# Influence of *Daphnia* Density on Survival and Growth of Paddlefish Larvae at Two Temperatures

**Steven D. Mims,**[1] *Department of Fisheries and Allied Aquacultures and Alabama Aquacultural Experiment Station, Auburn University, AL 36849*

**H. R. Schmittou,**[2] *Department of Fisheries and Allied Aquacultures and Alabama Aquacultural Experiment Station, Auburn University, AL 36849*

*Abstract:* Paddlefish (*Polyodon spathula*) larvae were fed live cultured *Daphnia* at 4 densities to determine if larval survival and growth were affected by *Daphnia* densities at low (ambient) (15.0° ± 1.5° C) and high (21.1° ± 0.5° C) temperatures. Survival of larvae increased with increasing densities of *Daphnia* in both experiments. Survival was higher in the low-temperature experiment than in the high-temperature experiment. However, larval survival was also influenced by cannibalism and a deformity affecting swimming behavior. Maximum growth of larvae during the 7-day experiments was 23.2 mm in length and 88.0 mg in weight and was determined graphically at *Daphnia* densities ranging from 200 to 240/liter in the high-temperature experiment. Short-term intensive culture of paddlefish larvae fed live *Daphnia* appears to be a viable method for producing large, hardy fish for further grow-out in ponds.

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Paddlefish (*Polyodon spathula*) have 2 distinct methods of feeding during different phases of their life cycle. Young fish (≤120 mm total length (TL)) are particulate feeders that select large, slow-moving prey such as *Daphnia* spp. (Ruelle and Hudson 1977, Unkenholz 1977, Rosen and Hales 1981, Michaletz et al. 1982). Older fish (>120 mm TL) are indiscriminate filter feeders with ability to utilize a more diverse diet (Rosen and Hales 1981, Michaletz et al. 1982). Paddlefish of all sizes detect prey by use of ampullary electroreceptors and not by sight (Kistler 1906, Nachtrieb 1908, Jorgensen et al. 1972).

Michaletz et al. (1982) reported rapid growth of paddlefish larvae (mean 2.4

[1]Current address: Aquaculture Research Center, Kentucky State University, Frankfort, KY 40601.
[2]Current address: Jakarta-USAID-OARD, Department of State, Washington, D.C. 20520

mm TL/day) when pond waters contained densities of daphnids between 50 and 250/ liter. When daphnid populations decreased to low levels (<10/liter), larval growth rates were reduced to 0.51 mm TL/day. Lack of proper type and quantity of zooplankton has been cited as the major reason for poor growth and low survival of paddlefish in nursery ponds (Unkenholz 1977, Michaletz et al. 1982).

In recent years, there has been a trend to intensify the rearing of species traditionally cultured in ponds. In intensive culture food must be provided (Huisman 1979), but control of water quality, temperature, and diseases is easier than in pond environments. The objective of this research was to investigate the effects of different *Daphnia* densities on survival and growth of paddlefish larvae under laboratory culture at 2 water temperatures. The authors gratefully acknowledge Leonard Lovshin, Ron Phelps, and Randall Goodman for their initial draft reviews. Special thanks to Karla Richardson for typing this manuscript.

## Methods

### Fish

Two lots of paddlefish eggs were obtained by artificial propagation of 2 females at the Fisheries Research Unit of the Alabama Agricultural Experiment Station at Auburn University in spring 1983. Yolk-sac larvae were acclimated to aerated well water in 2 114-liter aquaria. Yolk-sac larvae were observed several times daily, and experiments were started when about 80% of the fish, by gut analysis, had begun exogenous feeding (Toetz 1966). The day of initiation of exogenous feeding was designated as Day 0, and throughout this study "Day number" refers both to numbers of days of actively feeding and the feed age(s) of the larvae. Day–0 larvae were counted and stocked into 20 3.5-liter experimental jars at 14 larvae/jar. Jars were supplied with aerated well water. All experimental units were covered with black plastic to eliminate bright light (Mims 1984).

Twenty-five randomly selected larvae were weighed and measured at the start of each experiment. At the end of each experiment, surviving larvae from each container were counted and preserved in 10% buffered formalin. Total length (mm) of preserved larvae was later measured with a dissecting microscope and a ruler. Larvae were weighed on a Mettler balance to the nearest 0.1 mg.

### Temperature

The effect of *Daphnia* densities on growth and survival of paddlefish larvae was evaluated at low (15.0° ± 1.5° C (SD)) and high (21.1° ± 0.5° C (SD)) temperatures. A maximum/minimum thermometer was used to measure daily water temperature ranges. Each experiment represented feeding period of 7 days.

### *Daphnia* Culture

*Daphnia* spp. were cultured in 4 concrete tanks (7.4 × 2.7 × 0.6 m) filled with well water to prevent contamination by undesirable organisms. Manuring rate and schedule were as recommended by Ivleva (1969) with partial harvest every 3 to 4 weeks to sustain *Daphnia* growth (Ivleva 1969).

### Treatments

Two independent experiments were designed to test the influence of *Daphnia* density on growth and survival of paddlefish at 2 water temperatures. Each experiment had 4 treatments: (1) 10 *Daphnia*/liter, (2) 30 *Daphnia*/liter, (3) 90 *Daphnia*/liter, and (4) 270 *Daphnia*/liter. *Daphnia* were collected each morning using a 325-$\mu$m dip net and washed into a 19-liter bucket. At each feeding, average concentration of *Daphnia* in the bucket was determined by counting the *Daphnia* in 3 1-ml samples using a Hensen-Stempel pipette and a Sedgwick-Rafter counting cell. Volume of concentrate containing a known number of *Daphnia* was filtered through a fine mesh net, washed in clean water, and placed into the culture jar. Fish were fed 3 times daily at 0700, 1500, and 2300 hours.

Data from each experiment were analyzed by the general linear models procedure using the Statistical Analysis System (SAS) (Barr et al. 1976).

## Results and Discussion

### Survival

Larval survival increased with an increase in *Daphnia* density in both experiments (Fig. 1). Optimum *Daphnia* density for maximum paddlefish survival could not be determined graphically for either experiment; however, highest survival of 95.7% at 270 *Daphnia*/liter was demonstrated at both water temperatures.

At the high temperature, the relationship between *Daphnia* density and larval survival was highly significant ($P = 0.0001$). Many of the larvae in both the 10 and 30 *Daphnia*/liter treatments at the higher temperature appeared pale and emaciated and exhibited lethargic swimming behavior 3 days after experiments began. The relationship of *Daphnia* density to larval survival was not significant ($P = 0.10$) at the low temperature. The data suggest that paddlefish larvae could be held at lower temperatures and fed at low *Daphnia* density in an intensive system for 7 days without any detrimental effect on survival; however, fish at higher temperatures probably would require more food (higher *Daphnia* densities) for better survival. However, Brandt (1978) found that survival rate of paddlefish cultured for a longer period of time (40 days) at 21° ± 1.6° C was significantly higher ($P = 0.0005$) than at 16° ± 1.6° C.

Larval mortality cannot be entirely attributed to *Daphnia* density. Some mortality was caused by morphological deformities of larvae that inhibited proper feeding in some of the replicates in all treatments in both experiments. Deformities were observed to occur in yolk-sac larvae and in larvae up to Day 4. Deformed fish exhibited a whirling swimming behavior ("tail chasing") because of a vertical curvature of the notocord. No pathogens were found when stricken fish were examined. Similar swimming behavior in paddlefish larvae has been described by Friberg (1973), Russell (1971), and Brandt (1978).

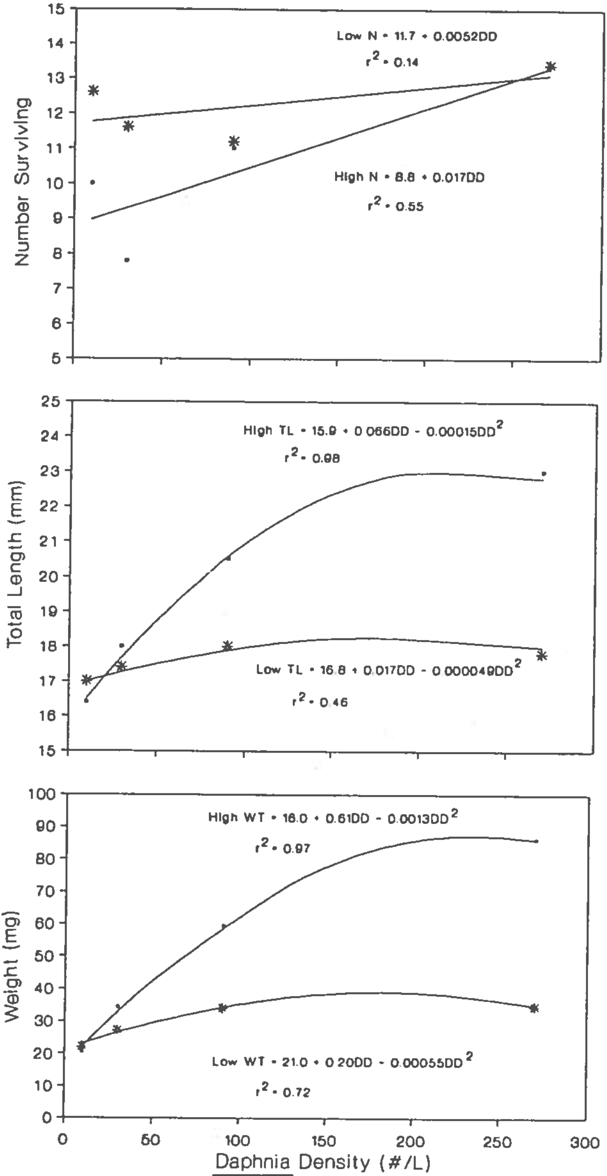


**Figure 1.** Number surviving (*N*), total length (TL), and weight (WT) of paddlefish larvae after 7 days at different densities of *Daphnia* (DD) in high- (⊡) and low- (*) temperature experiments.

Mortality was also caused by cannibalism in the 30 *Daphnia*/liter treatment of the high-temperature experiment. We assumed this behavior was a stress response to an inadequate food supply and did not occur at lower densities (10 *Daphnia*/liter) because fish were too weak to capture other fish. At higher densities, food availability was such that cannibalistic feeding behavior was unnecessary. Similar observations of cannibalistic behavior of paddlefish in intensive culture have been reported by Yeager and Wallus (1982), and Brandt (1978).

### Growth

Mean initial TL and weight of 25 larvae in low and high temperatures were 15.5 mm and 17.1 mg and 15.6 mm and 17.2 mg, respectively.

For the low-temperature experiment there was <1.0 mm difference in TL for larvae at the various *Daphnia* densities at Day 6 (after 7 days of feeding; Fig. 1). The quadratic regression obtained, however, was significant ($P = 0.015$). A maximum TL of 18.3 mm was determined graphically at 170 *Daphnia*/liter. Results indicated that at low *Daphnia* density (10–30/liter) fish at the lower temperature could be maintained without affecting their growth.

For the high-temperature experiment, a maximum TL of 23.2 mm was determined graphically at 225 *Daphnia*/liter (Fig. 1). The relationship between *Daphnia* density and TL was highly significant ($P = 0.0001$). The calculated maximum TL growth rate of the larvae at 225 *Daphnia*/liter was 1.1 mm/day. These results agree with those of Michaletz et al. (1982) who reported an average length increase of 1.2 mm/day during the first 7 days in a pond culture experiment, and are superior to the 0.4 mm/day growth rate reported by Brandt (1978) for larvae raised on artificial diets. This experiment indicates that paddlefish larvae must be fed high *Daphnia* densities (>200/liter) to produce a fast growing larvae at this temperature.

At the high temperature, maximum individual larva weight of 88.0 mg was determined graphically at 240 *Daphnia*/liter. The quadratic regression was significant ($P = 0.0001$). At the low temperature, maximum weight of 39.2 mg was determined graphically at 180 *Daphnia*/liter with only a slight overall increase in weight proportional to *Daphnia* density. The quadratic regression obtained was also significant ($P = 0.0009$).

Data indicate that short-term intensive culture of paddlefish larvae fed a *Daphnia* diet at densities ranging from 200 to 240 *Daphnia*/liter at a temperature of 21.0° C should produce larger, healthier fish for stocking ponds than fish reared at a temperature of 15.0° C. However, paddlefish at the low temperature could be maintained with little growth but good survival (>90%) at low *Daphnia* densities (<180/liter).

Survival data alone were inadequate to evaluate the effects of different *Daphnia* densities on culture of paddlefish larvae. Survival should be studied in reference to growth and temperature to account for the physical condition of the survivors. Though survival was higher at the low temperature, larval growth at *Daphnia* on densities from 200 to 240/liter was less at the low temperature than at the high temperature.

In conclusion, short-term intensive culture of paddlefish larvae fed *Daphnia* appears to be a viable method. This study provides information on temperatures and food densities that influence fish survival and growth, giving fish culturists flexibility in rearing paddlefish larvae. At low temperature (15° C) and <180 *Daphnia*/liter, the culturist can maintain the fish at high survival but low growth rates indoor to allow an additional week for pond conditions to be established before stocking fish. At high temperature (21.1° C) and >200 *Daphnia*/liter, high survival of large, hardy larvae can be produced which could increase survival rate and shorten the number of culture days in nursery ponds. Further research is needed to establish alternative food sources and optimum temperature for intensive culture of paddlefish larvae.

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