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ENDOGENOUS ENERGY SOURCES AS FACTORS AFFECTING MORTALITY AND DEVELOPMENT IN STRIPED BASS (*MORONE SAXATILIS*) EGGS AND LARVAE

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Since its introduction in 1879 the striped bass population in the San Francisco Bay-Delta estuary has fluctuated in abundance. During the last nine years the population has steadily declined causing concern among resource managers, scientists and citizens. Extensive field studies with 15 years of data available have found that variation in striped bass abundance relates directly to survival in the first 60 days of life (Chadwick et al., 1977; Chadwick, 1979). These studies, however, have not been able to determine the direct or primary causes of early life stage mortality. Current hypotheses contend that factors associated with freshwater outflow in the two major rivers and diversion of river water to the California aqueduct system directly affect striped bass eggs and larvae by physical removal or nursery habitat alteration. Four years ago we began laboratory studies on factors affecting egg and larval mortality (Eldridge et al., in press). Emphasis was placed on those factors associated with larval food and feeding. In the course of these studies we soon discovered the endogenous energy sources played critical roles in the survival, growth and differentiation of the embryos and early larvae.

A series of seven complete experiments were conducted closely examining daily survival, growth (tissue dry weight and standard length), differentiation (tissue histology, ossification, general organogenesis), and bioenergetics in relation to different live food rations. In conjunction with these laboratory experiments spawning adults were collected from the field and extensively autopsied to determine the extent parental conditions affected gametic viability and quality. Special attention was given to the ovarian eggs of these field specimens and the components which comprised the endogenous energy sources of the embryos and larvae.

Striped bass spawn pelagic eggs which become large (average diameter = 3.40 mm for Atlantic fish, Mansueti, 1958; 3.28 mm for Pacific fish, Meinz and Heubach, 1977) with a wide perivitelline space in which the embryo — yolk — oil complex floats. Prior to water hardening we found our eggs to average 1.03 mm in diameter. Eggs contain two energy sources — yolk and oil, the latter contained in a single, spherical oil globule. Chemical analysis showed that yolk was comprised mostly of proteinaceous material with an average lipid content of 3.8%. The oil globule makes up over half of the total dry weight and most of the energy of the egg (Table 1). Fatty acid scans of the oil globules showed no significant differences in the fatty acid compositions of oil globules in eggs from three different females. More definitive chemical analyses are planned to determine whether this homogeneous condition extends to all the lipid components of the oil globule. On a quantitative basis close examination of eggs from 34 spawning striped bass showed large differences in the proportions of yolk and oil to total egg dry weights, and differences in the amounts of yolk and oil in eggs from different females. Dry weights of yolk ranged 28 to 81% of the total egg dry weights. The coefficient of variation for the yolk weights was 20%. Oil contents ranged 12 to 67% with a c.v. of 19%. The average amounts of yolk and oil found in the eggs is given in Table 1. The ranges of weights extended from 41 to 226 μg for yolk and 34 to 251 μg for oil. Causes for these variations are still under study. Preliminary results suggest age, parental condition, genetic

Table 1. Dry weights, caloric, lipid, water and ash contents of eggs from 34 field-caught striped bass in spawning condition.

	Dry weight (μg)	Caloric content (Calories/g)	Lipid content (% of dry wt.)	H_2O content (% of wet wt.)	Ash content (% of dry wt.)
Yolk					
$\bar{X}$	104.0	5 657	3.8	53.7	3.0
S.D.	27.8	38	1.5	3.3	0.5
Oil					
$\bar{X}$	112.3	9 492	100.0	0.0	0.0
S.D.	27.9	297	—	—	—
Total Egg					
$\bar{X}$	232.3	7 803	52.0	53.7	3.0
S.D.	58.6	392	5.7	3.3	0.5

relation, pollutant load, and time are primary factors.

As embryonic and larval development proceeded yolk energy was consumed first. Total yolk absorption approximately coincided with the onset of feeding. Yolk utilization rates did not significantly differ. An average 62% of the original oil energy remained in the larvae at the time of initial feeding, seven days after fertilization. The rates at which this remaining oil energy was utilized directly depended on food availability. The larger the food ration the faster was oil consumed. At 18°C larvae feeding at a ration of 48.05×10^{-5} calories/ml consumed their oil energy within an average 19–21 days while starved larvae conserved their oil energy until death, as long as 29–34 days after fertilization.

Larvae with higher daily food rations and faster oil energy consumption rates survived at significantly higher rates than starved and low ration larvae. Starved larvae also exhibited no point-of-no-return (Eldridge et al., in press). Larvae which survived to the time of food introduction underwent an initial adjustment to feeding. They then continued to survive and develop similar to larvae which began feeding at a normal age.

Sizes of embryos and larvae correlated with the initial egg size, that is, the original amount of endogenous energy. This was reflected in the significant differences between the elevations of the growth curves of embryos and larvae from different females. Further differences, though less significant, were seen in the growth rates or slopes of offspring from different fish.

This complexity of growth suggested to us that some parental factor or condition could possibly be active and led us to examine parental tissues for pollutants. Preliminary chemical analyses showed that the eggs of field-caught spawning fish contained potentially toxic pollutants (Table 2). The presence of heavy metals and hydrocarbons can affect the mobilization of energy resources within the female as they are deposited in the egg resulting in reduced fecundity and/or smaller eggs. These pollutants can also affect later growth and survival of embryos and larvae as the toxicants are slowly released with the utilization of the yolk and oil. Experiments are currently underway to study the extent of these effects.

Table 2. Concentrations of heavy metal and hydrocarbon pollutants found in eggs of California striped bass.

	Heavy metals ($\mu g/g$; wet weight) n = 46			Cyclohexanes and aromatic hydrocarbons ($\mu g/g$; wet weight) n = 20
	Zinc	Iron	Copper	
Mean	26.7	11.7	3.2	0.053
Range	19.1–86.6	*0–19.5	*0–7.4	*0–0.426

*Concentrations were below the level of detectability of our procedure.

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