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Aquaculture Performance Comparison of Sunshine Bass, Palmetto Bass, and White Bass

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Abstract.—Aquaculture performance of phase II and phase III sunshine bass (a female white bass *Morone chrysops* × male striped bass *M. saxatilis*), palmetto bass (a female striped bass × male white bass), and white bass were evaluated in separate 12-week yield trials conducted in indoor recirculating-water systems. Phase II sunshine bass, palmetto bass, and white bass had mean initial weights of 40.0 g, 39.7 g, and 41.0 g, respectively. A diet containing 40.2% crude protein (CP) was fed to fish twice daily at a rate of 3% body weight/d. At the end of the trial, sunshine bass and white bass had mean weights of 124.2 g and 126.0 g, respectively and were significantly larger than palmetto bass (93.5 g mean weight). Phase II sunshine bass and white bass outperformed palmetto bass by having higher relative growth (*h*), mean daily growth, and relative weight, as well as better feed conversion ratios (weight of food fed/weight gained). Survival was 100% for all three taxonomic groups. In the phase III study, mean initial weights for sunshine bass (177.5 g) and palmetto bass (185.9 g) were similar but significantly greater than the mean initial weight of white bass (153.8 g). In this trial, fish were fed a floating trout chow (44.1% CP) to satiation twice per day. At the termination of the study, sunshine bass (611.1 g) and palmetto bass (517.8 g) had significantly greater mean weights than white bass (254.4 g). Significant differences among all three taxonomic groups were found for *h* and for mean daily growth rate. Both crosses of hybrid striped bass had lower feed conversion ratios when compared with white bass. Relative weight values (ratio of a fish's weight to the weight of a standard fish of the same length) for sunshine bass were significantly greater than values for palmetto bass and white bass. Survival rates ranged from 98% to 100% for the three taxonomic groups. Differences were not detected between sunshine bass and palmetto bass for eviscerated percentage, headed and eviscerated percentage, or dressout percentage. Sunshine bass outperformed palmetto bass at phase II and phase III sizes under the conditions of this study.

Hybridization of striped bass *Morone saxatilis* with white bass *M. chrysops* was first accomplished in 1965 by Robert Stevens in South Carolina (Bishop 1968). Since then, hybrid striped bass have grown in popularity for applications in fish management as well as an aquaculture food fish. The original objective of this hybridization program was to produce a fish with the size, longevity, fighting ability, and food quality of striped bass, while retaining the less stringent spawning habitat requirements and the greater adaptability to exotic environments of white bass (Bayless 1972; Bonn et al. 1976). Improvements in the technology used to spawn and culture striped bass and its hybrids provided new management opportunities in lakes and reservoirs and produced new recreational fisheries (Kerby 1993). By 1981, 456 reservoirs had been stocked with striped bass, hybrid striped bass, or both, and those reservoirs accounted for 57% (by area) of existing reservoirs in the USA (Stevens 1984). The primary purpose for stocking striped bass and its hybrids into reservoirs was to provide a sportfish that would serve as a biological control on gizzard shad (Kerby and Harrell 1990).

In addition to its uses in fisheries management, hybrid striped bass are well suited for aquaculture. Precipitous declines in natural coastal populations of striped bass in the late 1970s and early 1980s created an opportunity for aquaculturists to provide this product to the market because the commercial fishery was unable to sustain the demand. It was quickly recognized that hybrid striped bass exhibited heterosis of traits that were economically important (Harrell 1997). When compared with striped bass, both crosses of hybrid striped bass have greater disease resistance, improved survival rates, and faster growth rates during the first 2 years of life (Bishop 1968; Logan 1968; Williams 1971; Bayless 1972; Ware 1975; Bonn et al. 1976; Kerby and Joseph 1979; Kerby et al. 1983a; Kerby 1986). Also, the versatility of hybrid striped bass is evidenced by the wide range of culture systems

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in which they can be raised; these include ponds, cages, raceways, and tanks (Williams et al. 1981; Kerby et al. 1983b, 1987; Woods et al. 1983, 1985; Smith et al. 1985; Harrell et al. 1988; Jenkins et al. 1989; Kelly and Kohler 1996).

Culture of hybrid striped bass has become one of the most rapidly growing segments of aquaculture in the United States (USDA 1992). It was estimated that 6,600 metric tons (14.5 million pounds) of food-fish-size hybrid striped bass were produced in 1996 (Harrell and Webster 1997). Including outcrosses and backcrosses, 19 crosses have been produced within the genus *Morone* (McCraren 1984); however, two hybrids currently dominate production: palmetto bass and sunshine bass. Palmetto bass are produced by crossing a female striped bass with a male white bass; sunshine bass are produced by crossing a female white bass with a male striped bass.

The first hybrid produced was the palmetto bass. This cross was prevalent during the early production of hybrid striped bass. However, a transition to producing mainly sunshine bass has occurred within the industry for several reasons. First, the decline in the natural stocks of striped bass resulted in very restrictive fishing regulations, and consequently it became more difficult to capture large females. Secondly, when compared with striped bass, white bass females have reduced mortality after manual stripping. Lastly, white bass mature at an earlier age and are easier to handle and maintain as broodstock due to their smaller size (Kohler et al. 1994).

Following the transition from primarily producing palmetto bass to sunshine bass, it has generally been presumed that the production characteristics of the two crosses of hybrid striped bass are equivalent. Despite numerous studies that investigated the performance attributes of these two hybrids, we found no documentation in the literature comparing the simultaneous aquaculture performance of palmetto bass and sunshine bass. In addition, no comparisons have been documented between the performance of either cross of hybrid striped bass with white bass. Accordingly, we compared selected aquaculture performance characteristics of sunshine bass, palmetto bass, and white bass at advanced fingerling to harvest sizes.

Methods

The size of fish used in the two feeding trials corresponded to particular phases in the culture process of striped bass and hybrid striped bass. Fish in the first feeding trial corresponded to a segment of the culture process known as phase II. This culture stage refers to rearing hybrid striped bass from 25–75 mm total length (TL) until lengths of 75–250 mm are attained. The second feeding trial was conducted with fish that corresponded to the phase III segment of the culture process. Phase III culture represents rearing of the advanced fingerlings produced in phase II to subadult or adult sizes (Brewer and Rees 1990). These studies will hereinafter be referred to as the phase II feeding trial and the phase III feeding trial.

Phase II feeding trial.—The feeding trial was conducted in a recirculating-water system consisting of 30 glass aquaria (35 L), floss particulate filters, a submerged biofilter (303-L) with limestone rock as media, and a water chiller (model BHL-1150, Frigid Units, Inc., Toledo, Ohio). The water source for the recirculating-water system was charcoal-filtered city water.

Juvenile sunshine bass and palmetto bass were obtained from commercial producers (Keo Fish Farms, Keo, Arkansas, and Miss-Ark Fisheries, Greenville, Mississippi, respectively). Multiple females and males were spawned to produce the hybrid striped bass used in this study. Juvenile white bass were obtained from at least five female and eight male parentals collected from the Illinois River. Spawning trials to produce the white bass used in this study were conducted at Southern Illinois University at Carbondale (SIU-C). Fifty each of white bass, palmetto bass, and sunshine bass were randomly selected and stocked at a rate of five fish/tank, with 10 replicate tanks per treatment. Fish were acclimated to the culture system and experimental conditions for 14 d before the initiation of the trial. Following the acclimation period, fish were individually measured and weighed. Initial total lengths and weights (mean $\pm$ SE) of sunshine bass, palmetto bass, and white bass were 159.8 $\pm$ 0.7 mm and 40.0 $\pm$ 0.6 g, 161.1 $\pm$ 1.0 mm and 39.7 $\pm$ 0.5 g, and 159.4 $\pm$ 1.1 mm and 41.0 $\pm$ 0.9 g, respectively.

Fish were fed a floating bass feed (40.2% crude protein, 8.8% lipid, 4.1% moisture) which was 6.4 mm in diameter (Arkat Feeds, Inc., Dumas, Arkansas). Feed was offered two times per day with rations being divided equally between morning and evening feedings. Fish were fed at a rate of 4% body weight/d for the first 3 days of the study; however, feeding rate was reduced to 3% body weight/d for the remainder of the study to minimize overfeeding while still approaching satiation. Uneaten food and fecal waste were siphoned as necessary from each aquarium. The floss filters were rinsed two times per day to remove accumulated particulates. Fish from each tank were measured for total length to the nearest millimeter and weighed to the nearest 0.1 g every 14 d, and feed rations were adjusted accordingly. The duration of the trial was 84 d. Temperature, dissolved oxygen (model 58, YSI, Inc., Yellow Springs, Ohio), pH (model pH 57, Engineered Systems & Designs), salinity (model SR-1, Aquatic Ecosystems), total ammonia-N and nitrite-N were measured daily, while alkalinity, hardness, and nitrate-N were measured weekly. Total ammonia-N, nitrite-N, and nitrate-N were measured with a spectrophotometer (model DREL/1C, Hach Co., Loveland, Colorado). Alkalinity and hardness were measured with a digital titrator (model 16900-01, Hach Co.). Un-ionized ammonia nitrogen was calculated with conversion factors based on temperature and pH (Piper et al. 1982). Lighting was provided by 25-W incandescent light bulbs, and a photoperiod of 14 h light : 10 h darkness, centered at 1300 hours, was maintained by an automatic electric timer. Subsamples of each stock of fish ($N = 20$) were randomly chosen from each tank after the feeding trial and frozen; subsequently, muscle tissue was subjected to proximate analysis. Feed was withheld from fish for 24 h before they were euthanatized with a lethal dose of tricaine methanesulfonate (MS-222) that was buffered with sodium bicarbonate at a ratio of 2:1.

Phase III feeding trial.—The feeding trial was conducted in a recirculating-water system consisting of six 1,337-L circular tanks, a sand filter, and a submerged biofilter (1,669 L), with limestone rock as media. The water source was dechlorinated city water.

Sunshine bass and palmetto bass were obtained from private and state hatcheries (Keo Fish Farms and Possum Kingdom State Fish Hatchery, Graford, Texas, via Jake Wolf Memorial Fish Hatchery, Manito, Illinois, respectively). Multiple females and males were spawned to produce the hybrid striped bass used in this study. White bass were obtained from at least five female and eight male parentals collected from the Illinois River. Spawning trials to produce the white bass in this study were conducted at SIU-C. Fifty fish of each stock were randomly selected and stocked at a rate of 25 fish/tank. There were two replicate tanks per treatment. Fish were acclimated to the culture system and experimental conditions for at least 14 d before the initiation of the trial. Following the acclimation period, fish were individually measured for total length to the nearest millimeter and weighed to the nearest 0.1 g. Initial total lengths and weights (mean ± SE) of sunshine bass, palmetto bass, and white bass were 252.0 ± 0.0 mm and 177.5 ± 2.1 g, 254.0 ± 0.0 mm and 185.9 ± 0.7 g, and 233.5 ± 1.5 mm and 153.8 ± 3.8 g, respectively.

Fish were fed a floating trout chow (44.1% CP, 11.7% lipid, 8.9% moisture) that was 5.5 mm in diameter (Nelson & Sons, Inc., Murray, Utah). Fish were fed to satiation twice daily. The sand filter was backflushed twice per day, and uneaten food and fecal waste were siphoned from each tank as necessary. Fish from each tank were weighed as a group every 14 d. In addition, seven to eight fish from each tank were individually measured for total length and weight. The duration of the trial was 84 d. Temperature, dissolved oxygen, pH, total ammonia-N, and nitrite-N were measured daily; alkalinity, hardness, and nitrate-N were measured weekly. Lighting was provided by 40-W incandescent light bulbs, and a photoperiod of 14 h light : 10 h darkness, centered at 1300 hours, was maintained by an automatic electric timer. Subsamples of each stock of fish ($N = 20$) were randomly chosen from each tank after the feeding trial and frozen; subsequently, muscle tissue was subjected to proximate analysis. Feed was withheld from fish for 24 h before they were euthanatized with a lethal dose of tricaine methanesulfonate (MS-222) that was buffered with sodium bicarbonate at a ratio of 2:1.

Evaluation of performance.—Performance during the phase II and phase III feeding trials was based on the following production criteria: relative growth rate (h) (Ricker 1975), mean daily absolute growth rate, feed conversion ratio (FCR), survival rate, relative weight (W_r), eviscerated percentage, headed and eviscerated percentage, dressout percentage, hepatosomatic index (HSI), gonadosomatic index (GSI), and viscerosomatic index (VSI). Some criteria were not used in each feeding trial. The formula for relative growth rate is as follows: $h = e^G - 1$, where $G = \log_e (w_t/w_0)$, when $t = 1$, w_t is the weight of a fish at time t, and w_0 is the weight at $t = 0$. Formulas for other production criteria are as follows (all weights in grams): mean daily growth rate = wet weight gain/days of experiment; FCR = dry weight of feed offered/wet weight gained; survival rate = 100 × (number of surviving fish/number of stocked fish); $W_r = 100 \times (W/W_s)$, where W is the weight of an individual fish, and W_s is a length-specific standard weight. Standard weights were defined by the following equations (Brown and Murphy 1991):

TABLE 1.—Means (±SEs) and ranges (in parentheses) for water quality variables measured in an indoor recirculating-water system during feeding trials of phase II and phase III sunshine bass, palmetto bass, and white bass.

Variable	Phase II feeding trial		Phase III feeding trial	
Temperature (°C)	23.5 ± 0.1	(18.0–26.0)	24.8 ± 0.3	(19.0–29.0)
pH	7.0 ± 0.02	(6.8–7.5)	7.4 ± 0.01	(6.9–7.7)
Dissolved oxygen (mg/L)	6.6 ± 0.09	(5.5–12.8)	7.6 ± 0.06	(6.5–9.0)
Salinity (g/L)	3.13 ± 0.15	(0.0–6.0)	NA[a]	
Total ammonia-N (mg/L)	0.26 ± 0.01	(0.00–0.65)	0.23 ± 0.01	(0.05–0.45)
Un-ionized ammonia-N (mg/L)	0.005 ± 0.0004	(0.000–0.019)	0.004 ± 0.0002	(0.001–0.009)
Nitrite-N (mg/L)	0.24 ± 0.02	(0.04–0.80)	0.09 ± 0.02	(0.01–1.60)
Nitrate-N (mg/L)	19.92 ± 2.15	(3.00–28.00)	18.50 ± 1.35	(7.50–26.00)
Alkalinity (mg/L as $CaCO_3$)	38.8 ± 2.0	(26.0–50.0)	43.1 ± 0.8	(40.0–49.9)
Hardness (mg/L as $CaCO_3$)	214.2 ± 8.7	(174.0–279.0)	196.3 ± 10.0	(149.0–284.0)

[a] Data not available.

$\log_{10}W_s = -5.066 + 3.081 \log_{10}\text{TL}$ (white bass); $\log_{10}W_s = -5.201 + 3.319 \log_{10}\text{TL}$ (palmetto bass); a standard weight equation has yet to be determined for sunshine bass, so the assumption that it would not be significantly different from the equation for palmetto bass was made. Market weight variables and indexes were calculated as follows: eviscerated percentage = 100 × (weight of eviscerated fish/weight of fish); headed and eviscerated percentage = 100 × (weight of eviscerated fish without head/weight of fish); dressout precentage = 100 × (weight of fillet/weight of fish); HSI = 100 × (liver weight/weight of fish); GSI = 100 × (gonad weight/weight of fish); and VSI = 100 × (viscera weight/weight of fish).

Proximate analysis procedures.—Percent moisture was determined by drying samples for at least 7 d at 60°C in a convection oven (model 1349, Fisher Scientific, Cincinnati, Ohio). Ether extraction was used to determine percent lipid with the method detailed in AOAC (1975). Ash was determined by weighing the remaining residue after a sample was placed in a muffle furnace for 2 h at 610°C. The Hach (1990) modification of the AOAC (1975) method was used to determine percent protein. The Hach modification and the AOAC method have been shown to produce similar results (Watkins et al. 1987). Proximate analysis was determined for random samples of fish from each treatment group, as well as subsamples (N = 5) for all feeds used in this research.

Statistical analyses.—All data were analyzed with one-way analysis of variance (ANOVA) using the Statistical Analysis System (SAS Institute, Cary, North Carolina). If the ANOVA indicated significance ($P < 0.05$), then treatment means were subjected to Duncan's multiple-range test to observe where the differences occurred. In cases in which two means were being compared, t-tests were performed at an alpha level of 0.05. All percentage data were transformed to arcsine values or log values before analysis (Zar 1996). However, results given in tables represent untransformed data.

Results

Phase II Feeding Trial

The means for most water quality variables measured in this study remained within recommended ranges for hybrid striped bass culture (Table 1; Nicholson et al. 1990). The only exception was alkalinity, which had a mean value (38.8 mg/L) lower than is recommended (≥150 mg/L); however, this value was similar to the suggested minimum (40 mg/L) for general aquaculture (Boyd 1990).

Mean final weights of sunshine bass and white bass (124.2 g and 126.0 g, respectively) were significantly higher ($P < 0.05$) than the final weight for palmetto bass (93.5 g; Figure 1). Fish of each taxonomic group were equivalent in size at the time of stocking, but sunshine bass and white bass outgrew ($P < 0.05$) palmetto bass by day 14 of the study. This trend continued, and the margin of growth among the groups of fish widened until the termination of the study.

Sunshine bass and white bass had higher ($P <$ 0.05) relative growth (h), mean daily growth, and relative weight, as well as lower feed conversion ratios, than palmetto bass (Table 2). Survival for the taxonomic groups was excellent and did not significantly differ ($P > 0.05$). Sunshine bass had higher ($P < 0.05$) mean values for HSI and VSI than palmetto bass and white bass (Table 2). Differences ($P > 0.05$) among taxonomic groups were

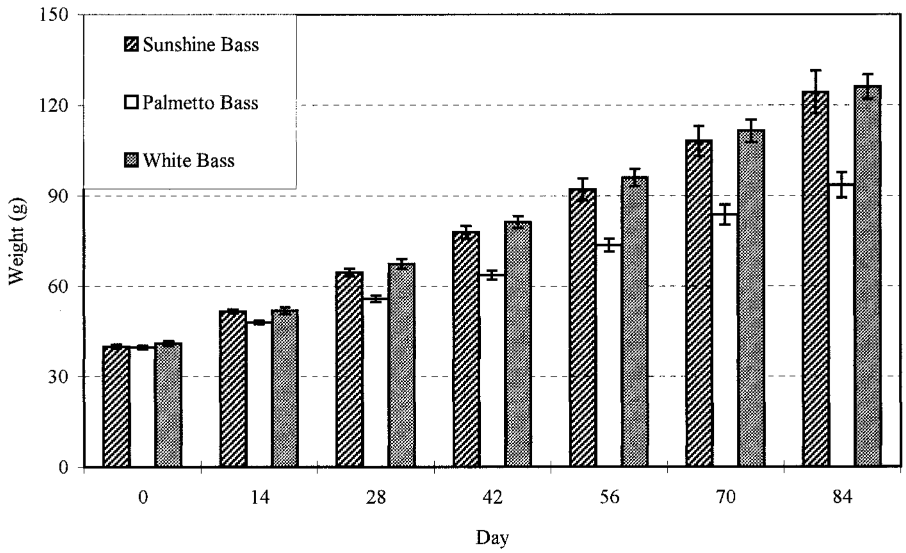

FIGURE 1.—Mean weights at 2-week intervals of phase II sunshine bass, palmetto bass, and white bass reared in an indoor recirculating-water system. Values are means (±SEs) of 10 replications.

not found for GSI mean values. GSI values for males and females are not reported separately because gonads between sexes were not visually distinguishable. Proximate analyses data were not significantly different ($P > 0.05$) among taxonomic groups (Table 3).

Phase III Feeding Trial

The ranges for most water quality variables remained within recommended ranges for hybrid striped bass culture throughout the duration of the study (Table 1; Nicholson et al. 1990). The mean value for alkalinity was again lower (43.1 mg/L) than is recommended (≥150 mg/L) but was above the minimum (40 mg/L) suggested for general aquaculture (Boyd 1990).

Mean final weights were significantly different ($P < 0.05$) among all taxonomic groups (Figure 2), with sunshine bass having the highest mean final weight (611.1 g), followed by palmetto bass (517.8 g) and white bass (254.4 g). At the initiation of the study, sunshine bass and palmetto bass had higher ($P < 0.05$) mean weights (177.5 g and 185.9 g, respectively) than white bass (153.8 g). Although initial mean weights differed, both crosses of hybrid striped bass had larger ($P < 0.05$) values for h (Table 4) than white bass, indicating higher relative growth, irrespective of initial weight. Mean weights of sunshine bass and palmetto bass were significantly different ($P < 0.05$) from one another on day 56 of the study.

Significant differences ($P < 0.05$) existed among all taxonomic groups for h and mean daily growth rate (Table 4). For these variables, sunshine bass exhibited the highest mean value, and palmetto bass and white bass had intermediate and lower values, respectively. White bass had a higher ($P < 0.05$) feed conversion ratio than either cross of

TABLE 2.—Performance of phase II sunshine bass, palmetto bass, and white bass reared in an indoor recirculating-water system. Values are means (±SEs) of 10 replications. Row means without a letter in common are significantly different ($P < 0.05$). See Methods for definitions of variables.

Variable	Sunshine bass	Palmetto bass	White bass
Relative growth (%)	210.07 ± 18.34 z	135.08 ± 10.18 y	212.38 ± 11.84 z
Mean daily growth (g/d)	1.00 ± 0.08 z	0.64 ± 0.05 y	1.01 ± 0.05 z
Feed conversion ratio	2.02 ± 0.14 z	2.63 ± 0.18 y	1.98 ± 0.06 z
Relative weight (%)	92.15 ± 1.18 z	83.96 ± 1.00 y	92.61 ± 0.68 z
Survival rate (%)	100.0 ± 0.0 z	100.0 ± 0.0 z	100.0 ± 0.0 z
Hepatosomatic index (%)	1.79 ± 0.10 z	1.31 ± 0.05 y	1.49 ± 0.10 y
Viscerosomatic index (%)	9.73 ± 0.21 z	7.84 ± 0.36 y	7.93 ± 0.22 y
Gonadosomatic index (%)	0.30 ± 0.04 z	0.34 ± 0.06 z	0.27 ± 0.04 z

TABLE 3.—Proximate analyses of muscle tissue (wet weight basis) of phase II sunshine bass, palmetto bass, and white bass reared in an indoor recirculating-water system. Values are means (±SEs) of 10 replications. Row means without a letter in common are significantly different ($P < 0.05$).

Component	Sunshine bass	Palmetto bass	White bass
Moisture (%)	76.5 ± 0.4 z	77.2 ± 0.3 z	77.0 ± 0.1 z
Crude protein (%)	18.3 ± 0.3 z	18.0 ± 0.5 z	18.2 ± 0.1 z
Lipid (%)	2.0 ± 0.1 z	2.0 ± 0.5 z	1.8 ± 0.1 z
Ash (%)	1.3 ± 0.03 z	1.3 ± 0.03 z	1.2 ± 0.07 z

hybrid striped bass. Survival was excellent for all three taxonomic groups ($P > 0.05$); only one fish died during the study, and it appeared to be due to handling stress. Mean relative weights for sunshine bass were higher ($P < 0.05$) than relative weights of palmetto bass and white bass.

There were no significant differences ($P > 0.05$) in eviscerated percentage, headed and eviscerated percentage, and dressout percentage between sunshine bass and palmetto bass (Table 4). These data were not collected for white bass because marketable size had not been attained at the termination of the study.

Sunshine bass had lower ($P < 0.05$) mean HSI values than palmetto bass and white bass (Table 4). Although not differing significantly from each other, both hybrid striped bass crosses had a higher ($P < 0.05$) mean VSI than white bass. No significant differences ($P > 0.05$) were detected for GSI between males and females within each taxonomic group (Table 5). Additionally, no significant differences ($P > 0.05$) were found for male GSI among taxonomic groups. However, female sunshine bass displayed a lower ($P < 0.05$) GSI than female palmetto bass and white bass.

Analysis of proximate composition data yielded significant differences ($P < 0.05$) in percent moisture and percent lipid among taxonomic groups, but no differences ($P > 0.05$) were found for percent ash and percent crude protein (Table 6). Sunshine bass had a significantly lower mean value for percent moisture when compared with palmetto bass and white bass. Significant differences ($P < 0.05$) for percent lipid were found among all three taxonomic groups, with sunshine bass having the highest mean value and white bass had the lowest.

Discussion

Phase II sunshine bass and white bass outperformed palmetto bass. Comparison of growth rates between crosses of hybrid striped bass yielded the same results for phase III fish: sunshine bass outperformed palmetto bass. In contrast to the phase II study, phase III sunshine bass and palmetto bass

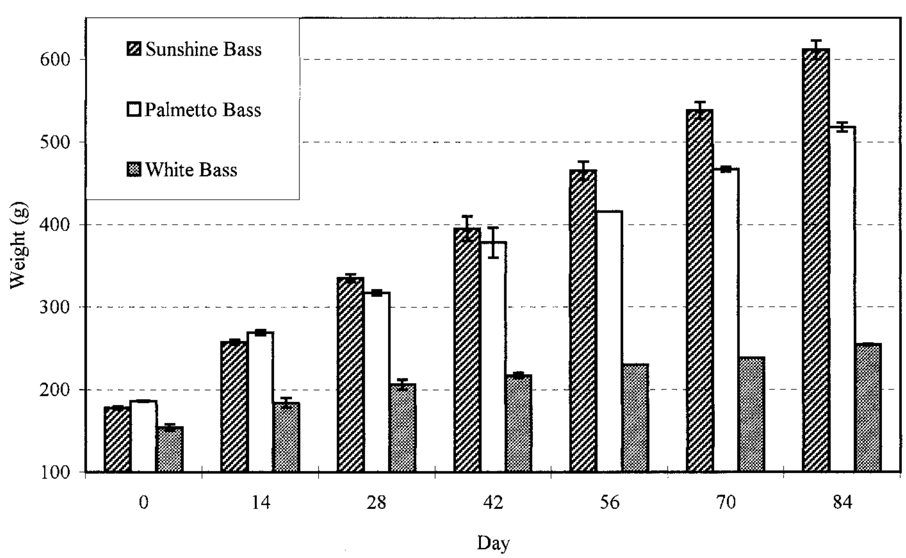

FIGURE 2.—Mean weights at 2-week intervals of phase III sunshine bass, palmetto bass, and white bass reared in an indoor recirculating-water system. Values are means (±SEs)of two replications.

TABLE 4.—Performance of phase III sunshine bass, palmetto bass, and white bass reared in an indoor recirculating-water system. Values are means (±SEs) of two replications. Row means without a letter in common are significantly different ($P < 0.05$). See Methods for definitions of variables.

Variable	Sunshine bass	Palmetto bass	White bass
Relative growth (%)	246.1 ± 2.6 z	180.7 ± 3.1 y	66.4 ± 3.4 x
Mean daily growth (g/d)	5.16 ± 0.11 z	3.95 ± 0.06 y	1.20 ± 0.03 x
Feed conversion ratio	1.28 ± 0.01 z	1.26 ± 0.03 z	1.88 ± 0.06 y
Relative weight (%)	116.6 ± 1.6 z	104.2 ± 2.6 y	98.5 ± 1.4 y
Survival rate (%)	100.0 ± 0.0 z	98.0 ± 2.0 z	100.0 ± 0.0 z
Eviscerated (%)	86.96 ± 0.13 z	87.83 ± 0.19 z	NA[a]
Headed and eviscerated (%)	63.18 ± 0.37 z	63.43 ± 0.24 z	NA[a]
Dressout (%)	33.6 ± 0.6 z	33.2 ± 0.1 z	NA[a]
Hepatosomatic index (%)	2.89 ± 0.04 z	3.41 ± 0.08 y	3.30 ± 0.05 y
Viscerosomatic index (%)	13.32 ± 0.07 z	12.55 ± 0.18 z	9.22 ± 0.52 y
Sex ratio[b] (%)	40:60:0	50:50:0	70:20:10

[a] Data not available because white bass had not attained marketable size at the termination of the study.
[b] Male : female : immature.

grew faster than white bass. Mean daily growth and feed conversion ratios of phase II palmetto bass and sunshine bass were similar to values reported in the literature (Table 7). Phase III sunshine bass and palmetto bass exhibited higher mean daily growth rates and lower feed conversion ratios than had been previously reported in the literature (Table 7). However, caution must be used when making comparisons of production variables among studies because experimental conditions such as size of fish, feed type, stocking density, tank size and shape, water quality, etc., can vary and affect growth positively or negatively. No reports were found describing growth of white bass in an aquaculture setting.

Performance of white bass relative to both crosses of hybrid striped bass was good at the phase II size but poor in the phase III study. One possible explanation for this decrease in performance is the onset of sexual maturity. It was hypothesized that the decrease in the growth rate of white bass corresponded with the onset of sexual maturity. This hypothesis seemed plausible because the lengths at which white bass begin the transition to sexual maturity matched lengths for white bass in the phase III study. In addition, lengths at which hybrid striped bass become sexually mature had not been attained and fish in the phase III study were presumably partitioning 100% of energy above maintenance costs into somatic growth. However, this hypothesis did not appear to be tenable because gonadosomatic values observed for the three taxonomic groups indicated that white bass gonads were as small or smaller than either cross of hybrid striped bass (Table 5). Although the onset of sexual maturity was not a factor in the decreased growth rate of white bass in the phase III study, it probably would be a factor for white bass at larger sizes.

TABLE 5.—Gonadosomatic index of phase III male and female sunshine bass, palmetto bass, and white bass reared in an indoor recirculating-water system. Values are means (±SEs) of two replications. Row means without a letter in common are significantly different ($P < 0.05$). Within taxonomic group, *t*-tests did not yield significant differences ($P > 0.05$) for gonadosomatic index between males and females.

Sex	Sunshine bass	Palmetto bass	White bass
Male	0.82 ± 0.17 z	0.95 ± 0.02 z	0.76 ± 0.03 z
Female	0.66 ± 0.02 z	0.89 ± 0.03 y	1.00 ± 0.00 y

A more reasonable explanation for the relatively poor performance of white bass in the phase III feeding trial considers differences in the maximal sizes that white bass and hybrid striped bass can attain. Hybrid striped bass can reach sizes greater than 10.9 kg, whereas a very large white bass may weigh about 1.8 kg (Kohler 1997). Therefore, it is reasonable to assume that white bass growth rates would decrease before those of hybrid striped bass, resulting in decreased relative performance in the phase III feeding trial.

A marked increase in growth was observed for palmetto bass in the phase III feeding trial versus the phase II study. It was initially thought that tank shape might account for the relatively poor performance of palmetto bass in the phase II grow-out trial. However, the results of a preliminary study that investigated the effects of tank shape on growth indicated that palmetto bass performed as well or better in square enclosures as in round ones (Rudacille 1998). Another possible explanation for the difference in performance was stock-

TABLE 6.—Proximate analyses of muscle tissue (wet weight basis) of phase III sunshine bass, palmetto bass, and white bass reared in an indoor recirculating-water system. Values are means (±SEs) of two replications. Row means without a letter in common are significantly different ($P < 0.05$).

Component	Sunshine bass	Palmetto bass	White bass
Moisture (%)	73.9 ± 0.2 z	75.9 ± 0.4 y	76.6 ± 0.1 y
Crude protein (%)	18.6 ± 0.2 z	18.0 ± 0.2 z	18.1 ± 0.1 z
Lipid (%)	5.8 ± 0.21 z	3.7 ± 0.39 y	2.6 ± 0.04 x
Ash (%)	1.2 ± 0.031 z	1.3 ± 0.071 z	1.3 ± 0.001 z

ing density. The stocking density in the phase II trial was much higher than in the phase III trial (142 fish/m³ versus 19 fish/m³). This decrease in stocking density could have accounted for the increase in growth rate. A third explanation involves the lapse of knowledge regarding growth between the sizes of 125 g and 175 g for sunshine bass, palmetto bass, and white bass. Results from the phase II study indicated that palmetto bass grew slower than sunshine bass or white bass up to a size of 125 g, but both crosses of hybrid striped bass started at similar sizes (~182 g) at the initiation of the phase III study. Like the phase II study, sunshine bass outperformed palmetto bass

TABLE 7.—Values for mean daily growth and feed conversion ratio in the phase II and phase III feeding trials of sunshine bass, palmetto bass, and white bass and values found in the literature, as well as additional variables known to influence production.

Taxonomic group	Tank shape	Feed type (% protein, % lipid)	Density (fish/m³)	Initial weight (g)	Mean daily growth (g/d)	Feed conversion ratio	Reference
Sunshine bass	Rectangular	Bass (42, 8)	142	40.0	1.00	2.02	Phase II feeding trial
Palmetto bass				39.7	0.52	2.63	
White bass				41.0	1.01	1.98	
Sunshine bass	Circular	Trout (40, 10)	19	177.5	5.16	1.28	Phase III feeding trial
Palmetto bass				185.9	3.95	1.26	
White bass				153.8	1.20	1.88	
Striped bass	Circular	Trout	35	30.0	NA[a]	2.57	Smith et al. 1985
Palmetto bass			66	46.6		2.61	
Palmetto bass	NA[a]	35% protein	66	23.0	0.94	5.5	Wolters and DeMay 1996
Palmetto bass	Circular	Trout (38, 8)	9	53.0	1.31	1.56	Woods et al. 1985
			18		0.99	1.94	
Palmetto bass	Cylindrical	Trout (38)	56	23.2	1.46	1.7	Jenkins et al. 1998
			19	474.9	1.90	2.7	
Striped bass	Circular	Trout	32	4.4	1.05	2.32	Smith et al. 1985
Sunshine bass				6.4	1.78	2.21	
Sunshine bass	Circular	Trout (36, 10)	100	100.0	2.3	1.4	Kelly and Kohler 1996
	Rectangular				2.4	1.4	
Sunshine bass	Rectangular	Trout (44, 8)	250	5.0	0.61	1.19	Brown et al. 1993
		Trout (35, 10)			0.39	1.25	
		HSB[b] (42, 4)			0.31	1.41	
Sunshine bass	Rectangular	Trout (35, 10)	250	11.3	0.86	1.04	Brown et al. 1993
		Catfish (36, 8)			0.57	1.33	
		Salmon (55, 15)			1.31	0.83	
Sunshine bass	Rectangular	Experimental (54, 16)	1.5	207	2.82	1.05	Tucker et al. 1993
		Trout (42, 9)		205	2.04	1.34	
Sunshine bass	Circular	Experimental (54, 16)	2.9	213	2.18	1.05	Tucker et al. 1993
		Trout (42, 9)		214	1.30	1.56	
Sunshine bass	Rectangular	Experimental (54, 16)	1.5	348	2.82	2.92	Tucker et al. 1993
		Trout (42, 9)		307	1.56	4.87	

[a] Data not available.
[b] Hybrid striped bass.

at phase III sizes, but the margin of growth may have been even larger between the two crosses of hybrid striped bass if a study had run continuously from phase II (40 g) to market size (~575 g).

In the phase III study, values for eviscerated percentage, headed and eviscerated percentage, and dressout percentage were similar for both crosses of hybrid striped bass, and were comparable to those values reported by Swann et al. (1994). Results regarding HSI and VSI indicate that different strategies for the partitioning of stored energy may be employed at different sizes. Significant amounts of lipid and glycogen can be stored in the livers of fish (Hoar and Randall 1971). Sunshine bass had smaller mean HSI values in the phase II study, but larger mean values in the phase III study. A possible explanation for this difference may lie in changes in energy storage strategies at different growth intervals. Similar to the liver, intraperitoneal fat (IPF) is the primary way that energy reserves are expressed in fish. Observations in these studies showed that IPF was a major contributor to the total weight of the viscera. Palmetto bass had much higher VSI values in the phase III study versus the phase II study. Once again, this finding may signify changes in energy storage strategies during different growth stanzas and shows that further investigation is needed to understand these ontogenetic differences.

Numerous studies demonstrate that both crosses of hybrid striped bass have tremendous potential for aquaculture development. However, an assumption was made that production characteristics of sunshine bass and palmetto bass are equivalent. The present study indicates that for the strains of fish used, and under the conditions of these studies, sunshine bass significantly outperform palmetto bass at phase II and phase III sizes. This finding is significant, and if it holds true for other strains and rearing conditions, then sunshine bass should become the preferred hybrid for performance features as well as convenience for fingerling production. Results of these studies support producers rearing sunshine bass under similar conditions. However, for producers rearing palmetto bass under comparable conditions, these results indicate that their choice may need to be reconsidered. Factors specific to their facility, such as historical growth rates, stocking density, feed qualities and regime, and other local conditions, should be compared with those in the present studies. Comparing these factors will indicate whether that producer should continue to culture palmetto bass or make the transition to rear sunshine bass. Further studies examining additional strains in various culture systems, including ponds, are needed to verify the apparent performance advantages of sunshine bass.

Other findings of this research showed that white bass performed well in the phase II study but performed relatively poorly in the phase III feeding trial. Both crosses of hybrid striped bass grow faster than striped bass during the first two years of life. Based on results from these studies, it appears that the same is true of the other parental species, white bass.

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