

## DIEL FLUCTUATIONS OF LARVAL FISH IN THE LOWER MISSISSIPPI RIVER<sup>1</sup>

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**Abstract:** Larval fish were collected in the Lower Mississippi River at Sunnyside Revetment on 27-28 June 1978 to investigate diel fluctuations in diversity and abundance and to determine whether samples collected for 1-2 hours and from opposite sides of the boat can be considered replicate samples for a time period. Number of taxa and density differed significantly ( $P < 0.01$ ) between time periods of the diel cycle. Number of taxa and density were greatest at dusk. Twelve taxa were collected only in dusk, night, and dawn samples. *Aplodinotus grunniens*, *Carpiodes* spp. and clupeids accounted for 95 percent of the larvae collected. *A. grunniens* and *Carpiodes* spp. were more abundant in dusk and night samples. Clupeids were more abundant diurnally. Variance component analyses indicated that samples collected for 1-2 hours during each time period can be considered replicate samples for diversity and abundance estimates for that time period and samples collected from opposite sides of the boat can be considered replicate samples for diversity but not density estimates for each time period.

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Diel variations in the distribution and abundance of larval fish have been well studied in standing-water environments (Faber 1963, Taber 1969, Houser and Netsch 1971, Netsch et al. 1971, Hess and Winger 1978, Edwards et al. 1977, Storek et al. 1978) but not in river systems. Samples collected in 30 cm/sec current at the upstream end of a Tennessee River impoundment indicated that larval freshwater drum (*Aplodinotus grunniens*) were more abundant in night samples, and larval shad (*Dorosoma* spp.) were more abundant in daytime samples (Tuberville 1979). Gallagher and Conner (1980) found clupeids (primarily *Dorosoma* spp.), cyprinids, catostomids, and sciaenids comprised 98 percent of the larval fish collected in diel samples in the Lower Mississippi River near St. Francisville, Louisiana. Cyprinids showed no diel variations in abundance; but catostomids, primarily river carpsucker (*Carpiodes carpio*), and threadfin shad (*Dorosoma petenense*) were more abundant at night, whereas freshwater drum and gizzard shad (*Dorosoma cepedianum*) were more abundant in diurnal samples.

To establish efficient methodologies for sampling larval fish in many habitats in the lower Mississippi River, and in light of reported diel fluctuations of larval fish in rivers, it was necessary to investigate:

1. The effect of time of day on diversity and abundance of larval fish in the Lower Mississippi River;
2. Whether samples collected from opposite sides of the sampling boat are replicates; and
3. Whether samples taken during a 1 or 2 hour time interval are replicates.

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## METHODS

Diel samples of larval fish were collected in the Lower Mississippi River along Sunnyside Revetment on 27-28 June 1978. The sampling station was located 10 m from the right bank at river mile 526.8 above Head of Passes. The revetment in this area is large limestone rock (2-50 kg) rip rap extending from the top of the bank to approximately +4 m on the Greenville, Mississippi gauge. Articulated concrete mattress extended downward into the river from the rip rap to the toe of the channel. Depth at this station ranged from 5-12 m. Water temperature was 27.5°C and dissolved oxygen was 6.9 mg/l at 10 cm below the surface. Water clarity measured with a Secchi disc was 15 cm. Current velocity 10 m from the bank at river mile 526.8 was 70 cm/sec at 50 cm below the water surface; however, the water was turbulent and several large eddies were present along the sampling transect. The river stage was 6.9 m on the Greenville gauge and slowly rising.

Samples were collected at midday (1140-1410 hr), afternoon (1530-1610 hr), dusk (2050-2150 hr), night (0100-0200 hr) and dawn (0515-0610 hr). The dusk samples commenced 0.5 hr before total darkness and the dawn samples commenced 0.25 hr before first light. Ten replicate samples were collected at midday and 5 replicate samples were collected at each of the other time periods. Each replicate consisted of a pair of samples taken simultaneously from opposite sides of the boat. The sample collected from the side of the boat closest to shore will be referred to as "shore sample" and the sample from the opposite side of the boat will be referred to as "river sample". The midday and afternoon samples were collected from a 4.9 m jon boat by towing downstream at approximately 70 cm/sec faster than the current; tows were started at river mile 526.8. The other samples were collected from a 12.2 m launch by holding the boat under power at river mile 526.8. Individual samples were 5 minute duration. Forty to 60 m<sup>3</sup> of water per sample were filtered during the midday and afternoon sampling; 60-80 m<sup>3</sup>/sample were filtered during the dusk through dawn sampling. The increased volume filtered for the samples collected from the launch probably resulted from the suction created by the 2 propellers of the launch.

Samples were collected with 0.5-m diameter, 505-u mesh, 1/3 taper, nylon plankton nets. The nets were fitted into a yoke on an aluminum handle and fished 0.5 m below the surface of the water and 1 m away from the side of the boat at midships. With the gear used, the nets could be instantly raised and lowered into the water, the mouths of the nets were not impeded by towing bridles, and the nets were positioned away from any bow wake or prop wash of the sampling vessel. A flowmeter (General Oceanics Model 2030) was mounted in the center of the net to measure volume of water filtered. After each tow was completed the nets were washed to flush all collected larval fish into the cod-end plankton bucket. Samples were immediately fixed with 5 percent buffered formalin.

## RESULTS

### Evaluation of Replicate Sampling

The variance component analysis from a nested ANOVA (Table 1) showed that time within time periods did not constitute significant amounts of the variation in number of taxa or density of larval fish. Therefore samples collected within a 1-hour time interval in the afternoon and at dusk, night, and dawn and a 2-hour time interval at midday were considered replicate samples for each time period during this diel study.

The same analysis (Table 1) showed that samples collected from opposite sides of the boat did not constitute a significant portion of the variation in number of taxa, but did constitute a significant portion of the variation in density of larval fish. Therefore, samples collected on opposite sides of the boat were not considered replicate samples for analysis of diel differences in density of larval fish in this study.

Table 1. Variance component analysis to determine sources of variation in number of taxa and density (number/100 m<sup>3</sup>) of larval fish collected during diel sampling at Sunnyside Revetment, 27-28 June 1978.

Source	Percentage of Variance Accounted for	
	Density	Number of Taxa
Time Periods	58 a	74 a
Time Interval (Time Periods)	0	0
Error	42	26
Time Periods	52 a	73 a
Side (Time Periods)	17 a	0
Error	31	26

<sup>a</sup> Statistically significant,  $P < 0.01$ .

#### Diel Fluctuations in Larval Fish

Sixteen species, 11 genera, and 8 families were collected (Tables 2 and 3). Freshwater drum was the most abundant taxon and comprised 66 percent and 72 percent of the total larvae collected in the shore and river samples, respectively. Unidentified clupeids and *Carpiodes* each comprised about 10 percent of the total larvae in both shore and river samples; *Dorosoma cepedianum* and *D. petenense* were next most prevalent but did not exceed 4 percent of the total larvae. Total clupeids (unidentified clupeids plus *Alosa chrysochloris*, *Dorosoma* spp., *D. cepedianum*, and *D. petenense*) comprised 21 percent and 13 percent of the total larvae in the shore and river samples respectively. The remaining taxa were infrequent.

The number of taxa differed significantly during the diel cycle (Table 1). The number of taxa was lowest at the midday period (1200), increased sharply to a maximum during the dusk period (2100) then decreased through night (0100) and dawn (0600) periods (Fig. 1).

Mean density/100 m<sup>3</sup> differed significantly between the time periods of the diel cycle (Table 1). Density was greatest at dusk and substantially less at both midday and dawn (Fig. 2). Night and dawn densities for the shore samples were lower than afternoon and midday densities, respectively. Night and dawn densities for the river samples were higher than afternoon and midday densities, respectively.

The diel trend in density of *Aplodinotus grunniens* paralleled the diel trend for total larval fish. *A. grunniens* constituted 54 - 78 percent of the total density during the 5 time periods. At dusk, when the density of all taxa combined was highest, 76 percent (shore samples) and 78 percent (river samples) of the total number of larvae caught were *A. grunniens*.

Density of *Carpiodes* declined from high values at midday to lowest density in the afternoon, increased to a maximum at dusk and decreased through the night. Density at dawn was lower than at midday. *Carpiodes* constituted 11 percent (shore samples) and 13 percent (river samples) of the total densities at midday and 8 percent (shore samples) and 11 percent (river samples) of the total densities at dusk.

Densities of total clupeids were highest during midday and afternoon, declined to low densities at dusk and night, and increased at dawn. At midday total clupeids were 30 percent (shore samples) and 28 percent (river samples) of the total densities of larval fish. During the afternoon, total clupeids were 34 percent (shore samples) and 20 percent (river samples) of the total densities of larval fish. During dusk and night samples, total clupeids constituted less than 14 percent of the total densities. At dawn total clupeid densities

Table 2. Mean density' of larval fish (no./100 m<sup>3</sup>) collected in the shore samples during diel sampling at Sunnyside Revetment, 27-28 June 1978.

Taxon	Time (24-hr clock)						Total	Frequency
	1200	1500	2100	0100	0600			
<b>Clupeidae</b>								
<i>Alosa chrysochloris</i>	0.6	0.6	1.0	-	-	2.2	0.01	
<i>Dorosoma</i> spp.	-	-	4.0	2.8	-	6.8	0.02	
<i>D. cepedianum</i>	-	9.4	4.2	3.0	0.8	17.4	0.04	
<i>D. petenense</i>	-	10.8	1.6	4.0	1.4	17.8	0.04	
unidentified clupeids	15.7	15.0	4.2	2.4	7.0	44.3	0.10	
<b>Hiodontidae</b>								
<i>Hiodon alosoides</i>	-	-	-	-	-	-	-	
<i>H. tergisus</i>	-	-	-	0.4	-	0.4	< 0.01	
<b>Cyprinoidae</b>								
unidentified cyprinoids	0.3	-	1.4	2.6	2.2	6.5	0.02	
<b>Cyprinidae</b>								
<i>Hybopsis aestivalis</i>	-	-	0.4	-	-	0.4	< 0.01	
<i>H. storeriana</i>	-	-	-	-	0.2	0.2	< 0.01	
unidentified cyprinids	0.9	0.6	2.8	0.8	0.4	5.5	0.01	
<b>Catostomidae</b>								
<i>Carpoides</i> spp.	5.9	2.8	10.0	11.6	6.4	36.7	0.09	
unidentified catostomids	0.3	-	-	-	-	0.3	< 0.01	

Table 2. Con't.

Taxon	Time (24-hr clock)						Total	Frequency
	1200	1500	2100	0100	0600			
<b>Ictaluridae</b>								
<i>Ictalurus furcatus</i>	-	-	0.2	-	-	-	0.2	< 0.01
<i>I. punctatus</i>	-	-	-	0.4	-	-	0.4	< 0.01
<i>Pylodictus olivaris</i>	-	-	0.2	0.2	-	-	0.4	< 0.01
<b>Percichthyidae</b>								
<i>Morone</i> spp.	-	-	-	0.4	-	-	0.4	< 0.01
<i>M. chrysops</i>	-	-	0.2	-	-	-	0.2	< 0.01
<i>M. mississippiensis</i>	-	-	0.2	-	-	-	0.2	< 0.01
<i>M. saxatilis</i>	-	-	-	0.2	-	-	0.2	< 0.01
<b>Centrarchidae</b>								
<i>Lepomis</i> spp.	-	-	0.8	0.4	0.2	-	1.4	< 0.01
<i>Pomoxis annularis</i>	-	-	-	-	-	-	-	-
<i>P. nigromaculatus</i>	-	-	0.2	-	-	-	0.2	< 0.01
unidentified centrarchids	0.8	-	0.6	1.0	-	-	2.4	0.01
<b>Sciainidae</b>								
<i>Aplodinotus grunniens</i>	30.1	66.4	100.4	60.0	23.0	-	279.9	0.66
Total	54.6	105.6	132.4	90.2	41.6	-	424.4	1.00
Frequency	0.13	0.25	0.31	0.21	0.10	-	1.00	

<sup>1</sup>Each density value is the density of the taxon at the specified level of identification; e.g., the density of *Dorosoma* spp. is the density of larvae identified as *Dorosoma* spp. and is not the sum of larvae identified as *Dorosoma* spp. *D. cepedianum*, and *D. petenense*.

Table 3. Mean density<sup>1</sup> of larval fish (no./100 m<sup>3</sup>) collected in the river samples during diel sampling at Sunnyside Revetment, 27-28 June 1978.

Taxon	Time (24-hr clock)						Total	Frequency
	1200	1500	2100	0100	0600			
<b>Clupeidae</b>								
<i>Alosa chrysochloris</i>	-	1.0	0.4	-	-	1.4	<0.01	
<i>Dorosoma</i> spp.	-	-	0.4	-	2.2	2.6	<0.01	
<i>D. cepedianum</i>	-	1.0	6.2	1.0	1.8	10.0	0.02	
<i>D. petenense</i>	-	1.4	1.6	1.0	6.2	10.2	0.02	
unidentified clupeids	13.9	14.8	5.4	4.0	12.2	50.3	0.09	
<b>Hiodontidae</b>								
<i>Hiodon alosoides</i>	-	-	0.2	-	0.2	0.4	<0.01	
<i>H. tergisus</i>	-	-	0.2	0.2	-	0.4	<0.01	
<b>Cyprinoidae</b>								
unidentified cyprinoids	0.9	0.4	1.0	6.0	4.4	12.7	0.02	
<b>Cyprinidae</b>								
<i>Hybopsis aestivalis</i>	-	-	-	-	-	-	-	
<i>H. storeriana</i>	-	-	-	-	-	-	-	
unidentified cyprinids	0.6	-	1.2	0.4	-	2.2	<0.01	
<b>Catostomidae</b>								
<i>Carpoides</i> spp.	6.5	3.6	20.4	15.4	7.6	53.5	0.10	
unidentified catostomids	0.2	0.4	-	-	-	0.6	<0.01	

Table 3. Con't.

Taxon	Time (24-hr clock)					Total	Frequency
	1200	1500	2100	0100	0600		
<b>Ictaluridae</b>							
<i>Ictalurus furcatus</i>	-	-	0.2	-	-	0.2	<0.01
<i>I. punctatus</i>	-	-	0.6	1.6	-	2.2	<0.01
<i>Pylodictus olivaris</i>	-	-	-	0.2	-	0.2	<0.01
<b>Percichthyidae</b>							
<i>Morone</i> spp.							
<i>M. chrysops</i>	-	-	0.4	-	-	0.4	<0.01
<i>M. mississippiensis</i>	-	-	0.2	-	0.2	0.4	<0.01
<i>M. saxatilis</i>	-	-	-	0.2	0.4	0.6	<0.01
<b>Centrarchidae</b>							
<i>Lepomis</i> spp.							
<i>Pomoxis annularis</i>	0.4	-	0.2	0.2	1.0	1.8	<0.01
<i>P. nigromaculatus</i>	-	-	-	0.2	-	0.2	<0.01
unidentified centrarchids	-	-	-	-	-	-	-
	0.4	-	0.4	0.2	0.8	1.8	<0.01
<b>Sciaenidae</b>							
<i>Aplodinotus grunniens</i>	26.6	66.2	143.2	105.6	57.6	399.2	0.72
Total	49.5	88.8	182.6	136.6	94.6	552.1	1.00
Frequency	0.09	0.16	0.33	0.25	0.17	1.00	

<sup>1</sup>Each density value is the density of the taxon at the specified level of identification; e.g., the density of *Dorosoma* spp. is the density of larvae identified as *Dorosoma* spp. and is not the sum of larvae identified as *Dorosoma* spp. *D. cepedianum*, and *D. petenense*.

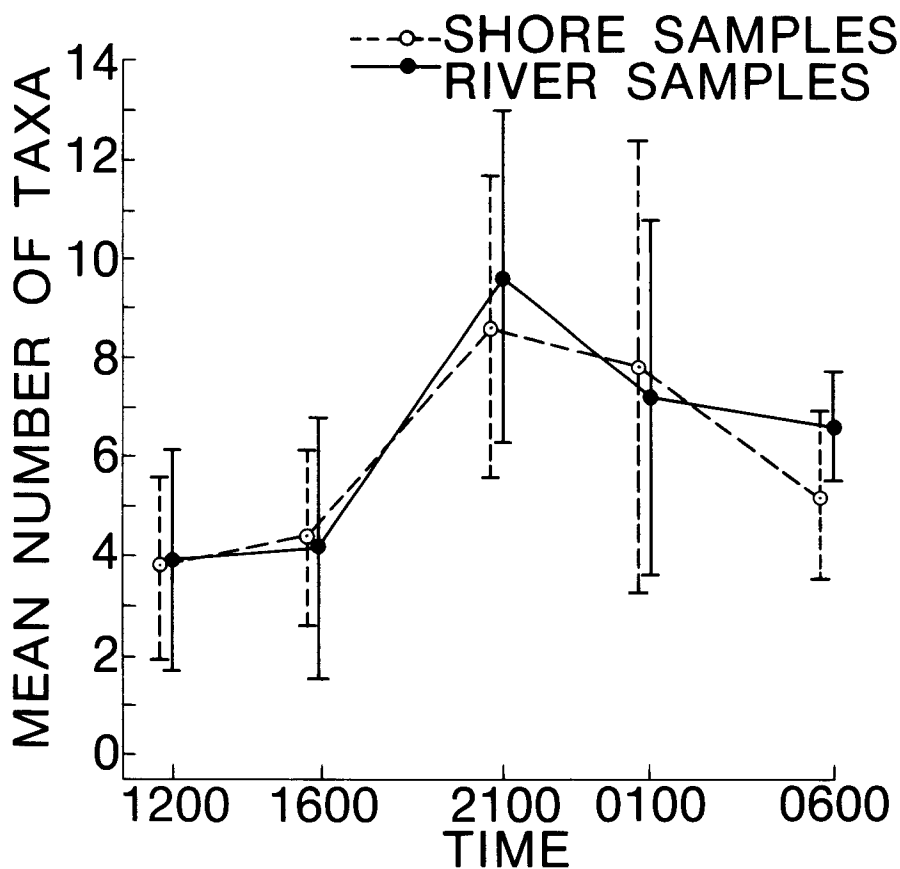


Fig. 1. Mean number of taxa of larval fish collected during diel sampling at Sunnyside Revetment, 27-28 June 1978. Vertical lines indicate standard error.

increased and constituted 22 percent (shore samples) and 24 percent (river samples) of the total densities of larval fish.

Densities of unidentified clupeids were highest during midday and afternoon, declined to minimum density at night and increased at dawn. Unidentified clupeids were 29 percent (shore samples) and 28 percent (river samples) of the total larval fish at midday. In the afternoon unidentified clupeids, although still abundant, constituted only 14 percent (shore samples) and 17 percent (river samples) of the total larval fish. In the dusk and night samples unidentified clupeids were only 3 percent of the total larvae. At dawn unidentified clupeids were 17 percent (shore samples) and 13 percent (river samples) of the total larvae.

The diel changes in densities of *Dorosoma cepedianum* and *D. petenense* did not follow the diel trend in densities of total Clupeidae or unidentified clupeids. In the shore samples, *D. cepedianum* was absent at midday, collected in highest density in the afternoon, and declined continuously to dawn. In the river samples *D. cepedianum* was absent at midday, collected at highest density at dusk, and present in low densities during the remaining sampling periods.



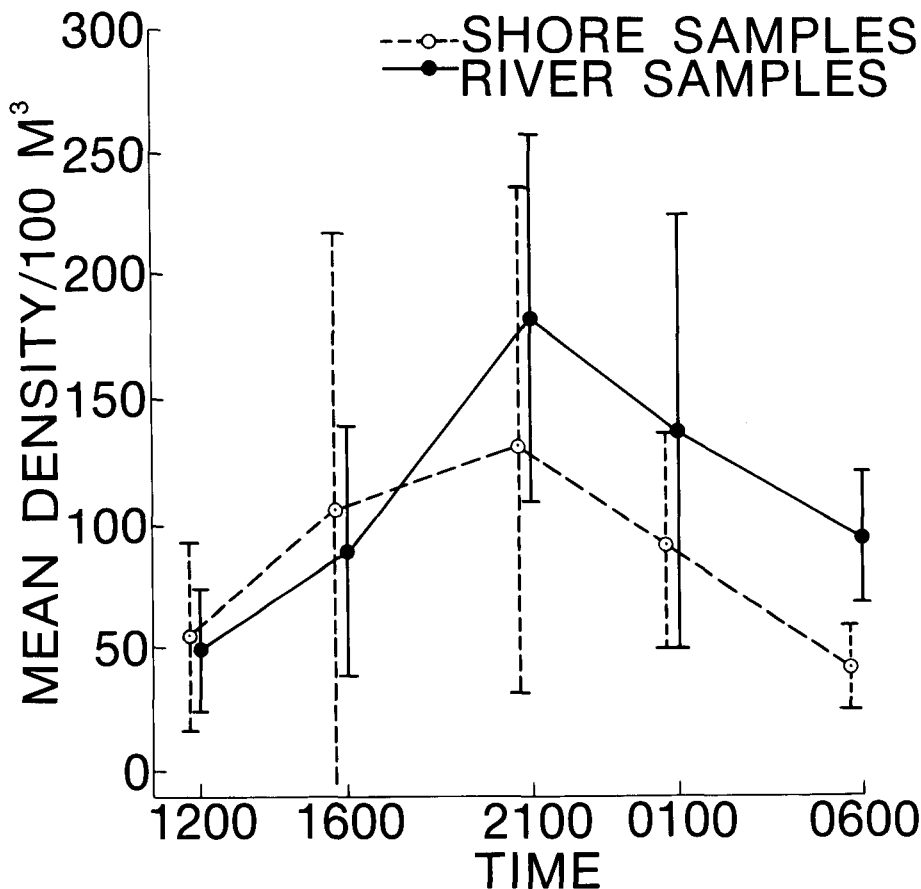


Fig. 2. Mean density of larval fish (number/100 m<sup>3</sup>) collected during diel sampling at Sunnyside Revetment, 7-28 June 1978. Vertical lines indicate standard error.

In the shore samples *D. petenense* was not collected at midday, collected at the highest density during afternoon, and lower densities during dusk through dawn. *D. petenense* was not collected at midday, collected in uniformly low densities in afternoon, dusk and night samples and in relatively high densities at dawn in the river samples.

## DISCUSSION

### Evaluation of Replicate Sampling

The lack of significant variation of time interval within time periods indicated that samples collected during 2 hours at midday and during 1 hour at each of the other time periods were replicate samples for each time period. A potentially important question which remains is the variation during 2 hours of sampling at dawn and dusk.

Analysis of the same samples indicated that there was a significant amount of variation in density of larval fish between samples collected on opposite sides of the boat; hence, samples collected from opposite sides of the boat were not considered replicate samples for a given time period. This is a surprising result considering that variation in number of taxa collected on opposite sides of the boat was not significant. Further, the nets on opposite

sides of the boat were separated by no more than 4 m and the area sampled was very turbulent which should, expectedly, cause a large amount of mixing of water masses. Although unexplainable at this time, this result corroborates those of Johnson (1972) who found up to 3-fold differences in density of striped bass (*Morone saxatilis*) eggs between samples collected simultaneously with identical plankton nets fished adjacent to each other in the Chesapeake and Delaware Canal.

#### Diel Fluctuations in Larval Fish

The diel distribution of taxa indicated numbers of taxa were similar in the daytime samples, maximum at dusk, and high in the night and dawn samples. Twelve taxa were collected only during the dusk, night or dawn sampling periods. Therefore, sampling under conditions of "darkness" resulted in an important increase in the number of taxa collected. Sampling during dusk through dawn was particularly important for collection of hiodontids, ictalurids, and percichthyids.

The 3 most frequently collected taxa, clupeids, *Carpiodes*, and freshwater drum, accounted for 95 percent of the total larvae. Gallagher and Conner (1980) found clupeids, cyprinids, catostomids, and sciaenids were 98 percent of the total larvae collected in diel samples on the Lower Mississippi River near St. Francisville.

There were significant differences in density of larval fish collected during the 24-hour cycle. Total densities were lowest at midday, increased during the afternoon to a maximum at dusk and decreased during the night to a low, similar to midday, density at dawn. Increased nocturnal abundance of larval fish has been repeatedly observed (Faber 1963, Taber 1969, Netsch et al. 1971, Gale and Mohr 1978, Storck et al. 1978, Graser 1979, Kindschi et al. 1979, Tuberville 1979, Gallagher and Conner 1980). Although decreased net avoidance at night may possibly contribute to higher catch rates (Kindschi et al. 1979, Tuberville 1979), diel fluctuations in distribution would also influence the abundance of larvae collected in surface samples. Upward vertical migrations of larval fish at night have been documented for various species (Taber 1969, Netsch et al. 1971, Gale and Mohr 1978, Graser 1979, Kindschi et al. 1979, Tuberville 1979), and Tuberville (1979) suggested diel horizontal migration for shad. In the highly turbid and turbulent water of the Mississippi River daytime net avoidance is probably minimal; the increased abundance at dusk and night was most probably due to migrational patterns or a change in behavior which makes the larvae more susceptible to drift.

The diel fluctuations in total density were largely a result of the diel fluctuations of density of freshwater drum. Tuberville (1979) found increased density of freshwater drum at night when samples from all depth strata were pooled. Larger drum larvae were present at the surface at night. Gallagher and Conner (1980) found that drum were 4 times more abundant in daytime samples than in nighttime samples, but noted that larger drum (metalarvae and juveniles) were collected in greater abundance at night. In this study the densities of different larval stages were not determined, but the findings of Gallagher and Conner (1980) suggest that the drum collected were later larval stages.

The densities of *Carpiodes* paralleled, in general, the densities of freshwater drum except for the slightly higher density of *Carpiodes* at midday. Gallagher and Conner (1980) also collected *Carpiodes* in greater abundance in night samples in the lower Mississippi River.

Total clupeids and unidentified clupeids were most abundant in dawn, midday, and afternoon samples. Gallagher and Conner (1980) and Tuberville (1979) also found clupeids more abundant during daylight hours in flowing water systems. High densities of total clupeids at midday and dawn made important contributions to the total densities during these time periods; hence, the diel fluctuations of density of total clupeids reduced the magnitude of the fluctuations of total larval fish density.

While total clupeids and unidentified clupeid larvae were most abundant in dawn

through afternoon samples, *Dorosoma cepedianum* and *D. petenense* were absent at midday and of variable abundance in the afternoon through dawn samples. The identification of clupeids to species requires advanced larval stages, whereas younger larvae would be identified to higher taxa; viz., *Dorosoma* spp. or unidentified clupeids. This discrepancy between the diel trends of *D. cepedianum* and *D. petenense* may result from the younger larval stages in the drift during the day and the advanced stages present from afternoon to dawn. Gallagher and Conner (1980) and Tuberville (1979) observed increased abundance of later larval stages of shad in nighttime larval fish samples; smaller larvae were abundant diurnally. Apparently the larger larvae exhibit a time-dependent behavior pattern which influences their abundance in surface samples. The 3-to 4-fold lower abundance of unidentified clupeids at night would indicate that smaller larvae were also able to migrate and/or remain in a sheltered area despite the high velocity currents and turbulence in this section of the Mississippi River.

This single investigation of diel occurrence of larval fish presents some important considerations for future larval fish sampling. The results suggest that densities of samples collected between dawn and midday are comparable. On the other hand the number of taxa are comparable for samples collected between midday and mid-afternoon. Peak density and maximum number of taxa occurred at dusk. Further, 4 taxa were collected only during the dusk sampling period. Therefore, dusk is an important time to sample, and density and number of taxa do not differ significantly between samples taken during the time interval 0.5 hour before dusk to 0.5 hour after dusk. However, since dusk is a rather unique temporal phenomenon, as shown by rapid increases and decreases in density and number of taxa before and after dusk, results obtained during a large-scale sampling effort requiring several hours may not be comparable.

Second highest values of density and number of taxa were obtained in the night samples. Pending further investigation of temporal variation in density and number of taxa during nighttime hours, night sampling may be the most fortuitous time to sample larval fish in the Mississippi River. Although high densities and number of taxa were collected at night, nighttime sampling must be considered a compromise since not all taxa were represented in these samples.

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