Comparison of Growth, Feed Conversion and Survival of *Morone saxatilis* female x *M. mississippiensis* male and *M. saxatilis* female x *M. chrysops* male Hybrids Reared in Recirculating Aquaculture Systems

B.G. Bosworth*[1], G.S. Libey[1] ,W.R. Wolters[2]

[1] Department of Fisheries and Wildlife Sciences
Virginia Polytechnic Institute and State University
Blacksburg, VA 24061 USA

[2] Catfish Genetics Research Unit
USDA-Agricultural Research Service
P. O. Box 38
Stoneville, MS 38776 USA

*Corresponding author, present address:
Catfish Genetics Research Unit
USDA-Agricultural Research Service
P. O. Box 38
Stoneville, MS 38776 USA

ABSTRACT

Striped bass female (*M. saxatilis*) x white bass male (*M. mississippiensis*), (SBxWB, n = 300) and striped bass female x yellow bass male (*M. chrysops*) (SBxYB, n = 300) fingerlings, initial mean weight 91 g and 62 g, respectively, were reared in recirculating aquaculture systems at densities of 118 fish/m^3 for 120 days. Mean weight increased 309 g and 151 g in SBxWB and SBxYB, respectively. Final mean weight and total length, and rate of weight and length increase were higher for SBxWB than SBxYB. Condition factor and survival were higher for SBxYB (1.04 and 99.3%, respectively) than for SBxWB (1.01 and 96.0%, respectively). Mean feed conversion ratio (FCR) was lower for SBxWB (1.4) than for SBxYB (1.6). Significant time x hybrid interactions indicated that growth rate of SBxYB improved, relative to SBxWB, as the study progressed. Positive linear trends for total ammonia, unionized ammonia, and nitrite indicate water quality deteriorated as the study progressed. Time x hybrid interactions for

growth rate may have been due to differential responses of SBxYB and SBxWB to deterioration of water quality. Although SBxYB had slightly better survival than SBxWB and their growth rate improved relative to that of SBxWB, the slow overall growth of SBxYB limits its potential for recirculating system production.

INTRODUCTION

Hybrids among species of the genus *Morone* appear to have good potential for commercial aquaculture (Van Olst and Carlberg 1990). All crosses attempted among the four *Morone* species endemic to North America [striped bass (*M. saxatilis*), white bass (*M. chrysops*), white perch (*M. americanus*), and yellow bass (*M. mississippiensis*)] have produced viable offspring (Kerby and Harrell 1990). The interspecies fertility of *Morone* allows production of a variety of species crosses, but the majority of studies have focused on evaluation of production traits of striped bass x white bass, F_1 hybrids. Compared to pure striped bass, striped x white bass hybrids (SBxWB) exhibit superior growth, disease resistance, survival and feed conversion (Logan 1968; Ware 1975; Smith et al. 1985; Kerby 1986; Tuncer et al. 1990).

Striped Bass x White Bass (SBxWB) hybrids generally have been superior to other *Morone* species hybrids in pond or flow-through production systems (Kerby and Joseph 1979, Kerby et al. 1987a, Zhang et al. 1994, Wolters and DeMay 1996). However, little information is available on performance of different *Morone* hybrids in the recirculating aquaculture system (RAS) environment. In RAS, water is filtered and reused, allowing production of more fish per unit volume of water used than in pond or flow-through systems. Due to high fish densities and low water exchange rates, maintenance of optimal water quality in RAS is problematic (Lucchetti and Gray 1988). Therefore, RAS represent a different environment than pond or flow-through systems. Striped Bass x Yellow Bass (SBxYB) hybrids may be useful for RAS production if they are more tolerant of poor water quality or are generally hardier than SBxWB. The objective of this study was to compare growth, feed conversion, and survival of SBxYB and SBxWB reared in RAS.

MATERIALS AND METHODS

RAS Design

The rearing system consisted of two, 1.2 m diameter (840 L capacity) fiberglass tanks, a rotating biological contactor filter (RBC) and a sump. The RBC, which provided a substrate for nitrifying bacteria, was constructed from polyvinyl chloride disks (BIOdeck12060, Munters Corp., Fort Myers, FL,USA). Rotating biological contactor (RBC) disks were connected to an aluminum shaft, which was rotated at 6 RPM by a 1/4 HP electric motor. The sump contained a multi-tube clarifier and a four inch layer of crushed oyster shell to facilitate collection of particulate matter. A submersible pump, located in the sump, circulated water through the system at 30 L/minute/tank. Aeration was provided by a surface agitator in each tank. Three replicate systems were used in the study.

Fish and Husbandry

Striped bass females from Toledo Bend Reservoir, Louisiana (USA), and yellow bass males from several lakes in Louisiana were used to produce SBxYB. Striped bass females from the Roanoke River, VA, USA; and white bass males from the Hyco River, VA, USA, were used to produce SBxWB. Prior to the study, SBxWB were reared in 5.8m diameter, circular fiberglass tanks at the Aquaculture Research Facility at Virginia Polytechnic Institute and State University (Blacksburg, VA, USA). SBxYB were initially reared in ponds at Ben Hur Research Farm, Louisiana State University, Baton Rouge, LA, USA. SBxYB hybrids were removed from ponds, transported to the Aquaculture Research Facility at Virginia Tech and acclimated to tank conditions for 7 weeks prior to initiation of this study. After the acclimation period SBxYB and SBxWB fingerlings were weighed, measured for total length, and stocked in separate tanks in each system at a density of 118 fish/m^3 (100 fish/tank). A total of 300 fingerlings from each hybrid were used in this study.

Fish were fed a 44% protein, floating pellet (Biosponge, Sheridan, WY, USA) to satiation twice daily. Weight of feed consumed by fish in each tank was recorded after each feeding. Sumps were drained and rinsed periodically to remove collected particulate matter. Sodium bicarbonate was added to increase water alkalinity to 150 ppm if levels fell below 75 ppm.

Data Collection and Analysis

A portable meter (YSI Co., Yellow Springs, OH, USA) was used to measure water temperature and dissolved oxygen in each tank daily. Total ammonia nitrogen (TAN), nitrite (NO_2-N), pH and alkalinity were measured 3 times per week, and water hardness and nitrate (NO_3-N) were measured weekly. TAN, NO_2-N, and NO_3-N were measured with a spectrophotometer (HACH Co., Loveland, CO, USA), pH was measured with a HACH pH pen, and alkalinity and hardness were measured by titration. Concentration of unionized ammonia (NH_3-N) was calculated according to Emmerson et al. (1975).

Fish were weighed, and measured for total length every 30 days. Absolute growth rate for length and weight, FCR (feed conversion ratio), and condition factor were determined for each 30 day period. SBxWB and SBxYB hybrids differed for length and weight at the beginning of this study, and it was not known if the differences were due to differences in pre-study environments or growth potential of hybrids. To alleviate biases due to initial size differences, relative and instantaneous growth rates for weight, which are less influenced by initial size (Hopkins 1992), were included in the analysis. Traits were defined as follows:

absolute weight gain = $(W_t - W_{t-1}) / (T_t - T_{t-1})$,
relative weight gain = $(W_t - W_{t-1}) / (W_{t-1}) \times 100$,
absolute length gain = $(L_t - L_{t-1}) / (T_t - T_{t-1})$,
FCR = (feed consumed from T_{t-1} to T_t)/ $(W_t - W_{t-1})$,
condition factor = W_t/W_{ts}.

W_t = fish weight at time t,
W_{t-1} = fish weight at time t-1,
L_t = length at time t,
L_{t-1} = length at time t-1,
T_t = number of days at time t,
T_{t-1} = number of days at time t-1, and
W_{ts} = length-specific standard weight at time t.

W_{ts} was calculated using an equation developed for *Morone* hybrids by Brown and Murphy (1991).

A randomized complete block design, with rearing system as the blocking factor and hybrid as the treatment, was used to compare means of traits of SBxYB and SBxWB. Tank means for water quality variables, growth traits, FCR and condition factor for each 30 day interval were analyzed with a repeated measures ANOVA (GLM Procedure, SAS 1985). Orthogonal polynomial contrasts, through the third degree, were used to analyze trends in variables over time. Polynomial coefficients for all variables were estimated and tested for differences between hybrids using procedures developed for repeated measures designs (Meredith and Stehman 1991). Survival of the two hybrids was compared with a 2x2 contingency table, adjusted for system effects (Frequency Procedure, SAS 1985). A p-value of < 0.05 was considered significant in all statistical analysis.

RESULTS

Water Quality

Of the water quality variables measured, only pH differed between hybrids, overall mean 7.9 and 7.8 (±0.01) for SBxYB and SBxWB, respectively. Means (±SE) for other water quality variables were: temperature 22.5°C (±0.01), dissolved oxygen 7.0 ppm (±0.01), TAN 0.64 ppm (±0.01),NH_3-N ppm 0.02 (±0.001), NO_2-N 0.26 ppm (±0.01), hardness 253.6 ppm (±3.0), and alkalinity 161 ppm (±1.0). Time x hybrid interactions were not significant for any water quality variables. Significant linear polynomial coefficients indicated water temperature, TAN, NH_3-N, NO_2-N, NO_3-N, and hardness increased; and dissolved oxygen and pH decreased as the study progressed. Polynomial coefficients for water quality variables were not different between hybrids.

Growth, FCR, Condition Factor and Survival

Mean weight, length, and all measures of growth rate were higher for SBxWB than SBxYB (Table 1). Time x hybrid interactions were significant for all measures of growth rate, and indicated that growth rate of SBxYB improved, relative to growth rate of SBxWB, during the study.

Table 1. Means (±SE) for weight, length, absolute weight gain (AWG), relative weight gain (RWG), absolute length gain (ALG), feed conversion ratio (FCR), condition factor, and survival for striped bass x yellow bass (SBxYB) and striped bass x white bass (SBxWB).

Time	Weight (g)	Length (mm)	AWG (g/day)	RWG (%)
Day 0				
SBxYB	61.6	166	—	—
SBxWB	91.7	194	—	—
(SE)	(1.0)	(1)		
Day 0-30				
SBxYB	95.8	189	1.1	55.9
SBxWB	173.3	227	2.7	88.7
(SE)	(6.1)	(1)	(0.2)	(5.8)
Day 30-60				
SBxYB	130.7	208	1.2	38.1
SBxWB	265.1	259	3.1	53.9
(SE)	(1.8)	(1)	(0.1)	(2.9)
Day 60-90				
SBxYB	170.3	228	1.3	29.5
SBxWB	336.9	285	2.4	27.1
(SE)	(3.2)	(1)	(0.3)	(1.0)
Day 90-120				
SBxYB	212.2	243	1.4	24.7
SBxWB	400.1	304	2.1	18.7
(SE)	(2.2)	(1)	(0.2)	(1.7)
Overall Mean				
SBxYB	—	—	1.3	37.1
SBxWB	—	—	2.6	47.1
(SE)			(0.02)	(0.8)
Effects[1]	(T,H,TxH)	(T,H,TxH)	(H,TxH)	(T,H,TxH)

[1] Effects of time (T), hybrid (H), or time x hybrid interactions (TxH) significant at $P < 0.05$

ALG (mm/day)	FCR	Condition Factor	Survival (%)
—	—	0.99	—
—	—	0.91	—
		(0.02)	
0.8	1.3	1.04	100
1.1	1.0	1.06	100
(0.02)	(1.0)	(0.02)	—
0.7	1.5	1.08	100
1.1	1.1	1.08	99.7
(0.03)	(0.02)	(0.02)	(0.3)
0.7	1.6	1.04	100
0.9	1.6	1.03	99.3
(0.02)	(0.02)	(0.01)	(0.1)
0.5	1.9	1.06	99.3
0.6	2.1	0.99	96.0
(0.04)	(0.21)	(0.01)	(0.2)
0.7	1.6	1.04	—
0.9	1.4	1.02	—
(0.01)	(0.04)	(0.004)	
(T,H,TxH)	(T,H)	(T,H,TxH)	(H)

Table 2. Polynomial coefficients for weight, length, absolute weight gain (AWG), relative weight gain (RWG), absolute length gain (ALG), feed conversion ratio (FCR), and condition factor for striped bass x yellow bass (SBxYB) and striped bass x white bass (SBxWB).

Polynomial coefficients[1,2]	Weight (g)	Length (mm)	AWG (g/day)	RWG (%)	ALG (mm/day)	FCR	Condition Factor
SBxYB							
Linear	37.6*	19.6*	0.1	-10.2*	-0.1*	0.01	0.2*
Quadratic	1.3	-1.1*	-0.01	3.2	0.0	-0.01	0.1
Cubic	0.1	-0.1	0.0	-0.9	-0.05	-0.01	0.04
SBxWB							
Linear	78.2*	27.8*	-0.3*	-23.6*	-0.2*	0.01	0.4*
Quadratic	-4.2*	-2.5*	-0.2	6.6	-0.1*	-0.03*	0.1
Cubic	-1.5	-0.5*	-0.2	1.7	0.02	0.01	-0.03
SBxYB vs. SBxWB	L	L,Q,C	L	L	L,Q		

[1] Values of coefficients are scaled to represent change per time period,
[2] L, Q, C indicate that linear, quadratic or cubic coefficients differed between SBxYB and SBxWB.
* indicates that the coefficient is different from 0 at $P < 0.05$.

Mean weight increased 309.2 g and 150.6 g in SBxWB and SBxYB, respectively, during the study. Overall mean (day 0-120) absolute weight gain, relative weight gain, and instantaneous rate of weight gain were 2.57 g/day, 338.1%, and 1.23 g/day, respectively, for SBxWB; and 1.26 g/day, 248.9%, and 1.03 g/day, respectively, for SBxYB. Absolute weight gain was highest (3.1 g/day) for SBxWB from day 30 to 60, and lowest (2.1 g/day) from day 90-120. Absolute weight gain of SBxYB was lowest (1.1 g/day) from day 0-30 and highest (1.4 g/day) from day 90-120.

Overall mean FCR was lower for SBxWB (1.4) than for SBxYB (1.6). The time x hybrid interaction was not significant for FCR. Feed conversion ratios were lowest from day 0-30 and highest from day 90-120 for both hybrids. Overall mean condition factor was higher for SBxYB (1.04) than for SBxWB (1.01). Time x hybrid interaction was significant for condition factor. Condition factor was lowest at the beginning of the study, and highest at day 60 in both hybrids. Survival of SBxYB (99.3 %) was higher than survival of SBxWB (96.0%).

Linear polynomial coefficients (Table 2) were positive for mean weight and length, and negative for relative weight gain in both hybrids. Linear coefficients were negative for absolute weight gain in SBxWB, but not different from zero in SBxYB. Quadratic coefficients were negative for length in both hybrids; and negative for absolute length gain and condition factor in SBxWB. Hybrids differed for linear coefficients for mean length, mean weight, and all measures of growth rate; quadratic coefficients for mean length and absolute length increase; and cubic coefficients for mean length. Linear coefficients for mean length and weight were greater for SBxWB than SBxYB. Linear coefficients absolute and relative weight gain were lower for SBxWB than SBxYB, indicating growth rate of SBxYB improved, relative to SBxWB, as the study progressed.

DISCUSSION

Because of its economic importance and ease of interpretation, researchers often include only rate of absolute weight gain in results of *Morone* growth trials. To facilitate comparison of the results of this study with other studies, the discussion of growth focuses primarily on absolute weight gain. Differences between hybrids for other measures of weight gain (relative and instantaneous) were similar to absolute weight gain; i.e. SBxWB had superior overall growth,but growth of SBxYB improved, relative to SBxWB, as the study progressed.

Mean absolute growth rate of SBxWB in this study (2.6 g/day), was similar to rates of 1.7-2.8 g/day (Nunley 1992) and 2.6 g/day (Smith et al. 1985) reported for similar size SBxWB reared in RAS. Growth rates of SBxWB reared in ponds, cages and flow-through systems range from 0.9 to 2.2 g/day (Williams et al. 1981; Woods et al. 1983; Kerby et al. 1987b; Zhang et al. 1994, Wolters and DeMay 1996), and are typically lower than growth rates of SBxWB reared in RAS. Mean FCR for SBxWB in this study (1.41) was at the lower end of the range of FCRs (1.3-2.4) reported for SBxWB in other studies (Woods et al. 1983; Smith et al. 1985; Kerby et al. 1987; Nunley 1992). A pattern of increased FCR with increased fish size was observed in both hybrids, and is typical for fish (Brett 1979). Survival of SBxWB, 96%, was similar to survival of SBxWB in other RAS trials, > 90% (Smith et al. 1985; Nunley 1992), and generally higher than survival of SBxWB (47%-95%) observed in previously cited pond and flow-through trials.

Absolute weight gain, FCR, and survival (1.26 g/day, 1.59, and 99.3%, respectively) of SBxYB in this study, were superior to the same traits for SBxYB reared in pond water, flow-through systems (0.59 g/day, 3.8, and 64.7%, respectively, DeMay and Wolters 1996), and in static ponds (1.17 g/day, 1.48, and 74.0%, respectively, Zhang et al. 1994). Our results and those of Zhang et al. (1994) and Wolters and DeMay (1996) indicate that SBxWB grow faster than SBxYB in all rearing environments tested. The difference in survival of SBxYB and SBxWB observed in this study was significant but small (3.3%). However, fish from this study were maintained in tanks for further studies and mortalities of SBxWB increased to about 20% while mortalities of SBxYB remained near zero during this time.

For the size range of fish used in this study, absolute weight gain of pond-reared SBxWB increased or stabilized as fish size increased. However, in this and other RAS studies (Smith et al. 1985; Nunley 1992) declines in growth of SBxWB have been reported. In contrast, absolute weight gain of SBxYB increased slightly over time. The presence of time x hybrid interactions for measure of weight gain in RAS, and the lack of similar interactions in flow-through systems (Wolters and DeMay 1996) suggest that genotype x rearing environment interactions influence performance of *Morone* hybrids.

Prolonged exposure to deteriorated water quality has been proposed as the cause of the decreased growth rates observed in SBxWB reared in RAS (Smith et al. 1985; Nunley 1992). Specific water quality variables responsible for inhibiting growth of SBxWB in RAS have not been identified, but unionized ammonia (NH_3-N), nitrite (NO_2-N) and dissolved organics have been implicated in inhibiting growth of other intensively reared fishes (Robinette 1976; Colt and Armstrong 1981; Sodeberg et al. 1983; Hirayama et al. 1988). Levels of NH_3-N, NO_2-N and dissolved organics are expected to increase with time in RAS, due to increases in fish biomass and feed inputs (Easter 1992). Dissolved organics were not measured in this study, but NH_3-N and NO_2-N did increase as this study progressed, and may have resulted in the reduced absolute growth rate observed in SBxWB.

Regardless of the specific cause, it appears SBxYB were less negatively impacted by prolonged exposure to the RAS environment than SBxWB. Water quality was similar for both hybrids, thus the differences in growth patterns between hybrids appeared to be due to different responses to a common environment. Different responses of SBxWB and SBxYB to deteriorating water quality seems to be the most probable explanation for the time x hybrid interactions for growth.

Potential confounding factors in this study were the use of different striped bass parental stocks in the two hybrids and differences in pre-study rearing environments. We were unable to use the same striped bass parental stocks due to differences in the availability of reproductively mature fish from the required male and female species. However, Wolters and DeMay (1996) observed similar differences in growth (SBxWB grew faster than SBxYB) using striped bass female parents from a common stock, suggesting the differences we observed were more likely due to differences in male parental species used than striped bass female stocks used as parents. There were differences in pre-study rearing environments between the two groups of fish, but all fish were reared in the RAS environment for 7 weeks prior to beginning data collection, which should have helped to reduce pre-study environmental differences.

The apparent superior resistance of SBxYB to prolonged exposure to the RAS environment may be of some benefit. However, the slow growth of SBxYB limits their commercial aquaculture potential. Incorporation of yellow bass genome in *Morone* crossbreeding programs would be beneficial if hardiness of progeny can be improved, without unacceptable decreases in growth rate. Design of appropriate crossbreeding strategies, coupled with improved water treatment technology, should result in improved fish growth, and improve economic feasibility of RAS culture of *Morone*.

REFERENCES

Brett, J.R. Bioenergetics and Growth. In Fish Physiology, Volume VIII. Hoar, W.S., Randall, D.J., and Brett, J.R., Eds. **1979**. Academic Press: London, UK.

Brown, M.L., Murphy, B.R. Standard Weight (Ws) Development for Striped Bass, White Bass, and Hybrid Striped Bass. *North American Journal of Fisheries Management* **1991**. *11*, 451-467.

Colt, J.E., Armstrong, D.A. Nitrogen Toxicity to Crustaceans, Fish and Mollusks. In Proceedings of the Bio-engineering Symposium for Fish Culture. Allen, L.J. and Kinney, E.C., Eds., **1981**. Fish Culture Section, American Fisheries Society, Bethesda, MD, USA.

Easter, C.C. **1992**. Water Chemistry Characterization and Performance of a Recirculating Aquaculture System Producing Hybrid Striped Bass. Master's thesis, Virginia Polytechnic Institute and State University, Blacksburg, VA, USA.

Emmerson, K., Russo, R.C., Lund, R.E., Thurston, R.V. Aqueous Ammonia Equilibrium Calculations: Effect of pH and Temperature. *Journal of the Fisheries Research Board of Canada* **1975**. *32*, 2379-2383.

Hirayama, K., Mizuma,H., Minze, Y. The Accumulation of Dissolved Organic Substances in Closed Culture Systems. *Aquaculture Engineering* **1988**. *7*, 73-87.

Hopkins, K.D. Reporting Fish Growth: A Review of the Basics. *Journal of the World Aquaculture Society* **1992**. *23*, 173-179.

Kerby, J.H. Striped Bass and Striped Bass Hybrids. In Culture of Nonsalmonid Freshwater Fishes. Stickney, R.R., Ed. **1986**. CRC Press: Boca Raton, FL, USA.

Kerby, J.H., Harrell, R.M. Hybridization, Genetic Manipulation, and Gene Pool Conservation of Striped Bass. In Culture and Propagation of Striped Bass and its Hybrids. Harrell, R.M., Kerby, J.H., and Minton, R.V., Eds. **1990**. Striped Bass Committee, Southern Div., American Fisheries Society, Bethesda, MD, USA.

Kerby, J.H., Joseph, E.B. Growth and Survival of Striped Bass and Striped Bass x White Perch. *Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners* **1979**. *32*, 715-726.

Kerby, J.H., Woods, L.C., Huish, M.T. Pond Culture of Striped Bass x White Bass Hybrids. *Journal of the World Mariculture Society* **1983**. *14*, 613-623.

Kerby, J.H., Hinshaw, J.M., Huish, M.T. Increased Growth and Production of Striped x White Bass Hybrids in Earthen Ponds. *Journal of the World Aquaculture Society* **1987**a. *18*, 35-43.

Kerby, J.H., Huish, M.T., Klar, G.I., Parker, N.C. Comparative Growth and Survival of Two Striped Bass Hybrids, a Backcross, and Striped Bass in Earthen Ponds. *Journal of the World Aquaculture Society* **1987**b. *18*, 10A (Abstract).

Logan, H.J. Comparison of Growth and Survival Rates of Striped and Striped x White Bass Hybrids Under Controlled Environments. *Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners* **1968**. *21*, 260-263.

Luchetti, G.L., Gray, G.A. Water Reuse Systems: A Review of Principal Components. *The Progressive Fish Culturist* **1988**. 50:1-6.

Meredith, M.P., Stehman, S.V. Repeated Measures Experiments in Forestry: Focus on Analysis of Response Curves. *Canadian Journal of Forestry Research* **1991**. *21*, 957-965.

Nunley, C.E. **1992**. Production of Hybrid Striped Bass (*Morone chrysops* x *Morone saxatilis*) in a Recirculating Aquaculture System. Master's thesis, Virginia Polytechnic Institute and State University, Blacksburg, VA, USA.

Robinette, R.H. Effect of selected sublethal levels of ammonia on the growth of channel catfish (*Ictalurus punctatus*). *The Progressive Fish Culturalist* **1976**. *38*, 126-141.

SAS. **1985**. SAS User's Guide: Statistics. SAS Institute Inc., Cary, NC, USA.

Smith, T.I.J., Jenkins, W.E., Snevel, J.F. Production Characteristics of Striped Bass (*Morone saxatilis*) and F1, F2 hybrids (*M. saxatilis* x *M. chrysops*) Reared in Intensive Tank Systems. *Journal of the World Mariculture Society* **1985**. *16*, 57-70.

Soderberg, R.W., Flynn, J.B., Schmittou, H.R. Effects of Ammonia on Growth and Survival of Rainbow Trout in Intensive Static Water Culture. *Transactions of the American Fisheries Society* **1983**. *112*, 448-451.

Tuncer, H., Harrell, R.M., Houde, E.D. Comparative Energetics of Striped Bass (*Morone saxatilis*) and Hybrid (*M. saxatilis* x *M. chrysops*). *Aquaculture* **1990**. *66*, 387-400.

Van Olst, J.C., Carlberg, J.M. Commercial Culture of Hybrid Striped Bass: Status and Potential. *Aquaculture Magazine* **1990**. *16*, 49-59.

Ware, F.J. Progress with *Morone* Hybrids in Fresh Water. *Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners* **1975**. *28*, 48-54.

Williams, J.E., Sandifer, P.A., Lindbergh, J.M. Net-pen Culture of Striped x White Bass Hybrids in Estuarine Waters of South Carolina: A Pilot Study. *Journal of the World Mariculture Society* **1981**. *12*, 98-110.

Wolters, W.R., DeMay, R. Production Characteristics of Striped Bass x White Bass and Striped Bass x Yellow Bass Hybrids. *Journal of the World Aquaculture Society* **1996**. *27*, 202-207.

Woods, L.C. III, Kerby, J.H., Huish, M.T. Estuarine Cage Culture of Hybrid Striped Bass. *Journal of the World Aquaculture Society* **1983**. *14*, 595-612.

Zhang, Q., Reigh, R.C., Wolters, W.R. Growth and Body Composition of Pond-raised Hybrid Striped Basses, *Morone saxatilis* x *M. chrysops* and *M. saxatilis* x *M. mississippiensis*, Fed Low and Moderate Levels of Dietary Lipid. *Aquaculture* **1994**. *125*, 119-129.