Culture and Controlled Spawning of Striped Bass (*Morone saxatilis*) to Produce Striped Bass and Striped Bass × White Bass (*M. chrysops*) Hybrids[1]

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Abstract: Controlled spawning techniques for cultured striped bass (*Morone saxatilis*) to produce striped bass and striped bass/white bass (*M. chrysops*) hybrids were demonstrated. Some striped bass males matured at age 2 while almost all were mature by age 3 (mean weight 2.3 kg, 550 mm TL). In contrast, no female striped bass were mature at age 2 and only 16% were ripe at age 3 (3.4 kg, 623 mm TL). By age 4, an estimated 59% of the females were mature (4.9 kg, 692 mm TL). In 1985 and 1986, striped bass were conditioned using controlled temperatures and photoperiod regimes to spawn 1–3 months before the natural spawning season in South Carolina. Wild white bass matured in outdoor tanks and were spawned with striped bass to produce original and reciprocal cross hybrids. Reciprocal cross hybrids can easily be obtained as striped bass males and white bass females readily mature in outdoor tanks under natural conditions. Further, this maturation occurs about 2 months before wild striped bass females are running ripe.

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Currently, federal, state, and private hatcheries depend on collection and use of wild broodstock to produce striped bass and striped bass/white bass hybrids (Harrell 1984). Such reliance results in some uncertainty as to exact timing of natural spawning runs and whether sufficient broodstock will be available to support desired production levels. In fact, climatic conditions and other natural factors as

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well as discharges from man-made water control structures often determine the outcome from various hatcheries. Historically, the use of wild brood fish has been generally satisfactory but today this may no longer be the case as demand for fish for stocking purposes has increased substantially (Stevens 1984). Concomitantly, recreational fishing pressure for potential broodstock is high (Watt et al. 1982).

Dependence on wild broodstock to support hatchery operations places the private aquaculturists, at least conceptually, in the position of competing with the public sector for "their" fish and may in fact limit commercial development. In an examination of the potential of striped bass and striped bass hybrids for aquaculture the Joint Subcommittee on Aquaculture of the Federal Coordinating Council on Science, Engineering, and Technology (1983) stated: "the major constraint to private striped bass aquaculture in the United States is the nonavailability of seed stock." Although many state hatcheries produce striped bass and hybrids, such hatcheries are typically unwilling to provide fish for commercial aquaculture.

In developing a model for aquaculture of striped bass and striped bass/white bass hybrids Smith and Jenkins (1985*a*) suggested that development of controlled spawning techniques using cultured broodstock may be necessary. Further, they indicated that out-of-season production of juveniles may be required if pan-size fish are to be produced in a single outdoor growing season in most temperate areas. Their initial studies focused on induced maturation of cultured F_1 striped bass × white bass hybrids using temperature and photoperiod control (Smith and Jenkins 1984). This approach worked satisfactorily with F_1 hybrids and so research was directed to the culture of striped bass for use as broodstock to produce striped bass and striped bass hybrids.

Initial efforts to spawn 3-year-old cultured female striped bass using controlled spawning techniques were partially successful during 1985 (Smith and Jenkins 1985*b*, Smith et al. 1985*b*). In 1986, research continued using the then 4-year-old fish. The purpose of this manuscript is two-fold: 1) to provide rearing and maturity data for cultured striped bass; and 2) to summarize results of the spawning trials conducted during 1985 and 1986.

Materials

Striped bass, progeny of wild adults, were received as small juveniles (mean weight 0.27g, 28 mm total length, TL) from the Moncks Corner Hatchery, South Carolina. These small fish were reared to advanced fingerlings in intensive nursery systems described by Smith and Jenkins (1984). In April 1984, they were moved into 3.7-m diameter × 0.9-m deep grow-out tanks housed in environmental control rooms. Recirculated brackish water (~16 ppt salinity) was utilized during much of the growth and maturation phase.

Photoperiod and temperature manipulation were used to mature the fish (Fig. 1). Lighting was controlled with three double tube fluorescent lights (cool white 34 w light tubes) suspended 1.9 m above the tank. These lights had separate timers and were phased on and off over a 2-hour period to simulate dawn and dusk condi-

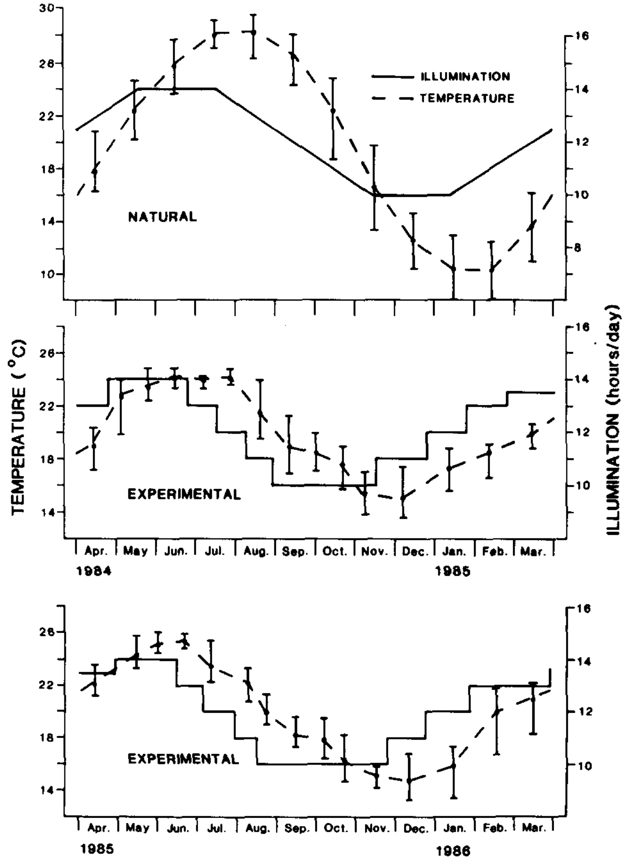

Figure 1. Photoperiod and temperature regimes used in conditioning cultured striped bass during 1984–1986. Natural (top) represents the 10-year average conditions in Charleston Harbor.

tions. Water temperature was maintained using 5 or 6 submersible coil water chillers (Aquarium Systems Inc., Mentor, Ohio) suspended in the biological filter tank. Additional cooling was provided by window air conditioner units (10,000 to 25,000 btu) installed in the environmental control rooms. The conditioning system contained 3 culture tanks and is shown schematically in Fig. 2. Water quality was usually monitored weekly and the data for April 1984 to February 1986 are summarized in Table 1.

Fish were fed primarily pelleted trout rations (Rangen/Zeigler Brothers Inc.) although some supplementation with chopped squid and live mud minnows (*Fundulus* spp.) occurred, especially during 1–3 months before and after the spawning trials. Typically 10 to 20 fish were reared in a tank, and during 1986 standing

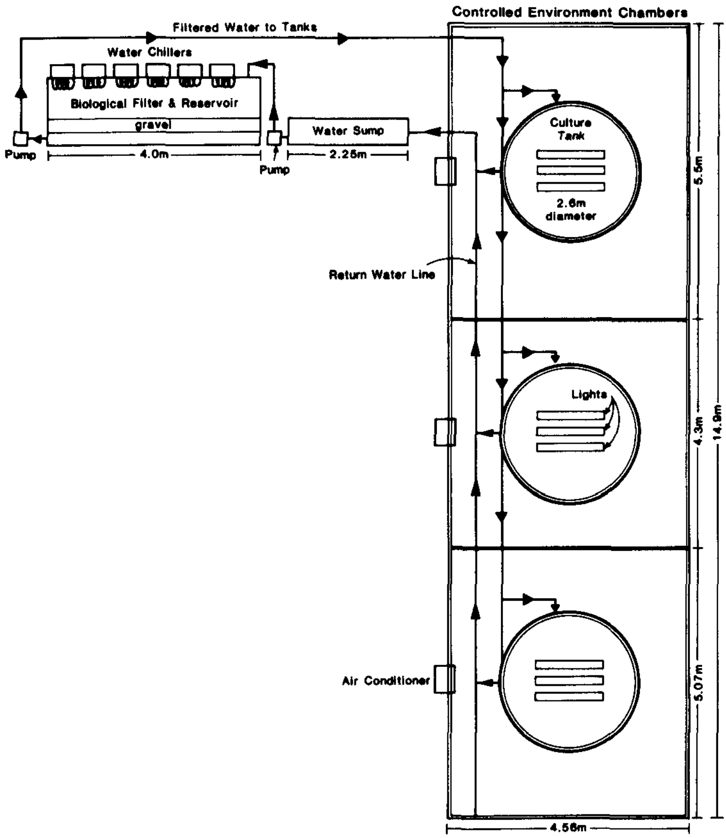

Figure 2. Schematic diagram of the environmental control system used to condition striped bass.

Table 1. Summary of water quality data in controlled conditioning system for striped bass from April 1984 to February 1985 and from March 1985 to February 1986.

	April 1984–February 1985		March 1985–February 1986	
Parameter	Mean	Range	Mean	Range
pH[a]	7.0	6.5–7.5	6.8	6.4–7.2
NH_4-N(mg/1)[b]	1.0	0.0–1.5	<1.0	—
NO_2-N(mg/1)[c]	0.1	0.0–0.2	0.1	0.0–0.3
NO_3-N(mg/1)[d]	5.9	1.8–10.8	10.7	5.8–23.3
Salinity (ppt)[e]	15.5	12.6–20.0	17.2	5.2–22.6
Oxygen (mg/1)[f]	—	—	8.1	7.6–8.9

[a]Measured with LaMotte Chemical Co. pH Test Kit Model P-5085 and Litmax Co. digital pH meter, Model CP-20.
[b]Measured with LaMotte Chemical Co. Test Kit Model PAN.
[c]Measured with LaMotte Chemical Co. Test Kit Model PLN.
[d]Measured with LaMotte Chemical Co. Test Kit Model ENA.
[e]Measured with American Optical Refractometer Model 10423 or BioMarine Chemical Refractometer.
[f]Measured with Yellow Springs Instrument Company Oxygen Meter Model 57.

biomass at time of initiation of spawning trials averaged 9.7 kg/m^3 (1.4 fish/m^2) of tank volume.

Wild white bass were used to produce hybrids. These fish were field collected and stocked in a 6.1 m × 1.5 m deep cylindrical fiberglass tank containing fresh water. This outside tank was connected to a 3.7 m × 0.9 m deep tank which served as a biological filter and reservoir. Conditioning of white bass was strictly through natural ambient conditions. These wild fish were fed live mud minnows, squid, and also commercial trout pellets and in most cases the white bass adjusted to captivity.

The spawning trials were conducted during 29 January to 12 February 1985 and from 5 February to 4 March 1986. In South Carolina the natural spawning season for striped bass is April to mid-May. Males were identified by applying abdominal compression and stripping of milt. Female striped bass were identified by catherization of fish during 1–2 months prior to spawning trials. Pre-1986 attempts to identify females employed a 3 mm o.d. glass catheter but in 1986 a flexible 1.5 mm o.d. plastic catheter was used. Near time of spawning trials, selection of females was based arbitrarily on egg size. A minimum egg diameter of 700 um was selected based on previous spawning trials with female striped bass × white bass hybrids (Smith and Jenkins 1984). Fish used in the trials were injected intramuscularly with human chorionic gonadotropin (HCG, 330–660 I.U./kg body weight for female striped bass and 319–330 I.U./kg for male striped bass). White bass were also HCG-injected (1,550 to 2,200 I.U./kg for females and 431–862 I.U./kg for males). Staging of eggs, determination of time of ovulation, and incubation of eggs followed general procedures described by Bayless (1972), Bonn et al. (1976), and Starling (pers. commun., Fla. Game Fresh Water Fish Comm., Webster). Hybrids were produced only by manual stripping of sex gametes and artificial mixing. Some striped bass were similarly produced by manual stripping while others resulted from tank spawning of adults in a 1.8 m × 0.6 m deep tank receiving flow-through well water (Bishop 1975). During handling, fish were anesthetized with MS 222 and antibiotics were added to the anesthetizing water to reduce post-handling infections.

Results

Growth and Survival

Cultured striped bass grew rapidly in the recirculating water systems (Fig. 3). At 1 year of age mean size was 593 g while by year 3 the fish weighed 2,600 g (range 1,650 – 3,530 g). By 4 years of age, mean fish weight had increased to 4,100 g (range 2,560–6,040 g). Survival of the striped bass was high and rarely did a fish die in the culture system. However, as a result of manual inspection and actual spawning trials, 2 females (7.7%) of a total of 26 fish died in 1985 while 3 females and 2 males (total 17.2%) died in 1986. Typically, after intensive handling, fish would stop feeding for 1–4 weeks and some would develop hemorrhagic areas or lesions. Normally these fish would recover after being returned to saltwater (≥15 ppt salinity) if the condition was not too severe. Female broodstock which were

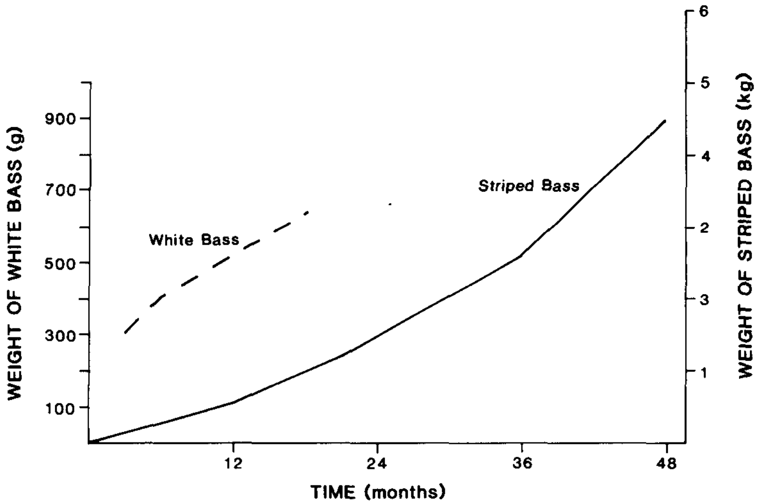

Figure 3. Growth of cultured striped bass and wild caught white bass in tanks.

checked and stripped several times over a 24-hour period would often develop a severe hemorrhagic condition known as "red tail." All females which died exhibited the "red tail" syndrome. To a much lesser extent, males also exhibited the "red tail" syndrome but in most cases they did not die.

White bass also grew considerably in captivity (Fig. 3). After 12 months, fish increased in size from 424 g (318 mm TL) to 640 g. White bass were typically much more resistant to handling stress although 50% of the females died as a result of the handling in 1985 and in 1986. Handling of females was intensive both years while we were learning proper staging and stripping techniques. No males died as a result of handling. Losses could be substantial after wild fish were placed in captivity. Outbreaks of "Ich" would occur but suitable prophylactic treatments shortly after capture typically eliminated this problem. Other disease problems did occur which sometimes resulted in mortality during the course of this study.

Maturation

As in the wild, male and female striped bass matured at different ages and sizes (Lewis 1962). In 1984, no ripe females were observed among the 2-year-old fish; however, 8% of the fish were running ripe males. In 1985, 12% were apparently mature females (egg diameter $\geq$ 700 um) while 31% were ripe males at this time. In 1986, sampling of the 4-year-old fish indicated that 28% were mature females, 31% were mature males and the remainder were immature females. It is worth noting that all males were mature by age 3 and that males remained in ripe condition for at least 8 weeks. Mean size of the 4-year-old ripe males was 3.87 kg (640 mm TL) as compared to 4.95 kg (692 mm TL) for the mature females (Table 2).

Table 2. Growth and maturity data for striped bass reared in indoor culture systems.

Age (years)	Mature males[a]					Mature females[b]					Unknowns & immature fish[c]				
		Total length (mm)		Weight (kg)			Total length (mm)		Weight (kg)			Total length (mm)		Weight (kg)	
	N	Mean	Range	Mean	Range	*N*	Mean	Range	Mean	Range	*N*	Mean	Range	Mean	Range
1.75											25	453	395–475	1.2	0.6–1.4
3.00	8	550	494–612	2.3	1.6–3.5	3	623	613–628	3.4	3.2–3.5	15	581	539–621	2.7	1.9–3.5
4.00	9	640	561–725	3.9	2.6–4.9	8	692	664–733	4.9	4.3–6.0	3[d]	715	665–756	5.0	4.4–5.6

[a]Fish which express milt when abdominal pressure is applied.
[b]Females with eggs greater than 700 μ in diameter.
[c]Fish which do not meet criteria of ripe males or females.
[d]Four additional unknowns were not weighed or measured.

Table 3. Summary of spawning trials in 1985 and 1986 using cultured striped bass females.

Date	Fish I.D.	Fish length (mm)	Fish weight (kg)	Egg dia. (μ)	Hormone dosage (IU/kg)	Latency period (hr)	Eggs spawned (*N*)	Larvae hatched (*N*)
				1985				
29 Jan	85-01	628	3.5	1,088	330	54[a]	Died before spawning	
29 Jan	85-02	628	3.5	903	330	72	Tank spawned[b]	
12 Feb	85-03	613	3.2	787	660[c]	142	Tank spawned[b]	
				1986				
5 Feb	86-01	724	5.0	870	330	55	206,250	59,848(H)[d]
5 Feb	86-02	685	4.9	795	660[c]	Did not spawn		
10 Feb	86-03[e]	695	5.1	1,021	330	39	340,170	23,730(S)[d]
							683,675	34,258 (H)
10 Feb	86-04	665	4.4	989	660[c]	Did not spawn		
19 Feb	86-05[e]	682	5.0	986	330	39	567,630	0
19 Feb	86-06[e]	733	5.0	1,125	660	39	646,980	0
4 Mar	86-07	680	4.3	923	510	52	91,564	~500(S)

[a]Estimate based on egg stage at death.
[b]Number of eggs tank-spawned were not estimated however, viability was very low.
[c]Received 2 doses at 330 IU/kg.
[d]S = Striped bass, H = Striped bass × white bass hybrids.
[e]Fish exhibited abdominal swelling and laid on the tank bottom during 5–6 hours prior to ovulation. Females subsequently died.

All white bass were mature during the first spawning season following their capture. Females were easily identified from January to April as they exhibited distended abdomens. Milt could easily be expressed from the males during a similar period.

Spawning Trials

In 1985, there were 3 attempts (from 29 January to 12 February) to produce striped bass using 32 to 34-month-old cultured broodstock (Table 3). To reduce stress on fish, these spawning attempts utilized tank spawning techniques. In the first case, the female swelled up but died several hours before estimated time of ovulation. In the second case, tank spawning occurred but the eggs clogged the center standpipe screen and the tank overflowed. In the third case, 2 injections of HCG were required but a tank spawning did occur (Table 3) and ~43 hours post-spawning several thousand larvae hatched. During 1985, attempts to produce "original cross" female striped bass × male white bass hybrids, were not successful due to lack of female striped bass. However, larvae of the "reciprocal cross," female white bass × male striped bass, were produced during March.

In 1986, 4 separate attempts were made from 5 February to 4 March to produce striped bass and or striped bass/white bass hybrids (Tables 3,4). In the first trial 1 of 2 striped bass females was stripped and 59,848 original cross hybrids were made. In the second trial, 1 of 2 female striped bass ovulated and 23,730 striped bass and 34,258 original cross hybrids were produced. In the third attempt both female striped bass ovulated and ~1.2 million eggs were obtained. However, these fish exhibited abnormal swelling and loss of equilibrium prior to ovulation and died shortly after ovulation. None of their eggs hatched. During the last trial on April 7, four female white bass were stripped and 198,000 reciprocal cross hybrids were produced (Table 4).

Table 4. Summary of spawning trials in 1985 and 1986 using wild tank reared female white bass and cultured striped bass males to produce reciprocal cross hybrids. Number of eggs spawned was not estimated. Size data are for the female white bass.

Date	Fish length (mm)	Fish weight (kg)	Egg diameter (μ)	Hormone dose (IU/kg)	Latency period (hours)	Larvae hatched (N)
			1985			
12 Mar	346	0.63	660	2,200	29	33,992
12 Mar	319	0.46	725	2,174	29–30	37,247
27 Mar	343	0.55	756	2,000	8–10	few[a]
27 Mar	283	0.30	740	3,333	18–24	few[a]
			1986			
4 Mar	—	0.64	612	1,570	33–35	84,185
4 Mar	—	0.64	672	1,570	35	0
4 Mar	—	0.61	716	1,641	29–32	17,870
4 Mar	—	0.64	716	1,548	33	87,950

[a]PAM vegetable cooking spray used in an attempt to prevent eggs from sticking to McDonald hatching jars.

Discussion

This research demonstrated that it is possible to grow, mature, and spawn striped bass under controlled culture conditions. However, additional work is needed to refine the techniques. The problem of females displaying abdominal distention and loss of equilibrium within a few hours of expected time of ovulation needs diagnosis (Table 3). We suspect that perhaps catheter induced damage to the urogenital opening, especially at 2–3 years of age when the larger glass catheter was used, may be partially responsible. However, similar problems do occur with wild fish on occasion during hatchery operations. Two cultured female striped bass exhibited apparently well developed eggs (diameters 795 and 989 um) yet these eggs did not further develop or respond to injection of HCG. Examination of the artificial conditioning sequence shows that the lower natural temperature of ~10° C was never achieved in either 1985 or 1986 due to cooling system limitations. Perhaps this lower temperature is required for proper development of mature eggs. However, it is also possible that nutritional and or photo-conditioning parameters were not fully adequate.

Controlled spawning of cultured broodstock provides a number of advantages to hatchery operators. First, it would lessen the reliance on wild spawning fish and allow better predictability as to timing and numbers of larvae. Second, such techniques could be used to allow a "double cropping" or increased utilization of pond facilities by extending the spawning season to before and or after the natural spawning season. Third, this approach may eventually become the only allowable and acceptable approach for the private aquaculturist. Indeed, aquaculture development by private growers is currently restricted by availability of seed stock and no assistance is anticipated in the future from state and federal hatcheries which are having increasing difficulty meeting their own production goals.

The striped bass and white bass hybrids appear well suited for aquaculture development (Williams et al. 1982; Kerby et al. 1983*a*, *b;* Woods et al. 1983; Carlberg et al. 1984; Collins et al. 1984; Smith et al. 1985*a;* Smith and Jenkins 1985*a*, *b*). These fish exhibit hybrid vigor, are tolerant of broad environmental conditions, and appear suitable to existing markets (Gordon 1985). Direct comparison of the original and reciprocal crosses of the striped bass/white bass hybrids has not been performed but related comparisons suggest that they will perform similarly (Smith et al. 1985*a*). Both types of hybrids were produced using cultured striped bass and cultured wild white bass in 1986. The original cross hybrid requires a female striped bass. However, female striped bass appear more difficult to mature and handle in comparison to female white bass. Male striped bass mature at a younger age than females and become ripe prior to the normal spawning season for females. Further, striped bass males remain ripe for at least 8 weeks and readily respond to injections of HCG. Female white bass mature earlier (late winter/early spring) than do female striped bass, and are easily conditioned for spawning using natural outdoor ambient conditions. Thus, it may be practical for the culturist to naturally mature both female white bass and male striped bass in outdoor tanks as was done at our Charleston laboratory in 1984, and to produce reciprocal hybrids ahead of the normal striped bass spawning season. The major considerations to this approach are that: 1) fewer eggs are produced from white bass females than from striped bass females, however, adult white bass can easily be maintained and matured in captivity, and 2) the newly hatched reciprocal hybrid fry are smaller and require zooplankton for initial feeding. This latter point can be addressed through the use of small greenhouse covered ponds (if larvae are produced when pond water temperature is too cold) or through intensive tank production techniques.

From an aquaculture perspective, utilization of striped bass males and white bass females to produce reciprocal cross hybrids appears attractive. However, additional grow-out information is needed on the production characteristics of these hybrids.

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