Diel Activity Levels of Centrarchid Fishes in a Small Ohio Lake

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Abstract.—We used three different sizes of trap nets (small, medium, and large sizes of both mesh and throats) sampled at 6-h intervals to determine peak activity time(s) for fish along the deep vegetation line in Sandy Lake, Portage County, Ohio. Over 90% of the total catch comprised bluegill *Lepomis macrochirus*, largemouth bass *Micropterus salmoides*, pumpkinseed *L. gibbosus*, and black crappie *Pomoxis nigromaculatus*. All four species had their lowest catch per unit effort (CPUE) at night (2200–0400 hours). Different length-classes of pumpkinseeds and black crappies had peak CPUE during different times of the day. Smaller length-classes of all species (i.e., those captured in small and medium trap nets) had peak CPUE during either dawn (0400–1000 hours) or midday (1000–1600 hours), whereas the only piscivores captured in high abundance (black crappies 150–303 mm total length captured in large trap nets) had higher CPUE at dusk (1600–2200 hours) than during any other time of the day. It is possible that these activity patterns are affected by predation risk or food availability. These findings indicate that individual species or length-classes do not typically interact directly even though they use the same habitat. Therefore, when predicting potential species interactions in natural systems, it is important to consider diel changes in behavior. When possible, sampling schedules should take into account the activity patterns of the species of interest to ensure that information is obtained from the most appropriate time(s) of day to more accurately assess species interactions.

A fundamental focus of ecology is determining the role of individual species in ecosystem processes. From a management standpoint, it is important to understand the basic ecology (e.g., diet and habitat selection) of each organism in a system, so that potential competitive and predator–prey interactions can be identified. Understanding how these ecological characteristics vary throughout the day is equally important. For example, when planktivorous fish are introduced into a system, zooplankton abundance is expected to decrease, ultimately leading to large algal biomass through top-down, cascading trophic interactions

(Hairston et al. 1960; Carpenter et al. 1985). However, many zooplankton species are only in the epilimnion where fish can effectively feed on them at night because of diel vertical (Wetzel 1983) and horizontal (Timms and Moss 1984; Lauridsen et al. 1996) migration behavior. Therefore, if the fish species of interest is not efficient at feeding on zooplankton under low light levels, a trophic cascade may not occur in systems with strong diel zooplankton migrations.

The effects of predation risk and competition on diet, habitat selection, and growth of centrarchids have been well studied (e.g., predation risk: Mittelbach 1981; He and Kitchell 1990; Turner and Mittelbach 1990; Chick and McIvor 1997; competition: Werner and Hall 1976, 1977, 1979; Laughlin and Werner 1980). Much less is known about how these interactions change throughout the day. For predation or interference competition to occur, the organisms involved must be in the same location and active at the same time.

The diel activity levels of centrarchids in nature are not well known. Beitinger (1975) found juvenile bluegill *Lepomis macrochirus* were most active during the day and least active at night under laboratory conditions. Demers et al. (1996) found adult largemouth bass *Micropterus salmoides* and smallmouth bass *M. dolomieu* were more active during the day than night under laboratory conditions ($n = 2$ for each species). We know of no other published studies that measured the diel activity of centrarchids. Many studies have investigated diel diet changes in centrarchids (e.g., Keast and Welsh 1968; Baumann and Kitchell 1974; Booth 1990; Keast and Fox 1992; Dewey et al. 1997). However, it is not clear if the times of day when fish stomachs were less full (typical of nighttime samples) indicate periods of inactivity, or if the fish are actively searching for food but are inefficient at locating or capturing prey at that time of the day, possibly because of low light levels. The purpose of this study was to test for diel changes in activity of centrarchids along the littoral-pelagic ecotone of Sandy Lake, Portage County, Ohio, in order to determine potential predator–prey and competitive interactions.

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TABLE 1.—Fish species captured from Sandy Lake, Ohio on eight sample dates between July 12 and August 9, 1999, by trap nets with three different mesh and throat size combinations. Net sizes were defined as follows: large = 2.5-cm mesh, 12.7-cm^2 throat; medium = 1.3-cm mesh, 7.6-cm^2 throat; and small = 0.6-cm mesh, 3.8-cm^2 throat.

Species	Net size			Total
	Large	Medium	Small	
Bluegill *Lepomis macrochirus*	204	192	168	564
Largemouth bass *Micropterus salmoides*	0	12	79	91
Pumpkinseed *L. gibbosus*	43	37	4	84
Black crappie *Pomoxis nigromaculatus*	46	1	25	72
Redear sunfish *L. microlophus*	12	5	3	20
Warmouth *L. gulosus*	1	7	2	10
Yellow perch *Perca flavescens*	4	1	5	10
Brown bullhead *Ameiurus nebulosus*	8	1	0	9
White crappie *P. annularis*	3	1	4	8
Black bullhead *A. melas*	2	1	3	6
Walleye *Sander vitreus*	2	1	1	4
Gizzard shad *Dorosoma cepedianum*	1	0	0	1
Green sunfish *L. cyanellus*	0	0	1	1
Yellow bullhead *A. natalis*	1	0	0	1
Unidentified centrarchids	0	0	1	1
Unidentified lepomids	1	0	0	1
Total	328	259	296	883

Methods

The capture rate of fish in passive capture gear such as trap nets is a function of fish activity (Hubert 1996). Therefore, catch per unit effort (CPUE) from the trap nets represents a reasonable estimate of relative activity. To increase the range of fish lengths captured while minimizing the potential for predation within the nets, we used three trap net designs varying only in mesh and throat size (2.5-, 1.3-, and 0.6-cm mesh with 12.7-, 7.6-, and 3.8-cm^2 throats for large, medium, and small net designs, respectively). The construction details and length-specific catch bias of these nets have been described elsewhere (Shoup et al. 2003a). Same-sized nets were deployed in pairs in Sandy Lake, as described by Hubert (1996), with a shared lead net set parallel to shore and the opening of the nets facing each other (opening perpendicular to shore). Each net also had a single wing set at a 45° angle to the lead net. Each pair of nets was set with the lead net along the 1.8-m depth contour, approximately 1 m offshore from a fairly distinct vegetation line. Preliminary studies where nets were rotated among sampling locations found no significant difference in the CPUE and total length (TL) of fish captured by the nets at the different sampling stations ($F_{2,25}$ = 0.42, 0.10; P = 0.66, 0.91 for CPUE and TL, respectively).

Nets were sampled on eight dates between July 12 and August 9, 1999, several weeks after centrarchid peak spawning times in Sandy Lake. As a part of a concurrent study, these nets were set on June 18, 1999, and remained in the water con-tinually until the conclusion of this study. Nets were emptied at 2200 hours (on four dates) or 1600 hours (on four dates) and then sampled every 6 h for the following 24 h. This produced samples from four periods of the day: dawn (0400–1000 hours), midday (1000–1600 hours), dusk (1600–2200 hours), and night (2200–0400 hours). When possible, all captured fish were identified to species and measured (TL in millimeters). Dead fish, hybrids, and juvenile fish that could not be reliably identified to species were identified to the lowest taxonomic level possible in the field.

Diel CPUEs (number of fish captured per hour) were tested by means of a three-factor analysis of variance (ANOVA) with repeated measures. Individual trap nets were treated as subjects, net size and time of day were specified as fixed factors, and sample date and sample date × time-of-day interaction were specified as random factors. Separate ANOVAs were performed on the species-specific CPUE of all species that accounted for 5% or more of the total catch from all nets. When ANOVA procedures detected significant differences (P < 0.05), a Tukey's test was used to determine which levels of the factors differed.

Results

A total of 883 fish were captured on the eight sampling dates (Table 1). Bluegills (64%), largemouth bass (10%), pumpkinseeds (10%), and black crappies (8%) each accounted for 5% or more of the total catch (Table 1). Together, these taxa accounted for over 90% of the total catch.
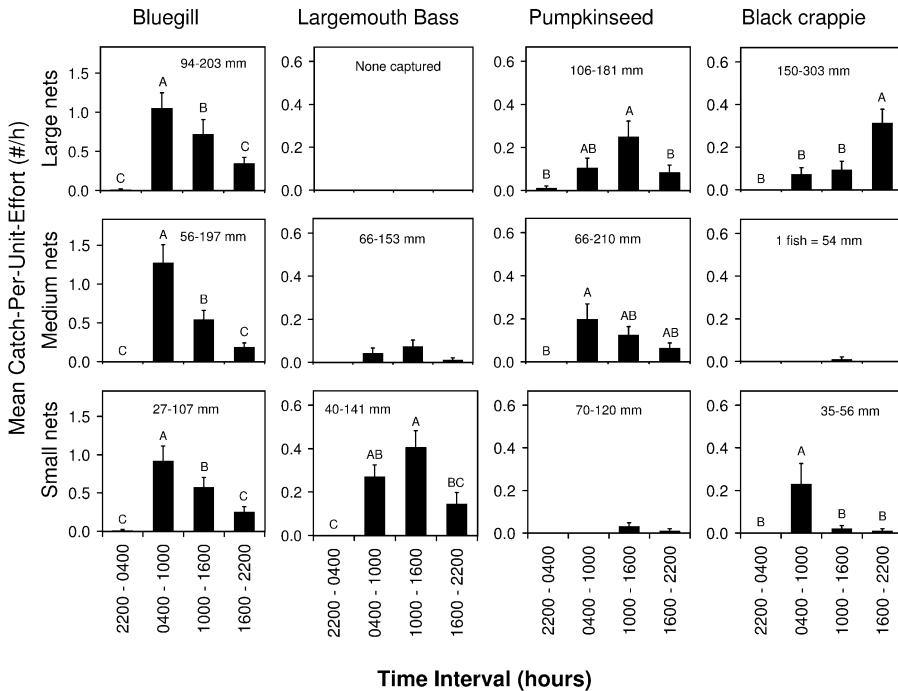
FIGURE 1.—Diel catch per unit effort (number per hour from 6-h samples) from trap nets with one of three mesh and throat size combinations fished in Sandy Lake, Ohio, on eight sample dates during the summer of 1999. Error bars indicate SEs. Different letters indicate significant differences ($P < 0.05$) among times of day within each species and net size. The length range of fish (mm; TL) captured by each net size is given on each graph. Note the different y-axis scale on the graphs for bluegills.

Bluegill CPUE differed among sample times ($F_{3,21} = 15.3$, $P < 0.01$; Figure 1). For all net sizes, bluegill CPUE was highest during the dawn samples, followed by the midday, dusk, and night samples. All comparisons except dusk and night samples were significantly different (Tukey's test: $P < 0.05$ for all comparisons, except dusk and night samples where $P = 0.06$).

The diel pattern for largemouth bass CPUE differed among net sizes (net size × time of day: $F_{6,152} = 7.9$, $P < 0.01$; Figure 1). No largemouth bass were captured in the large net during the study. In the medium nets, CPUE was similar among sample times (Tukey's test: $P > 0.92$). In the small trap nets, largemouth bass CPUE was higher during midday than during the night and dusk samples ($P < 0.01$). Additionally, the CPUE of bass in the small nets was lower during the night than dawn samples ($P < 0.01$).

The diel pattern for pumpkinseed CPUE differed among net sizes (net size × time of day: $F_{6,152} = 3.38$, $P < 0.01$; Figure 1). Pumpkinseed CPUE from large nets during midday was higher than during dusk (Tukey's test: $P = 0.05$) or night (P

< 0.01). Pumpkinseed CPUE from medium nets during dawn samples was higher than during night samples ($P = 0.01$). A difference did not exist in the CPUE among sampling times in the small nets ($P > 0.99$); however, this may be a function of the low number of fish captured ($N = 4$; Table 1).

The diel pattern for black crappie CPUE differed among net sizes (net size × time of day: $F_{6,152} = 8.0$, $P < 0.01$; Figure 1). Black crappie CPUE from large nets during the night was higher than during all other sample times (all Tukey tests: $P < 0.01$). Only one black crappie was captured in the medium nets during the study (during the midday sample interval). Black crappie CPUE from small nets during the dawn samples was higher than at all other sample times ($P < 0.01$).

Discussion

The CPUE patterns indicated that different species, and even different length-classes of the same species, were most active at different times of the day. This pattern may allow for temporal niche partitioning among centrarchids in Sandy Lake. It also illustrates the importance of understanding

diel patterns when predicting species interactions in a system.

The only large piscivorous fish (i.e., those having gape sizes large enough to prey on fish lengths captured in the small nets) that we captured in our trap nets were adult black crappies, which had high CPUE during the dusk samples. All small juvenile fish (i.e., fish captured in the smallest net size and those that would be most vulnerable to black crappie predation) had their peak activity time earlier in the day. Juvenile fish CPUE during dusk samples was significantly lower than during their peak time (except for small pumpkinseeds, which showed no significant diel pattern and had low catch rates in the small nets). Even small black crappies had a very different activity pattern from adult crappies. This pattern may indicate predator avoidance behavior by small juvenile fishes. Savino and Stein (1989) found that when bluegills observed a foraging bass, they moved out of predation range and remained motionless. If fish decreased activity to avoid predation they would not be as likely to enter the trap nets. These fish may also have changed habitats to avoid predation (e.g., moved further into the vegetation adjacent to the trap nets: He and Kitchell 1990; Diehl and Eklov 1995; Chick and McIvor 1997), making them less likely to be captured by our nets. Black crappies are probably not as great a predation risk as largemouth bass and walleye *Sander vitreus* in Sandy Lake based on their abundance and length structure (D. Shoup, personal observation). However, the CPUE of adults of these two species in the trap nets was not high enough to determine any diel pattern in their activity.

It is also possible that the timing of prey availability drives changes in activity. We did not perform extensive stomach content analysis (D. Shoup, unpublished data) of the fish captured in the nets because of the long sampling intervals and the bias that could be introduced by fish feeding while in the nets. However, several studies have investigated diel changes in the feeding intensity of centrarchid fishes, which in most cases closely corresponded with our activity level estimates. Bluegill CPUE in our study was highest from dawn samples, corresponding with the morning peak feeding periods found by other studies (Keast and Welsh 1968; Sarker 1977; Booth 1990; Keast and Fox 1992). However, we did not detect any increase in activity during late afternoon or evening when some studies have found a second peak feeding time for bluegill (Keast and Welsh 1968; Johnson and Dropkin 1993). Juvenile large-mouth bass CPUE in our study was highest at midday, which was not significantly different from the CPUE during dawn. This pattern is similar to the pattern of feeding intensity of juvenile bass found by Olmsted (1974), except that the feeding intensity in Olmsted's study was also high at dusk when our CPUE was low relative to midday CPUE. Pumpkinseed CPUE in our study was highest from dawn (medium nets) or midday samples (large nets). This pattern corresponded with the peak feeding times found by Collins and Hinch (1993) and Keast and Welsh (1968), but only loosely fit the pattern found by Johnson and Dropkin (1993). Black crappie CPUE in our study was highest for adults from dusk samples and for juveniles from dawn samples. The adult pattern matched the peak feeding period found by Keast and Fox (1992), but not the peak feeding period found by Schneider (1990). However, Schneider (1990) also found a trap net CPUE pattern similar to ours, indicating that the activity level and feeding intensity of black crappies may not be related.

All species had low activity during the night samples. Some fish do not relate to protective cover as much during low light periods (Keast 1978; Gaudreau and Boisclair 2000; Shoup et al. 2003b) because the risk of predation is reduced (Howick and O'Brien 1983; McMahon and Holanov 1995). Therefore, our low catch rates over night could be the result of fish moving farther offshore from the edge of the vegetation where the nets were set, or at least not staying close enough to the net to find their way inside. If this were the case, then the pattern should be more apparent in the small nets than in the large nets because of the difference in vulnerability to predation of the fish lengths captured by these nets. However, all net sizes showed the same pattern. Alternatively, our low catch rates over night could indicate that fish were present near the net but were inactive, which is consistent with other centrarchid studies that found low nighttime activity (Beitinger 1975; Demers et al. 1996). Additionally, we often observed fish setting motionless in the water around the trap nets at the 0400 hours sample time (D. Shoup, personal observation).

Because many fishery management decisions must be made without a detailed analysis of the system being managed, these decisions typically are based on conventional wisdom of how species interact. Our results show that species and even length-classes of the same species may not be active in the same areas at the same time during the day. Adult bluegills, pumpkinseeds, and black

crappies had different activity patterns. While there is likely some niche partitioning based on prey selection among these three species, there is likely even reduced competition with respect to the similar parts of their diets based on temporal niche partitioning. However, there does not appear to be much difference in the activity pattern of juveniles of these three species, indicating that temporal niche partitioning among these species is not likely. Juvenile largemouth bass activity, however, had a different pattern. This may cause less competition among largemouth bass and the other centrarchids in this study at the juvenile stage. Therefore, when predicting potential species interactions in natural systems, it is important to consider diel changes in behavior. When possible, sampling schedules should take into account the activity patterns of the species of interest to ensure that information is obtained from the most appropriate time(s) of day to more accurately assess species interactions.

Acknowledgments

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