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Effect of Suspended Sediment on Feeding by Larval Herring (*Clupea harengus harengus* L.)

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Larval herring are visual predators (BLAXTER 1965; BLAXTER & STAINES 1971) feeding initially on zooplankters such as copepod and cirripede nauplii less than 150 um in length. The size of the prey organism increases with the age of the larvae. At the end of the yolk-sac stage, less than 5% of the feeding actions are successful, increasing to 90% at approximately 70 days after hatching (BLAXTER & STAINES 1971). The distances that larval herring can perceive prey increases from 2-6 mm at the end of the yolk-sac stage up to 40 mm for larvae 15-20 mm long (ROSENTHAL & HEMPEL 1970). BLAXTER & STAINES (1971) observed that the volume of water searched by herring larvae increases from 0.1-2.4 $L \cdot h^{-1}$ over the first 8-week period after hatching.

The purpose of this study was a preliminary attempt to determine if increased levels of suspended sediment occurring, for example, after dredging and dumping activity, and resultant decreases in light intensity, reduce prey visibility for larval herring to such an extent that the feeding rate is affected. The effect of suspended sediment on larvae of different ages was also investigated.

MATERIALS AND METHODS

Egg collection and larval rearing

Ripe male and female herring were stripped in Grand Manan, N.B., in September 1980. The eggs were fertilized in 3-L buckets, rinsed, and transported to St. Andrews Biological Station in aerated, thermal coolers kept at 7-9°C. The hatching and rearing facilities consisted of an enclosed area illuminated by 40-watt, fluorescent-strip lighting. The light intensity at the surface of the water was 300 phototopic lux and was uniform over the entire tank. Photoperiod was controlled at 16 h light, 8 h dark. The hatching, rearing, and experimental systems were supplied with sea water at 9.5 $\pm$ 1.0°C.

The eggs were incubated in aerated water until hatching 10-14 days later. The water was changed every 2-3 days to prevent buildup of excretory products. Upon hatching, the larvae were transferred to 150-L, continuous-flow, circular tanks painted black. Sea water flowed into the bottom of the tank at a rate of 20-30 $L \cdot h^{-1}$. The water level was kept constant by a continuous-flow siphon (BREDER 1964). Larvae were fed initially on wild

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zooplankters collected in Passamaquoddy Bay by towing a 64-µm mesh plankton net. The bucket contents were filtered through a 250-um sieve to eliminate zooplankters known to be too large (BLAXTER 1965) for newly hatched herring larvae. Larvae older than 2 weeks were fed on a combination diet of Artemia nauplii and wild zooplankton.

Experimental methods

The experimental apparatus consisted of circular, continuous-flow tanks of 12-L capacity painted black on the inside surfaces. The flow rate in the tanks was approximately 8 $L \cdot h^{-1}$. Larvae were transferred to the experimental tanks 18 h prior to the experiment to allow them to acclimate and clear their guts of food. All experimental larvae were fed at a concentration of 4 Artemia per mL. Artemia were added to the experimental tank every 30 min in an attempt to maintain constant density during the experiment.

Sediment was collected from the Digdeguash estuary and was frozen while in storage. Sediment characteristics were as determined by AKAGI & WILDISH (1975) and are typical of many local estuaries (Table 1).

TABLE 1. Sediment sorting characteristics and Walkley-Black organic carbon as percentage dry weight of the sediment (from MESSIEH et al. 1981).

Number	Source	Md Ø (µ)	QDØ	SkqØ	% carbon
I	Digdeguash Estuary	7.94 (4.5)	0.79	-0.13	3.11
II	Pottery Creek	6.68 (10.0)	2.57	-0.69	1.30
III	Miramichi Estuary	7.40 (6.0)	1.51	-0.27	3.33

Experiment 1: suspended sediment

A known weight of wet sediment was added to the experimental tank. During the experiment, additional sediment was added from a continuously stirred slurry to maintain the test concentration. To check concentration during the experiment, 500-mL water samples were filtered through matched weight membrane filters of 45-µm nominal pore size. Concentrations of suspended sediment were calculated from the dry weight of the residue and the filtrate volume.

Three larvae were used in each run of the experiment which continued for a standard time of 3 h. The larvae were then removed, the total length measured, and the number of Artemia consumed/larvae counted by dissecting the gut under a binocular microscope. Experimental concentrations tested were 0, 4, 8, and 20 mg dry sediment$\cdot L^{-1}$ (± 0.5 mg$\cdot L^{-1}$). A minimum of three runs were conducted per sediment concentration.

Experiment 2: reduced light

Details of the protocol followed were similar to Experiment 1 except that no sediment was added and the experiments were conducted at three different light intensities: 65, 105, and 300 phototopic lux measured just above the water surface.

Experiment 3: larval position in tank

A known amount of wet sediment was added to the experimental tank as outlined in Experiment 1. Four larvae were used in each of the two runs of the experiment and observations continued for 3 h. Counts of the number of larvae were made at four depths within the tank (Figure 1) every 15 min with observations beginning at zero time. The number of larvae observed in each section throughout the 3-h period was expressed as a percentage of the total number of observations. Experiments were conducted at 0, 10, and 20 mg$\cdot$dry weight sediment$\cdot L^{-1}$ ($\pm$ 1.0 mg$\cdot L^{-1}$).

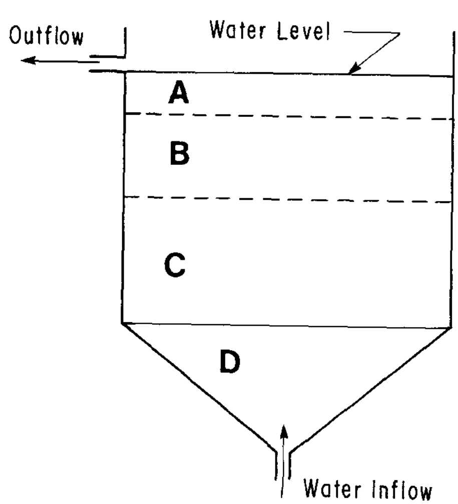

Figure 1. Scale drawing of the depth sections in the Tank Position Experiment. Tank diameter is 20 cm.

RESULTS AND DISCUSSION

Larvae fed in water containing 4 and 8 mg dry sediment$\cdot L^{-1}$ did not consume significantly fewer Artemia nauplii than did the control larvae. However, larvae fed at 20 mg dry sediment$\cdot L^{-1}$ (Figure 2) did consume significantly fewer Artemia nauplii than did the controls ($F=7.72$, $p < .05$). Similarly, larvae fed at 65 and 105 phototopic lux consumed significantly fewer Artemia nauplii than those fed at 300 lux (Figure 3) in the control tanks ($F=11.60$, $p < .05$). In both suspended sediment and light-intensity experiments, smaller larvae consumed significantly fewer (at $p=.05$) Artemia than did the larger larvae.

There were significantly fewer ($p < .05$) larvae in the bottom section of the tank in the suspended sediment treatments compared with the controls. As the concentration of suspended sediment increased, there was a movement of larvae to the upper layer (Table 2). No larvae were observed in section "D" of the tank, presumably due to high water circulation in this area.

TABLE 2. Percentage of larvae in each tank section as shown in Figure 1. Exposure to three different sediment concentrations (as dry weight/L).

	Trial 1	Trial 2
Control 0	A - 15.3 B - 34.7 C - 50.0	A - 21.1 B - 30.8 C - 48.1
10 mg L	A - 34.6 B - 34.6 C - 30.8	A - 30.8 B - 34.6 C - 34.6
20 mg L	A - 44.2 B - 26.9 C - 28.9	A - 38.5 B - 26.9 C - 34.6

As the suspended sediment concentrations are increased, light intensity and visibility of prey decreases with a greater effect in the deeper parts of the tank with overhead lighting. As a result, the larvae move into the better illuminated surface layers to feed. At lower suspended sediment concentrations (4 and 8 mg$\cdot L^{-1}$), the decrease in light intensity in the surface waters is not sufficient to result in a depression of feeding rates. In greater

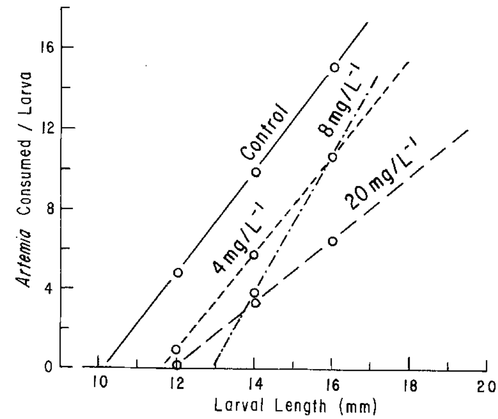

Figure 2. Number of Artemia consumed per larvae for different larval lengths at four suspended sediment concentrations. Control Y = 2.0X - 20, r = 0.74; 4 mg/L, Y = 3.4X - 44, r = 0.88; 8 mg/L, Y = 2.4X - 28, r = 0.88; 20 mg/L, Y = 1.6X - 19.6, r = 0.71.

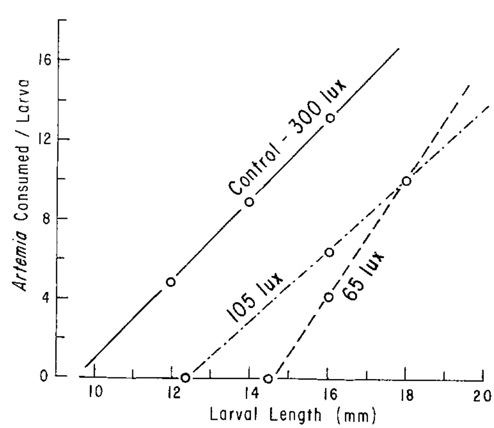

Figure 3. Number of Artemia consumed per larvae for different lengths at three light intensities.

concentrations of suspended sediment (20 $mg.L^{-1}$), the visibility of prey and light intensity are significantly decreased and the feeding rate is depressed.

As larval size increases, their feeding success (Figure 4), motility, visual development, and mouth size also increase (BLAXTER 1965; ROSENTHAL & HEMPEL 1970; BLAXTER & STAINES 1971). As a result, the smaller larvae are more affected by increased levels of suspended sediment than are larger larvae. Thus, the level of suspended sediment resulting in a depression of feeding rate by herring larvae will also be a function of larval age/size. The present results, although consistent with the hypothesis that suspended sediments inhibit feeding by interfering with vision of predators, do not provide conclusive evidence that this is the case.

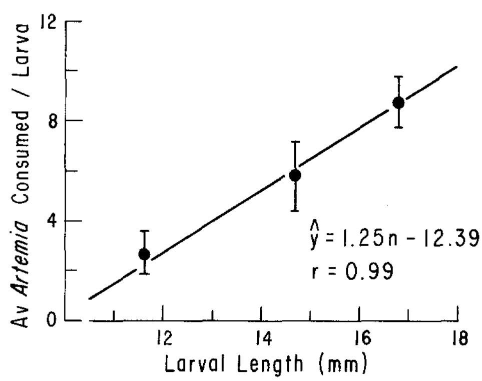

Figure 4. Number of Artemia consumed by different herring larval lengths averaged for 300, 105, and 65 lux light experiments.

Our results have important implications in cases where human activities, such as dredging and dumping, are planned in areas near herring spawning grounds. One such case has been recognized in the Miramichi estuary (MESSIEH et al. 1981) where dredging activity must be halted during spawning and immediately thereafter.

BLAXTER (1966) found that the minimum amount of white light, as measured by an underwater photometer, necessary for larval herring to feed on Artemia was 0.3 lux whereas for faster moving prey, such as Balanus nauplii, it was 13.0 lux. Our results also demonstrate an effect of light intensity on feeding rate, although they cannot be compared with those of BLAXTER (1966) because the light measurements were made at the water surface.

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