Ecological Characteristics of a Northern Population of the Pallid Shiner

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Abstract.—The pallid shiner *Notropis amnis*, a rare minnow with an unknown life history, was collected from the Kankakee River, Illinois, over a 9-year period (1978–1986). The total length (L , mm)–weight (W , g) relationship for 88 specimens was $\log_{10} W = -4.97 + 2.87(\log_{10} L)$. Condition factors ($K = 10^5 W/L^3$; mean, 0.69; range, 0.53–0.83) for specimens collected in July and August showed no trend by size and were lower than those of specimens collected in November. The annual catch per unit effort of juvenile pallid shiners (≤ 36 mm TL) was positively correlated with minimum flows in May and June, and negatively correlated with March air temperatures. The total catch was positively related to March maximum flow. Habitat suitability curves indicate that this species occurs in shallow areas with little or no current velocity and in moderately clear waters that are average in pH and warm and well oxygenated in summer. Juvenile pallid shiners occurred in shallower and more turbid waters than adults. Pallid shiners were associated with 45 other fish species. A cluster analysis, based on habitat and water quality variables associated with cyprinids, indicated that both juvenile and adult pallid shiners were found in conditions most similar to those of the bullhead minnow *Pimephales vigilax*.

The pallid shiner *Notropis amnis* Hubbs and Greene (Figure 1) is one of the rarest and least known American fishes (Smith 1979). Its known range extends from the Mississippi Valley north to the St. Croix River of Minnesota and Wisconsin, south to the Amite River in Louisiana, and west to the Guadalupe River in Texas (Clemmer 1980). The historical distribution and abundance of this fish are vague due to uncritical acceptance of literature records and past confusion with the blacknose shiner *N. heterolepis* and bigeye chub *Hybopsis amblops*. This uncertainty has led to reassessment of the distribution of the pallid shiner using only extant specimens (Smith 1979; Warren and Burr 1988). Hubbs (1951) discussed population variability and the confused nomenclatural history of the pallid shiner, which was separated into two intergrading subspecies. The validity of these subspecies has been disputed recently due to broad overlap in the Mississippi Valley (Clemmer 1971, 1980), and a proposed transfer of this species to the genus *Hybopsis* has been suggested (Clemmer 1971; Mayden 1989).

The pallid shiner is very rare in its northern range, occurring only in isolated local populations (Hubbs 1951; Pflieger 1975; Smith 1979; Becker

1983). The status of its northern populations is a matter of concern. Pflieger (1975) noted that no other Missouri fish has shown such a marked decline in abundance, and that the pallid shiner has probably been eliminated or is on the verge of elimination from the state. It has shown a dramatic loss of range and may also be extirpated from inland waters of other northern states as well (Smith 1979; Phillips et al. 1982; Becker 1983; Burr and Warren 1986). The recent northern distribution of the pallid shiner is restricted to the Mississippi River and the mouths of its larger tributaries, with the exception of the population studied in this report. Currently, the pallid shiner is legally protected in Wisconsin and receives special concern in Kentucky, Missouri, and Minnesota (Johnson 1987). Until recently, the pallid shiner was assumed to have been extirpated from Illinois (Smith 1979) and thus received no protection in the state. Recent consecutive annual collections have indicated the persistence of a localized population in the Kankakee River (Skelly and Sule 1983; Kwak 1987), and the pallid shiner now has endangered status in Illinois (IESPB 1989).

The life history of the pallid shiner is virtually unknown. Reports of length, weight, and age relationships are rare (Becker 1983); habitat descriptions are conjectural or qualitative (Hubbs 1951; Harlan and Speaker 1956; Smith 1979; Becker 1983); and nothing is known about the spawning or food habits of this species. Species associations

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FIGURE 1.—Freshly preserved pallid shiner (35 mm TL, 0.28 g) collected from the Kankakee River, Illinois, on 4 August 1986. (Photograph by D. A. Carney.)

and habitat measurements were reported for 18 pallid shiners collected from the Kankakee River (Skelly and Sule 1983). This note remains as the most substantial quantitative habitat description of the species.

The purpose of this study was to examine and synthesize data gathered on 88 specimens collected over 9 years from the Kankakee River. This information, in association with the analyses presented here, provides insight into population structure, environmental influences on catch and recruitment, critical habitat and water quality, and species associations of this species.

Study Area

Pallid shiners were collected from the Braidwood Station Aquatic Monitoring Area, a 2.5-km reach of the Kankakee River near Custer Park, Will County, Illinois. This area is 23.5 km upstream of the confluence of the Kankakee River with the Des Plaines River (Figure 2). At the study site the Kankakee River drains an area of 12,485 km² (Healy 1979) and has a slope of 1.05 m/km (Barker et al. 1967). Riverside intake and discharge structures for Commonwealth Edison's nuclear generating station are within stations 3R and 4R, respectively, and were preoperational during this study.

Pallid shiners were collected at stations 1L, 3R, 5L, 5R, and 6R, which had lentic characteristics during sampling. Water velocity was reduced at stations 1L and 3R by extensions of rocky shoals into the river channel, and at stations 5L, 5R, and 6R by a widening of the river. Habitat was generally similar at these stations and can be characterized as slack-water depositional, particularly during periods of low discharge. Gradually sloping banks and fine substrates of silt and sand were prevalent at stations 1L, 5L, and 6R; steep shorelines and coarser substrates, including gravel or cobble, were present at stations 3R and 6R. Ri-

FIGURE 2.—Locations of sampling stations within the Braidwood Station Aquatic Monitoring Area of the Kankakee River, Will County, Illinois.

parian vegetation and shading varied at these stations.

Methods

Sampling.—Fish were collected primarily with a nylon seine (7.65 m long $\times$ 1.22 m high; 4.76-mm King square mesh) outfitted with a bag (1.22 m $\times$ 1.22 m $\times$ 1.22 m). Two discrete sites, each 15 m in length, were seined in a downstream direction within each station on each of two dates approximately 1 week apart. Total effort, therefore, was four seine hauls per station in each sampling month. Sampling was conducted during May, August, and November of 1977 through 1979 and during late July or early August of 1981 through 1987. Small fish were fixed in a 10% formalin solution and later preserved in 70% ethanol. Preserved specimens were measured for total length (± 1 mm TL) and weighed (± 0.01 g). Pallid shiners were remeasured (± 0.5 mm) at a later date for total length and standard length (SL) to estimate a conversion function. Large fish were processed streamside and released. A boat-mounted, boom-type electrofisher, powered by a 230-V, 3,000-W, 3-phase AC generator, was employed for sampling a fixed distance and time period at each station during each sampling month. Although electro-

fishing efforts were designed to capture large fish, one pallid shiner was collected by this method.

Habitat and water quality measurements were taken concurrently with the fish samples at each station, and included depth, surface velocity, temperature, dissolved oxygen, turbidity, conductivity, and pH. Measurements were collected from a single location within each station.

Sampling stations, methods, and effort remained constant throughout the study and are identical to those reported by Skelly and Sule (1983). Analyses and results presented in this report incorporate data presented by Skelly and Sule (1983) for pallid shiner collections from this population during the period of 1978 to 1982. All pallid shiners collected in this study have been deposited in the fish collection of the Illinois Natural History Survey.

Analysis.—Scales were removed from a subsample of pallid shiners and magnified for aging, but this method proved unsuccessful. Becker (1983) also noted the difficulty in aging pallid shiners from scales. Because no other practical aging method applicable to this species was available, age structure of the pallid shiner population was determined by analyzing a single length-frequency distribution based on all specimens collected from all years and disaggregated by sampling month. These fish were also used for determining length-weight and condition relationships. A Fulton-type condition factor was calculated for each fish as $K = W(10^3)/L^3$, where W = weight in grams and L = total length in millimeters (Anderson and Gutreuter 1983).

Measures of river discharge and air temperature during probable spawning periods and early pallid shiner life stages were examined as independent variables in regression analyses to detect significant relationships between the number of pallid shiners caught and environmental conditions. The following independent variables were included: mean, minimum, maximum, and delta (i.e., cumulative daily change) values of discharge, and mean and delta air temperature during each of the monthly periods from March through June. The same measures for the 2-month periods of March–April and May–June were also included. Mean and delta discharge during sampling was examined to detect possible influences of sampling conditions on catch. The dependent variables were the catch of juveniles (≤ 36 mm TL) and the total catch during July and August of 1977 through 1987 (excluding 1980), including values of zero (no catch) for 1977 and 1987. The significance of the

regressions was tested with analysis of variance.

Catch data collected after 1987 (no catch) were not included in the analysis of environmental influences because of the potential effects of water withdrawal and effluent from pumping facilities in the sampling area. Discharge volume and water temperature data were obtained from a gaging station in Wilmington, Illinois (USGS 1976–1987). Air temperature, recorded at Kankakee, Illinois (NOAA 1976–1987), was used as an index of water temperature because post-1977 water temperature data were not available. The surrogate use of air temperature in this case is justified by highly significant linear relationships ($P \leq 0.0001$) found between mean daily water temperature and air temperature from March through June in 1976 ($N = 122$, $r^2 = 0.85$) and 1977 ($N = 118$, $r^2 = 0.81$).

To quantify and characterize critical habitat, suitability curves were constructed from physical measurements associated with sites where pallid shiners were collected. Unweighted measurements were tabulated and grouped into increments of equal size. Frequencies of measurements for each variable were normalized to unity; the modal range of each habitat parameter was assigned a value of 1.0, and frequencies of other intervals were expressed as a proportion of the mode. Utilization (the relative frequency of observations for each microhabitat variable; Bovee 1986) was plotted for each variable, and a curve was then fitted to the data by interpolation. To facilitate a smooth curve, a range of no use between two ranges of a habitat variable used by pallid shiners was not incorporated into the curve. Bovee (1986) suggested that such distributions are likely the result of schooling, inadequate sample size, or measurement error rather than of discriminatory behavior on the part of the fish, and he advocated smoothing. Separate curves were constructed for juvenile and adult pallid shiners for each habitat variable, excluding conductivity.

The habitat and water quality characteristics at each station were assigned to each fish collected, and weighted (by number of individuals) mean habitat values for each species were calculated for all fishes collected during July and August 1984. A hierarchical cluster analysis, employing the single-linkage method (Hartigan 1975; Wilkinson 1987) and using these mean habitat values, was performed on all cyprinids to detect groupings of species by common habitat use. The weighted mean values for each parameter were standardized to a mean of zero in units of one standard deviation in order to compare measures of differ-

ent scales. Other linkage methods (complete, centroid, average, and median) were also used for comparison (Wilkinson 1987).

Results and Discussion

Eighty-eight pallid shiners were collected from 1978 to 1986 (Table 1). With the exception of three specimens collected in November 1978, all were collected in late July or early August.

Length, Weight, and Condition

The pallid shiner is a small terete minnow; total lengths and weights of Kankakee River specimens varied from 22 to 54 mm and from 0.08 to 1.13 g. The standard length (SL)–total length (TL) conversion ($N = 86$) was $SL = 0.76TL$. Hubbs (1951) reported that the species was not known to exceed 55 mm SL (72 mm TL), and later documentation of large pallid shiners from Wisconsin (64.5 mm TL; Becker 1983) and Louisiana (70 mm TL; Douglas 1974) did not reveal a larger specimen.

The length-frequency distribution of Kankakee River pallid shiners from all years indicates that at least two distinct size-classes exist during July and August (Figure 3). Two dominant size-groups are separated by the low number of individuals in the 34–36-mm range during that period. The two distinct size-groups most likely correspond to different age-classes, suggesting that juvenile (age 0) pallid shiners attain a TL of up to 36 mm by August in the Kankakee River and that longer individuals collected at that time are age 1. The two largest individuals (53 and 54 mm TL) collected in November may represent a third age-class (age 2) or additional growth of age-1 individuals from August to November. These results are consistent with the findings of Becker (1983), who estimated total lengths of 34 and 49 mm at the first and second annuli, respectively, based on tentative scale readings of seven pallid shiners col-

FIGURE 3.—Length-frequency distribution of 88 pallid shiners collected during November and July–August 1978–1986 from the Kankakee River, Illinois.

lected from the Mississippi River. Becker (1983) also noted that the annulus appeared to be deposited in July in those specimens. A review of available life history information for small cyprinids (Becker 1983) indicates that most species mature at age 1. The relatively small size and short life span of the pallid shiner suggest that it also follows this trend.

The length–weight relationship of the 88 pallid shiners ($r^2 = 0.98$) was $\log_{10} W = -4.97 + 2.87 \log_{10} L$, where W = weight in grams and L = total length in mm. The slope of this relationship is similar to that of other cyprinid fishes (excluding common carp *Cyprinus carpio*) which show slopes evenly distributed about 3.0 with a range of 2.7 to 3.6 (Carlander 1969).

Condition factors ranged from 0.53 to 0.83 with a mean of 0.69 for pallid shiners collected in July and August. There was no trend in condition with size (length or weight). The mean (0.79) and minimum K -values (range, 0.74–0.85) of 10 pallid shiners collected from the Mississippi River in Wisconsin during early August (Becker 1983) were greater than those values from Kankakee River

TABLE 1.—Years, dates, and locations of pallid shiner catches from the Kankakee River, Illinois.

Year	Dates	Number of juveniles	Number of adults	Total catch (number)	Stations
1978	9 Aug	0	1	1	5R
1978	9, 15 Nov	0	3	3	3R, 5L
1979	9, 15 Aug	1	8	9	5L, 5R
1981	6, 11 Aug	2	1	3	5L, 5R
1982	2 Aug	1	1	2	5L
1983	9 Aug	0	1	1	5L
1984	30 Jul	44	5	49	5L, 5R
1985	29 Jul; 6, 8 Aug	1	15	16	5L, 5R, 6R
1986	4, 12 Aug	4	0	4	1L, 5L

pallid shiners collected during the same period (July and August), but maximum values from the two populations were equivalent. The K -values (0.71, 0.76, 0.81) of three specimens collected from the Kankakee River in November were greater than the July–August average.

Mean K -values of Kankakee River pallid shiners decreased progressively from 0.71 in 1984 to 0.62 in 1986, the lowest average condition of any year (Figure 4). This annual decline in condition of the fish was followed by the absence of pallid shiners in two successive August sampling efforts (1987 and 1988) using the identical methods, stations, and effort.

Environmental Influences

Although sampling effort was consistent among years, the catch of pallid shiners varied widely (Table 1). A catch of 49 individuals, averaging only 29.5 mm TL, occurred in 1984, suggesting exceptional recruitment into the population that year. Environmental conditions can influence year-class strength or sampling efficiency and thereby lead to variations in catch. There is inherent difficulty in comparing catch per unit effort between years as an index to fluctuations in population size. However, no significant relationship was detected between pallid shiner catch and mean or delta discharge during sampling, a finding that adds support to the assumption that sampling conditions did not have a large effect on catch and that the catches by seine in this case may be considered indices of pallid shiner population size.

A statistical danger is inherent in exploratory correlations to assess relationships between the environment and reproduction or year-class abundance. Because of the wide range of environ-

mental variables available, a high degree of correlation between a variable and year-class abundance may occur by chance (Gulland 1965). Thus, investigators are faced with the paradox described by Ricker (1975): the more factors they test, the more likely they are to include the effective ones in their search, but the less likely they are to be able to recognize them. A mitigating measure in selecting environmental parameters is to test only those that have a sound biological basis, may be related to a provisional hypothesis, or seem likely to be significant from gross inspection of data.

The density and dynamics of stream fish assemblages dominated by cyprinids have been clearly related to environmental conditions, and flow regime and temperature have been implicated as major influences (Ross et al. 1985; Mathews et al. 1988; Schlosser and Ebel 1989). In addition, literature summarized by Hynes (1970) indicated that reproduction and the survival of fry, small specimens, and even adults were influenced by fluctuations in discharge and temperature; therefore, these two factors were selected to examine the relationships between environmental conditions and the catch of pallid shiners.

Linear regression analyses, including both $\log_e$ -transformed and untransformed variables, yielded four significant relationships ($P \leq 0.05$; Table 2). The catch of juvenile pallid shiners was positively related to minimum discharge in the Kankakee River during June and May–June of the same year and was negatively related to mean air temperature during March; the total pallid shiner catch was positively correlated with maximum discharge during March. Caution should be exercised in the application of these models, however, because the purpose of their development was not to accurately predict catch but to detect potential environmental influences and describe the general form of the relationship.

Habitat Characteristics

The moderately streamlined body of the pallid shiner with its delicate fins and skin suggests that this fish is best adapted for habitats with slow currents and vegetation (Hubbs 1951; Smith 1979; Becker 1983). Qualitative descriptions of areas where the pallid shiner has been taken are variable. In its northern distribution, it is confined mainly to large lowland rivers and is collected over sandbars, in sloughs, and from impoundments (Hubbs 1951; Harlan and Speaker 1956; Becker 1983). In the south, it commonly inhabits small and medium-sized streams and is found in some

FIGURE 4.—Mean ($\pm$ SE) condition factors for pallid shiners collected from the Kankakee River, Illinois, according to year.

TABLE 2.—Regression equations and statistics relating the pallid shiner catch from the Kankakee River, Illinois (y), to measures of temperature and discharge during selected periods (x), 1977–1987 (excluding 1980); $N = 10$.

Equation	Independent variable (x)	Dependent variable (y)	r^2	P (F -test)
$\log_e (y + 1) = -0.87 + 0.02x$	Minimum mean daily discharge (m^3/s) during May–June	Number of juveniles	0.43	0.04
$\log_e (y + 1) = -0.85 + 0.02x$	Minimum mean daily discharge (m^3/s) during June	Number of juveniles	0.40	0.05
$y = 238.4 - 64.59 \log_e x$	Average mean daily air temperature ($^{\circ}C$) during March	Number of juveniles	0.42	0.04
$\log_e (y + 1) = -4.94 + 1.04 \log_e x$	Maximum mean daily discharge (m^3/s) during March	Total catch (number)	0.40	0.05

reservoirs and oxbow lakes (Hubbs 1951; Robison and Buchanan 1988). Habitat bottom types range from very soft mud to sand, gravel, and rock (Hubbs 1951). The Kankakee River, characterized as a large lowland river at the study site, conforms to this broad-scale description of habitats where pallid shiners are found in their northern range.

Habitat use by pallid shiners in the Kankakee River was similar for juveniles ($N = 10$ locations) and adults ($N = 17$ locations) for most variables (Figure 5). Adults and juveniles were found most often at depths of 0.50 to 0.74 m, but adults occurred in a wider range of depths (0.4–1.5 m) than juveniles (0.5–1.0 m). Current velocity and July–August water temperature utilization associated with each life stage was equivalent and ranged from 0 to 5.2 cm/s and 20.4 to 30.0 $^{\circ}C$, respectively. Habitats with current velocities less than 1.0 cm/s and temperatures in the 28.0–29.9 $^{\circ}C$ range were used most frequently. Juvenile and adult pallid shiners occurred in the same range of dissolved oxygen concentrations (6.9–12.9 mg/L) in July and August. Juveniles occurred in water of higher turbidity (8–74 nephelometric turbidity units, NTU) than adults (3–37 NTU). Juveniles also showed a higher modal utilization for turbidity (20–29 NTU) than adults (<10 NTU). Juvenile and adult fish occurred in pH ranges from 7.9 to 9.2; the range of 8.0 to 8.4 used most frequently. Conductivity at collection sites ranged from 500 to 750 $\mu S/cm$.

Pallid shiner habitat in the Kankakee River consists of shallow areas with little or no current in moderately clear waters that are warm, average in pH, and well oxygenated during summer daylight hours. This description falls well within the

broad range of qualitative descriptions of pallid shiner habitat that have accompanied collected specimens (Hubbs 1951). Water velocity reports appear about equally divided between “none” or “almost none” and “slow” to “rapid,” with slow current recorded most frequently. Recorded summer temperatures for pallid shiner habitat vary from “cold” (presumably meaning cool) to “warm,” ranging from average records of nearly 23 $^{\circ}C$ in northern portions of the species’ range to 33 $^{\circ}C$ in the south. Most turbidity reports vary from “clear” to “muddy,” but include a few that were recorded as “murky” or “very muddy.”

The habitat requirements of the pallid shiner have been associated with distributional patterns of this species. Hubbs (1951) concluded that the pallid shiner is tolerant of a wide range of turbidity as well as other environmental factors. Avoidance of excessive turbidity and silt in larger southern streams may nonetheless be a chief factor in the differential habitat selection by pallid shiners in northern and southern populations, and water temperature may play a role in the avoidance of small streams by this species in the northern parts of its range (Hubbs 1951). Intolerance of excessive turbidity, siltation, and pollution are the most frequently cited reasons for the relatively recent drastic decimation of this species (Lopinot and Smith 1973; Pflieger 1975; Clemmer 1980). The observed differences in turbidity between juvenile and adult habitat in the Kankakee River suggest that young pallid shiners are able to tolerate relatively higher turbidities.

Species Associations

The fishes collected within a given sampling month at stations where the pallid shiner occurred

FIGURE 5.—Utilization (frequency of use) curves for habitat and water quality variables measured concurrently with juvenile and adult pallid shiner collections from the Kankakee River, Illinois. NTU = nephelometric turbidity units.

included 45 species representing nine families. The pallid shiner was most commonly associated with the bluntnose minnow *Pimephales notatus*, bullhead minnow *P. vigilax*, spotfin shiner *Notropis spilopterus*, sand shiner *N. stramineus*, and orangespotted sunfish *Lepomis humilis*; all of these species are adapted to a lentic environment with the exception of the spotfin shiner. In Wisconsin, one pallid shiner specimen was associated with 28 fish species, including the four species most commonly associated with pallid shiners in the Kankakee River, but not including the orangespotted sunfish (Becker 1983).

The cluster analysis, based on weighted mean habitat and water quality values assigned to each cyprinid species collected during July and August 1984, revealed that adult pallid shiners, juvenile

pallid shiners, and the bullhead minnow were closely associated and clustered into one of five groups at a Euclidean distance of 0.76 (Figure 6). These species were quite distant from all others based on physical attributes of utilized habitat. Other linkage methods yielded a similar arrangement of species.

The 1984 sample ($N = 49$) of pallid shiners, on which the cluster analysis was based, was composed primarily of juveniles (90%); a similar analysis was performed on a 1979 collection of nine, primarily adult (89%), specimens taken by Skelly and Sule (1983). Although life stage of the fish in the 1979 sample was not known, similar results were attained. The pallid shiner was grouped with the bullhead minnow and fathead minnow *Pimephales promelas*; the latter species was not col-

FIGURE 6.—Tree diagram depicting groupings and distances between cyprinid species (and life stage for pallid shiner) determined by a cluster analysis based on site-specific habitat and water quality variables during July–August 1984, Kankakee River, Illinois. Number of individuals of each species or life stage included in the analysis is given in parentheses.

lected in 1984. The distribution of the pallid shiner is more restricted, but similar to that of the bullhead minnow (Clemmer 1980; Lee and Kucas 1980). This resemblance was also noted by Hubbs (1951) and is most likely due to similar habitat requirements of the two species.

Hypotheses Warranting Further Study

The results presented in this report raise several questions that could not be adequately addressed within the scope of the study. The downward trend in mean condition factors from 1984 through 1986 and the absence of pallid shiners in subsequent summer collections may indicate a period of increased stress, which may have led to a reduced abundance of this population. The absence of pallid shiners in subsequent samples does not indicate the extirpation of this population, however, as evidenced by the localized abundance of this species in a survey of the same approximate area during spring 1989 and its presence in impingement samples collected from the riverside intake structure (G. L. Seegert, EA Science and Technology, personal communication). The seasonal variation in pallid shiner catches suggests that subtle seasonal or behavioral movements may be occurring and could, in part, contribute to annual catch during the summer sampling period.

The floodplain of the Kankakee River, like those of other large temperate rivers, provides critical spawning and nursery habitats for fishes (Guillory 1979; Welcomme 1979; Kwak 1988), and fluc-

tuations in fish abundances and assemblage structure have been attributed to flooding and the floodplain (Starrett 1951; Ross and Baker 1983; Finger and Stewart 1987). The pallid shiner breeds during the late winter and early spring in the southern portions of its range. Ripe adults have been collected in the Mississippi River in Arkansas as late as March (Clemmer 1980). Breeding information in its northern range remains unknown, but based on spawning dates of southern populations, the pallid shiner could be expected to spawn some time after March in the Kankakee River. The positive relationship between juveniles and minimum discharge during June and May–June suggests that access to the floodplain for spawning or at critical stages of development may be essential for the reproduction and survival of the pallid shiner. Temperature during spawning or early life stages may also act as an environmental pressure on this species; furthermore, optimal conditions for spring spawners such as the pallid shiner may occur during years when flooding and temperature rise are coupled, as suggested by Junk et al. (1989). Timely fluctuations and stability in flow and temperature probably interact with other vital physical (e.g., photoperiod, habitat, water quality) and biotic factors (e.g., population and assemblage structure) to create optimal breeding and survival conditions for the pallid shiner.

Localized areas of fringing floodplain habitat at station 5, where 84 of the 88 pallid shiners were

collected, should be studied, and their value as spawning or nursery habitats for this species assessed. Intensive seasonal sampling at established stations and other habitats, in conjunction with standardized annual summer sampling, is required to determine the relationship between behavior and catch per unit effort and to more precisely identify critical habitat and environmental influences.

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