SURVIVAL AND GROWTH OF STRIPED BASS, *MORONE SAXATILIS*, AND *MORONE* HYBRID LARVAE: LABORATORY AND POND ENCLOSURE EXPERIMENTS[1]

EDWARD D. HOUDE[2] AND LAWRENCE LUBBERS III[3]

ABSTRACT

Survival and growth of striped bass, *Morone saxatilis*, and its hybrids were compared in the first 30 days after hatching to determine if the reported heterosis of hybrid striped bass is evident in the larval stage. Larvae of striped bass (SB); striped bass × white bass (WBX), *M. saxatilis* ♀ × *M. chrysops* ♂; and striped bass × white perch (WPX), *M. saxatilis* ♀ × *M. americana* ♂, were reared under controlled conditions in the laboratory (19°C, 3‰) and under ambient conditions in freshwater pond enclosures. In the laboratory SB had a significantly higher mean survival rate at 30 days of age than either hybrid. In the pond enclosures neither mean survival nor size at 30 days differed significantly among the types of larvae. Mean rates of growth in length, which ranged from 0.28 to 0.36 mm d^{-1} in the laboratory and from 0.30 to 0.32 mm d^{-1} in the enclosures did not differ significantly among the types of larvae. Mean rates of growth in weight of 15.0 to 19.0% d^{-1} were not significantly different in the laboratory, but the rates did differ significantly in the pond enclosures, where the WBX (17.9% d^{-1}) and WPX (17.3% d^{-1}) rates were significantly higher than the SB (15.5% d^{-1}). If 30-day-old fry were to be reared in hatcheries, there is no clear production advantage for hybrids. A possible initial expression of hybrid vigor, recognized by faster rates of growth in weight, was evident in WBX and WPX at 1 month of age in the pond enclosures but not in the laboratory tanks.

A series of recruitment failures (Cooper and Polgar 1981; Boreman and Austin 1985) has stimulated the development of hatcheries to culture juvenile striped bass, *Morone saxatilis*, or its hybrids for stocking in the Chesapeake Bay region. The striped bass and the striped bass × white bass, *M. chrysops*, hybrid have been cultured for stocking in freshwater and estuarine systems for several years and also have potential for commercial aquaculture (Bonn et al. 1976; Kerby et al. 1983). A second hybrid, striped bass × white perch, *M. americana*, has been produced (Bayless 1972; Kerby and Joseph 1979) although its potential is less known. The striped bass × white bass hybrid demonstrates an apparent heterosis and usually grows and survives better during the first two years of life than does striped bass under similar culture conditions (Logan 1968; Ware 1975; Williams et al. 1981; Kerby et al. 1983).

The objective of our experiments was to determine if the apparent heterosis of the striped bass × white bass hybrid is established in the larval stage, between hatching and 30 d posthatch. We compared growth and survival of striped bass, striped bass × white bass, and striped bass × white perch (referred to hereafter as "striped bass", "white bass hybrid", and "white perch hybrid") in laboratory experiments and in fine-mesh enclosures within hatchery ponds.

METHODS

Laboratory Experiments

Larvae originated from eggs of a single female striped bass, 15.4 kg, gillnetted in the Patuxent River, transported to the Manning Hatchery, Cedarville, MD, on 24 April 1982 and spawned by injection of human chorionic gonadotropin on 27 April. Sperm from 2 male striped bass (Patuxent River), 12 male white bass (Tennessee Fish Commission), and 2 male white perch (Patuxent River) were used to fertilize portions of the spawned eggs. Embryos were incubated in 114 L polyethylene incubation chambers and larvae were held there in 15°-16°C freshwater until 6 d after hatching when some were brought to the Chesapeake Biological Laboratory.

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[1] Contribution No. 1721, Center for Environmental and Estuarine Studies of the University of Maryland.

[2] University of Maryland, Center for Environmental and Estuarine Studies, Chesapeake Biological Laboratory, Solomons, MD 20688-0038.

[3] University of Maryland, Center for Environmental and Estuarine Studies, Chesapeake Biological Laboratory, Solomons, MD; present address: Maryland Department of Natural Resources, Tidewater Administration, Tawes State Office Building, Annapolis, MD 21401.

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Rearing Systems

The striped bass and hybrid larvae were reared from 6 to 30 d after hatching in 36 L, rectangular glass aquaria. Each aquarium was lighted by two 61 cm, 40-W fluorescent lights 25 cm overhead on a 12-h light-12-h dark cycle. Immersion heaters controlled the temperature. For additional control, the aquaria sat in a shallow, refrigerated waterbath. An airstone in each aquarium provided oxygen and kept food dispersed.

Temperature was maintained at 19° ± 1°C. Salinity was held at 3‰ by diluting 5 μm filtered Patuxent River water with well water. All larvae were fed *Artemia* nauplii, eggs of which originated from Shark Bay, Australia. Water quality was maintained by replacing half of the water in each aquarium on alternate days. Feces, dead *Artemia*, and dead larvae were siphoned off each day. Ammonia levels were checked on 13 May (16 d after hatching) and were <0.25 ppm in all tanks. The pH in the nine rearing tanks ranged from 8.0 to 8.4 on 11 May (14 d after hatching) and from 8.3 to 8.4 on 26 May (29 d after hatching).

Food Levels, Larval Densities, and Sampling

Two *Artemia* nauplii levels, 100 L^{-1} and 500 L^{-1}, were tested. The lower level is similar to zooplankton densities in Chesapeake Bay subestuaries where striped bass larvae occur (Miller 1978). For each of the larval types duplicate experiments were run at the 500 L^{-1} level but only a single experiment was run at 100 L^{-1}. Food was first offered at 6 d after hatching when the experiments started. *Artemia* nauplii concentrations in each aquarium were checked twice daily by counting the number in pipetted 100 cc aliquots. Food levels were maintained and adjusted by adding suspensions of *Artemia* of known concentration to the aquaria.

In each aquarium, 144 larvae were stocked at an initial, relatively low density of 4.0 L^{-1}. Some larvae were preserved in 5% Formalin[4] at the start of experiments (6 d after hatching). Three or four larvae from each aquarium were sampled and preserved on days 8, 10, 13, 16, 19, and 25 for growth rate determination. Samples (15-27 larvae) of survivors were preserved at 30 d when experiments were terminated. Preserved larvae were measured and wet-weighed (nearest 0.1 mg after blotting).

Analysis

The expected number of survivors in each experiment is the number that would have survived had no larvae been sampled and preserved during the experiments. If $Z = F + M$, where Z is instantaneous total mortality and F is preservation mortality, then M is mortality from all other causes. The expression $N_t = N_0 e^{-(F+M)t}$ applies, where N_t is number of survivors at age t (30 d) and N_0 is initial number of stocked larvae (144 at 6 d). Knowing N_0, N_t, Z, and F, we solved for M and then estimated expected survivors, if no larvae had been preserved, as $N'_t = N_0 e^{-Mt}$. Analysis of variance was used to test for survival differences among types of larvae and between food levels.

Lengths and weights of the three types of larvae were compared at 6 d after hatching and when experiments terminated. In addition, lengths and weights at the 100 L^{-1} and 500 L^{-1} food levels were compared to determine if food concentration affected mean sizes. Comparisons were carried out using analysis of variance followed by the SNK multiple comparison test.

Growth in length was described by linear regressions of standard length on days after hatching, $l_t = a + bt$, where l_t is estimated length (mm) at age t and b is daily growth rate (mm day^{-1}). Growth in weight was determined from the exponential regression of wet weight (mg) on days after hatching, $W_t = W_0 e^{Gt}$, where W_t is estimated weight at age t and G is the instantaneous daily growth coefficient (day^{-1}). Percent daily weight gains were calculated as $100 (e^G - 1)$. Weight-length relationships were obtained from the power function, $W = aL^b$, where W is wet weight (mg), l is standard length (mm), and a and b are coefficients from the fitted regression.

Enclosure Experiments

Cubic enclosures, 1.32 m on each side, open at the top, and constructed of wood frames and 500 μm Nitex mesh, were submerged to a depth of 1.12 m in a 1-acre, freshwater pond of 1.5 m mean depth at the Manning Hatchery. The nine enclosures, each holding 2 m^3, were placed in the pond from 3 to 5 d before larvae were stocked. Enclosures were assigned to the striped bass and two hybrids using a linearized Latin-square design (Steel and Torrie 1960) with three replicates for each type of larva. The larvae were progeny of a single 10.4 kg female

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[4] Reference to trade names does not imply endorsement by the National Marine Fisheries Service.

striped bass from the Patuxent River. Sperm from Patuxent River male striped bass were used to fertilize eggs. The hybrids resulted from fertilization by Tennessee white bass males and Patuxent River white perch males.

Larvae were held in hatchery troughs and fed *Artemia* nauplii from 6 to 8 d after hatching. A total of 2,500 9-d-old larvae were stocked in each enclosure on 12 May 1983. Larvae were sampled by dipnet and preserved in 5% Formalin at 13, 17, 20, 23, and 27 d after hatching. At 30 d all survivors from each enclosure were counted and samples preserved. Temperatures in the pond ranged from 18.5° to 22.0°C during the course of the experiment.

Pond Zooplankton

The kinds and abundances of potentially edible zooplankton were sampled on each day that larvae were collected, using a 15 cm diameter, 72 μm mesh plankton net that was lifted vertically in each enclosure. For comparison, zooplankton also was collected in three vertical lifts of the net outside the enclosures.

Analysis

Survival, lengths and weights at age, growth rates, and weight-length relationships were calculated as for the laboratory experiments. Variance, covariance, and regression analyses were used to test for differences in means among the striped bass and two types of hybrid larvae.

RESULTS

Laboratory Experiments

Survival

Survival at 30 d after hatching ranged from 45.8 to 85.4% (Table 1). Mean percentage survivals were striped bass, 84.7%; white bass hybrid, 60.4%; and white perch hybrid, 73.1%. The mean expected number of survivors differed significantly among types of larvae (ANOVA, $P < 0.05$). Mean survival of striped bass was significantly higher than that of the white bass hybrids (SNK multiple comparison procedure, $P < 0.05$). There were no detectable differences in mean survival between the two *Artemia* nauplii feeding levels (ANOVA, $P > 0.05$).

Size-at-Age

The white perch hybrid larvae were significantly shorter and weighed less than either striped bass or white bass hybrid larvae when the experiments began at 6 d after hatching, before larvae had been fed (Table 2; ANOVA, $P < 0.05$).

At 30 d after hatching there were some statistically significant differences in mean lengths and weights among the three types of larvae, and between the two food levels, but no clear result was obtained (Table 2). No significant differences among mean lengths or weights of the white bass hybrid larvae were detected between the 100 L^{-1} and 500 L^{-1} food levels. But, the striped bass and white

TABLE 1.—Survival at 30 d after hatching of striped bass (SB), striped bass × white bass (WBX), and striped bass × white perch (WPX) larvae in laboratory experiments at two food levels.

Larvae and experiment numbers	*Artemia* concentration (number L^{-1})	Number preserved	Number of survivors	Expected number[1] of survivors	Expected instantaneous daily mortality rates (*Z*)	Expected percentage survival
SB-1	500	20	106	123	0.0066	85.4
SB-2	500	18	108	123	0.0066	85.4
SB-3	100	19	104	122	0.0069	83.3
SB mean			106.0	[2]122.0	0.0069	84.7
WBX-1	500	18	58	66	0.0325	45.8
WBX-2	500	20	93	108	0.0120	75.0
WBX-3	100	18	76	87	0.0210	60.4
WBX mean			75.7	87.0	0.0210	60.4
WPX-1	500	22	85	100	0.0152	69.4
WPX-2	500	18	100	114	0.0097	79.2
WPX-3	100	18	89	102	0.0144	70.8
WPX mean			91.3	105.3	0.0130	73.1

[1] Expected number of survivors is the adjusted number, accounting for samples of larvae that were preserved during the experiment (see Methods).

[2] The SB mean differed significantly from the WBX and WPX means (Analysis of variance followed by SNK multiple comparison procedure, $P < 0.05$).

TABLE 2.—Mean standard lengths and wet weights of larvae of striped bass (SB), striped bass × white bass (WBX), and striped bass × white perch (WPX) from specimens preserved at 6 d after hatching, immediately before the experiments began and at 30 d after hatching when the experiments were terminated.

SIX DAYS

Larvae	Number preserved	Mean length (mm) and standard error		Mean wet weight (mg) and standard error	
		$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$
SB	15	5.49	0.06	0.95	0.04
WBX	19	5.29	0.03	0.96	0.03
WPX	17	[1]5.20	0.06	[1]0.85	0.02

THIRTY DAYS

Larvae and experiment number	*Artemia* concentration (number L^{-1})	Number preserved	Mean length (mm) and standard error		Mean wet weight (mg) and standard error	
			$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$
SB-3	100	18	[2]12.39	0.17	[2]25.7	1.4
SB-1	500	20	[3]14.26	0.17	[4]49.1	2.2
SB-2	500	19	[3]14.57	0.17	[4]50.4	1.8
SB mean			13.74		41.7	
WBX-3	100	15	13.02	0.30	30.1	2.1
WBX-1	500	18	12.68	0.26	28.8	2.2
WBX-2	500	19	12.73	0.38	29.3	3.6
WBX mean			12.81		29.4	
WPX-3	100	21	[2]11.86	0.25	[2]21.1	1.6
WPX-1	500	18	13.22	0.31	33.6	2.2
WPX-2	500	27	13.15	0.22	35.0	2.2
WPX mean			12.74		29.9	

[1] Differ significantly, $P < 0.05$, from both SB and WBX. ANOVA followed by SNK multiple comparison procedure.

[2] Differ significantly, $P < 0.05$, from the 500 L^{-1} means. ANOVA.

[3] Differ significantly, $P < 0.05$, from all WBX and WPX mean lengths. ANOVA followed by SNK multiple comparison procedure.

[4] Differ significantly, $P < 0.05$, from all WBX and WPX mean weights. ANOVA followed by SNK multiple comparison procedure.

perch hybrid larvae were longer and heavier at the 500 L^{-1} level (ANOVA, $P < 0.05$). At the 500 L^{-1} food level the striped bass were significantly heavier than either hybrid (ANOVA and SNK multiple comparison procedure, $P < 0.05$). The mean lengths of 30-d-old striped bass at 500 L^{-1} food level were significantly longer than the mean lengths of the hybrids (Table 2) (ANOVA and SNK multiple comparison procedure, $P < 0.05$).

Growth Rates

From 6 to 30 d after hatching larvae grew in length at mean rates ranging from 0.28 to 0.36 mm d^{-1} (Table 3, Fig. 1). There were no significant differences in the growth-in-length rates among the three types of larvae at the 500 L^{-1} *Artemia* food level.

The exponential regressions of mean weights on age (Table 3, Fig. 2) gave instantaneous growth coefficients ranging from 0.1396 to 0.1739 d^{-1}, equivalent to 15-19% d^{-1} weight gains. None of the coefficients differed significantly from each other (ANCOVA, $P > 0.50$).

There were no significant differences in weight-length relationships among types of larvae or between food levels (ANCOVA, $P > 0.50$). An average relationship, based on the total regression component of the ANCOVA, is $W = 7.17 \times 10^{-4}\, l^{4.2399}$.

Enclosure Experiments

Survival

Survival of striped bass and hybrid larvae at 30 d after hatching ranged from 13.1 to 33.8% in the nine enclosures. At 30 d there was no indication that striped bass or either hybrid was superior in survival capability. The mean percentage survivals for the three types of larvae ranged from 22.0 to 28.5% (Table 4B) and did not differ significantly (ANOVA on arcsin mean percent survivals). The mean overall survival rate for the three kinds of larvae was 25.0%.

TABLE 3.—Linear regressions describing growth in length and exponential regressions describing growth in weight of striped bass (SB), striped bass × white bass (WBX), and striped bass × white perch (WPX) during the period 6-30 d after hatching. In the linear regression, l is standard length in mm, t equals days after hatching, b equals growth rate in mm, and a is the y-axis intercept. In the exponential regressions, W is wet weight in mg, t equals days after hatching, G is the instantaneous growth coefficient, and W_0 is the theoretical weight in mg at time zero.

LENGTH

Larvae and experiment number	*Artemia* concentration (number L^{-1})	Equation $l = a + bt$	Standard error of b	r^2
SB-3	100	[1]$l = 3.64 + 0.29t$	0.01	0.99
SB-1	500	$l = 3.13 + 0.36t$	0.02	0.99
SB-2	500	$l = 3.20 + 0.36t$	0.01	0.99
WBX-3	100	$l = 3.10 + 0.34t$	0.02	0.98
WBX-1	500	$l = 3.36 + 0.32t$	0.01	0.99
WBX-2	500	$l = 3.31 + 0.32t$	0.02	0.98
WPX-3	100	[1]$l = 3.70 + 0.28t$	0.02	0.98
WPX-1	500	$l = 3.18 + 0.32t$	0.01	0.99
WPX-2	500	$l = 3.22 + 0.32t$	0.01	0.99

WEIGHT

Larvae and experiment number	*Artemia* concentration (number L^{-1})	Equation $W = W_0 e^{Gt}$	Standard error of G	r^2	Percent gain (% d^{-1})
SB-3	100	$W = 0.51 e^{0.1472t}$	0.0158	0.94	15.9
SB-1	500	$W = 0.41 e^{0.1713t}$	0.0141	0.96	18.7
SB-2	500	$W = 0.42 e^{0.1739t}$	0.0146	0.96	19.0
WBX-3	100	$W = 0.41 e^{0.1581t}$	0.0147	0.95	17.1
WBX-1	500	$W = 0.41 e^{0.1576t}$	0.0145	0.95	17.1
WBX-2	500	$W = 0.31 e^{0.1645t}$	0.0154	0.95	17.9
WPX-3	100	$W = 0.48 e^{0.1396t}$	0.0123	0.96	15.0
WPX-1	500	$W = 0.33 e^{0.1625t}$	0.0073	0.96	17.6
WPX-2	500	$W = 0.35 e^{0.1520t}$	0.0091	0.98	16.4

[1] Differ significantly from SB-1 and SB-2, $P < 0.01$. ANCOVA followed by SNK multiple comparison procedure.

The mean instantaneous mortality rates during the 9-30 d after hatching ranged from 0.0601 to 0.0713 d^{-1}, equivalent to 5.8 to 6.9% d^{-1} (Table 4B). Cannibalism probably occurred during the last 10 d of the experiment. Some large survivors had small larvae in their stomachs when the experiments ended.

Size-at-Age

When larvae were stocked in the enclosures at 9 d after hatching, white bass hybrid larvae were significantly heavier (ANOVA, $P < 0.01$) and slightly, but not significantly, longer than white perch hybrid and striped bass larvae (Table 4A). Because all larvae had been fed *Artemia* nauplii in the hatchery for 3 d prior to stocking it is not known if the sizes at stocking reflect the relative weights and lengths of the three kinds of larvae before they began to feed.

At 30 d after hatching mean lengths of striped bass and hybrid larvae from the enclosures ranged from 12.58 to 12.96 mm SL (Table 4C). Mean wet weights ranged from 38.38 to 43.28 mg (Table 4C). There were no significant differences in mean lengths or weights among the three types of larvae or among the nine enclosures (ANOVA, $P > 0.25$).

Growth Rates

Mean rates of growth in length for the striped bass and hybrid larvae ranged from 0.30 to 0.32 mm d^{-1} (Table 4D; Fig. 3). There were no significant differences in the rates among types of larvae or among replicate enclosures (ANCOVA, $P > 0.10$).

The common, instantaneous rates of growth in weight were 0.1444 for striped bass (= 15.5% d^{-1}), 0.1650 for white bass hybrids (= 17.9% d^{-1}) and 0.1593 for white perch hybrids (= 17.3% d^{-1}). The rates of growth (Table 4E; Fig. 4) differed significantly among the three types of larvae (ANCOVA, $P < 0.05$) but not among enclosures ($P > 0.10$). The

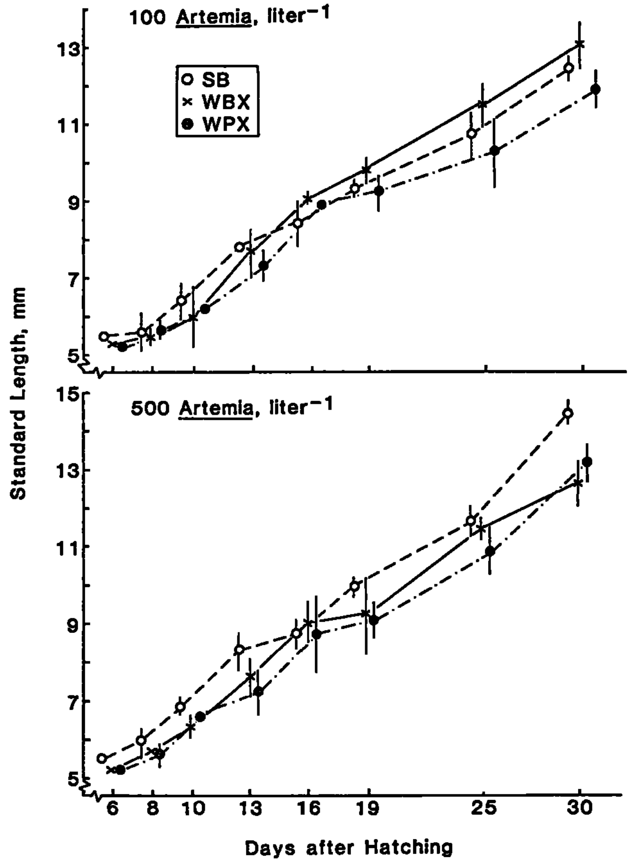

FIGURE 1.—Mean standard lengths ±2 standard errors of striped bass (SB), striped bass × white bass (WBX), and striped bass × white perch (WPX) larvae from 6 to 30 d after hatching, reared at two food levels in the laboratory.

white bass hybrid and white perch hybrid rates were significantly higher than that for striped bass larvae (SNK multiple comparison procedure, $P < 0.05$).

Weight-Length Relationships

The wet weight-standard length relationships differed significantly among the three types of larvae (ANCOVA, $P < 0.001$). The power coefficient of the white bass hybrid larvae was higher than those of the striped bass and white perch hybrid larvae (SNK multiple comparison test, $P < 0.01$) (Table 4F).

Pond Zooplankton

Copepod nauplii and adults (*Diaptomus* spp. and other calanoid species) and cladocerans (*Bosmina*, *Scapholebris*, *Ceriodaphnia*, and *Daphnia*) were abundant in the pond and in the enclosures (Fig. 5). The summed cladoceran and copepod densities declined rapidly in the pond from >1,000 L^{-1}, when the larvae were stocked, to approximately 400 L^{-1} during the last 10 d of the experiment. Densities within the enclosures declined from approximately 1,000 L^{-1} at the time larvae were stocked to 100 L^{-1} when the experiments ended.

Samples of 12-20 larvae of each type were examined for stomach contents on day 30. The smallest larvae of each type had eaten cladocerans and copepods. The largest individuals had eaten chironomid larvae and zooplankton. Two of 20 individuals of striped bass and white bass hybrids had eaten fish larvae, proof that cannibalism was occurring.

DISCUSSION

Neither striped bass nor hybrid larvae, in the lab-

TABLE 4.—Summary of data and analyses from 2 m^3 enclosure experiments in the Manning Hatchery pond, 1983. Three replicate enclosures were run for each type of larva: Striped bass (SB), striped bass x white bass (WBX), and striped bass x white perch (WPX). A) Mean standard lengths and wet weights at 9 d after hatching, prior to stocking in enclosures. B) Percent survivals at 30 d after hatching. C) Mean lengths and weights at 30 d after hatching. D) Growth-in-length equations (l_t = standard length in mm at age t; t = days after hatching; S_b = standard error of the regression coefficient; r^2 = coefficient of determination). E) Exponential, growth-in-weight equations (W_t = wet weight in mg at age t; t = days after hatching; S_G = standard error of the exponential coefficient; r^2 = coefficient of determination). F) Power function equations of the wet weight-standard length relationships (W = wet weight in mg; l = standard length in mm; S_b = standard error of the power coefficient; r^2 = coefficient of determination).

A. Type of larva		Standard length (mm)		Wet weight (mg)	
	n	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$
SB	13	6.12	0.06	1.15	0.08
WBX	13	6.19	0.14	[1]1.66	0.11
WPX	15	5.87	0.13	1.33	0.11

B. Type of larva	Percent survival		Instantaneous mortality rate (d^{-1})
	$\bar{x}$	$s_{\bar{x}}$	
SB	22.1	3.4	0.0713
WBX	22.0	6.2	0.0695
WPX	28.5	2.1	0.0601

C. Type of larva		Standard length (mm)		Wet weight (mg)	
	n	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$
SB	78	12.58	0.24	38.38	3.57
WBX	78	12.90	0.23	43.28	3.86
WPX	78	12.96	0.12	39.73	1.23

D. Type of larva	Equation			
	$l_t = a + bt$	n	S_b	r^2
SB	$l_t = 3.09 + 0.30t$	253	0.0136	0.66
WBX	$l_t = 3.22 + 0.31t$	245	0.0130	0.70
WPX	$l_t = 2.96 + 0.32t$	263	0.0100	0.79

E. Type of larva	Equation			
	$W_t = W_0 e^{Gt}$	n	S_G	r^2
SB	$W_t = 0.37 e^{0.1444t}$	253	0.0044	0.81
WBX	[2]$W_t = 0.26 e^{0.1650t}$	245	0.0041	0.87
WPX	[2]$W_t = 0.30 e^{0.1593t}$	263	0.0037	0.88

F. Type of larva	Equation			
	$W = al^b$	n	S_b	r^2
SB	$W = 6.23 \times 10^{-4} L^{4.2879}$	253	0.0469	0.97
WBX	[3]$W = 2.27 \times 10^{-4} L^{4.7114}$	245	0.0536	0.97
WPX	$W = 5.44 \times 10^{-4} L^{4.3496}$	263	0.0512	0.97

[1] Significant at $P < 0.05$. ANOVA.

[2] The WBX and WPX exponential coefficients differed significantly, $P < 0.05$, from the SB coefficient. ANCOVA followed by SNK multiple comparison procedure.

[3] The WBX power coefficient differed significantly, $P < 0.05$, from the SB and WPX coefficients. ANCOVA followed by SNK multiple comparison procedure.

oratory and in freshwater pond enclosures, demonstrated clearly superior growth or survival. The apparent heterosis in young-of-the-year and subadult white bass hybrids (Logan 1968; Ware 1975; Bonn et al. 1976; Williams et al. 1981; Kerby et al. 1983) was not evident during the first month after hatching. Survival and growth rates of the three types of larvae were relatively high in all of our experiments, indicating that striped bass and its hybrids may have near-equal production potential up to 30 d of age.

Larvae grew and survived surprisingly well at the relatively low food concentrations that we offered in the laboratory. There was evidence that striped bass and white perch hybrid larvae grew faster at the 500 L^{-1} than at the 100 L^{-1} *Artemia* concentration but there was no significant difference in size of white bass hybrid larvae reared at those two food levels. Survival of all three types of larvae did not differ between the two food levels, demonstrating that high survival and favorable growth can be ob-

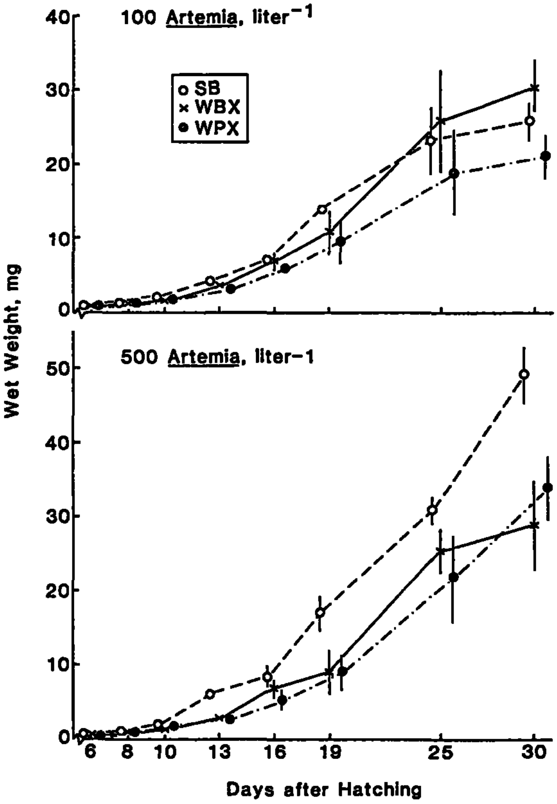

FIGURE 2.—Mean wet weights ±2 standard errors of striped bass (SB), striped bass × white bass (WBX), and striped bass × white perch (WPX) larvae from 6 to 30 d after hatching, reared at two food levels in the laboratory.

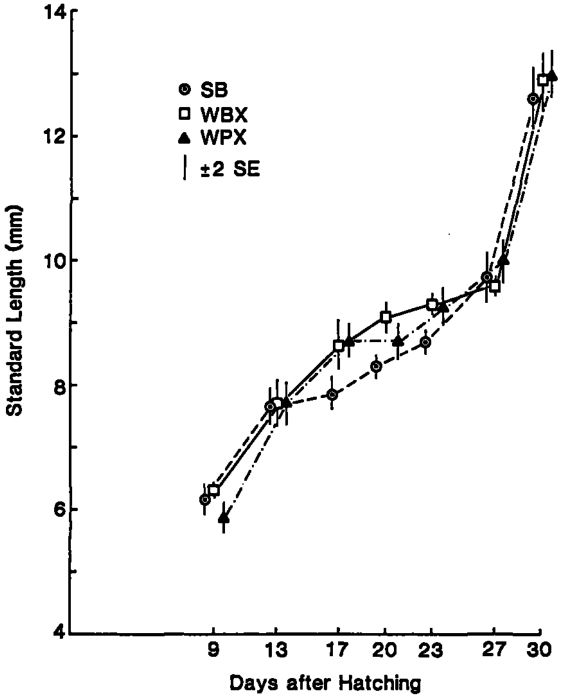

FIGURE 3.—Mean standard lengths (±2 standard errors) of striped bass (SB), striped bass x white bass (WBX), and striped bass x white perch (WPX) larvae on seven dates in 2 m^3 enclosure experiments, Manning Hatchery pond.

tained for *Morone* larvae at low *Artemia* concentrations, if those concentrations are maintained at the nominal levels. Our laboratory survival rates at low food levels were higher than those reported for striped bass larvae in the literature (e.g., Doroshev 1970; Miller 1978; Rogers and Westin 1981; Eldridge et al. 1981, 1982), which generally had indicated that nominal *Artemia* concentrations nearly an order of magnitude higher than 500 L^{-1} were required to obtain high survival rates.

The laboratory and pond enclosure methods to assess striped bass and hybrid larvae performance differed in many respects and could have influenced results. Besides great differences in enclosed volumes (36 L vs. 2 m^3), environmental factors and foods differed. Laboratory experiments were run at 19.0°C and 3‰ salinity, because low salinities are known to improve striped bass larvae survival (Bonn et al. 1976; Kerby et al. 1983). Temperature increased from 18.5° to 22.5°C in the Manning Hatchery freshwater pond during the 3-wk experiment. The laboratory-reared fish were fed only *Artemia* nauplii at controlled concentrations while enclosure fish had a variable zooplankton diet.

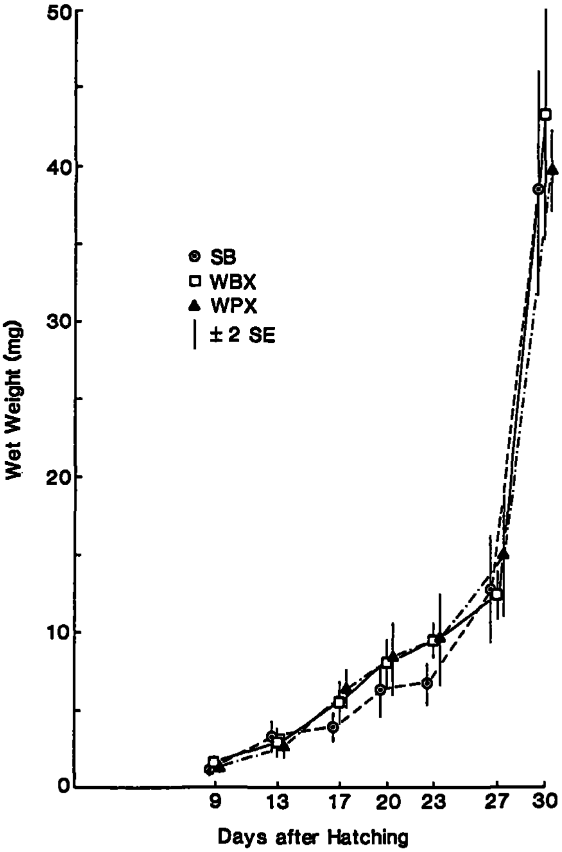

FIGURE 4.—Mean wet weights (±2 standard errors) of striped bass (SB), striped bass x white bass (WBX), and striped bass x white perch (WPX) larvae on seven dates in 2 m^3 enclosure experiments, Manning Hatchery pond.

Survival of all larvae was lower in the pond enclosures than in the laboratory tanks (Tables 1, 4). White bass hybrids had the lowest mean survival rate in the laboratory but they survived as well as striped bass and white perch hybrids in the pond enclosures. At the relatively high 500 L^{-1} *Artemia* level laboratory-reared striped bass larvae were longer and heavier than either of the hybrids at 30 d after hatching. In the pond enclosures no significant differences in mean lengths or weights among the three types of larvae were detected at 30 d. The weight-length relationship of pond enclosure, white bass hybrid larvae had a relatively high exponential coefficient, indicating that they were heavier at a given length than the other types of larvae. Mean weights of both hybrids at 30 d were considerably heavier in the pond enclosures than in the laboratory tanks. Relatively great size variability in the

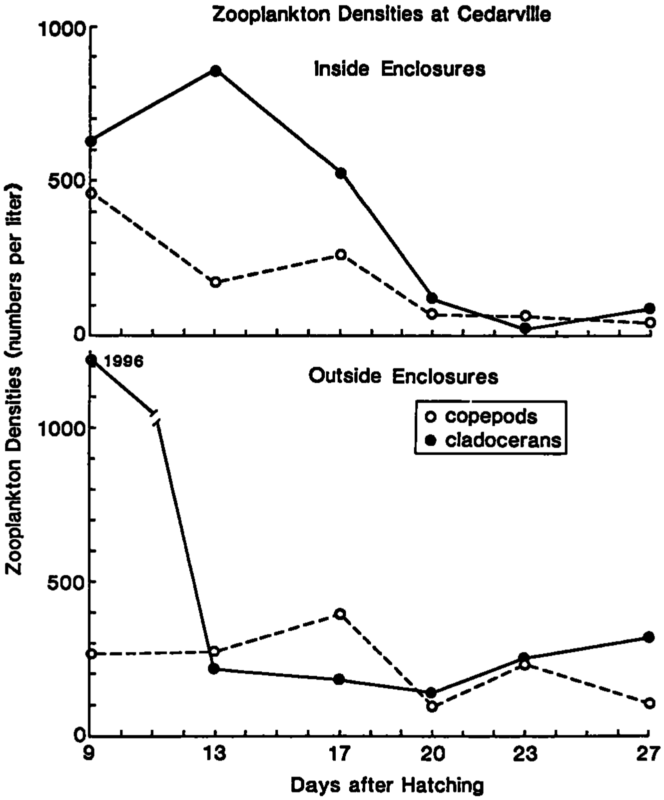

FIGURE 5.—Mean densities of copepods and cladocerans inside and outside of the 2 m^3 enclosures used for striped bass and hybrid larvae experiments in the Manning Hatchery pond.

enclosures may have resulted in part from cannibalism and consumption of chironomids by some larvae, promoting their relatively rapid growth.

Although mean weights and lengths of 30-d-old striped bass and the two hybrids from the pond enclosures did not differ, the instantaneous rate of growth in weight of striped bass larvae was significantly lower than that of either hybrid (Table 4E). Had the enclosure experiments proceeded for a few more days the hybrids would have attained larger size than the striped bass. For example, at 35 d after hatching the striped bass would have weighed 20 mg less than either hybrid. The heterotic effect may begin to express itself at approximately 1 mo of age. Alternatively, the freshwater environment, increasing temperatures, and the prey available in the pond may have selectively favored growth of hybrids during the last few days of the experiment.

If 30-d-old fry are to be produced for stocking, there is no apparent immediate advantage to rear hybrids rather than striped bass. Our laboratory and pond enclosure studies did not demonstrate advantages in survival or production of hybrids. The pond enclosure results did suggest that hybrids may begin to achieve an advantage in growth rates just prior to 1 mo of age. Important questions about comparative energetics, nutrition, and genetics still remain to be answered to understand the biology of larval *M. saxatilis* or its hybrids and the consequences of their possible release into natural systems such as Chesapeake Bay.

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