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Influence of Diel Period on Electrofishing and Beach Seining Assessments of Littoral Fish Assemblages

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Abstract.—At two sites in each of two lakes, we sampled days and nights to evaluate diel and gear (pulsed-DC boat electrofisher versus large beach seine) differences in species richness, total fish abundance, assemblage similarity, and size structure of populations of bluegills *Lepomis macrochirus*. Both gears produced significantly greater species richness at night than during the day. Total catch per unit effort for electrofishing was significantly greater for nighttime than for daytime samples. Diel differences in total density for seining samples were not statistically significant. Ordination of the electrofishing data tended to separate night samples from day samples at sites because of greater abundance of bluegills, black bullheads *Ameiurus melas*, walleyes *Stizostedion vitreum*, and white suckers *Catostomus commersoni* in night samples. Ordination of the seining data indicated a high degree of similarity among day and night samples within three of the four sites and separated West Okoboji sites from East Okoboji sites. We found few significant diel differences in bluegill size distributions for a given gear, but the two gears generally produced differing size distributions within a given diel period. Diel differences were more prevalent for electrofishing than for seining, whereas differences among sites were more apparent for seines. Our results should help biologists make more informed choices regarding diel periods to sample and gear to use in their littoral zone sampling programs.

Assessment of fish populations and species assemblages is important in managing fisheries and environmental quality in freshwater systems (Murphy and Willis 1996; Simon 1998). To conduct such assessments, a key decision is the sampling method that will be used; that is, both the choice of gear and method of deployment (Willis and Murphy 1996). Likewise, in environmental quality assessments using fish, choice of sampling method is a fundamental part of planning (Yoder and Smith 1998). Direct comparisons of fish population and assemblage characteristics, as revealed by different sampling gears in common systems, have contributed greatly to our understanding of strengths and weaknesses of these gears (Summers and Axon 1980; Bayley and Dowling 1990; Boxrucker et al. 1995).

For a variety of reasons (e.g., differences in fish activity, distribution, and vulnerability to capture), sampling during day or night is recognized as a potentially important determinant of the qualitative and quantitative results (Thorpe 1978; Helfman 1986; Murphy and Willis 1996). Because of convenience or for safety reasons, most fish sampling is conducted during the day, despite the widespread belief that night sampling may often be more effective. More quantitative studies of the potential effects of diel period are needed to evaluate differences in results, which in turn can be weighed against practical and safety concerns when planning sampling programs.

The primary purpose of this study was to examine the influence of diel period on electrofishing and beach seining assessments of littoral fish populations and assemblages. A secondary purpose was to compare results of two sampling gears (pulsed-DC boat electrofisher versus large beach seine), especially with respect to diel period. Our approach was to sample two sites in each of two lakes using each gear during daytime and nighttime. Our specific objectives were to evaluate diel and gear differences in species richness, total fish abundance, assemblage similarity, and size structure of populations of bluegills *Lepomis macrochirus*.

Methods

Study sites.—East and West Okoboji lakes (43°23′N; 95°8″W) are part of an interconnected

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chain of lakes near the Iowa–Minnesota border in northwest Iowa. Although connected by a narrow channel, the lakes have very different morphometry and water quality. East Okoboji has a surface area of 743 ha, mean depth of 3.2 m, and maximum depth of 6.7 m; West Okoboji has a surface area of 1,558 ha, mean depth of 11.5 m, and a maximum depth of 41 m (Bachmann et al. 1995). Secchi transparency during the study period averaged 0.9 m in East Okoboji and 3.5 m in West Okoboji (S. Fisher, Iowa Lakeside Laboratory, personal communication). Conductivity is similar in the two lakes: 486 μS in East Okoboji and 432 μS in West Okoboji (Bachmann and Jones 1974).

We sampled at two sites in each lake. The East Okoboji sites, Hinshaw Bridge and Narrows, were located along undeveloped shorelines, with moderate amounts of woody debris present in the shallow littoral zone. The bottom in the littoral zone of both these sites was gently sloping, with a mixture of silt, sand, gravel and cobble substrate. A few small, scattered boulders were present at the Hinshaw Bridge site. Submersed vegetation was very sparse and widely scattered at both sites. The West Okoboji sites, Gull Point and Millers Bay, both had gently sloping bottoms, but differed markedly in other respects. The Gull Point substrate was a mixture of primarily sand, cobble, and occasional small boulders and included sparse, scattered vegetation and relatively little woody debris; its shoreline included private cottages with docks and the natural shoreline of a state park. The Millers Bay site, located along Iowa Lakeside Laboratory property, was undeveloped; its substrate was a mixture of silt, sand, and gravel, and its littoral zone had moderate amounts of both woody debris and submersed vegetation.

Sampling.—We sampled the littoral zone fish assemblages at each of the four sites four times between June 20 and July 7, 2000. We electrofished and beach seined each site during both daytime and nighttime. For practical reasons, all the electrofishing samples were completed before seining commenced; otherwise, sites were sampled in haphazard order, depending largely on weather and the direction of shoreline exposure. Daytime sampling was between 1000 and 1600 hours, and nighttime sampling was between 2200 and 0200 hours. Sites were not sampled more that once during a 24-h period.

Electrofishing samples were obtained using a pulsed-DC boat electrofisher with a single, spherical anode (Reynolds 1996). Electrofisher settings were 450 V, 10 A, 60 pulses/s, and 30% pulse width. Two workers, positioned on either side of the single anode, dipped stunned fish from the front of the boat with long-handled nets (6-mm-bar mesh). We sampled along the shoreline at depths ranging from 0.5 to 2 m, with docks and fallen trees occasionally altering our course. Duration of electrofishing samples averaged 41 min and ranged from 19 to 79 min, depending on catch rates and length of shoreline available for sampling.

Seine samples were obtained with a 6-mm-bar mesh beach seine (100 × 3.5 m, enclosing 0.16 ha, with floats on the top line and a lead-core bottom line; bag was 3.5 × 3.5 m; Hayes et al. 1996). From the front deck of a boat, the seine was deployed in a semicircle extending out from an obstruction-free portion of shoreline and then pulled to shore from both ends simultaneously. At each site, sampled depths ranged from 0 to 2.5 m.

Captured fish were processed quickly at the site in an attempt to release all fish alive. Species were sorted into tubs containing lake water and individual fish were identified to species, counted, and measured (total length) to the nearest 1 mm. In three of the seine samples, we measured subsamples of roughly 100 specimens as described above, to estimate length distributions of large age-0 catches. Lengths were assigned to unmeasured individuals from such catches as random numbers drawn from normal distributions with means and standard deviations obtained from the measured subsamples. Lengths assigned in this way were constrained within the observed range of subsample lengths. From all these counts and lengths we calculated electrofishing catch per unit effort (CPUE; number/h) and beach seining density (number/ha) for individual species and total fish in each sample. Additionally, for each sample we calculated length frequencies and proportional stock density (PSD) estimates (Anderson and Neumann 1996) for bluegills and species richness of the entire assemblage. Bluegill was chosen for length-frequency and PSD analysis because it was the only species sufficiently abundant at all sites to allow meaningful analysis of length frequency. We analyzed PSD because it focuses on fish above stock size (i.e., ≥ 80 mm for bluegill), excluding age-0 fish.

Statistical analyses.—We used a nested analysis of variance (ANOVA) with untransformed data to test for effects of diel period, sampling gear, lake, and site (nested within lake) on species richness. We used separate nested ANOVAs with log-transformed data to test for effects of diel period, lake,

TABLE 1.—Fish species collected, lakes in which the species were collected (E = East Okoboji, W = West Okoboji), mean catch per unit effort (CPUE; electrofishing; number/h) and density (seining; number/ha), and the percentage of samples containing the species. Species are listed in descending order of overall mean CPUE.

Species name		Lakes found in	Electrofishing				Seining			
			Mean CPUE		% samples		Mean density		% samples	
Scientific	Common		Day	Night	Day	Night	Day	Night	Day	Night
Lepomis macrochirus	Bluegill	E, W	14.05	53.31	100	100	941.8	3706	100	100
Perca flavescens	Yellow perch	E, W	8.64	13.83	75	100	485.8	132.1	75	100
Morone chrysops	White bass	E, W	1.29	11.02	25	75	17.3	40.9	50	75
Aplodinotus grunniens	Freshwater drum	E, W	1.47	10.24	75	100	58.2	78.6	100	100
Micropterus dolomieu	Smallmouth bass	E, W	1.00	8.74	50	50	3.1	3.1	25	50
Stizostedion vitreum	Walleye	E, W	0	8.30	0	75	1.6	7.9	25	100
Ameiurus melas	Black bullhead	E, W	1.29	6.02	25	100	133.6	45.6	100	75
Micropterus salmoides	Largemouth bass	E, W	1.90	5.37	75	75	20.4	9.4	75	75
Cyprinus carpio	Common carp	E, W	4.89	1.82	50	50	34.6	29.9	75	100
Notropis hudsonius	Spottail shiner	E, W	0.38	4.97	25	75	36.2	18.9	25	50
Lepomis gibbosus	Pumpkinseed	E, W	0.57	1.22	25	50	1.6	11.0	25	50
Percina caprodes	Logperch	E	0	1.58	0	25	0	0	0	0
Ictalurus punctatus	Channel catfish	E	0.60	0.79	25	25	7.9	9.4	50	25
Catostomus commersoni	White sucker	E, W	0	1.22	0	50	4.7	4.7	50	25
Carpiodes cyprinus	Quillback	E, W	1.20	0	25	0	0	3.1	0	25
Lepomis cyanellus	Green sunfish	E, W	0	1.07	0	50	0	6.3	0	25
Pimephales notatus	Bluntnose minnow	W	0	0.86	0	25	0	0	0	0
Esox lucius	Northern pike	W	0.19	0.43	25	25	1.6	6.3	25	25
Esox masquinongy	Muskellunge	E	0.43	0	25	0	0	0	0	0
Ictiobius cyprinellus	Bigmouth buffalo	E, W	0	0.28	0	25	20.4	11.0	50	75
Pomoxis nigromaculatus	Black crappie	E, W	0	0	0	0	18.9	50.3	50	25
Etheostoma nigrum	Johnny darter	W	0	0	0	0	3.1	0	25	0
Cyprinella lutrensis	Red shiner	E	0	0	0	0	1.6	0	25	0
Ameiurus natalis	Yellow bullhead	E	0	0	0	0	0	3.1	0	25

and site (nested within lake) on total CPUE (from electrofishing) and total density (from seining). The ANOVAs were performed using the GLM procedure of SAS (SAS Institute Inc. 1988).

Using a multivariate approach, we explored apparent similarities in the fish assemblages (i.e., presence and abundance of multiple species) within and among the four sites, as reflected in samples from the two diel periods. The two sampling gears we used yielded different response variables, so they were analyzed separately. Electrofishing CPUE and seining density data for individual species were log-transformed ($\log_{10}[x + 1]$) before analysis. For each analysis, we first calculated pairwise similarities between all samples using the Bray–Curtis similarity coefficient (also known as Czekanowski's index of similarity; Pielou 1984; Clarke and Warwick 1994). The resulting similarity matrices were then used as input for nonmetric multidimensional scaling (MDS) ordinations. To assist interpretation of ordinations, we calculated Pearson correlations of MDS dimension scores with the transformed abundance data for each species. Similarity matrix calculations and MDS ordinations were performed using PRIMER (Carr 1997; Clarke and Warwick 1994), and correlations were tested using the CORR procedure (SAS Institute Inc. 1988). Clarke and Warwick (1994) provide a detailed explanation and rationale of this approach.

We tested for differences in bluegill length-frequency distributions that were due to diel period and sampling gear by using the chi-square approximation of the Kruskal–Wallis statistic and the NPAR1WAY procedure (SAS Institute Inc. 1988). Diel period differences were tested separately by lake and gear; gear differences were tested separately by lake and diel period. Finally, we evaluated differences in bluegill PSD estimates due to diel period and sampling gear using 95% confidence intervals approximated according to Gustafson (1988).

Results

Species Richness

We captured 24 species overall, 21 in East Okoboji Lake and 19 in West Okoboji Lake (Table 1). For both sampling gears, night sampling in each lake yielded significantly more species than day sampling (Table 2; Figure 1). Species richness did not differ significantly between gears, lakes, sites,

TABLE 2.—Summary of analysis of variance (ANOVA) testing for the effects of diel period (D), sampling gear (G), lake (L), and site (S) on species richness (number of species) for two Iowa lakes, East Okoboji and West Okoboji. Sites were nested within lakes.

Source	df	MS	*F*	*P*
D	1	39.06	5.89	0.045
G	1	14.06	2.12	0.189
L	1	0.56	0.08	0.779
S(L)	2	6.31	0.95	0.431
D × G	1	7.56	1.14	0.321
D × L	1	7.56	1.14	0.321
G × L	1	0.06	0.01	0.925

or their interactions (Table 2). Walleyes showed the most pronounced diel difference, appearing in seven of eight nighttime samples but in only one daytime sample, and that a single individual. Green sunfish appeared in three daytime samples but no night samples. White bass were collected in six of eight nighttime samples, but in only three daytime samples (Table 1).

Variable sampling duration did not significantly bias electrofishing estimates of species richness. The correlation (Pearson's r) of species richness with sampling duration was -0.36 ($N = 8$, $P > 0.05$).

Total CPUE and Density

Total CPUE for nighttime electrofishing samples was significantly greater than for daytime samples

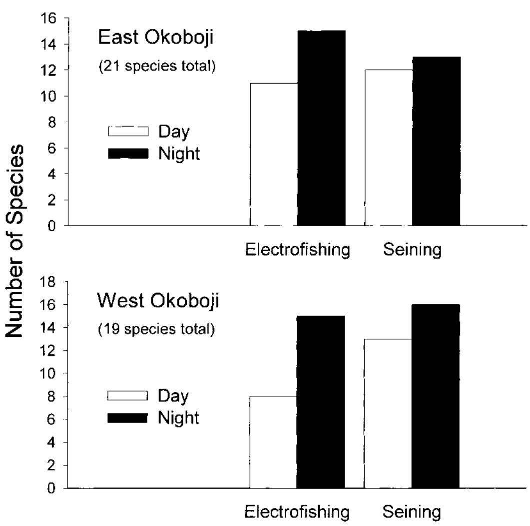

FIGURE 1.—Species richness (number of species) estimates from day and night electrofishing and seining in East Okoboji (upper panel) and West Okoboji (lower panel) lakes, Iowa. Each bar shows cumulative species richness from two sampling sites in each lake.

TABLE 3.—Summary of ANOVA testing the effects of diel period (D), lake (L), and site (S) on electrofishing catch per unit effort in two Iowa lakes, East Okoboji and West Okoboji. Sites were nested within lakes.

Source	df	MS	*F*	*P*
D	1	3.12	26.19	0.036
L	1	0.74	6.17	0.131
S(L)	2	0.46	3.84	0.207
L × D	1	0.25	2.09	0.285

(Table 3) at all four sites (Figure 2). Total CPUE did not differ significantly between lakes, sites or the lake × diel period interaction.

Variable sampling duration did not significantly bias electrofishing estimates of total CPUE. The correlation (Pearson's r) of species richness with sampling duration was -0.38 ($N = 8$, $P > 0.05$).

Total density did not differ significantly between diel periods and lakes (Figure 2; Table 4). However, differences due to site were significant (Table 4), driven by an abundance of age-0 bluegills and yellow perch at the Millers Bay site. The lake × diel period interaction was not statistically significant.

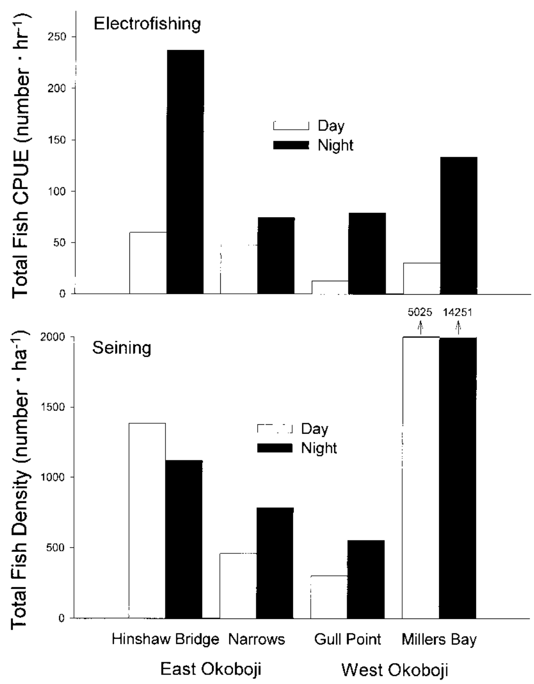

FIGURE 2.—Day and night electrofishing (total fish catch per unit effort [CPUE]; upper panel) and seining (total fish density; lower panel) at four sampling sites in East Okoboji and West Okoboji lakes, Iowa. Day and night sample pairs are grouped by site.

TABLE 4.—Summary of ANOVA testing the effects of diel period (D), lake (L), and site (S) on total density (fish/ha) from seining in two Iowa lakes, East Okoboji and West Okoboji. Sites were nested within lakes.

Source	df	MS	*F*	*P*
D	1	0.49	5.17	0.151
L	1	1.17	12.48	0.072
S(L)	2	4.85	51.58	0.019
L × D	1	0.22	2.32	0.267

Assemblage Similarities

The MDS ordination of Bray–Curtis similarity matrices provided two-dimensional representations of the similarities in the species composition and relative abundance among samples for electrofishing and seining (Figure 3). Stress values of both ordinations were below 0.1, which in these examples indicates that two-dimensional ordinations were sufficient to represent multidimensional (i.e., multispecies) similarities among samples (Clarke and Warwick 1994).

Dimension 1 of the electrofishing ordination (Figure 3) tended to separate night samples (on the right half of the plot) from the day samples (on the left half of the plot). This separation was generally related to greater CPUE of bluegills, black bullheads, walleyes, and white suckers in night samples. Dimension 2 of the electrofishing ordination tended to separate East Okoboji samples (upper half of the plot) from West Okoboji samples (lower half of the plot). This separation was primarily related to greater CPUE of common carp in East Okoboji samples. Only one of the four sites (Narrows) showed a high degree of similarity between day and night electrofishing samples.

Dimension 1 of the seining ordination (Figure 3) separated the Gull Point samples from the other three sites. This separation was due to generally greater density of smallmouth bass and lower densities of common carp and yellow perch in Gull Point samples. Dimension 2 of the seining ordination separated the Millers Bay samples from the other three sites, and to a lesser extent separated the West Okoboji samples from the East Okoboji samples. This separation was due to generally greater densities of bluegill, northern pike, and spottail shiner and to lower densities of freshwater drum and white bass in West Okoboji samples, particularly in Millers Bay samples. In contrast with the electrofishing samples, day and night seining samples at three sites showed a high degree of similarity, as indicated in Figure 3 (bottom) by the very close proximity of the sample pairs from Hinshaw Bridge, Narrows and Millers Bay.

Bluegill Length-Frequency Distributions and PSD

Day and night length-frequency distributions of bluegills were similar for both sampling gears in East Okoboji Lake (electrofishing: $\chi^2 = 1.8$, df = 1, $P = 0.18$; seining: $\chi^2 = 0.44$, df = 1, $P = 0.51$), and for electrofishing in West Okoboji Lake ($\chi^2 = 2.1$; df = 1; $P = 0.15$) (Figure 4). Day and night length-frequency distributions from seine samples were significantly different in West Okoboji ($\chi^2 = 26.6$; df = 1; $P < 0.0001$), age-0 fish accounting for a greater proportion of the total catch in the night sample. Electrofishing and seining length-frequency distributions were significantly different for both diel periods in West Okoboji (day: $\chi^2 = 15.5$, df = 1, $P < 0.0001$; night: $\chi^2 = 59.5$, df = 1, $P < 0.0001$) and for day sampling in East Okoboji ($\chi^2 = 4.8$; df = 1; $P = 0.03$). Electrofishing and seining length-frequency distributions were not significantly different for night sampling in East Okoboji ($\chi^2 = 0.04$; df = 1; $P = 0.85$). The differences between sampling gears, particularly evident in West Okoboji, were due to larger proportions of age-0 fish in seine samples.

Bluegill PSD estimates were fairly consistent between diel periods and sampling gears in both lakes (Figure 4). The PSD estimates ranged from 50 to 74 in East Okoboji and 47–67 in West Okoboji. Confidence intervals generally encompassed means of contrasted diel periods and sampling gears, which suggests that these factors did not have significant effects on PSD estimates.

Discussion

The diel differences in electrofishing samples we demonstrated for species richness, total CPUE, and assemblage similarity are consistent with findings from previous studies. Paragamian (1989) found that electrofishing CPUE for smallmouth bass in an eastern Iowa stream was higher at night than during the day, and noted that smallmouth bass were observed actively swimming away from the boat during the day. He also reported higher smallmouth bass PSD in night samples, although the significance of those differences is questionable because the 95% confidence interval for daytime PSD overlapped the nighttime mean PSD. McInerny and Cross (2000) reported higher electrofishing CPUE for largemouth bass at night than during the day in Minnesota lakes and noted that daytime CPUE increased with turbidity. Other examples of greater CPUE and greater species rich-

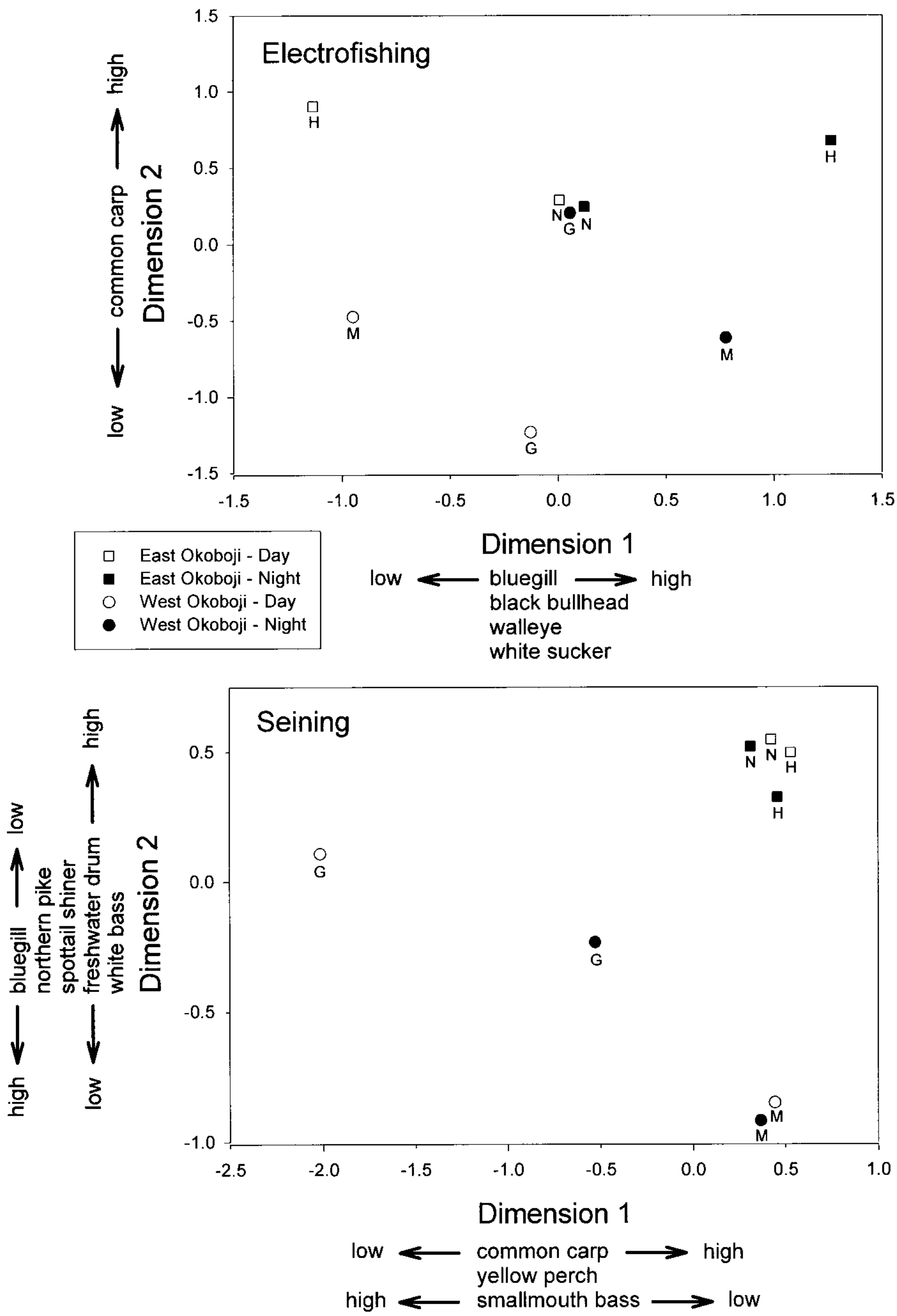

FIGURE 3.—Nonmetric multidimensional scaling ordinations of assemblage similarities from day and night electrofishing and seining in East Okoboji and West Okoboji lakes, Iowa. Ordinations were based on Bray–Curtis similarity matrices constructed from log-transformed ($\log_{10}[x + 1]$) electrofishing (catch per unit effort as number/h) and seining (density as number/ha) data. Species listed along ordination axes were significantly correlated with dimension scores (Pearson's r; $P < 0.05$) and are included to facilitate interpretation. Sites are indicated by letters below symbols as follows: H = Hinshaw Bridge, N = Narrows, G = Gull Point, M = Millers Bay. Ordination stress values were 0.08 (top panel) and 0.01 (bottom panel).

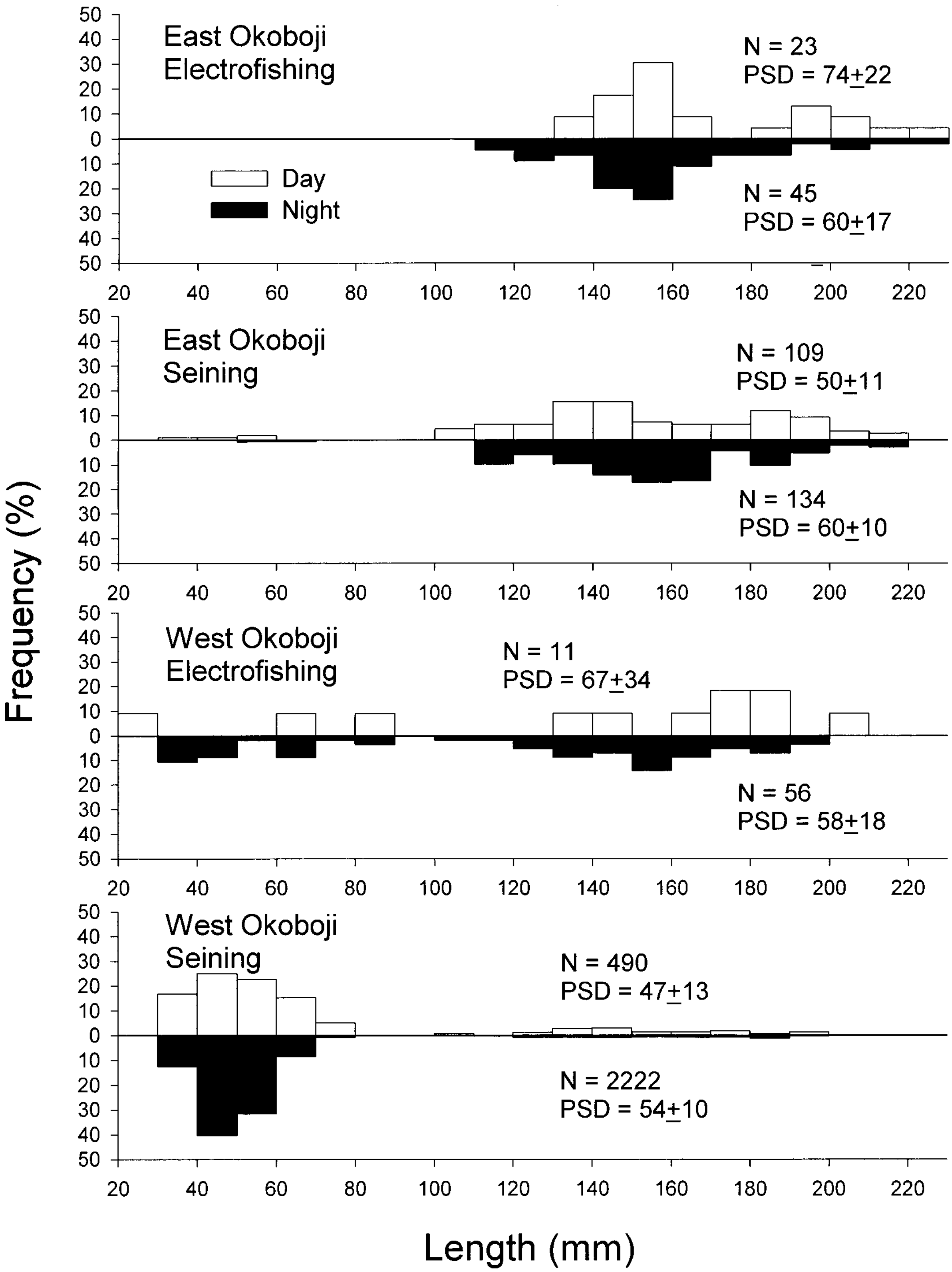

FIGURE 4.—Bluegill length frequencies and proportional stock density (PSD; ±95% confidence interval) from day and night electrofishing and seining in East Okoboji (two upper panels) and West Okoboji (two lower panels) lakes, Iowa. Sample sizes (*N*) include all bluegill size-classes.

ness at night are cited by Reynolds (1996), and much of this difference is probably due to reduced avoidance at night. In our study, diel electrofishing differences in species richness and CPUE were greater in relatively clear West Okoboji Lake (mean Secchi transparency of 3.5 m during the study) than relatively turbid East Okoboji Lake (mean Secchi of 0.9 m). These results are in accordance with McInerny and Cross's (2000) positive relationship of daytime CPUE and turbidity and suggest that visual avoidance was an important determinant of the diel differences in all these studies.

Although previous studies of diel effects on electrofishing have been conducted, none used a multivariate, assemblage-level analysis, as we present here. Our MDS ordination separated nighttime electrofishing samples from daytime samples, and although this was based on a matrix of pairwise similarities in composition and abundance of the entire assemblage, certain species emerged as having the strongest influence on this pattern. Nighttime samples were characterized by having generally greater CPUE for bluegills, black bullheads, walleyes, and white suckers. In addition to the likelihood of greater daytime avoidance by some species, as discussed above, it seems likely that changes in spatial distribution due to diel onshore–offshore movements might also play a role. Carlander and Cleary (1949) reported nighttime onshore movement of black bullheads, walleyes, and white suckers, a pattern confirmed in other studies, particularly for walleyes (e.g., Kelso 1978; Helfman 1981).

Unlike the relatively well-documented day–night differences in electrofishing, we are unaware of previously published studies on effects of diel period on beach seining. As with electrofishing, seining at night resulted in significantly higher species richness estimates than during the day, although absolute differences were less dramatic than with electrofishing. Our analysis of seining total density did not show a significant effect of diel period but did indicate significant differences among sites.

In contrast to the electrofishing ordination, which showed considerable dissimilarity in samples collected during different diel periods within sites, our MDS ordination of seining samples indicated a high degree of diel similarity within three of the four sites and separated West Okoboji from East Okoboji sites. This general lack of diel differences but presence of among-site differences mirrored the results of the total density analysis. Together, these results suggest that compared with electrofishing, seining is less likely to be affected by the choice of diel sampling period and more likely to detect differences among sampling locations.

Our length-frequency results suggest that, at least for species like bluegill, diel differences would probably be minor, especially for electrofishing. However, the choice of sampling gear could potentially make a large difference in resulting size distributions, as evidenced by our differences between electrofishing and seining length-frequency distributions of bluegill. This difference might be especially pronounced where abundant age-0 fish are present, as was the case in West Okoboji. Neumann et al. (1995) reported similar size distributions for juveniles of both striped bass *Morone saxatilis* and white bass in electrofishing and seine samples, so apparently the differences we found between gears will not necessarily occur with other species or in other situations.

In contrast with our comparisons of bluegill size distributions spanning the entire length range, our bluegill PSD comparisons, which only included fish 80 mm or longer (omitting age 0), showed a fairly consistent picture of adult size structure, regardless of diel period or sampling gear. This further emphasizes the role that age-0 fish played in the length-frequency differences we demonstrated and suggests that, for assessments focusing on adult size structure such as PSD, the choice of either gear or diel period would probably not bias the results.

Sampling fish populations and assemblages for fishery management and environmental assessment requires an understanding of the strengths and weaknesses of the many available techniques. Frequently, choices are made based on tradition, cost, availability and convenience. Depending on the goals of sampling, the most appropriate gear and method of deployment may vary. Information on the nature and magnitude of differences in the resulting population and assemblage characteristics, as revealed by our day versus night and gear results, should help biologists make better choices in their littoral zone sampling programs.

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