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Effect of Water Temperature on Food Evacuation Rate and Feeding Activity of Age-0 Gizzard Shad

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Abstract.—A study was conducted to evaluate the influence of water temperature on food evacuation and feeding activity in age-0 gizzard shad *Dorosoma cepedianum* fed pulverized food. Fish kept at 5°C exhibited little feeding activity. At temperatures of 10, 15, and 20°C, food was evacuated through the digestive tract in 8.5, 4.9, and 4.4 h, respectively. Frequency of feeding acts also increased significantly with increased water temperature. These data, along with information on the dry weights of natural detritus in full digestive tracts of gizzard shad (ages 0–2) from Acton Lake, Ohio, were used to estimate the daily amounts of natural detritus consumed by age-0 fish. We concluded that a 6-g, age-0 fish can ingest and process natural detritus (dry weight) in amounts ranging from 3.2 to 7.7% of wet body weight per day.

Few data are available on the food evacuation rates of fish species that are detritivorous during part or all of their life cycle (Bray and Ebeling 1975; Payne 1975). The gizzard shad *Dorosoma cepedianum* is an important forage fish in lakes and reservoirs throughout the eastern United States (Eddy and Underhill 1978) as well as in impoundments in the western U.S., where it has been introduced (Jester and Jensen 1972). Gizzard shad feed typically on zooplankton, phytoplankton, or other living foods when these are available and abundant (Jester and Jensen 1972; Jude 1973; Drenner et al. 1982; Ringler and Johnson 1982). However, in systems where these foods are unavailable for part or all of the growing season, gizzard shad feed mainly on organic detritus (Dalquest and Peters 1966; Baker and Schmitz 1971; Pierce et al. 1981).

In Acton Lake, a 253-hectare impoundment in southwestern Ohio, gizzard shad of all ages feed on organic detritus grazed from bottom sediments, retaining walls, and submerged tree limbs and logs (Pierce et al. 1981; Mundahl 1984). The present study was designed to determine the effects of water temperature on food evacuation and feeding activity in age-0 gizzard shad fed in the laboratory and to estimate the amount of detritus consumed daily by fish in the field.

Methods

Gizzard shad were collected from Acton Lake by electroshocking in the summer and autumn of 1981, 1983, and 1984. Age-0 to age-2 fish collected in 1981 and 1984 were used to determine the amount of detrital food materials contained in a full digestive tract (esophagus to anus). Collections were made in early afternoon (1200–1500 hours) because digestive tracts are fullest during this period in summer and autumn (Pierce et al. 1981). Fish were placed immediately on ice, and no regurgitation of food materials was observed. After the fish were weighed and measured, detrital materials were extruded and scraped gently from the digestive tracts and were oven-dried to constant weight at 60°C.

Age-0 gizzard shad (mean wet weight ± SE, 5.92 ± 0.14 g; mean standard length ± SE, 72 ± 1 mm) collected in 1983 were used in laboratory feeding experiments. Fish were acclimated in a 492-L Living Stream (Frigid Units, Incorporated) at a temperature approximating seasonal field water temperatures; windows in the laboratory provided a natural photoperiod. Gizzard shad were

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TABLE 1.—Total organic, carbon, and nitrogen contents of laboratory food and organic detritus ingested by gizzard shad in several lakes and reservoirs.

Food	Lake or reservoir	Food component (% of dry weight)			Reference
		Total organic	Total carbon	Total nitrogen	
Laboratory food		89.3	45.5	6.7	Mundahl and Wissing, unpublished data
Detritus	Acton Lake, Ohio	9.8–22.6	5.6–12.8	0.2–2.2	Mundahl (1984)
Detritus	Lake Diversion, Texas	82.6		7.1	Dalquest and Peters (1966)
Detritus	Beaver and Bull Shoals reservoirs, Arkansas	15–95			Baker and Schmitz (1971)
Detritus	Lake Erie, Michigan	5.35–58.5	3.3–22.7	0.3–4.1	Mundahl (1984)

provided with food made from equal portions (by weight) of pulverized Zeigler trout pellets and Tetra conditioning food. This food had the approximate particle size (≤100 μm) of natural detritus ingested by age-0 gizzard shad in the field (Mundahl 1984). Although this material did not possess the bacterial coating of natural detritus, its nutritional quality (e.g., organic, carbon, and nitrogen content) was similar or superior to that of natural detritus ingested by gizzard shad in many natural systems (Table 1). The food mixture sank within minutes of introduction into the Living Stream and formed a thin layer of particles on the bottom, where it was fed on readily by the fish.

After acclimating the fish for one week, we gradually raised or lowered the water temperature 2–3°C/d to one of four experimental temperatures—5, 10, 15, or 20°C. Five groups (6 fish/group) of age-0 gizzard shad were allowed to feed at each temperature (six groups at 10°C) following a 48–72-h starvation period. Two groups of fish were allowed to feed simultaneously; each group was restricted to a 100-L section of the Living Stream. Food (5% of wet body weight) was fed to each group for 90 min; any food material remaining after this period was removed by siphon. (Fish became accustomed to siphoning during the acclimation period and were not disturbed by it during the experiments.) Fish were then fed an equal portion of marked food (dyed with rose carmine protein stain). The amount of food offered to the fish was always in excess of that consumed. After introduction of the marked food, one fish from one group was sacrificed every 0.5 h, one fish from a second group was sacrificed every 0.75 h, and those from the remaining three groups were sacrificed every 1.0, 1.25, and 1.5 h, respectively. After each fish was weighed and measured, the complete digestive tract was removed, and the length of the intenstine (pylorus to anus) was measured. The distance moved by the interface between the marked and unmarked food material (clearly visible through the intestinal wall) was determined for each fish and was used to derive the "percent of intestinal passage."

To assess the effect of temperature on feeding activity, a group (N = 7; 72–107 mm standard length, SL) of age-0 gizzard shad at each experimental water temperature was videotaped while the fish were feeding. Frequency of feeding acts (defined as single incidents of ingestion of food from the bottom of the chamber) was determined from 5-min recordings of the fish at each temperature.

Relationships of fish wet weight to dry weight of digestive tract contents and of percent of intestinal passage to time were determined by linear regression analyses (Sokal and Rohlf 1981). Slopes of the regression equations were compared among water temperatures by analysis of covariance (Sokal and Rohlf 1981). The level of significance for all statistical tests was set at 0.05.

Results

The laboratory feeding experiments with age-0 fish demonstrated a significant ($P < 0.05$) influence of water temperature on food passage. Marked food appeared in the intestine approximately 1 h after feeding began, and moved steadily through the tract (Figure 1). The rate of food evacuation through the intestine, as evidenced by the linear relationship, did not change significantly during the course of the experiments at each temperature. However, the rate of food movement increased significantly ($P < 0.05$) with increased temperature. The food passed through the complete digestive tract of a representative 6-g (wet body weight) gizzard shad in 4.4 h at 20°C, 4.9 h at 15°C, and 8.5 h at 10°C (see the regression equations in Figure 1). Rates of food evacuation (slopes of the regression lines) at 15 and 20°C were similar and were significantly greater ($P < 0.05$) than that observed at 10°C. No significant relationship among the values at 5°C was observed, as intestines of only eight of 30 fish tested at this temperature contained food (Figure 1). Several of the values for fish at 5°C may have reflected the presence of food consumed prior to the starvation period, but not egested as a result of the low temperature.

Feeding activity of the age-0 gizzard shad was also influenced by changes in water temperature. Feeding acts by fish at 5 and 10°C were infrequent (0.00 and 0.11 acts·fish^{-1}·min^{-1}, respectively). At 15°C, feeding activity (1.26·fish^{-1}·min^{-1}) increased sharply, and continued to increase (1.86·fish^{-1}·min^{-1}) at 20°C.

Data on food evacuation rates and field data on weights of food in full digestive tracts were used to estimate the amount of detritus consumed daily by age-0 gizzard shad in the field. Age-0 to age-2 fish (1.96–62.22 g wet weight, 47–152 mm SL) collected from Acton Lake during peak feeding periods exhibited a significant linear relationship between wet body weight (g) and dry weight (g) of digestive tract contents (tract contents = −0.0109 + 0.0245·fish wet weight; $r^2 = 0.75$; $N = 33$). If it is assumed that feeding is limited to 12–15 h of daylight (Pierce et al. 1981) and that the laboratory food and natural detritus have equal rates of passage (see Discussion), a 6-g (wet body weight) gizzard shad (i.e., the size used in the feeding experiments) can process 0.19–0.24 g dry weight of natural detritus per day at 10°C, 0.33–0.42 g at 15°C, and 0.37–0.46 g at 20°C. These values correspond to 3.2–4.0, 5.5–7.0, and 6.2–7.7% of wet body weight at 10, 15, and 20°C, respectively.

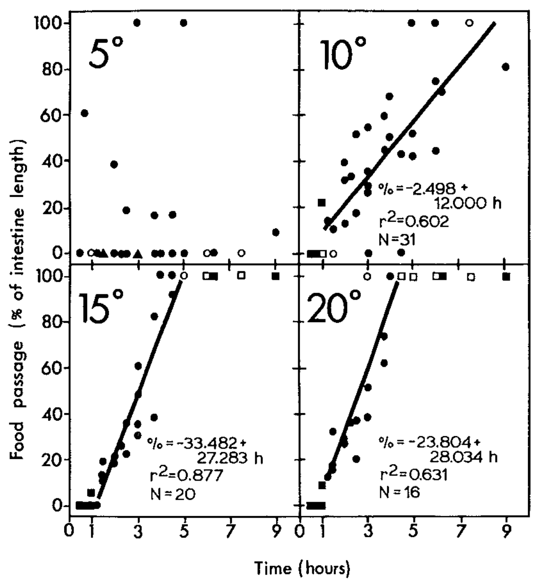

FIGURE 1.—Food passage (percent of intestinal length traversed by food) over time in age-0 gizzard shad at 5, 10, 15, and 20°C. Solid circles represent one observation; open circles, two observations; and solid triangles, three observations. Regressions are based only on those observations from 1.25 h through the time after which the intestines of all fish examined were filled completely with marked food. Observations not included in the regressions are shown as squares (solid, one observation; open, two observations).

Discussion

The influence of water temperature on food evacuation has been analyzed for a number of fish species (see review by Fange and Grove 1979). Persson (1979) noted that food evacuation rates initially increase rapidly with rising temperature, but then level off or decline as water temperature continues to rise. In the present study, temperature had a similar effect on food evacuation, with little or no food movement in the fish at 5°C, a rapid increase in food evacuation rate (decrease in food passage time) betwen 5 and 15°C, and little change in evacuation rate between 15 and 20°C. It is not known how food evacuation rate in gizzard shad responds to water temperatures greater than 20°C, as temperatures higher than this could not be maintained adequately in the Living Stream. Gizzard shad in the field continue to feed heavily on detritus at temperatures up to 30°C (Mundahl 1984), but information on how rapidly this material is processed is lacking.

At the temperatures tested, the lengths of time required for food evacuation in age-0 gizzard shad were typical of those for most microphagous fishes (Fange and Grove 1979). Apparently, fish whose diets comprise small particles (e.g., detritus, phytoplankton, and zooplankton) process these materials at a relatively constant rate at a given temperature. Therefore, it is possible that the food evacuation rates of gizzard shad feeding on detritus, phytoplankton, or zooplankton are similar to those of fish fed a particulate laboratory diet.

Increases in feeding activity with increased temperature generally paralleled those of food evacuation rate over the range of temperatures tested. This was not unexpected, as appetite and the various physiological processes (e.g., gut motility, digestive enzyme secretion and activity, and intestinal absorption) that influence food evacuation in fishes are temperature sensitive (Kapoor et al. 1975). At present, the temperature at which gizzard shad can optimize energy intake and assimilation in Acton Lake is not known. However, a computer simulation of the bioenergetics of age-0 gizzard shad in this system indicated that the energy available for growth (i.e., energy ingested minus energy egested and respired) was maximal at 20°C (Megrey 1978).

It is apparent from the present study that small, age-0 gizzard shad can ingest and process substantial amounts of detritus daily. Although feeding activity and rates of food evacuation in adult gizzard shad may differ from those observed for age-0 fish, our results can be used to estimate daily food consumption in systems where organic detritus is the main constituent of the diet of young gizzard shad.

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