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Ecology of Larval White Bass in a Large Kansas Reservoir

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Abstract.—Knowledge of the early life history of sport fish is important for understanding recruitment and population dynamics. Unfortunately, little is known about the early life history of the white bass *Morone chrysops*. Therefore, this study was conducted to describe the spatial and temporal distribution, age structure, growth, mortality, and food habits of larval white bass in a Kansas reservoir. Larval white bass and zooplankton were sampled weekly from March to July 1999 in Glen Elder Reservoir; 92% of these fish were sampled from the upper reservoir. The larval white bass varied in age from 3 to 35 d and grew approximately 0.32 mm/d. Cohort-specific instantaneous mortality rates varied from 0.02 to 0.15. Differential mortality among early- and late-spawned fish was not apparent. The white bass first hatched during late April and continued hatching until late May. We estimated that most fish spawned during early and mid-May and that spawning activity was closely related to high reservoir inflows (10–25 m^3/s). The diets of the larval white bass were dominated by adult copepods and *Bosmina* spp.; fish consumed adult copepods, *Bosmina*, and *Diaphanosoma* spp. in greater proportions than those available and avoided other prey taxa (e.g., *Daphnia* spp. and rotifers).

The year-class strength of fish populations is often established during early life history stages (Sammons and Bettoli 2000); thus, understanding the early life history of fish has been a central focus of basic and applied fisheries research. A complete understanding of early ontogeny is especially important for sport fish species, for which apparently minor fluctuations in abiotic and biotic conditions can have a dramatic influence on growth, survival, and subsequent recruitment to the fishery. Unlike with many species (e.g., largemouth bass *Micropterus salmoides*), little is known about the ecology of larval white bass *Morone chrysops* in reservoir ecosystems (Colvin 1993).

White bass are abundant throughout the Missouri, Mississippi, and Ohio river drainages (Colvin 1993). They are common in large rivers and natural lakes and are often very abundant in reservoir systems. Consequently, white bass provide important sport fisheries and also play an important ecological role in piscivore fish communities. The objectives of this study were to describe the distribution, age structure, growth, mortality, and food habits of larval white bass in a Kansas reservoir. We also investigated the role of temperature and reservoir inflow on the spawning activity of white bass.

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Methods

This study was conducted on Glen Elder Reservoir, a 5,093-ha reservoir on the Solomon River in Mitchell County, Kansas. Glen Elder dam was constructed in 1969 for flood control; however, the reservoir also provides municipal water, recreational opportunities, and wildlife conservation benefits. The primary sport fish species include white crappie *Pomoxis annularis*, channel catfish *Ictalurus punctatus*, white bass, and walleye *Stizostedion vitreum*.

Larval white bass were sampled weekly from 24 sites located in four habitat types (i.e., dam, pelagic, littoral, and riverine) from March to July 1999 (Figure 1). The riverine sampling sites were in areas without detectable flow. White bass were collected using paired bongo nets (0.5 m in diameter, 1.5 m long, 500-μm mesh) pushed from the bow of the boat at a depth of 0–0.5 m. In addition, a meter net (1.0 m in diameter, 3 m long, 500-μm mesh) was towed at a depth of 0.5–1.5 m at all sites except the riverine sites (depths $<$2 m). Fish collected with the meter net were included in

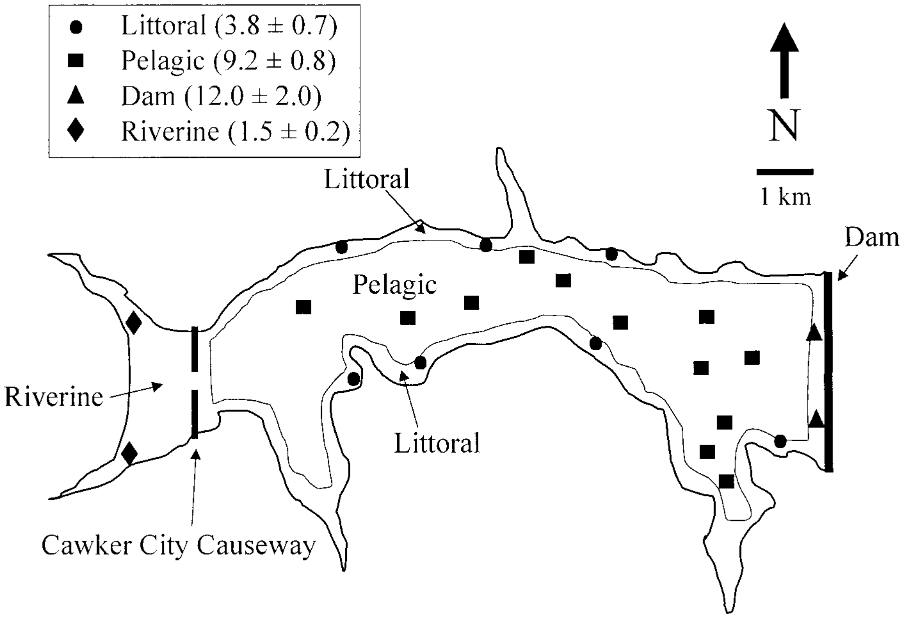

FIGURE 1.—Locations of sites sampled on Glen Elder Reservoir, Kansas, from March to July 1999. Numerical values in the legend represent the mean depth in meters (± SE) for each habitat type.

growth analyses; however, only data from the bongo net samples were used to estimate density (number/100 m^3). Nets were deployed for approximately 5–10 min at a speed of 1.5 m/s. Sample volume was determined from flow meters (General Oceanics, Inc., model 2030R) fixed to the mouth of all nets. Ichthyoplankton samples were immediately preserved in 90% ethanol (Stevenson and Campana 1992) and transported back to the laboratory for processing.

Larval white bass were identified using keys provided by Auer (1982) and May and Gassaway (1967). The total length of each fish was measured to the nearest 0.1 mm using an image analysis system. Sagittal otoliths were removed and mounted on glass slides using clear thermoplastic cement. Age in days was determined following the guidelines of Stevenson and Campana (1992). Although daily growth increments have not been validated for white bass, Secor and Dean (1989) and Secor et al. (1991) have validated the technique for striped bass *Morone saxatilis*. Two independent counts of growth rings were made for each otolith by one observer. If the counts differed by more than two rings (<3% of the otoliths), the otolith was read once more by the observer. If the last count differed from the two previous counts, the otolith was discarded; otherwise, the modal age was used in our analyses. The timing of initial increment formation has not been assessed for white bass; however, Secor et al. (1991) found that the first ring is deposited on the fifth day after hatching for striped bass. Therefore, fish age was assumed to be the ring count plus 4 d. Hatch date was estimated by subtracting age from the collection date, and spawning date was determined by subtracting incubation time (3–4 d at 12–18°C) from hatch date. Temperature-specific incubation rates were provided by McCormick (1978) and Auer (1982). Food habits were determined for all sampled white bass by removing the digestive tract and examining the contents under both dissecting and compound microscopes. Prey items were identified to species for fishes, to genus for Cladocera and Copepoda (excluding nauplii), to family for Insecta, and to order for other prey taxa (e.g., Amphipoda). The length of all prey items was measured to the nearest 0.01 mm using an image analysis system.

Full water column samples were collected at each ichthyoplankton sampling site with a conical plankton net (12 cm in diameter, 80-μm mesh) and immediately preserved in 70% ethanol to determine the availability of zooplankton. Zooplankton were enumerated by counting all organisms in a 5-mL subsample (Wetzel and Likens 1991). Lengths from each prey taxon were measured from

20 individuals at each site using an ocular micrometer.

Water temperature and dissolved oxygen were measured weekly from four fixed sites using a multi-probe (Yellow Springs Instruments, Inc., model 85). Reservoir inflow information was obtained from U.S. Geological Survey gauging stations. The two gauging stations were located upstream of the riverine sampling sites in North Fork and South Fork Solomon River.

Repeated-measures analysis of variance (ANOVA; Milliken and Johnson 1992; Littell et al. 1996) was used to determine whether the density of larval white bass differed over spatial and temporal scales. Growth rates were estimated using a linear growth model. When otoliths were damaged or lost during processing, age was estimated using the growth model. Ninety-two percent of the white bass were sampled from the riverine portion of the reservoir; therefore, we restricted our analysis of environmental spawning cues, mortality, and food habits to individuals collected in the riverine area. In addition, few fish (25.2%) contained prey items in their digestive tracts; therefore, analysis of food habits was limited to fish collected on May 25. Larval white bass were assigned to weekly cohorts (7 d; Michaletz 1997) beginning with cohort 0, which represented fish that were hatched during the week of April 18. Instantaneous daily mortality rates (Z) were computed for each weekly cohort by regressing the natural logarithm of fish abundance in a cohort against successive collection dates (Ricker 1975; Stevenson and Campana 1992; Michaletz 1997). The proportional use of zooplankton prey was assessed using Ivlev's electivity index (Ivlev 1961). Differences between the mean lengths of the zooplankton taxa that were available and those that were utilized were compared by means of *t*-tests with a Bonferroni adjustment for multiple tests (Kuehl 1994).

Results

A total of 267 larval white bass varying in length from 3.0 to 36.0 mm (mean $\pm$ SE, 7.3 $\pm$ 0.18) were collected. Larval white bass were first collected on May 18 and remained in the ichthyoplankton until the end of June. Densities were over 80 times higher in the upper reservoir (i.e., the riverine sites) than at sites located in littoral, pelagic, and dam habitats (Table 1). Consequently, densities were significantly higher ($P < 0.0001$) in the riverine area than in the other habitats on all dates when fish were collected. Larval white bass densities at dam, littoral, and pelagic sites were not significantly different ($P > 0.50$).

TABLE 1.—Mean density (number/100 m^3) of larval white bass collected from four habitat types in Glen Elder Reservoir, Kansas, from March to July 1999. Numbers in parenthesis represent one standard error.

	Habitat type			
Date	Dam	Littoral	Pelagic	Riverine
Mar 17	0	0	0	0
Apr 1	0	0	0	0
Apr 7	0	0	0	0
Apr 14	0	0	0	0
Apr 21	0	0	0	0
Apr 28	0	0	0	0
May 7	0	0	0	0
May 12	0	0	0	0
May 18	1.6 (1.6)	0	0	27.8 (8.5)
May 25	0	0	0.4 (0.3)	70.1 (8.1)
Jun 2	0	0	0.4 (0.3)	17.5 (8.9)
Jun 8	0	0.2 (0.2)	0	3.1 (3.1)
Jul 30	0	0	0	1.7 (0.8)

The larval white bass varied in age from 3 to 35 d, although 55% were less than 10 d old. Fish grew at a rate of 0.32 mm/d (length [mm] = 3.700 + 0.320 $\times$ age [d]; $r^2 = 0.93$, $P = 0.0001$). Instantaneous mortality rates were estimated for five weekly cohorts (Figure 2). Values of Z varied from 0.02 to 0.15, averaging 0.09 (SE = 0.02). Unfortunately, we only collected enough larval white bass to estimate mortality on five sampling dates, and individuals were generally absent from our samples once they reached 15 mm. Therefore, mortality rates for cohorts 0 ($Z = 0.06$), 1 ($Z = 0.02$), and 3 ($Z = 0.15$) were based on two sampling dates while those for cohorts 2 ($Z = 0.11$) and 4 ($Z = 0.15$) were based on three sampling dates.

White bass in the riverine area of Glen Elder Reservoir first hatched on April 21 (Figure 3), when water temperatures averaged 14°C, and continued hatching until the end of May. Peak hatches were observed during early and mid-May, followed by a smaller one in late May. We estimated that most white bass spawned on May 5 and May 19 and that hatching was closely related to abrupt rises in reservoir inflow once water temperatures exceeded 12°C (Figure 3).

The diets of larval white bass consisted primarily of adult copepods, *Daphnia galeata*, and *Bosmina* spp. (Figure 4A). In addition, amphipods, chironomids, and *Leptodora* spp. were occasionally consumed (frequency of occurrence, <1%). Larval gizzard shad *Dorosoma cepedianum* were the only fish consumed, and although white bass

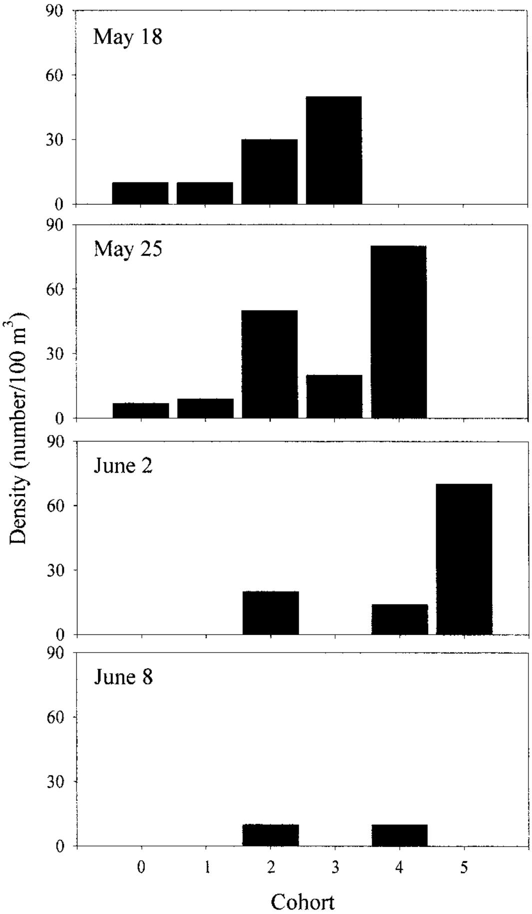

FIGURE 2.—Mean density of larval white bass sampled from the riverine habitat of Glen Elder Reservoir, Kansas, from March to July 1999. Cohorts represent weekly cohorts (7-d) beginning with the week of April 18, 1999.

as small as 11.8 mm consumed gizzard shad, the latter were present in less than 2% of the fish examined. Most white bass consumed only one or two prey items; however, the largest fish (36 mm) consumed several chironomids, gizzard shad, *Daphnia pulex*, and an amphipod. Adult copepods and *Bosmina* were the dominant organisms consumed by larval white bass (frequency by number, >20%; Figure 4A). *Cyclops* spp., *Diaptomus* spp., *Diaphanosoma* spp., and *Bosmina* were utilized in higher proportions than those available whereas copepod nauplii, *D. galeata*, *D. pulex*, and rotifers were avoided. Many of these trends are explained by the length of prey taxa. For example, copepod nauplii and rotifers were generally less than 0.2 mm and were consumed infrequently (Figure 4B). White bass consumed the smallest *D. pulex*, *Di-*

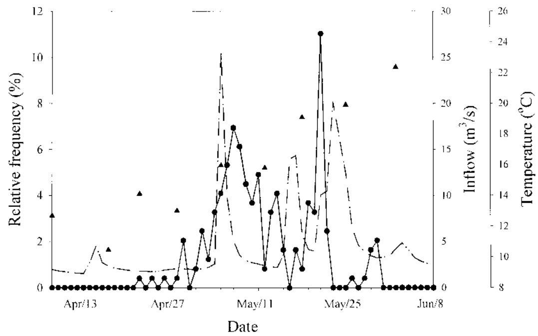

FIGURE 3.—Relative frequencies of the back-calculated hatch dates of white bass (circles and solid line; left scale), mean water temperature (triangles; outer right scale), and mean reservoir inflow (dashed line; inner right scale) in the riverine habitat of Glen Elder Reservoir, Kansas, March to July 1999.

aptomus, and *Diaphanosoma*, whereas the *Cyclops* and *Bosmina* consumed were slightly larger than those available.

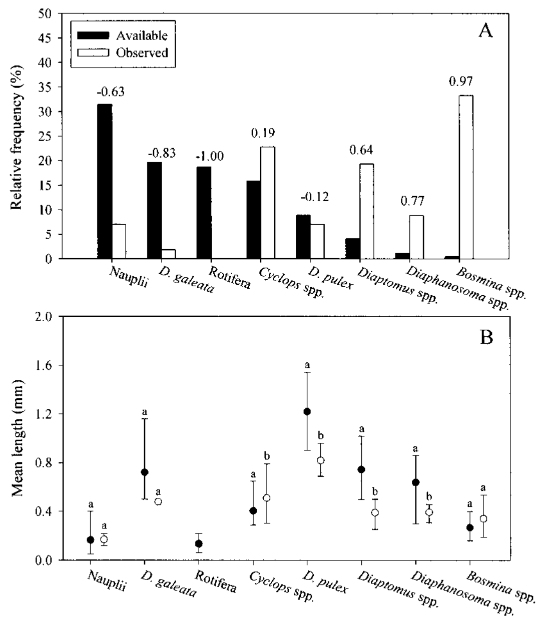

FIGURE 4.—**(A)** Relative frequencies and **(B)** mean lengths of the zooplankton that were available in the environment and those that were observed in the diets of white bass sampled on May 25, 1999, from the riverine habitat of Glen Elder Reservoir, Kansas. Numbers above the vertical bars in **A** are Ivlev's selectivity index values. The bars in **B** indicate the minimum and maximum lengths, with different letters denoting a significant difference in length within a taxon ($P \leq 0.05$).

Discussion

Several researchers have documented that white bass spawn in the tributaries of lakes and reservoirs (Dietz 1967; Myhr 1971; Moen and Dewey 1980; Colvin 1993). Although most white bass in Glen Elder Reservoir were produced in the riverine areas, some spawning activity occurred throughout the reservoir. The specific spawning areas in the upper reservoir are unknown; however, the capture of yolk sac fry and older fish on all dates suggests that white bass spawned throughout the North and South Forks of the Solomon River. In addition, most fish were sampled in the North Fork, which generally contributes more discharge to Glen Elder Reservoir than the South Fork.

White bass generally begin spawning at water temperatures of 14–20°C (Colvin 1993) but may spawn at temperatures as low as 10°C (Storck et al. 1982). White bass spawned at temperatures of 14–22°C in Glen Elder Reservoir, and spawning activity was closely related to peak reservoir inflows of 10–25 m^3/s. Storck et al. (1982) found that white bass spawned in the Kaskaskia River during decreasing discharge. However, other authors have reported that extremely high discharge or reservoir inflow and sudden declines in water temperature may temporarily halt spawning activity (Webb and Moss 1968; Myhr 1971; Starnes et al. 1983). Therefore, high flow events or delayed warming during the spawning season may inhibit white bass spawning activity in reservoirs.

Few studies have determined the growth rates of larval white bass. Kindschi et al. (1979) found that growth rates in a small Kentucky lake averaged 0.08 mm/d during the first 2 months posthatch and increased to 0.56 mm/d thereafter. White bass in Glen Elder Reservoir grew substantially faster than those reported by Kindschi et al. (1979). We used changes in mean length through time to estimate growth rates; therefore, the discrepancy likely reflects differences in methodology, especially if there are length-related gear biases. We are unaware of any previous studies that reported mortality rates for larval white bass. Our cohort-specific mortality rates based on two sampling dates should be interpreted with caution; however, the mortality rates observed during this study are similar to those reported for other closely related species. For example, Dey (1981) found that Z varied from 0.16 to 0.19 for larval striped bass in the Hudson River estuary. Similar results have been reported by Polgar (1977) and Turner and Chadwick (1972).

The food habits of larval white bass have been extensively studied. Ruelle (1971) found that the diet of white bass 4–11 mm long in Lewis and Clark Lake, South Dakota, was dominated by adult copepods (*Cyclops* and *Diaptomus*) and that *Daphnia* were not important prey items for any of the fish examined. Conversely, Priegel (1970) found that cladocerans (*Leptodora* and *Daphnia*) and copepods (*Cyclops* and *Diaptomus*) were the most important prey for white bass 18–25 mm long in Lake Winnebago, Wisconsin. In addition, Priegel found that zooplankton continued to dominate white bass diets throughout the first year of life. Similar results have been reported by Bonn (1952) and Voigtlander and Wissing (1974). Copepods and cladocerans were the dominant prey for larval white bass in Glen Elder Reservoir, suggesting the importance of crustacean zooplankton during early life history. In addition, white bass avoided prey items less than 0.3 mm and selected prey between 0.4 and 0.8 mm. Although white bass as small as 12.0 mm exhibited piscivory, fish are generally not an important component of white bass diets until they reach approximately 40 mm (Ruelle 1971; Saul et al. 1985; Colvin 1993).

Although this study was conducted during only one spawning season, our results provide additional information on the ecology of larval white bass in a reservoir system. Future research should focus on whether these results are consistent among years and reservoirs. Furthermore, little is known about the factors that influence the recruitment of white bass. Investigations of their entire first year would greatly enhance our understanding of white bass recruitment and population dynamics.

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