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Sediment processing by gizzard shad, *Dorosoma cepedianum* (Lesueur), in Acton Lake, Ohio, U.S.A.

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Gizzard shad are primarily detritivorous in Acton Lake, a 253-ha impoundment in southwestern Ohio, U.S.A. To determine the magnitude of sediment utilization by the gizzard shad population in Acton Lake, I used data on population density and age structure, daily ration, and feeding selectivity in estimating the mass of sediments processed by shad daily from April through November. At densities of 4595–10 645 fish ha^{-1} (wet weight biomass = 90–121 kg ha^{-1}), gizzard shad could process 3·8–23·0 kg of dry sediments ha^{-1} day^{-1}. On average throughout the growing season, gizzard shad could process a dry mass of sediments each day equivalent to 13% of shad wet weight biomass. Because of the high rate of sedimentation ($>$ 700 kg dry sediment ha^{-1} day^{-1}) in Acton Lake, gizzard shad can process $<$4% of the freshly deposited sediments each day, and therefore are likely to have little effect on benthic community dynamics in the system.

Key words: *Dorosoma cepedianum*; detritus; detritivory; sedimentation; reservoir.

I. INTRODUCTION

Detritus occurs in virtually all aquatic ecosystems, and is an important food resource for many species of invertebrates and fishes (e.g. Bowen, 1979; Cherry *et al.*, 1979; Zimmerman & Wissing, 1980; Bowen, 1983; Bowen *et al.*, 1984; Nelson & Wilkins, 1988; Taghon, 1988). However, organic detritus often is mixed with large quantities of undigestible inorganic matter in sediments (Bowen, 1983), requiring detritivores to sort through and/or ingest considerable volumes of sediments to obtain their daily rations of detritus (Odum, 1970; Zimmerman & Wissing, 1980; Taghon, 1988). Consequently, processing of sediments by detritivores may have a significant impact on the remainder of the aquatic community (Odum, 1970).

The gizzard shad *Dorosoma cepedianum* (Lesueur) (Clupeidae) is an important prey fish in many North American waters, where it often feeds heavily on detritus grazed from bottom sediments and submerged objects when preferred live foods (e.g. plankton) are in low abundance (e.g. Dalquest & Peters, 1966; Baker & Schmitz, 1971; Mundahl & Wissing, 1987; Mundahl, 1988). The species can actively process sediments to concentrate detritus before ingesting it (Mundahl, 1984; Mundahl & Wissing, 1988). Because gizzard shad populations can achieve high densities ($>$ 5000 fish ha^{-1}) in many systems (Jenkins, 1957; Houser & Netsch, 1971; Morris & Follis, 1978), their feeding behaviour could have a major influence on benthic habitats. The present study was designed to estimate the quantities of sediments processed daily throughout the growing season by a typical gizzard shad population in an Ohio reservoir, and to evaluate the relative impact of this sediment processing with respect to sedimentation dynamics within the reservoir.

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TABLE I. Mean wet weights, density (fish ha^{-1}), and wet biomass (kg ha^{-1}) of a simulated gizzard shad population in Acton Lake, Ohio. Weights were determined from growth equations in Pierce (1977) and Mundahl (1984). Apparent overwinter weight gains are not real, but reflect instead the differences in growth rates among year classes common in this system

Month	Wet weight (g)				Density	Biomass
	Age 0	Age 1	Age 2	Age 3		
Apr.	—	5·3	33·0	47·3	5650	91·8
May	—	10·0	34·7	47·3	5120	95·2
Jun.	—	13·9	31·9	61·7	4595	90·0
Jul.	2·4	16·8	30·8	72·1	10 645	103·0
Aug.	4·9	18·9	33·4	79·3	9710	119·9
Sept.	6·2	20·1	37·8	82·8	8745	121·5
Oct.	6·2	20·4	38·6	82·7	7980	111·0
Nov.	5·1	19·8	34·0	78·9	7215	90·5

II. MATERIALS AND METHODS

STUDY SITE

Gizzard shad dominate the fish community of Acton Lake, a shallow (mean depth <4 m), 253-hectare reservoir on Four Mile Creek in Butler and Preble counties, Ohio, U.S.A. Freshly deposited surface sediments are the major food resource for gizzard shad in this system (Mundahl & Wissing, 1987, 1988). Most sediments enter the lake via four tributaries that drain a predominantly agricultural, 270-km^2 watershed.

ESTIMATION OF SEDIMENT PROCESSING

To determine the amount of sediments processed by gizzard shad in Acton Lake, I simulated a gizzard shad population (Table I) with biomass, density, age structure, growth rates, and mortality rates based on previous investigations of the Acton Lake population (Pierce, 1977; Mundahl, 1984), as well as populations in other impoundments of similar size (Jenkins, 1968; Leidy & Jenkins, 1977; Carline *et al.*, 1984). Biomass values were based on the mean biomass of 103 kg/ha^{-1} for clupeids in Ohio River drainage-area reservoirs (Leidy & Jenkins, 1977), and were slightly higher than that (88 kg/ha^{-1}) reported for Acton Lake (Pierce, 1977). The total July biomass was set at 103 kg/ha^{-1} and was apportioned among the age groups as follows: age 0–15%, age 1–50%, age 2–30%, and age 3–5% (Carline *et al.*, 1984). Thereafter, biomass was allowed to fluctuate in response to growth and mortality. Density estimates (Table I) calculated from fish wet weight data and biomass estimates also were higher than values (mean June density = 3219 fish ha^{-1}) reported for Acton Lake (Pierce, 1977).

Feeding activity in gizzard shad is dependent on water temperature (Salvatore *et al.*, 1987) and spawning activity (Pierce *et al.*, 1981), and feeding occurs only during daylight hours (Pierce *et al.*, 1981). Therefore, information on Acton Lake water temperatures (Pierce, 1977; Mundahl, 1984), shad spawning period (Pierce, 1977), and daylength (Cincinnati Weather Bureau) was included in calculation of daily rations (Salvatore *et al.*, 1987) for each of the age categories of gizzard shad. Data from Salvatore *et al.* (1987) were used to estimate a water temperature–food passage time relationship: food passage time (h) = $76{\cdot}998 \times$ water temperature ($^\circ$C)$^{-0{\cdot}977}$. Daylengths were divided by food passage times to determine the number of times digestive tracts were filled each day. Weights of food in digestive tracts of fish of different sizes were estimated from the fish wet weight–digestive tract contents dry weight equation of Salvatore *et al.* [1987; tract contents

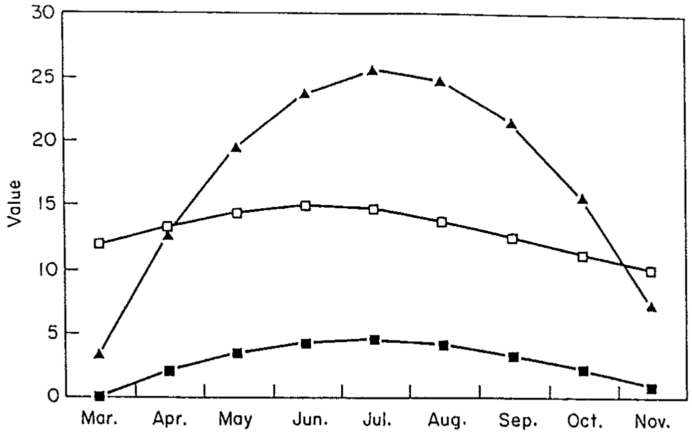

FIG. 1. Influence of daylength, □ and water temperature, ▲ on the frequency, ■ with which gizzard shad fill their digestive tracts throughout the growing season.

(g) = −0·0109 + 0·0245 fish wet weight (g)]. Calculated daily rations for ages 2 and 3 fish were reduced by 25% in May and 35% in June to compensate for reduced feeding activity during spawning (Pierce, 1977). It was assumed that food passage rates were similar for juvenile and adult fish (Salvatore *et al.*, 1987). It also was assumed that during selective feeding, gizzard shad sorted through or processed 2 g of sediment for each 1 g of materials actually ingested, and that this processing remained constant throughout the growing season (Mundahl & Wissing, 1988). The mass of sediments processed daily by the total gizzard shad population and each of the age groups was determined at mid-month throughout the entire growing season (April through November), and was expressed in kg dry weight of sediments ha^{-1}.

SEDIMENT COLLECTION

Sediment traps (Mundahl & Wissing, 1988) were placed in Acton Lake to determine the rate at which sediments settled from the water column and became available to benthic-feeding gizzard shad. Traps (four in 1982, three in 1983) were placed on the lake bottom once each month for a short period of time (generally <24 h to avoid vandalism) during July–November 1982 and April–November 1983. Collected sediments were oven dried at 60° C and weighed, and daily rates of sediment deposition were expressed in kg dry weight of sediments ha^{-1}.

III. RESULTS

SEDIMENT PROCESSING

Changing water temperatures and daylengths during the growing season had the effect of maximizing food intake by individual gizzard shad during June and July (Fig. 1). In these months, fish filled their digestive tracts with food nearly 4·5 times during the daily feeding period. By contrast, cooler temperatures and fewer daylight hours in November decreased the frequency of digestive tract filling to less than once per day. Water temperatures were too low (<8° C) from December through mid-March to support any significant feeding activity by gizzard shad.

Despite digestive tracts being filled most frequently in June and July, sediment processing by the entire simulated gizzard shad population was not maximized until August (Fig. 2). Ages 1, 2 and 3 fish all achieved peak processing rates in July, but increased processing by rapidly growing age 0 fish shifted peak processing for

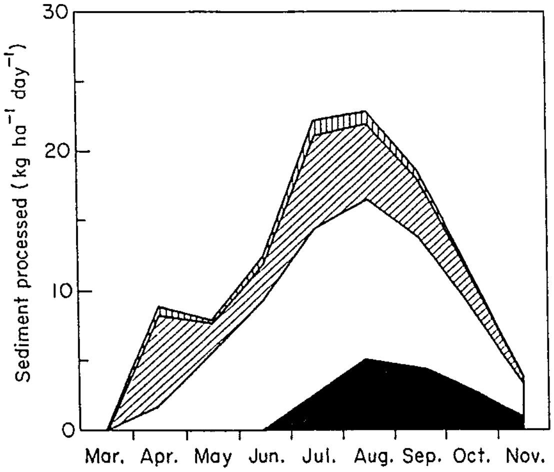

FIG. 2. Dry mass of sediments processed daily throughout the growing season by each age class of the simulated gizzard shad population in Acton Lake. ■, Age 0; □, age 1; ▨, age 2; ▥, age 3.

the entire population to August. At that time, the population theoretically processed 23·0 kg dry weight of sediment ha^{-1} day^{-1}. A low value of 3·8 kg of sediment ha^{-1} day^{-1} was estimated for November.

Age 1 fish, which comprised approximately 50% of the population biomass throughout the growing season, were responsible for processing 53·6% of the sediment during the year. Age 0 and age 2 fish processed approximately equal amounts (20·9 and 22·3%, respectively), whereas age 3 fish processed only 3·2% of the total. The reduced amounts of sediments processed by ages 2 and 3 fish during May and June (Fig. 2) coincided with reduced food intake during the spawning period.

SEDIMENT ACCUMULATION

Sediments accumulated in sediment traps in Acton Lake at highly variable rates during 1982 and 1983 (Fig. 3). In general, rates were highest in spring and decreased throughout summer and autumn. Significant differences in mean monthly sedimentation rates were observed in both years (1982: ANOVA $F=16{\cdot}40$, d.f. = 19, $P<0{\cdot}001$; 1983: ANOVA $F=4{\cdot}58$, d.f. = 23, $P<0{\cdot}01$). The mean (±S.D.) sedimentation rate for July–November 1982 was 2988±2311 kg dry weight of sediments ha^{-1} day^{-1} ($n=20$), and for April–November 1983 was 3470±4017 kg ha^{-1} day^{-1}. Comparing the 1983 mean value to gizzard shad sediment processing rates, the simulated gizzard shad population theoretically could process no more than 0·7% of the sediments settling out of the water column each day.

IV. DISCUSSION

Populations of benthic detritivores may have significant impacts on sediment dynamics in some aquatic systems, owing to the large volumes of sediments processed by these organisms during feeding. Odum (1970) estimated that a single

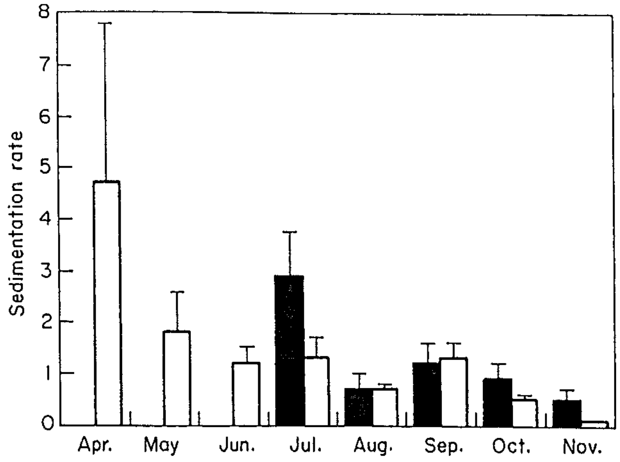

FIG. 3. Rate of sediment accumulation (mg dry weight cm^{-2} h^{-1}) in Acton Lake during 1982, ■ and 1983, □, as measured by sediment traps.

grey mullet *Mugil cephalus* Linnaeus (200 mm standard length) filters 1·5 kg dry weight of sediment day^{-1} in its search for detritus. An individual (0·006 to 0·040 g dry weight) deposit-feeding polychaete *Abarenicola pacifica* processes up to 280 times its dry body weight in sediments each day (maximum of 11·2 g day^{-1}) (Taghon, 1988), whereas a population (approximately 1000 individuals m^{-2}) of the burrowing mayfly nymph *Hexagenia limbata* (Serville) can ingest 10 to 25% (up to 5 g m^{-2} day^{-1}) of the sediments deposited throughout the year in an Ohio pond (Zimmerman & Wissing, 1980). In comparison, detritivorous gizzard shad can process up to 20% of their wet weight biomass in dry sediments each day (2·0 g m^{-2} day^{-1} for a population biomass of 100 kg wet weight ha^{-1}) under optimum conditions (average >13%; present study; Salvatore *et al.*, 1987). Because gizzard shad can digest 50 to 66% of the organic matter contained in ingested sediments (Mundahl & Wissing, 1988), a large population of benthic-feeding gizzard shad could alter significantly the composition of the sediments and their suitability as a habitat and/or food resource for other organisms.

Many fish and invertebrates depend on detritus as their major food resource. The diets of many North American cyprinids and catostomids include large quantities of detritus (Lee *et al.*, 1980; Trautman, 1981), and detritivorous midge larvae (Diptera: Chironomidae) and annelids (Oligochaeta) often dominate benthos standing crops in many lentic systems (e.g. Daniel, 1972; Rasmussen, 1984). Sediment processing by a large population of gizzard shad potentially could interfere with the feeding of other detritivorous fishes, and reduce benthic secondary productivity by reducing the availability of detritus for midge larvae and other invertebrates. Detritivorous invertebrates are important components of the diets of many young game fishes (e.g. bluegill *Lepomis macrochirus* Rafinesque; Doxtater, 1962; Lee *et al.*, 1980), suggesting that benthic feeding by gizzard shad ultimately may have some effect on the game fish community. Planktivorous populations of gizzard shad are known to have direct, negative effects on game fishes in many lakes and reservoirs because they are in direct competition with the young game fishes for food (see Bonneau & Radonski, 1984), but the possibility that detritivorous gizzard shad populations also could affect game species negatively has not been suggested previously.

Data from this study indicate that gizzard shad in Acton Lake process only an insignificant proportion of the freshly deposited sediments actually available to them. Even an impossibly high gizzard shad standing crop biomass of 1000 kg ha^{-1} (Heidinger, 1984) would at best be able to process only 6% of the sediments settling out of the water column. Based on data on long-term sedimentation rates for Acton Lake (2·3 cm yr^{-1}, 710 kg dry weight of sediments ha^{-1} day^{-1}; Daniel, 1972; N. Mundahl, unpublished data) to compensate for possible resuspension of sediments by wave action (Pierce, 1977; Zimmerman & Wissing, 1980), an average gizzard shad population (103 kg ha^{-1}) still potentially could process only up to 3·2% of the sediments deposited daily in Acton Lake.

The rapid rate of sedimentation in Acton Lake probably masks any possible negative effects that gizzard shad may have on other detritivores in this system. Erosion of agricultural lands upstream from the reservoir often results in heavy silt loads entering the lake via the tributary streams (N. Mundahl, personal observation). High sedimentation rates in reservoirs are common (e.g. Dendy, 1968; Ritchie & McHenry, 1977), suggesting that detritivorous gizzard shad populations in such systems may have little impact on benthic community dynamics. However, in waters with much lower rates of sediment deposition (i.e. reservoirs with forested drainages, natural lakes with limited inflows), sediment processing by gizzard shad could have significant effects on the benthos.

In conclusion, a detritivorous gizzard shad population can process large quantities of sediments during the growing season. In waters with (1) a dense population of gizzard shad, (2) plankton standing crops too low to support planktivory by shad, and (3) a low rate of sediment (or detritus) accumulation, sediment processing by shad potentially could have a negative effect on other benthic detritivores. However, in reservoirs with rapid sediment accumulation rates, even very dense populations of benthic-feeding gizzard shad would have virtually no impact on benthic community dynamics.

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