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Thomas E. Moen
U.S. Fish and Wildlife Service

Michael R. Dewey
U.S. Fish and Wildlife Service

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THOMAS E. MOEN and MICHAEL R. DEWEY
Multi-Outlet Reservoir Study
U. S. Fish and Wildlife Service
Arkadelphia, Arkansas 71923

ABSTRACT

Weekly samples of larval fish were collected from water discharged from the epilimnion of DeGray Lake into the tailwaters, for power generation, from April through August, 1976 and 1977. Peak rates of loss measured were 1.4 larvae/m^3 in May, 1976 and 2.7/m^3 in April, 1977. Sunfish, shad and crappie made up 97% of an estimated 83.3 million fish lost in 1976, and 98% of 122.4 million lost in 1977. The most critical period for larval fish loss extended from the last week of April to the first week of June. No definite relationships were noted between length of the power generation period or power generation rate, and rate of larval fish discharge. Diel collections showed the rate of larval fish discharge to be lower and more uniform during darkness than during daylight.

INTRODUCTION

In the design and construction of many multi-purpose reservoirs, selective regulation of the depth of water discharge makes it possible to control the temperature of water released. The multi-outlet design at DeGray Dam allows for epilimnial, intermediate, or hypolimnial discharge. A concentrated study of the ecosystems of DeGray Lake and its tailwaters is being undertaken by the U. S. Fish and Wildlife Service and the U. S. Corps of Engineers, in cooperation with state and private universities, to determine the effects of multi-outlet water release. Little information is available on larval fish losses resulting from releases through any type of discharge design (Walburg, 1971; Snyder, 1975). As part of the research on the problem, larval fish loss has been monitored at DeGray Lake in an attempt to determine the species and numbers of larval fish entrained during power generation and the seasonal and daily periods of greatest vulnerability.

The present study concerns larval fish loss during epilimnial release; in later studies we hope to monitor loss during hypolimnial release. Eventually, an attempt will be made to assess the impact of larval fish loss on the reservoir fish population.

DESCRIPTION AND OPERATIONS OF THE RESERVOIRS

The multi-purpose DeGray Reservoir was created by a dam built on the Caddo River in 1969. At normal pool elevation (124.4 m, mean sea level - msl), it has an area of 5,427 ha with maximum and minimum depths of 57 m and 15 m, respectively. The multi-outlet intake structure allows water to be selectively withdrawn from one of three 6.4 m^2 openings, the midpoints of which are at elevations of 120.4, 115.8 and 108.2 m - msl (Middleton, 1967). All water releases have been made from the upper (epilimnial) outlet since impoundment.

Discharge depends on "peaking" power demands and maintenance of established water levels necessary for flood control. During the present study (April - September, 1975, 1976 and 1977), daily periods of discharge varied from a few minutes to 24 hours. Most power generating periods lasted less than 5 hours. Discharge rates ranged from 35 m^3/s (1200 cfs) to 155 m^3/s (5500 cfs). At maximum discharge rates, water current velocities 20 m in front of the intake tower did not exceed 0.15 m/s; at the sampling site below the dam, current velocity was 1.2 m/s.

Because the bottom of the upper outlet coincided with the top of the thermocline at normal water levels, we assumed that the water discharged involved mostly epilimnial water and only a small portion of the metalimnion. Similar situations have been noted in other reservoirs (Wunderlich and Elder, 1967; Wunderlich, 1971). Temperatures of the discharged water were similar to those of water in the epilimnion, supporting the assumption of epilimnial discharge.

METHODS

Fish larvae were collected at a point 40 m downstream from the discharge openings by a 3 m long, one meter townet of 0.79 mm (1/32 in) mesh size. The net was equipped with a flow meter and a collecting bucket. Samples were taken near the middle of the water column ranging from 1.0 to 1.5 m from the surface. A 2 h discharge on a predetermined schedule of power generation rate and time on each sampling date was arranged through the U. S. Army Corps of Engineers and the Arkansas Power and Light Company. After allowing a 20 minute flushing period to clear the sampling area, we fished the net each sampling day for 5-minute periods, separated by 15-minute intervals (six samples) in 1976, and for 10 minutes, separated by 20-minute intervals (four samples) in 1977. All routine sampling was conducted during daylight. In 1976, the sampling periods were alternated weekly between morning (0930 - 1130 h) and afternoon (1300 - 1500 h); in 1977, we sampled only in the afternoon (1300 - 1500 h). Discharge rates on sampling dates varied from 85 to 155 m^3/s. It was estimated that the net filtered about 0.6% of the water being discharged during the fishing period, about 0.15% of the water discharged during the 2-hour sampling period, and as little as 0.003% of the water discharged during a typical week. Extra samples were taken during periods of long-term generation and during one 24-h period.

Larval fish were placed in 10% formalin solution and returned to the laboratory for determination of species, lengths, and weights and density (no./m^3). Because identification of the larvae to species was uncertain, some were identified only to genus. Shad over 20 mm long were identified to species. The volume of water discharged each week was calculated from weekly summations of daily discharge furnished by the U. S. Army Corps of Engineers. The midpoint of each weekly summation included the weekly sampling date. The mean number of larvae per cubic meter of water strained on the sampling date, multiplied by the total volume of water discharged during the corresponding week, provided the estimated larval fish loss.

Preliminary sampling in 1975 (18 April to 5 September) indicated that vulnerability of larvae to discharge was highest from April through August. Therefore, estimates of larval fish loss were confined to these 5 months in 1976 and 1977.

RESULTS AND DISCUSSION

Fish larvae collected, in order of abundance, included sunfish, *Lepomis* sp.; shad, *Dorosoma*, sp; crappie, *Pomoxis* sp; logperch, *Percina caprodes*; brook silverside, *Labidesthes sicculus*; shiners, *Notropis* sp; darters, *Etheostoma* sp; channel catfish, *Ictalurus punctatus*; flathead catfish, *Pylodictis olivaris*; centrarchid bass, *Micropterus* sp.; and white bass, *Morone chrysops*. Most larvae collected were 5 to 30 mm long. Sunfish, shad, and crappie made up 97% of the estimated 83.3 million larval fish lost in 1976 and 98% of the estimated 122.4 million lost in 1977 (Table I). On the basis of limited sampling, the larval fish loss in 1975 was estimated at 171 million.

The seasonal occurrence of larval fish in the discharge appeared to closely follow the expected abundance of larval fish in the reservoir. Darters were the first to appear in the discharge in early April, followed by crappie about mid-April, depending on early spring water temperatures. Peak numbers of crappie occurred in the discharge during the first week in May, 1976 and in the last week in April, 1977. No crappie were caught after the last week in June of either year. A few shad were in the discharge in early April, most were collected in May, and progressively decreasing numbers were taken during June, July, and August. Sunfish first appeared in the samples in the second week in May, peaked during June, and maintained relatively high numbers through July and August, reflecting their extended spawning period (Fig. 1). The critical period of spawning, hatching, and vulnerability to discharge for most species occurred during the 6-week interval from the last week in April through the first week in June. During most years, high discharge volumes coincided with this period (42% in 1974, 62% in 1975, 35% in 1976, and 34% in 1977 of the April-August total).

On a monthly basis, maximum losses for all species combined occurred during May of both 1976 and 1977 (Fig. 2). Estimates of total larval fish losses were higher in 1977 than in 1976, even though the discharge volume was lower than in 1976 (Table I, Fig. 2). Among the three major genera, only *Dorosoma* showed greater losses in 1976 than in 1977. In 1977 shad populations in the lake were low because of the poor reproduction of threadfin shad *(Dorosoma petenense)*, brought about by winter mortality of adults (Multi-Outlet Reservoir Study, U. S. Fish and Wildlife Service, unpublished data).

In 1976 we attempted to determine the effects of power generation rate on larval fish loss. Once each month (June-August), samples were collected at both a low discharge rate (90 m^3/s) and a high discharge rate (155 m^3/s). One set of six samples was collected during 2 hours of power generation in the morning, and another set during 2 hours of power generation in the afternoon. Significant differences (.05 level) between mean numbers of fish larvae collected at high and low discharge rates were noted for June and July, but not for August. The June and August tests indicated that more larvae per cubic meter were discharged at the lower power generation rate. The relation between length of power generation, discharge rate, and larval fish loss was not clearly established.

The rate of water discharge appeared to influence the size of fish entrained. Only shad larvae discharged at high and low power generation rates were compared, because they made up most of the catch when the comparisons were made. On 23 June, the mean length of shad collected was 13.0 mm during the low generation rate and 15.6 mm during the high generation rate. On 21 July, the respective mean lengths were 17.9 and 19.9 mm. There were too few shad in the August samples to support a sound comparison. The night before the 21 July samples were taken, midwater trawl catches from the lower portion of the lake showed the mean length of shad larvae to be 22.5 mm, indicating that the larger shad larvae evaded entrainment at both power generation rates (Multi-Outlet Reservoir Study, unpublished data).

Differences were also noted between larval fish discharge rates on routine sampling dates and the rates during long-term generation periods that occurred 1 to 3 days before or following a routine (2 h) sample (Table II). The comparisons did not show a trend toward an increase in fish discharge rate with an increase in the length of generating time, as might be expected. We thought that lake currents established during long periods of power generation might influence the rate at which larvae were entrained; however, further studies are needed to define the reservoir current patterns established by different discharge rates and lengths of power generating periods. The rate of fish loss (no./m^3) did show an increase with an increase in water discharge rate, except for the 15-17 June, 1977 comparison.

It has been shown that the vertical distribution of larval shad varies between day and night (Netsch et al., 1971). In daytime, fish larvae were shown to aggregate in scattered schools, whereas at night the distribution was more uniform. This could account for some of the

Table I. Estimated loss by number (thousands) and percentage (in parentheses) of larval fish through the discharge from DeGray Lake, 1976-77.

Species	Year	
	1976	1977
Shad	53,396 (64.1)	37,846 (30.9)
Sunfish	19,389 (23.3)	55,412 (45.3)
Crappie	8,871 (10.7)	25,244 (20.6)
Logperch	1,198 (1.4)	3,532 (2.9)
Brook silverside	349 (0.4)	136 (0.1)
Other	61 (0.07)	262 (0.2)
Total	83,264	122,432

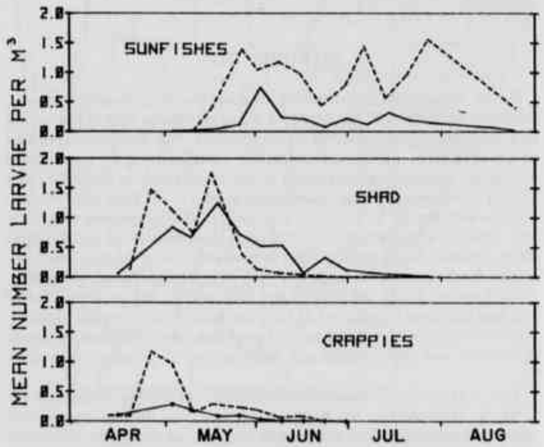

Figure 1. Seasonal variation in number of larval sunfish, shad, and crappie per cubic meter of water from DeGray Lake discharge 1976 (solid line) and 1977 (dashed line).

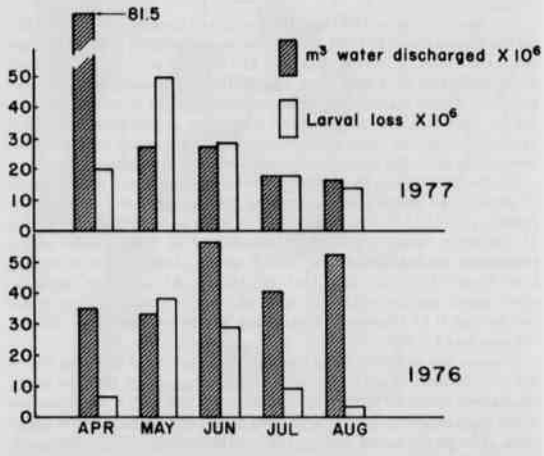

Figure 2. Monthly estimates of discharge volume and larval fish loss, DeGray Lake, 1976 and 1977.

variation in the numbers collected during daytime discharge. In a diel study to determine the relation between daytime and nighttime power generation and larval fish loss, we sampled during 2 hours of power generation every 6 hours from 1300 h on May 4 through 1500 h on May 5. The sampling interval followed the routine pattern. Rates of larval fish loss decreased during periods of twilight and darkness (Fig. 3). Ranges within the sampling periods indicated a more uniform rate of loss during periods of darkness, coinciding with the expected nighttime distribution of larval fish in the lake.

Our routine sampling was done during daylight because that was when most power generation occurred. We believe that the distribution of larval fish in the lower portion of the lake may have influenced the pattern of larval fish discharge to a greater degree than the power generation rate or the length of the power generating period. More intensive sampling is needed to evaluate the relation between power generation rate, length of the power generating period, and larval fish discharge.

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Table II. Comparisons of larval fish discharge rates during long-term power generation with those during routine sampling within similar time periods.

Date	Number of samples	Hours of discharge	Discharge rate (m^3/s)	Mean number/m^3
1976				
June				
21	4	7	99	0.163
23	6	2	125	0.420*
25	12	18	155	0.732
1977				
May				
9	4	12	99	0.164
10	3	15	113	0.445
11	4	2	122	0.953*
June				
15	4	2	120	1.137
17	4	21	114	1.143

*Significantly different (at .05 level) than long-term means for adjacent dates.

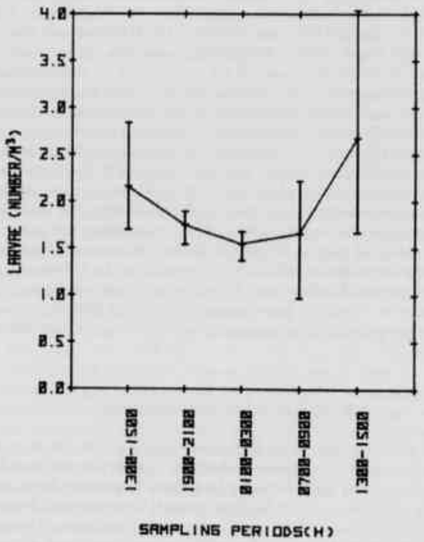

Figure 3. Rates of larval fish discharge (mean and range of four samples) during diel sampling May 4-5, 1977, DeGray Lake.