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ABSTRACT

We estimated instantaneous growth (G) and mortality (Z) rates of alevin channel catfish (*Ictalurus punctatus*) from the Oconee River, Georgia. We modeled growth and mortality with exponential equations and estimated G and Z with regression techniques. These efforts produced mixed results. Our estimate of G (0.0064; SE = 0.0012) was significantly different from zero ($P = 0.013$), whereas our estimate of Z was not different from zero ($P = 0.35$). If we assume that the estimated growth model was appropriate for larger young-of-the-year channel catfish, we predict that they would be 25 mm total length by mid-September. This size is smaller than that (i.e., ~60 mm) reported for similarly-aged alevins in other systems. Mechanisms responsible for the apparently low growth of alevin channel catfish in the Oconee River are unclear.

INTRODUCTION

Estimates of growth and mortality for young-of-the-year (YOY) fishes are essential for understanding fish population dynamics. If these estimates were made regularly, biologists could assess extrinsic factors that are correlated with growth and mortality of YOY fishes (Hatch and Underhill, 1988). Growth and mortality estimates for adult freshwater fishes are common; however, such estimates are rare for early life stages, even though these life stages are thought to dictate eventual year-class strength and could be used to predict recruitment (Cada and Hergenrader, 1980; Crecco et al., 1983). Thus, growth and mortality studies represent a significant first step toward understanding the early life history of fishes and how life history is affected by environmental conditions. For example, growth rates of fish are sensitive to physical and biological factors such as water quality and fish density (Freeberg et al., 1990; Brandt et al., 1992).

The channel catfish (*Ictalurus punctatus*) is a parental care species, and development of early life stages differs from the typical progression of yolk-sac larvae, larvae, and pre-juvenile phases found in most other fishes. Spawning occurs in dark, secluded nests usually between May and July when water temperature is about 21 - 30 C, with 27 C being optimum (Lippson and Moran, 1974; Jenkins and Burkhead, 1993). Males often build nests in burrows, undercut banks, log jams, or rocks, and guard the newly-hatched fish (6 - 9 mm total length; TL) until they leave the nest 7 or 8 days post-hatching (Lippson and Moran, 1974; Tin, 1982). The larval period, defined as the phase between yolk absorption and acquisition of adult fin ray complements, is absent from the development of ictalurids because adult fin ray complements are evident at yolk absorption (Jones et al., 1978; Tin, 1982). This early juvenile phase that begins after yolk absorption is termed alevin (Balon, 1975).

Population dynamics of alevin channel catfish have not been well studied even though the species is of considerable economic and recreational importance throughout North America. Our research goal was to present data on the seasonal occurrence and abundance of alevin channel catfish in the Oconee River, Georgia, along with estimates of instantaneous growth and mortality for this life stage.

METHODS

Study Area

Alevin channel catfish were sampled from a 4-km reach of the Oconee River, Georgia, located between the Central of Georgia Railroad bridge (at Wilkinson-Washington County line) and Commissioner Creek (in Wilkinson County). The Oconee River is a tributary of the Altamaha River, and the study reach was located in the Upper Coastal Plain physiographic province. Hydropower generation by Sinclair Dam, located at Milledgeville about 55 km upstream from the study site, resulted in an unpredictable, highly variable flow regime in the river. The mean daily discharge at a U.S. Geological Survey water stage recorder (No. 02223248), located about 4.4 km

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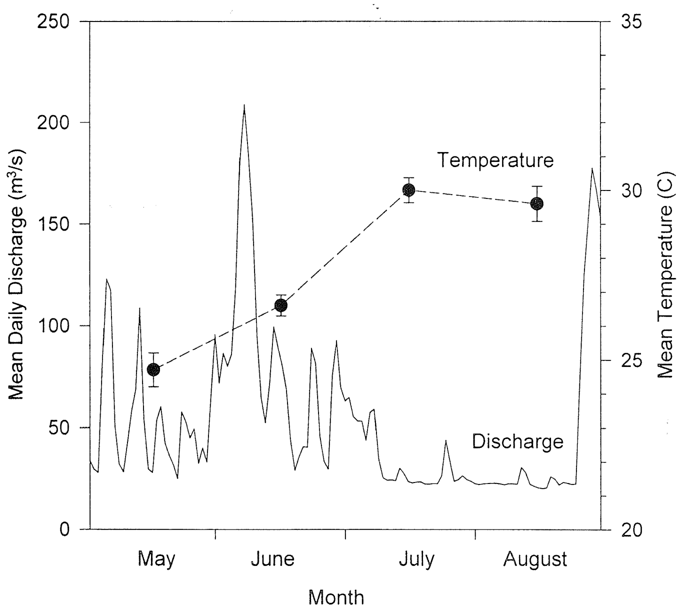

Figure 1. Mean daily discharge (m^3/s) calculated from a water-stage recorder located in the Oconee River, Georgia, about 4.4 km downstream of Commissioner Creek from 1 May to 31 August 1995 (Stokes and McFarlane 1995). Mean (± 1 SE) water temperature for each month measured during sample collection from 10 May to 21 August 1995.

downstream from the study site, ranged from 23 to 209 m^3/s between May and August (Stokes and McFarlane, 1995); however, mean daily discharge does not represent diel variation associated with generation (Fig. 1). The study reach was shallow (mean depth = 1.7 m; SD = 0.9) with moderate current velocity (mean = 0.32 m/s; SD = 0.09) in the thalweg (i.e., path of deepest water) of the river. Mean monthly dissolved oxygen concentrations ranged from a low of 6.7 mg/L during May to a high of 7.3 mg/L during July. Mean monthly water temperature increased from May to July, with minimal variation in July and August (Fig. 1). Water temperatures and dissolved oxygen concentrations were within the range required for adult channel catfish survival and spawning.

Sample Collection And Processing

Alevin channel catfish were sampled at least once weekly from 10 May to 21 August 1995. Water temperature, dissolved oxygen concentration, current velocity, and water depth were measured at the time of sample collection. A 505-μm-mesh pushnet (area = 0.20 m^2) was used to sample alevins in the surface drift (depth = 0.0 - 0.5 m) and a 800-μm-mesh modified D-ring net (area = 0.34 m^2) was used to sample the drift at the river bottom. Samples were collected in the thalweg of the river at nighttime when alevin channel catfish are most common in the drift (Armstrong and Brown, 1983; Brown and Armstrong, 1985; Holland-Bartels and Duval, 1988). The mouth of each net was equipped with a flow meter so that the volume of water sampled could be calculated. Nets were fished until about 100 m^3 of water was sampled (pushnet ~ 12 min; D-ring net ~ 10 min). Twelve samples (i.e., six with each gear) were collected during a sampling occasion. All samples were preserved in 10% buffered formalin.

In the laboratory, alevins were enumerated and placed in vials for later identification. Extraction efficiency, estimated by re-examining 20% of the sample residues, averaged 99.5% (SD = 3.1). Identification of ictalurids was based on morphometric and meristic descriptions (Lippson and Moran, 1974; Jones et al,. 1978; Cloutman, 1979; Wang and Kernehan, 1979; Tin, 1982). Channel catfish alevins in each sample were measured to the nearest 0.1 mm TL with dial calipers and assigned to 1-mm size classes (e.g. 14.0 - 14.9 mm TL). Catch data were expressed as a density (i.e., numbers of fish per 1,000 m^3 of water sampled).

Growth and Mortality Estimation

Instantaneous growth and mortality were estimated with a length-based method developed by Hackney and Webb (1978) that has been used successfully to estimate these parameters for larval fishes (Cada and Hergenrader, 1980; Hatch and Underhill, 1988; Zigler and Jennings, 1993). Catch data for pushnets and D-ring nets were pooled to develop estimates of instantaneous growth and mortality because both gear types were used during a sampling event to better represent alevins in the drift (i.e., upper and lower portion of the water column). Size classes with less than five fish were excluded from analyses because undue variation could be introduced by the small sample size (Van Den Avyle, 1993).

Growth rates were estimated by calculating a density-weighted mean date of collection for each 1-mm size class (Hackney and Webb, 1978). The density-weighted mean date (D) for each size class was estimated with the equation

$$D = \frac{\sum_{i=1}^{n} d_i J_i}{\sum_{i=1}^{n} d_i}, \qquad i = 1, 2, \ldots, n \tag{1}$$

where d_i was the alevin density for each collection date of a 1-mm size class, J_i was the Julian collection date, and n was the number of sampling occasions. Age was calculated for each 1-mm size class by subtracting the density-weighted mean date of the smallest size class collected from each of the subsequent size classes (Hackney and Webb, 1978). The age of the smallest size class examined was estimated to be zero. Instantaneous growth was estimated with the equation

$$\log_e(L_t) = \log_e(L_0) + Gt, \tag{2}$$

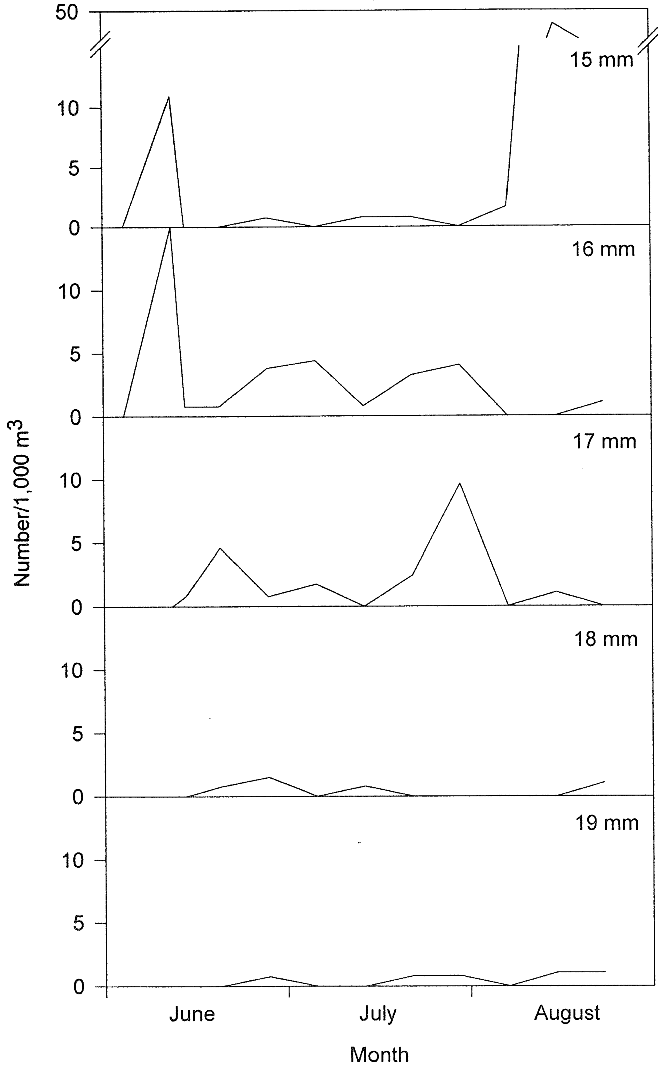

Figure 2. Density of selected 1-mm size-classes of channel catfish alevins collected by push-nets and D-Ring nets in the Oconee River, Georgia, from 10 May to 21 August 1995.

where L_t was the TL (mm) of the lower limit of each size class, L_0 was the length intercept, G was the coefficient of instantaneous growth, and t was age in days (Hackney and Webb, 1978). Instantaneous mortality was estimated with the equation

$$\log_e(N_t) = \log_e(N_0) - Zt, \quad (3)$$

where N_t was the predicted alevin abundance at age t, N_0 was the alevin abundance axis intercept, Z was the coefficient of instantaneous mortality, and t was age in days (Hackney and Webb, 1978). The mortality estimate was based on the descending limb of the catch curve to reduce gear bias from underrepresented small size classes that had not yet recruited to the sampling gear (Ricker, 1975). The portion of the descend-

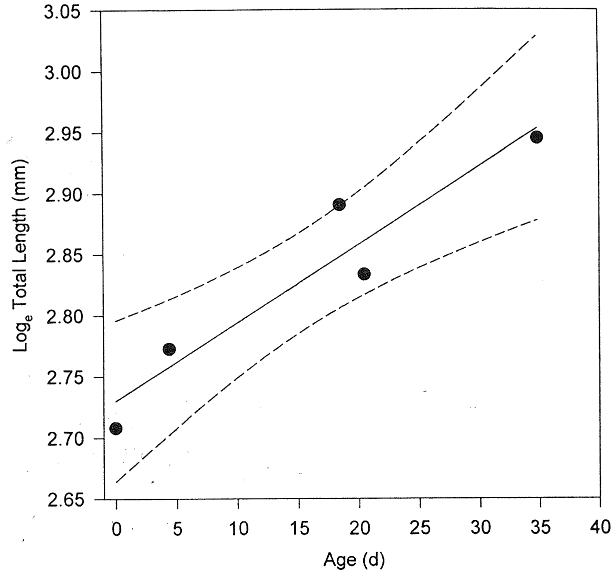

Figure 3. Estimated growth for selected age-groups of channel catfish collected by push-nets and D-Ring nets in the Oconee River, Georgia, from 10 May to 21 August 1995. The dashed lines represent the upper and lower 95 % confidence limits for regression estimates. Alevins from the second spawning peak were omitted from age and growth analyses.

ing limb of the catch curve used to estimate instantaneous mortality was shifted one size class to the right of the size class that occurred at the highest frequency (i.e., dome) because the dome of the catch curve may or may not be vulnerable completely to the sampling gear (Everhart and Youngs, 1981). Statistical significance of the slope of regression lines was assessed by treating values of $P < 0.05$ as significant.

RESULTS

Channel catfish were not collected in the drift until mid-June. One hundred sixty-four alevin channel catfish (14.0 - 22.9 mm TL) were collected from 19 June to 21 August 1995, and the mean density of these alevins in the catch was 13 fish per 1,000 m^3 of water sampled (SE = 0.03). Channel catfish recruited to drift nets at about 15 mm TL. Alevin channel catfish relative abundance was bimodal, attributed to two spawning peaks, one during late June and another during mid-August (Fig. 2). Each size class of fish less than 22 mm TL from the first spawning peak was represented in the collection. Channel catfish less than 17 mm TL collected on 14 and 21 August were excluded from estimates of growth and mortality because fish collected at these dates represent a second spawning peak. Cohorts from the second spawning peak were described incompletely because sampling ended during August, before abundance of most 1-mm size classes had peaked.

The range of fish lengths used to estimate growth was 15 - 19 mm TL. Regression analysis showed that the relationship

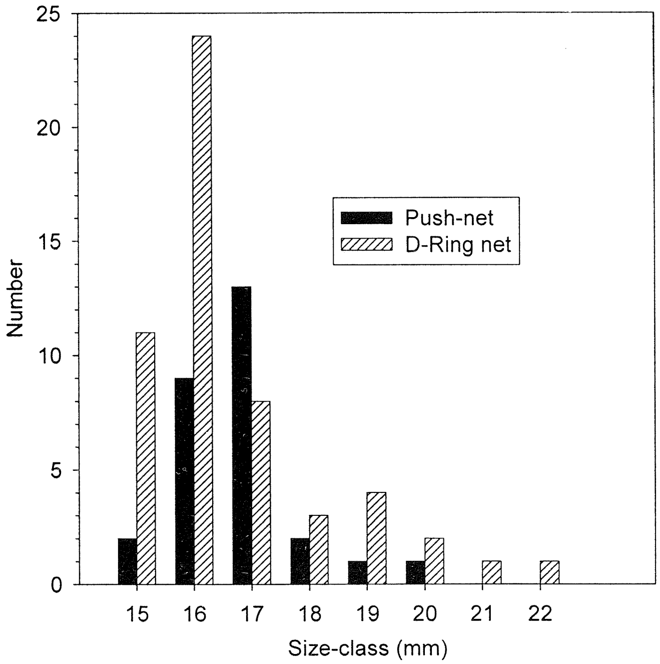

Figure 4. Number of channel catfish in each 1-mm size-class collected by push-nets and D-Ring nets in the Oconee River, Georgia, from 10 May to 21 August 1995. Alevins from the second spawning peak were omitted from the catch curve analysis.

between natural logarithm of channel catfish TL and age was significant (r^2 = 0.91; P = 0.013). The coefficient of instantaneous growth, estimated as the slope of the regression line, was 0.0064 (SE = 0.0012), and the complete growth equation was $\log_e(L_t) = 2.7 + 0.0064t$ (Fig. 3).

Fish less than 17 mm TL or greater than 19 mm TL were not used to estimate mortality because these size classes were sampled incompletely. Fish less than 16 mm TL, which should have been the most abundant, were underrepresented in the alevin catch (Fig. 4). The relationship between the natural logarithm of channel catfish abundance and age was not significant (r^2 = 0.72, P = 0.35). Nonetheless, instantaneous mortality, calculated as the slope of the regression line, was 0.089 (SE = 0.055).

DISCUSSION

Considerable information is available about growth and mortality of adult channel catfish (e.g., Carlander, 1969), but few such data exist for alevin channel catfish or other ictalurids. Nonetheless, the estimated instantaneous growth of alevin channel catfish in the Oconee River seems low because the estimate is an order of magnitude lower than published estimates of instantaneous growth for other fishes. If we assumed that the estimated growth model was appropriate for larger YOY fish through mid-September, we predict that channel catfish would be about 25 mm TL in mid-September. This size is smaller than lengths reported in mid-September for YOY channel catfish in riverine habitats in Wisconsin (67 mm TL; Becker, 1983) and the upper Mississippi River (60 mm TL; McInerny and Held, 1995). McInerny and Held (1995) collected fish from cooling water intake screens of a power plant, whereas the collection method used by Becker (1983) was not reported. Thus, the method we used to collect channel catfish differed from those used by McInerny and Held (1995), and size selectivity of the different sampling methods may have varied. Gear avoidance by channel catfish greater than 16 mm TL would artificially reduce our estimate of instantaneous growth. However, relative abundance of channel catfish greater than 16 mm TL in trawl collections was correspondingly low (Jennings, unpublished data), which suggests that avoidance by larger channel catfish to drift nets was not a likely explanation for the low instantaneous growth rate we observed in the Oconee River. Holland-Bartels and Duval (1988) showed that a trawl similar to ours was effective for collecting YOY channel catfish (15 - 70 mm standard length) in the upper Mississippi River.

Assumptions common for estimates of growth and mortality are similar to those derived by Ricker (1975) for use in traditional catch-curve analysis. These assumptions are: 1) mortality and growth rates are constant with age, 2) cohorts initially recruit to the sampling gear at about the same length, and 3) all size classes of cohorts used for estimates are equally vulnerable to sampling gear (Essig and Cole, 1986). We limited the length distribution of alevins in growth and mortality estimates to minimize violating the assumption that growth and mortality were constant with age and that all size classes of cohorts used for estimates were equally vulnerable to sampling gear. We also sampled at nighttime to minimize gear avoidance and used two different gear types to better represent alevins in the drift.

The number of alevin channel catfish we used to estimate instantaneous growth and mortality is smaller than the number of fish used in other growth and mortality studies (Hatch and Underhill, 1988; Zigler and Jennings, 1993). However, our sampling periodicity was similar to Cada and Hergenrader (1980), Hatch and Underhill (1988), and Zigler and Jennings (1993), and the time period we sampled (10 May - 21 August 1995) should have been sufficient to encompass the theoretical spawning season of channel catfish (Marzolf, 1957; Brown and Armstrong, 1985). Therefore, the low number of alevin channel catfish we collected probably was due to their low densities in the drift (13 alevins/1,000 m^3). We took several precautions outlined by Ricker (1975), Everhart and Youngs (1981), and Van Den Avyle (1993) to reduce the effects of sampling bias in our analyses. Further, we avoided small sample bias by limiting our analyses to size classes with at least five fish (Van Den Avyle, 1993).

The presence of two spawning peaks, the first in late June and second in mid-August, was apparent from the catch of alevins. Bimodal spawning is typical for channel catfish, and it occurs in lentic (Marzolf, 1957; Deacon, 1961) and lotic environments (Brown and Armstrong,1985; Holland-Bartels and Duval, 1988). We based our estimates of alevin growth and mortality on the data from the first spawning peak to minimize the likelihood of violating the assumption that each size class was equally vulnerable to sampling gear.

We hypothesized that yolk-sac larvae were not in the drift because newly-hatched fish do not leave the nest until 7 or 8 days post-hatch (e.g., Marzolf, 1957). Channel catfish hatch at about 6 - 9 mm TL and generally become abundant in the catch at about 15 mm TL (Lippson and Moran, 1974; Tin, 1982; Armstrong and Brown, 1983; Brown and Armstrong, 1985). Growth from hatch to 15 mm in eight days seems unlikely. Further, 7- or 8-day-old channel catfish were too large to be extruded through our sampling nets. Therefore, we should have collected channel catfish less than 15 mm TL had they been present in the water column. Their absence from the catch suggests that when channel catfish first leave the nest they are not vulnerable to drift nets, or alevins stay in the nest longer than the 7 - 8 days reported, or unexplained mortality is occurring.

Biologists must provide objective inputs to decision making about fisheries (Noble and Jones, 1993) and conservation manipulations. Therefore, biologists must understand fish population dynamics, but these data are lacking for many YOY fishes. Our results suggest that instantaneous growth of alevin channel catfish in the Oconee River is low, and several factors could explain this phenomenon. Further research is needed to ascertain if our results are consistent over larger time scales (i.e., year to year variability) and with other populations. Such data will allow fishery managers to better understand population dynamics of YOY channel catfish in riverine environments and better determine life history components in this commercially, recreationally, and community important species.

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