Sunshine Bass Fingerling Culture in Tanks

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Keywords: sunshine bass, striped bass hybrids, *Morone* species, tank culture

Year-round production is a top priority of hybrid striped bass producers. Most *Morone* culturists produce sunshine bass (white bass ♀ X striped bass ♂) that have very tiny fry and require rotifers as their first food. Almost 100 percent of the fingerlings are produced in ponds where high survival rates depend on fry being stocked at the right time – before rotifer concentrations peak and before copepods appear. Pond culture drawbacks include the inability to monitor growth and survival and seasonal limitations due to weather. Tank culture overcomes these problems and is necessary for year-round production. Little tank fingerling production has occurred because costs are higher than for pond culture. Supplying live food is a major expense. Sunshine bass larvae are stocked at 4 to 5 days post hatch (dph) and are fed enriched cultured rotifers. The rotifers require microalgae. Within a few days the fry are weaned to cultured *Artemia* nauplii. The culture of the larger palmetto bass and striped bass starts with feeding *Artemia* nauplii. By about 15 dph, weaning to an artificial diet begins and is completed by 26 dph. Grading at that time reduces cannibalism. Live food culture is risky, and requires time, space, costs, and expertise. Recent innovations may alleviate some of these problems. High-density (up to 16,000/mL) rotifer production methods are being developed. These systems require constant feeding, oxygen, pH and ammonia control, suspended particle removal, and proper harvesting. Fatty-acid enriched algae pastes can replace cultured algae. Ammonia and pH problems can be controlled with products like

International Journal of Recirculating Aquaculture 7 (2006) 53-68.

Chloram-X® and auto-sensing pH controllers. Water is conserved by utilizing recirculation systems for rotifer and fingerling production. Use of commercially available decapsulated brine shrimp eggs further reduces time and physical risk. Increased demand for fingerlings during the winter and reduced culture costs will increase tank fingerling production.

INTRODUCTION

Year-round production of sunshine bass is a top priority of hybrid striped bass producers (Anonymous 1998). Currently, fry and fingerling production is confined to March through June, the normal spawning periods of the parental stocks (Mike Freeze, Keo Fish Farm, personal communication; Becker 1983). Fish reach market-size in 10 to 20 months after hatching, depending on stocking rates, culture conditions, and diet (Carlberg *et al.* 1989). As a result, it is difficult for fish farmers to provide hybrid striped bass of uniform size and quality to markets year-round. Consequently, prices also vary considerably during the year. It is important to develop culture techniques that will provide for year-round availability of sunshine bass fingerlings.

The culture of striped bass (*Morone saxatilis*) and its hybrids with white bass (*M. chrysops*) for the food-fish market is a recent endeavor. The initial incentive for *Morone* culture was to replenish wild populations of striped bass whose stocks had been depleted by over-fishing and habitat degradation. However, hybrids between striped bass and white bass grow faster, have better survival, and tolerate pond culture conditions better than striped bass (Bishop 1968; Logan 1968; Ware 1974; Kerby *et al.* 1983; Smith 1988). The original cross, palmetto bass, with a striped bass female parent was stocked into many inland reservoirs. The establishment of hatcheries and inducement of spawning by hormone injection greatly facilitated propagation of these fish (Stevens and Fuller 1962), and by the early 1980s more cultured fish than wild fish were being caught (McCraren 1984). Commercial fishing for striped bass was also closed to allow recovery of the stocks. That action precipitated the birth of a food-fish industry during the mid 1980s (Harrell and Webster 1997).

Evaluations of the hybrids for use in aquaculture indicated that they had higher potential than striped bass (Williams *et al.* 1981; Kerby *et al.* 1987; Woods *et al.* 1983) and by 1997, 87 percent of *Morone* producers cultured hybrids for market (Kahl 1997). Hybrid bass can be raised to commercial sizes in ponds (Wawronowicz and Lewis 1979), net pens (Williams 1971), raceways and cages (Powell 1973), and tanks (Smith *et al.* 1985). Before 1995, most grow-out production resulted from intensive tank culture. Today that method produces 45 percent, while 55 percent is from pond culture systems (Carlberg, *et al.* 2000).

The two hybrids, palmetto bass and sunshine bass (*M. chrysops* X *M. saxatilis*), are difficult to distinguish as adults, but they differ significantly as fry. Sunshine bass fry are much smaller than palmetto bass fry and are more difficult to culture because they require rotifers or other very small size zooplankton for their first food (Ludwig 1993, 2004). In spite of that, more sunshine bass are produced because of brood stock considerations: white bass females mature a year earlier, have less spawning mortality, and are less susceptible to stress than striped bass females. White bass females are also more widely available than striped bass females and are smaller and more easily handled.

Food-fish production of striped bass and its hybrids with white bass has grown tremendously since its inception. Between 1986 and 1993 production increased from 10,000 to 6 million pounds (Hodson 1995). By 2000, the industry was growing at a 7 percent rate and had reached fifth in volume and fourth in value of all food fish grown in the U.S. with an estimated 10 million pounds production level (Carlberg *et al.* 2000).

Fingerling Pond Culture

Nearly 100 percent of sunshine bass fingerling culture is now done in ponds (Ludwig 2004). Early attempts found fingerlings of this hybrid difficult to culture. Survival rates were highly variable and averaged about 10 percent (Ludwig 1993) when farmers stocked 5-day-old larvae about 2 weeks after ponds were filled and fertilized and contained concentrations of large zooplankton (Geiger 1983a,b; Geiger *et al.* 1985; Geiger and Turner 1990). That procedure, however, provided good survival rates of about 45 percent by 30 to 45 dph for striped bass or palmetto bass (Hodson 1995). But, the much smaller sunshine bass larvae (ca. 3-mm total length) were being stocked into ponds that no longer held many rotifers (Ludwig 1993) and probably contained copepods that ate the larvae (Valderrama *et al.* 2000). Ludwig (1993) found that highest sunshine bass survival rates are achieved when larvae are stocked just before the rotifers reach their peak numbers, 3 to 19 days after pond filling, depending upon temperature (Li *et al.* 1996; Ludwig 2000). Sunshine bass survival rates in commercial ponds where fry were stocked before the initial peak in rotifer concentration now average about 35 percent when harvested at 35 to 40 days (Jackson Currie, Small Fry Fish Farm, Wilmot, AR, USA, personal communication).

However, fingerling production in ponds has many limitations. It is often difficult to predict larvae acquisition times because brood stock are still mainly wild caught fish. Pond temperatures and zooplankton populations are also highly variable during the early part of the spawning season. High pH or un-ionized ammonia levels that accompany intense phytoplankton blooms, insect predation, temperature or chemical shock at the time of stocking, low dissolved oxygen concentrations, and other causes contribute to mortality and are difficult to control. Before harvest, fish mortality is also very difficult to determine. When mortality is high, ponds must be drained, refilled, refertilized, and restocked. Invasion of rooted macrophytes into ponds increases the amount of work necessary to harvest fingerlings and contributes to harvest mortality. Pond culture is also limited by weather conditions that are too cold during winter to allow production. Pond production also requires extensive level land area and particular soil types. Year-round culture of sunshine bass fingerlings in the U.S. requires indoor production facilities while water and energy costs require that recirculation systems be used.

Tank Culture of Fingerlings

Producing fingerlings indoors in tanks may overcome many of the difficulties of pond culture. Tank culture of striped bass fingerlings was first described by Snow *et al.* (1980), who fed freshwater rotifers *Brachionus calyciflorus* to the larvae. Lewis *et al.* (1981) provided a manual for tank culture of striped bass, and started feeding with *Artemia* nauplii at an initial rate of 50 to 60 L^{-1}. However, the small size of sunshine bass larvae requires the use of rotifers as a starting diet. The first report of sunshine bass fingerlings being raised in tanks was by Ludwig (1994) who used cultured freshwater rotifers, *B. calyciflorus*, before weaning the fry to salmon starter meal by 26 dph. Denson and Smith (1997) obtained better growth by starting with brackish water rotifers, *B. plicatilis*, followed by brine shrimp nauplii, and then weaning to a microencapsulated diet. Significant increases in survival and growth were found when rotifer and brine shrimp nauplii concentrations were increased (Ludwig 2003). Freshwater rotifers and other zooplankton harvested from ponds with a rotating drum filter equipped with a 60-μm mesh screen were also used by Ludwig and Lochmann (2000) to raise sunshine bass larvae to the time they were weaned to dry feed.

The optimum feeding rates for live food or prepared feed for tank culture of sunshine bass have not been determined. Ludwig (1994) added *B. calyciflorus* to tanks until the concentration was 20/mL for 22 mornings. After 10 days, he supplemented the rotifers with a salmon starter meal (45 percent protein). Denson and Smith (1996) fed *M. chrysops* fry highly unsaturated fatty acid (HUFA) enriched rotifers once per day at 10/mL for 6 days before weaning the larvae to brine shrimp nauplii (3/mL/day) and later to a dry diet, and obtained up to 48 percent survival by 27 dph. Denson and Smith (1997) also cultured sunshine bass larvae with *B. plicatilis* at 10/mL, weaned the larvae to *Artemia* nauplii at 3/mL/day, and obtained 67 percent survival by the end of 8 days. Ludwig and Lochmann (2000) harvested rotifers from ponds with drum filters and fed them to sunshine bass fry at 10, 20, and 30/mL/day. After 5 days, the zooplankton was supplemented with a 50 percent protein microencapsulated larval feed. By age 22 days, survival rates were 3.1 percent, 14.2 percent and 24.3 percent respectively. Ludwig (2003) compared survival of larval fish fed at three levels of rotifers, brine shrimp nauplii, and microencapsulated feed. Larvae fed the highest amount (60 HUFA-enriched rotifers/mL/day, 6 *Artemia* nauplii/mL/day and then 3 g feed/day) had a 52.9 percent survival rate by day 21 post hatch. To summarize, the highest sunshine bass survival rates during these studies were obtained with a feeding protocol that started with enriched rotifers, changed to brine shrimp nauplii, and then to a high-protein dry feed.

Enrichment of rotifers and *Artemia* with HUFA before using them as live feed appears to increase growth and survival of a variety of fish larvae (Lubzens *et al.* 2001). Lemm and Lemarie (1991) found that larval striped bass survival increased greatly when the *Artemia* that they were fed were enriched with HUFA. Essential fatty-acid nutrition has been determined for larval striped bass and palmetto bass (Tuncer and Harrell 1992), but not for sunshine bass. For fingerlings, Harel and Place (2003) found that sunshine bass and striped bass weight gain was less affected by dietary changes in HUFA than were white bass. Clawson and Lovell (1992) found that palmetto bass and striped bass larvae required a supplementation of n-3 HUFA during the time they are fed *Artemia*. Research is needed to determine optimum feeding rates and perfect live food enrichment.

Dependence on live microalgae cultures for rotifers has impeded the development of fingerling tank culture. Microalgae cultures require constant care, precise growing conditions, specialized equipment, and isolation to avoid contamination (Hoff and Snell 1997). Monocultures of rotifers are also very unstable, having sudden crashes in density, often from high pH and un-ionized ammonia fluctuations or contaminants introduced when live microalgae are used (Snell 1991). The commercialization of microalgae paste has greatly facilitated the culture of rotifers and reduced the risk of culture crashes. *Nannochloropsis* sp., *Isochrysus* sp., and other microalgae are concentrated and then refrigerated or frozen for long-term storage. During culture, they are diluted and can be supplied to the rotifer culture vessels via timer-controlled peristaltic pumps. The use of ammonia control chemicals (Chloram-X®, AmQuel®) particle traps, algae paste, and oxygen resulted in a fairly stable, semiautomated, high-density rotifer production system (Pfeiffer and Ludwig 2002). Ludwig (2003) successfully cultured rotifers with this system to produce sunshine bass fingerlings in tanks. The recent production of live, decapsulated brine shrimp eggs should also ease the difficulty in culturing sunshine bass fingerlings since it will eliminate the danger of using harsh chemicals and the time needed to decapsulate brine shrimp cysts before hatching them.

Eliminating the need for live feed would greatly enhance fingerling production. Webster and Lovell (1990) obtained 18 percent survival to 19 dph for striped bass fed only a commercially available dry diet. However, their results are equivocal because they did not have an unfed control: Rogers and Westin (1981) found that unfed striped bass larvae could survive up to 22 dph at 24°C and up to 32 dph at 15°C. Survival of sunshine bass fed only prepared feed has not been determined. Ludwig (1994) was able to wean 27-dph fry (21 percent survival) to a microencapsulated feed while no unfed larvae survived beyond 9 dph. Further research to determine the earliest fry can be weaned to a commercial diet is needed.

Optimum physical, chemical and biological environment for effective tank culture of fingerlings has also not been resolved. Fingerlings grown at 22.6°C water temperature (Ludwig 2003) were shorter than those grown at 25.6°C (Denson and Smith 1997). Woiwode and Adelman (1984) determined that 31°C was the optimum temperature for sunshine bass juvenile growth, while 26.8°C was optimum for juvenile palmetto bass (Woiwode and Adelman 1991). Optimum growth for striped bass fingerlings was determined to be 24°C by Cox and Coutant (1981), while Kellogg and Gift (1983) found the greatest growth of juvenile striped bass occurs at 28.5°C. Optimum temperatures for growth may be influenced by other factors. Woiwode and Adelman (1991) determined that optimum temperatures for growth of palmetto bass increased significantly when spring photoperiods were experienced and decreased when fish were exposed to decreasing photoperiods.

Stocking rates may have significant effects on growth and survival during tank fingerling culture but optimum stocking rates have not been determined for sunshine bass larvae. Lewis *et al.* (1981) recommended stocking striped bass larvae at 100 larvae/L, while Ludwig (1994) initially stocked sunshine bass at about 20/L but later increased the rate to 75/L (Ludwig and Lochmann 2000) and then to 80/L (Ludwig 2003). These rates are similar to the 75/L that Denson and Smith (1996) used for sunshine bass and white bass. No justification for the chosen stocking rate was given in any of the cited publications.

Most research on tank culture of fingerling sunshine bass has been performed in static or flow-through systems, but economics will most likely require that future indoor fingerling production systems will involve recirculation technology. Recently, a recirculation system for high-density rotifer production has been commercialized (Aquatic Ecosystems, Inc., Apopka, FL, USA). Commercial sunshine bass producers are attempting to develop economical recirculating fingerling culture systems (Lindell *et al.* 2004). In order for their efforts to be economically feasible, much of the research alluded to above will have to be carried out. In addition, it will be necessary to develop efficient ways to prevent cannibalism, grade fish, minimize and treat disease problems, minimize handling to avoid stress, and seamlessly convert from fingerling production to restocking for grow out in tanks.

Spawning

Year-round production of fingerlings requires year-round spawning of the parental species. That may be accomplished by compressing the annual photothermal regime, a subject extensively reviewed by Bromage *et al.* (2001). By this technique, maturation was advanced by 2 to 5 months for striped bass, white bass, and palmetto bass (Blythe *et al.* 1994a, b; Kohler *et al.* 1994; Smith and Jenkins 1984, 1986). Smith *et al.* (1996) extended the spawning of captive white bass by 3 months by holding mature fish at reduced water temperatures. Tate and Helfrich (1998) also used photothermal compression to offset spawning and advance sexual maturity of sunshine bass. Although the parental stocks of striped bass and white bass have been induced to spawn out-of-season, none of these studies produced hybrid sunshine bass. Research is needed to determine if off-season spawning and production of sunshine bass can be sustained.

Broodstock Development

Development of improved and domesticated broodstock is a high priority in the hybrid striped bass industry. Improvement of heritable traits of fish stocks is a cost-effective means of increasing profits. The high fecundity and large genetic variation for growth rate and other desirable traits of striped bass and white bass should facilitate selection for increased production. Brown (1989) indicated that doubling the harvest size may triple the market. Tave (1993) cites production gains of 10 percent to 20 percent per generation for several fish species. However, genetic selection for the hybrid striped bass industry will be complicated because not only must desirable traits be selected for in both parental stocks, but they also must be expressed in the hybrid offspring. Genetic improvement will very likely involve a program of reciprocal recurrent selection. This program involves identifying, selecting traits, and maintaining parental stocks that produce desirable traits in hybrid offspring.

At present, the industry depends primarily on the capture of wild broodstock. However, for genetic improvement to occur, broodstock must be domesticated, a *de facto* form of selection for tolerance of hatchery conditions (Hallerman 1994, Harrell 1984, Smith and Jenkins 1984, Woods *et al.* 1990). This has been done on a very limited scale within the industry, at the University of Maryland Crane Aquaculture Facility, and at only a few research facilities (North Carolina Sate University, Southern Illinois University). Strain evaluation for desirable traits must occur concurrently with domestication. Both parental stocks have widespread natural distributions in eastern North America but appear to show limited morphological variation (Waldman *et al.* 1988, Waldman and Wirgin

1995). However, some northern strains of striped bass fry grow faster than fry from southern strains (Brown 1994, Brown *et al.* 1998). That gradient was not evident when Jacobs *et al.* (1999) evaluated 19 other families for growth rate and found Maryland and Florida strains grew faster than South Carolina and New York strains. Some white bass strains have also been domesticated (Kohler *et al.* 1994, Smith *et al.* 1996), and comparisons of sunshine bass production from these strains indicated greater fillet dress-outs for fish of northern decent (Kohler *et al.* 2001). Heritability of these traits is unknown but it is essential that baseline information of genetic correlations among commercially important traits such as growth rate, disease resistance, and dress-out percentages be determined for a selective breeding program to develop (Hallerman 1994).

ACKNOWLEDGEMENTS

The author wishes to thank Jason Brown, Nancy Ludwig, and Drs. Ken Davis, Tim Pfeiffer and Peter Perschbacher for reviewing the manuscript before it was submitted for publication. The use of trade names does not imply endorsement by the U.S. Department of Agriculture or the author.

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