to 199 mm TL

Independent variable	df	SS	MS	*F*	*P*
Sample period	3	1.58	0.52	11.86	<0.0001
Lake	15	8.62	0.57	12.97	<0.0001
Sample period * Lake	45	5.21	0.12	2.61	0.0002

Dependent variable: Log CPUE of largemouth bass 200 to 299 mm TL

Independent variable	df	SS	MS	*F*	*P*
Sample period	3	6.86	2.29	55.91	<0.0001
Lake	15	9.79	0.65	15.96	<0.0001
Sample period * Lake	45	5.15	0.11	2.80	0.0001

Dependent variable: Log CPUE of largemouth bass ≥ 300 mm TL

Independent variable	df	SS	MS	*F*	*P*
Sample period	3	3.94	1.32	20.13	<0.0001
Lake	15	6.21	0.41	6.34	<0.0001
Sample period * Lake	45	4.22	0.09	1.44	0.0908

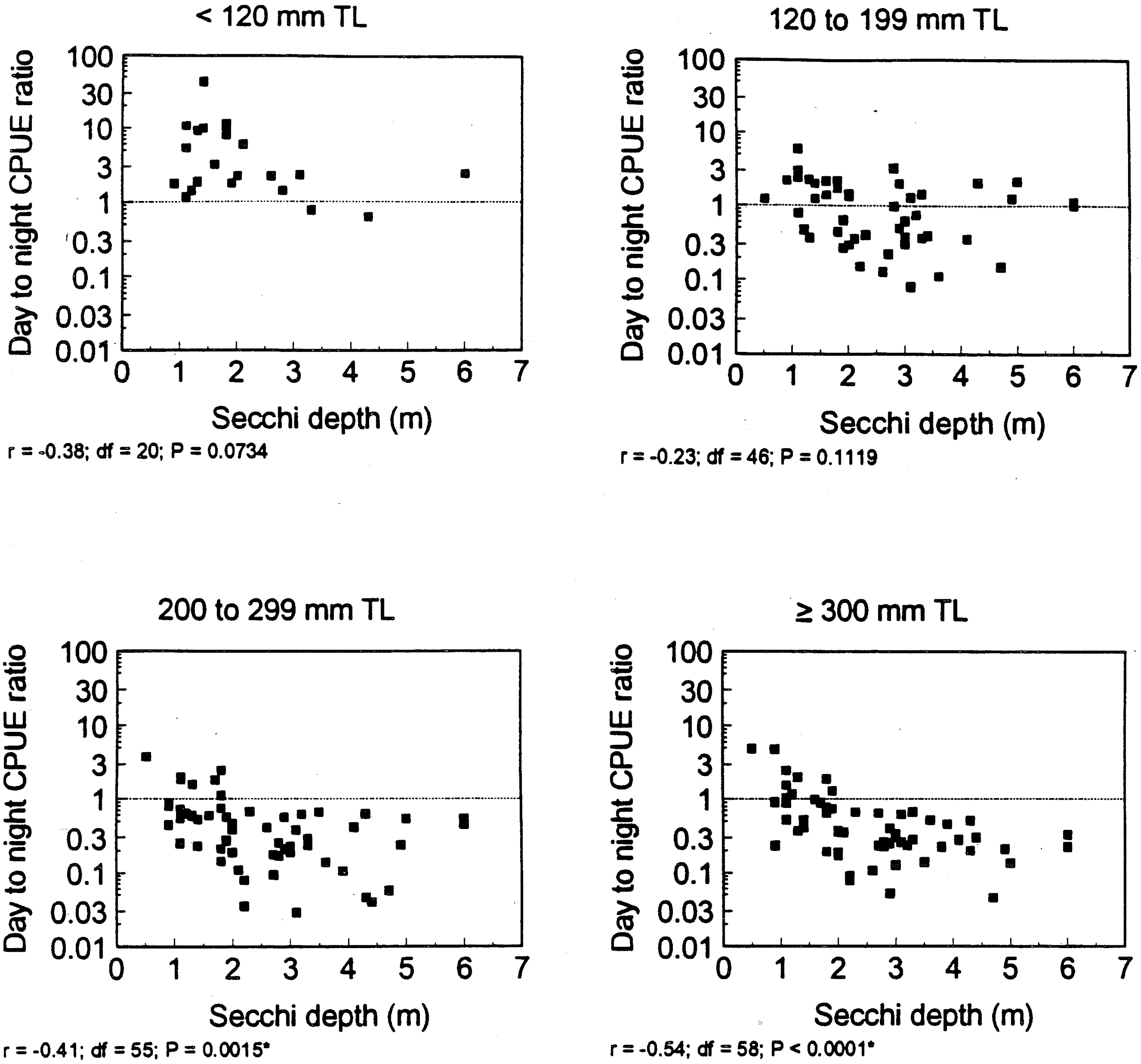
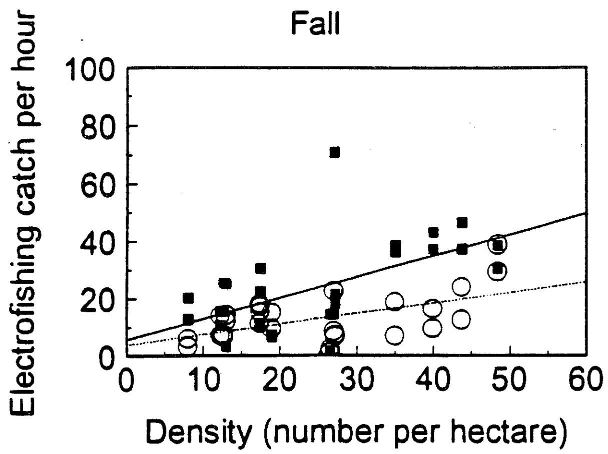


Figure 2. Ratio of day to night electrofishing catch per hour of largemouth bass < 120 mm, 120 to 199 mm, 200 to 299 mm, and ≥ 300 mm TL on a log scale versus Secchi depth (m) from 16 lakes in south central Minnesota (horizontal dashed line indicates where day and night CPUE are equal; * denotes correlation coefficient differs significantly from zero after Bonferroni adjustments).



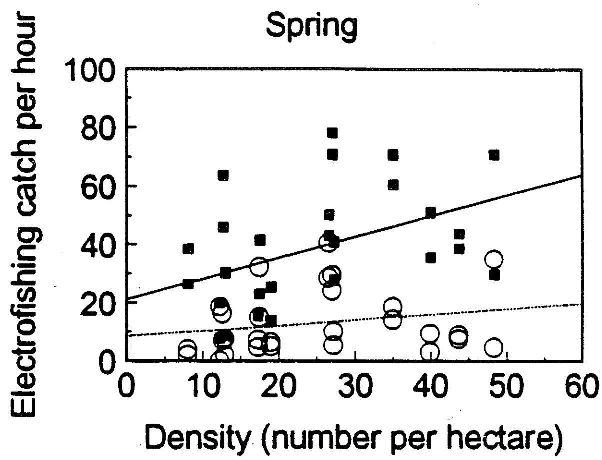


Figure 3. Plot of electrofishing catch per hour during the day (open circles) and night (dark squares) and population density (number per lake surface area) of largemouth bass ≥ 200 mm TL from 14 Minnesota lakes in south central Minnesota (* denotes correlation coefficient differs significantly from zero after Bonferroni adjustments).

per hour and population density differed significantly from zero, but correlations between spring CPUE and population density did not (Figure 3).

Patterns in size-selectivity were similar among sample periods, but length-frequencies differed more seasonally than dielly. Electrofishing during each sampling period selected against largemouth bass < 200 mm TL, but larger length groups were sampled similarly (Figure 4). However, size-selectivity curves were more stable across length groups in fall than in spring. Length-frequencies of largemouth bass ≥ 120 mm TL in day catches differed significantly from night length-frequencies in three lakes in fall and in two lakes in spring (Table 2). Length-frequencies in day samples from seven lakes and length-frequencies in night samples from six lakes differed significantly between seasons (Table 2). Medians of mean lengths were lowest during fall day samples (Figure 5). Sample period effects on mean lengths were significant ($KW = 8.44$; df = 3; $P = 0.0377$), but pairwise comparisons between sample periods were not significant.

Discussion

Size-selectivity was affected by length-related responses to electric shock, selection behavior of netters, and to the type of electric current used, but was not related to misindentification. Smaller fish undergo less electroshock than larger fish, smaller fish are less visible to netters, and smaller fish are less likely to be netted if larger fish are also observed (Reynolds 1983). Jackson and Noble (1995) reported that largemouth bass < 125 mm TL in a North Carolina reservoir were often caught with straight DC, but seldom caught with pulsed-DC. However, largemouth bass ≥ 150 mm TL were effectively captured with pulsed-DC. Although we exclusively sampled largemouth bass, identification of small largemouth bass relative to small fish of other species was not a concern. In Texas reservoirs, catch per hour of largemouth bass

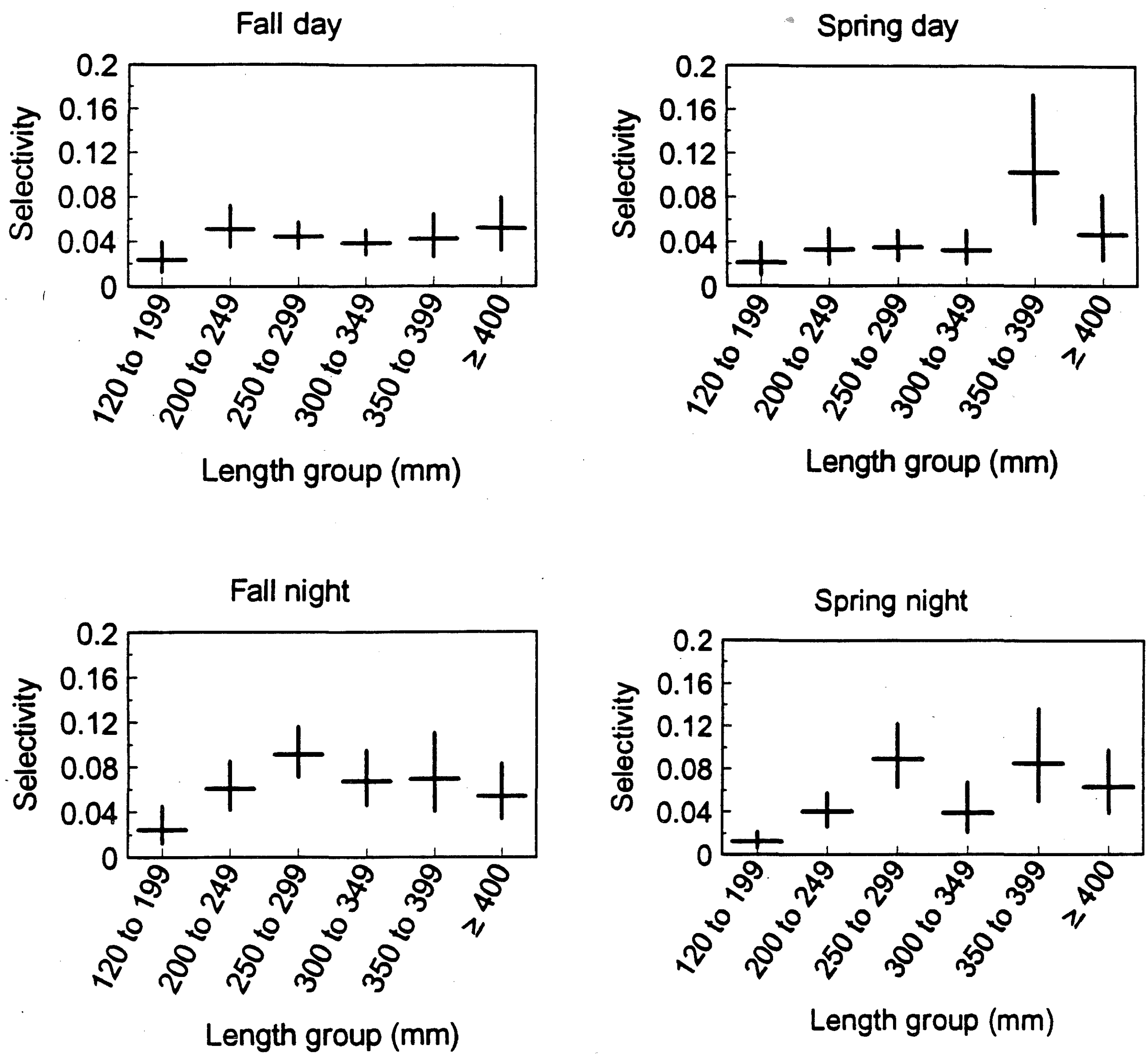


Figure 4. Size-selectivity (horizontal line; number captured/population size) with 95% confidence intervals (vertical lines) of largemouth bass ≥ 120 mm TL in lakes in south central Minnesota captured with day and night electrofishing in fall and spring.

Table 2. Kolmogorov-Smirnov statistics for comparisons between length-frequency distributions (10-mm length groups) in day and night electrofishing catches of largemouth bass $\geq$ 120 mm TL in fall and spring from 16 lakes in south central Minnesota (KS = Kolomorov-Smirnov statistic, n = sample sizes, and P = probability that length-frequency distributions are the same; * denotes length-frequency distributions differ significantly after Bonferroni adjustments).

Lake	Fall day vs fall night			Spring day vs spring night			Fall day vs spring day			Fall night vs spring night		
	KS	n	P	KS	n	P	KS	n	P	KS	n	P
Andrew	0.21	35,45	0.3551	0.52	37,319	<0.0001*	0.43	35,37	0.0029*	0.32	45,319	0.0006*
Bass	0.11	18,72	1.0000	0.22	10,129		0.30	18,10		0.10	72,129	0.8593
Camp	0.11	44,140	0.9187	0.22	18,116	0.4179	0.30	44,18	0.2150	0.23	140,116	0.0018*
Carnelian	0.35	41,89	0.0021*	0.12	62,312	0.4825	0.18	41,62	0.3727	0.24	89,312	0.0006*
Dog	0.18	25,35	0.8008	0.47	20,36	0.0065	0.20	25,20	0.8222	0.26	35,36	0.1753
Elkhorn	0.27	6,30		0.14	84,161	0.2315	0.56	6,84		0.34	30,161	0.0055
Erie	0.19	91,215	0.0237	0.09	76,282	0.8007	0.39	91,76	<0.0001*	0.25	215,282	<0.0001*
Games	0.14	124,65	0.3408	0.16	41,161	0.3614	0.25	124,41	0.0471	0.08	65,161	1.0000
Ida	0.21	80,86	0.0474	0.28	39,121	0.0176	0.53	80,39	<0.0001*	0.10	86,121	0.7540
Limestone	0.22	8,26		0.62	5,42		0.75	8,5		0.42	26,42	0.0078
Little Swan	0.13	31,53	1.0000	0.21	49,53	0.2106	0.13	31,49	1.0000	0.13	53,53	0.7934
Marion	0.14	184,141	0.0817	0.28	37,161	0.0207	0.45	184,37	<0.0001*	0.21	141,161	0.0023*
Mary	0.33	66,96	0.0003*	0.28	37,172	0.0190	0.33	66,37	0.0106	0.14	96,172	0.1893
Pleasant	0.21	73,207	0.0156	0.48	25,223	0.0001*	0.63	73,25	<0.0001*	0.22	207,223	0.0001*
St. Anna	0.32	63,141	0.0002*	0.21	75,225	0.0148	0.31	63,75	0.0024*	0.16	141,225	0.0234
Stahls	0.23	64,56	0.0851	0.34	18,63	0.0767	0.49	64,18	0.0024*	0.12	56,63	0.8153

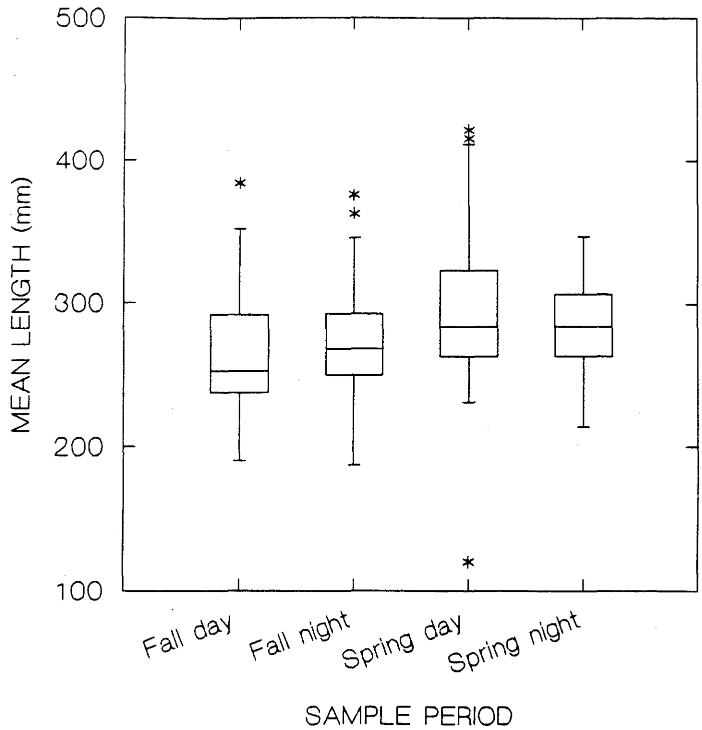


Figure 5. Box plots of mean lengths of largemouth bass ≥ 120 mm TL from 16 lakes in south central Minnesota captured with day and night electrofishing in fall and spring (horizontal line within box is median, the lower and upper horizontal lines on boxes are the lower and upper quartiles, the vertical lines are the range of values that fall within 1.5 times the interquartile range, and asterisks and open circles are outliers).

< 200 mm TL when netters selected only largemouth bass and when netters captured all observed small fish of every species did not differ significantly (Twedt et al. 1992). Reasons for more inconsistent size selectivity curves in spring than in fall are unknown.

Increased catch per hour of larger fish or greater mean lengths observed in spring were probably related to spawning behavior of mature (> 250 mm TL) largemouth bass, but catches were also affected by water clarity. In spring, mature largemouth bass spawn at depths less than 2 m (Heidinger 1975; Carlander 1977) where electrofishing is most effective. We also observed largemouth bass ≥ 200 mm TL in clear lakes actively avoiding the boat during day electrofishing. However, we could not determine if this same behavior occurred in turbid water or at night.

Small largemouth bass (< 120 mm TL) apparently move offshore at night in fall, and exhibit greater mortality rates than larger largemouth bass which helps explain lower catch per hour at night in fall and low catch per hour in spring. Although electrofishing selected against largemouth bass < 200 mm TL, many largemouth bass < 120 mm TL were still caught during the day in fall. The lack of small largemouth bass in night samples suggests that they moved from the shallow areas. Overwinter mortality of largemouth bass in Minnesota lakes was not known. However, annual mortality of age-0 largemouth bass after brood dispersal (late June) in a

Minnesota lake was greater than 90%, but annual mortality of older largemouth bass was 30 to 40% in two other Minnesota lakes (Kramer and Smith 1962; Newburg and Schupp 1986; Minnesota Department of Natural Resources, file data).

Some of the poor relationships between catch per hour and population density were related to the relatively narrow range of these variable among the study lakes. Ranges of night catch per hour (2 to 71 in fall and 8 to 78 in spring) and population densities (8 to 48 per hectare) of largemouth bass ≥ 200 mm TL were 3 to 36 times narrower than those reported in other studies where correlation coefficients ranged from 0.79 to 0.96 (Hall 1986; Coble 1992; Hill and Willis 1994).

Management Implications

Shoreline electrofishing during any of the four sampling periods will provide accurate data on size-structure of largemouth bass ≥ 200 mm TL, but only catch comparisons from the same time period will be meaningful. Furthermore, electrofishing catch per hour during any sampling period is not a useful indicator of population density of largemouth bass ≥ 200 mm TL, when expressed as the number per hectare. However, catch per hour could be useful if changes are greater than the ranges of the same variables reported herein. For long-term monitoring programs to provide meaningful information, electrofishing should be done during the same time of day and season, and when the water clarity is similar.

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