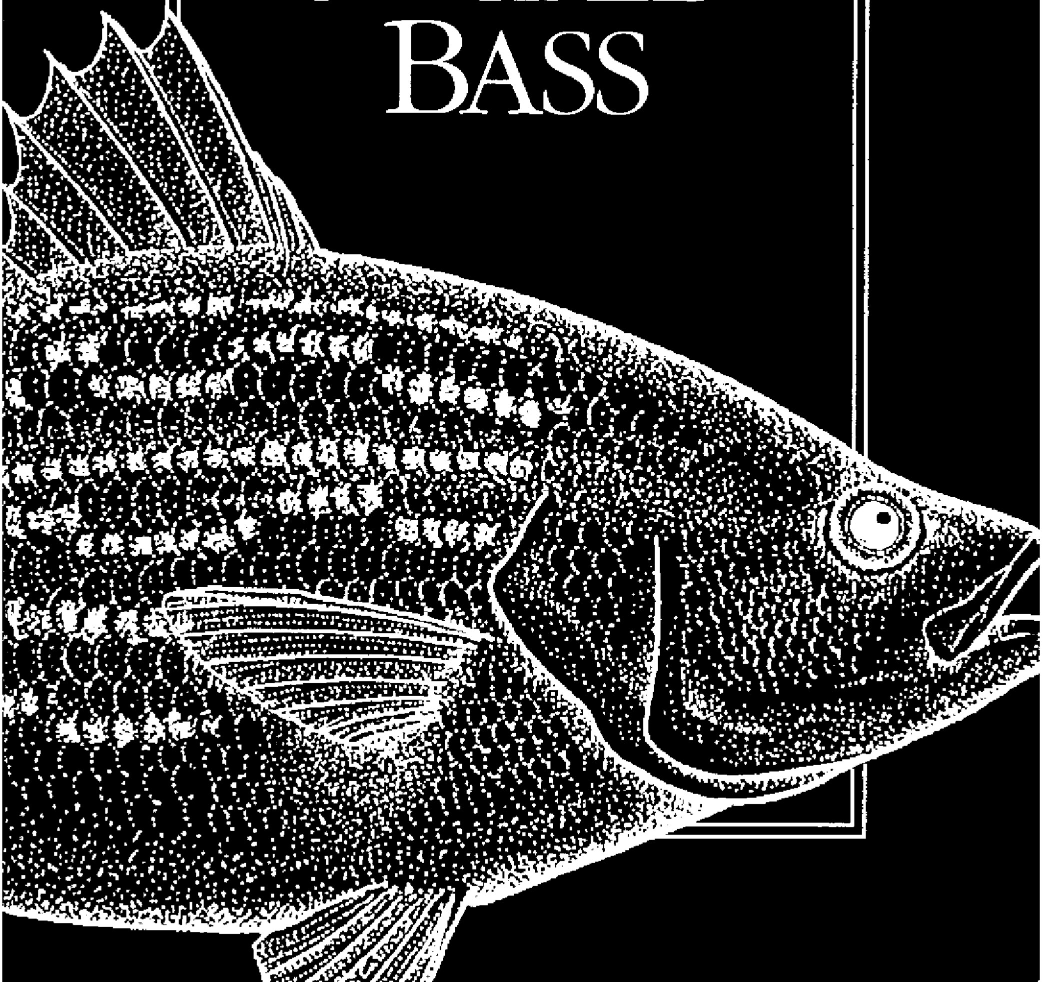
SCSGC-H-96-001

A GUIDE TO

POND CULTURE OF HYBRID STRIPED BASS



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This research and publication is a result of work funded by the S.C. Sea Grant Consortium, the NOAA Office of Sea Grant and Extramural Programs, U.S. Department of Commerce under Grant No. NA90AA-D-SG790 and the State of South Carolina. The U.S. Government is authorized to produce and distribute reprints for governmental purposes notwithstanding any copyright notation that may appear hereon. S.C. Department of Natural Resources, MRD Specific Scientific Report No. 16.

Revision date: October, 1996

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Preface. This manual focuses on the pond culture of hybrid striped bass, providing the reader with general guidelines and procedures associated with growing these fish. Many of the techniques discussed were developed through the support of the S.C. Sea Grant Consortium.

As with any business, success is a function of many considerations, including site selection, technical expertise and marketing opportunities. Prospective growers are encouraged to read other pertinent information in addition to this manual. A recommended reading list, as well as in-state sources of assistance, are found on pages 33–36. Interested individuals may also contact their local extension agent at the Clemson extension office in each county or the Waddell Mariculture Research and Development Center.

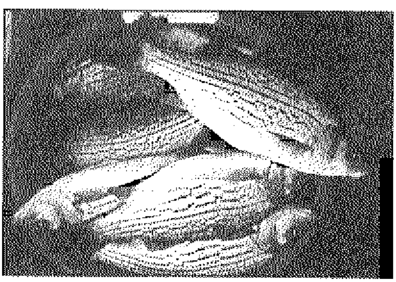
In South Carolina, the culture of hybrid striped bass is regulated by the S.C. Department of Natural Resources and a permit is required. For an aquaculture permit application and specific permit requirements, contact the Aquaculture Permit Office, S.C. Dept. of Agriculture, P.O. Box 11280, Columbia, S.C. 29211, phone (803) 734-2210.

Introduction. In recent years, efforts to farm striped bass, *Morone saxatilis*, and its hybrids have increased dramatically. This is partially due to restrictions on commercial landings of wild striped bass, which has resulted in a marketing niche for a cultured striped bass or a "striped bass-like" product. In addition, health concerns related to wild fishery products have stimulated consumer demand for cultured seafood products.

Cultured hybrid striped bass have been shown to be an acceptable market substitute for wild striped bass and grow more quickly to market size than do striped bass. From a business standpoint, hybrid striped bass exhibit a number of production characteristics which make them suitable for commercial farming.

Hybrid striped bass can be reared in a variety of culture systems including ponds, cages, raceways and tanks. Pond culture is the most popular, with farming operations being developed in many areas of the United States. This is particularly true in the Southeast where the climate allows outdoor pond production of food-sized fish in about 20 to 22 months. Also, a number of intensive tank culture operations have been established in which environmental parameters are controlled. These controlled culture systems are located in many areas of the country including the Northeast, Mid-Atlantic, Southeast and West Coast. Typically, investment costs are higher and the risks greater for the intensive tank systems as compared to pond culture operations.

Hybrid striped bass are a highly desirable seafood product.



Culturists prefer striped bass hybrids obtained from crossing white bass, *M. chrysops*, with striped bass. In South Carolina, wild white bass and striped bass broodstock must be caught by hook and line, abiding by recreational size and creel limits. Alternatively, broodstock can be obtained from legal commercial fisheries or by purchasing cultured progeny from permitted growers. In South Carolina, hybrids of striped bass and white bass can be legally cultured for food fish. Aquaculturalists who transfer fish in state must have a Hybrid Bass Aquaculture Permit. Retailers, wholesalers, processors and others in the food-service industry must obtain a permit to handle these fish in South Carolina. Permits are issued free to establishments selling to the final consumer.

Based on economic analyses of experimental and pilot-scale production data, opportunities for raising hybrids look promising. Prices received for cultured hybrids are generally higher than those for most other cultured fish and depend on the type of product (iced, gutted, live) and specific market (wholesaler, retailer, restaurant). Edibility and storage tests conducted by the Southeast Fisheries Center (National Marine Fisheries Service) in Charleston, S.C., indicate that the hybrid striped bass is a mild-flavored fish with good storage characteristics. Such qualities have high market appeal. Restaurant testing has shown that pond-reared hybrid bass have high consumer acceptance.

■ **Table 1.** Consumer Evaluation (1=Poor; 5=Excellent) of Hybrid Striped Bass in a Florida Restaurant.

Cooking Method	Evaluation Category				
	Appearance	Texture	Smell	Taste	Price*
Broiled	4.7	4.6	4.8	4.7	4.4
Fried	4.2	4.7	4.2	4.2	4.1
Grilled	4.4	4.4	4.4	4.3	4.3

* entrees priced at $10.95

Although the basic culture technology is known and production of hybrid bass is beginning to expand rapidly, there are still many unanswered questions. Concerns about diseases and parasites, nutrition, broodstock selection, water-quality requirements, marketing, etc., are only now starting to be addressed. Interested farmers should proceed with caution, recognizing that they will be entering at the development stage of an emerging industry. With proper nurturing, hybrid bass hold the promise of becoming the focus for a new and profitable industry.

Historical Development of Striped Bass Culture.

Striped bass were abundant and served as an important food source to early colonists. Commercial exploitation began during the 1800s, but by 1880, there was a noticeable decline in landings. This decline caused concern among fisheries workers and led to the first successful attempt at spawning ripe striped bass in 1880 on the Roanoke River in North Carolina. In 1884, the first striped bass hatchery was established at Weldon, N.C. This hatchery was supplied with ripe broodfish by fishermen. During the first year of operation, 298,000 larvae were hatched, of which 280,500 were released into the Roanoke River. During this period other hatcheries were established but were later discontinued due to the difficulty of obtaining ripe eggs and because benefits to commercial fisheries could not be documented based on releases of newly hatched fry. Of the early hatcheries, only the Weldon hatchery still operates.

In South Carolina, the Pinopolis Dam was completed in 1941 to form the Santee-Cooper Reservoir which was used to produce hydroelectricity. By 1950, large numbers of striped bass began to appear in recreational catches in this reservoir, and by 1953 the population was undergoing an exponential increase. Fisheries scientists determined that reproduction was occurring within the Santee Cooper system and that salt water was apparently not a physiological requirement for striped bass reproduction.

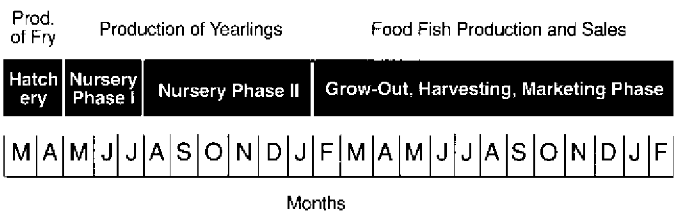
In other large reservoirs in South Carolina, gizzard shad, *Dorosoma cepedianum*, overpopulation had become a serious problem. In the Santee-Cooper Reservoir, striped bass fed on clupeid fishes such as gizzard shad and threadfin shad, *D. petenense*. Thus, fishery managers decided to introduce striped bass as a biological control in reservoirs overpopulated with shad. In 1954, several of the state's larger reservoirs were stocked with adult and subadult fish.

Likewise, other states began stocking striped bass to control shad populations. The stocked striped bass grew and survived well, but could not reproduce in most reservoirs, as the reservoirs did not have enough upstream river length and strong enough currents to keep the semi-buoyant striped bass eggs in suspension until they hatched. In 1961, a hatchery was constructed on the Tailrace Canal below Pinopolis Dam to produce striped bass for stocking various reservoirs and rivers in South Carolina. This hatchery, near Moncks Corner, was modeled after the one in Weldon, N.C. It operated until 1989 when a new hatchery was built in St. Stephen to use the rediverted flow of the Santee-Cooper Lake System.

Originally, all hatcheries had severe problems producing substantial numbers of fry. In 1961 at the Moncks Corner hatchery, more than 900 females were collected and examined, but none had free-flowing (ovulated) eggs. From 1962 to 1964, R.E. Stevens and co-workers tested seven hormones, alone and in various combinations, in an attempt to induce ovulation in striped bass. Of those tested, only human chorionic gonadotropin (hCG) and follicle stimulating hormone (FSH) induced ovulation when used alone. Of the two, hCG was the most practical because it was less expensive, acted more rapidly and required only one treatment.

This technique for hormone-induced spawning and detection of ovulation represented the first major breakthrough in striped bass culture and led to the rapid development of additional hatcheries and expansion of stocking activities. This spawning technique also allowed the development and testing of various hybrid crosses. The hybrids of choice for aquaculture today (crosses between striped bass and white bass) were first produced during 1965 to 1966 in South Carolina using this hormone-induced spawning technique, which allowed collection and artificial mixing of gametes from different species.

Hybrid Bass Aquaculture Production Plan. In the southeastern United States, pond production of market-size fish (about 1.5 to 2 lbs.) requires two growing seasons and usually consists of three production phases. Fish are spawned in March and April



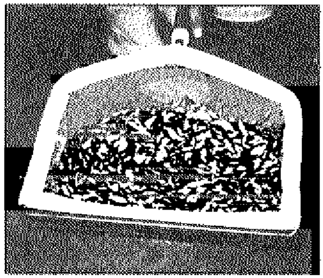
■ Figure 1. Generalized production scheme for pond culture of hybrid striped bass in temperate climates. Actual times may vary by location.

and the resulting fry stocked in nursery ponds (Phase I nursery ponds) where they are reared for about 30 to 60 days until they are about 1.5 to 2 inches long (Phase I fingerlings). Phase I fish are harvested and restocked at lower densities in Phase II nursery ponds and reared to 4 to 8 inches in length (Phase II fish or yearlings).

Between January and March, these fish are again harvested and restocked at lower density into grow-out ponds for final rearing to food-sized fish. Depending on many factors, including water quality, stocking density, type of feed and feeding techniques, the majority of these fish should grow to a size of 1.5 to 2 lbs. by late fall. Thus, production time required to produce food-sized fish is about 20 to 22 months.

During the past several years, the industry has developed substantially and the farmer can now enter at different levels of the production sequence. Thus, the farmer may wish to buy newly hatched fry for stocking Phase I nursery ponds, buy fingerlings for stocking Phase II nursery ponds, or buy Phase II yearlings for grow-out to food-sized fish. Fry, fingerlings and yearlings are all available, but at increasing costs depending on size. Most farmers purchase Phase I fingerlings and grow these to yearlings. These yearlings are then divided and grown to food size. However, in recent years some farmers bypass the second nursery phase and rear the small juveniles all the way to market size.

Fingerlings are typically produced in ponds.



The hybrid bass farmer may wish to specialize, becoming involved in either hatchery/fingerling production or food-fish production. In South Carolina, most of the larger-scale farmers attempt to integrate all production phases and sell their excess fish production from the various phases.

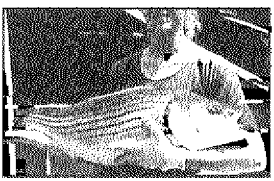
Site Selection. Site selection is one of the most critical determinants of the success of the aquaculture operation. Only areas with proper drainage and located out of the flood zone should be considered.

Soils must contain suitable amounts of clay to build ponds that hold water. They should be free of pesticide residues which are common to soils formally used for agricultural production. A dependable supply of high-quality water (fresh or brackish) must be available. Soils and water with marginal characteristics can sometimes be corrected through regular additions of various materials, but such modifications are often expensive and usually not economically acceptable in the long term.

It is far better to develop the correct site initially than to make major changes to a poor site. Site selection criteria should include sources of materials and labor, proximity to shipping and marketing channels, availability of technical assistance, ability to provide security to the facilities, etc.

Broodstock Collection and Maintenance. Wild broodstock can be collected using recreational fishing techniques (hook and line) or purchased through legal commercial fisheries in other states. If fishing by hook and line, creel and size limits must be followed. In some cases, adults are captured prior to the spawning season and reared in captivity using primarily live natural foods. The fish which mature in captivity can then be used during the natural hatchery season. More often however, ripe fish are obtained during the spawning season (typically March-April). When this occurs, the fish are normally provided spawning hormones shortly after capture to avoid regression of the gonads associated with the stresses of capture and handling.

Sexually mature striped bass female. Mature white bass are much smaller than striped bass.



In recent years, development of domesticated broodstocks has been a research priority. Results to date indicate that striped bass males can be produced in two years while females require 3-5 years to mature. In the case of white bass, both males and females can be grown to maturity in 2 years. In southern climates, striped bass broodstock are best produced in tanks to prevent the deleterious effects of high summer water temperatures on the females.

The care of broodstock will determine the usefulness of these fish to support hatchery operations. All captured/captive broodstock should be maintained in moderately sized holding tanks supplied with highly oxygenated clean water. A cylindrical tank receiving circulating water is preferred as such a system results in less stress than holding fish in small rectangular tanks containing static water. If fish are to be held for more than several days, they should be provided a nutritional diet consisting of natural foods and or high quality pelted rations.

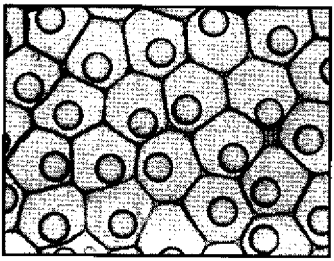
During the past decade, it has been shown that spawning of cultured/domesticated broodstocks can be accomplished by controlling the water temperature and photoperiod. Thus, it is now possible to conduct hatchery operations at different times during the year using different groups of broodstocks or 'cold-banked'(held in low temperature conditions ~12-14 C) populations.

For the new farmer, collecting and spawning broodstock, and producing fry can be difficult. It is suggested that new farmers wishing to focus on the food fish market purchase fry or fingerlings from established hatcheries to initiate grow-out production. Development of a hatchery can be phased into the operational plan once pond culture is underway.

Hatchery Techniques.

The first striped bass hybrids were produced in 1965 in South Carolina by crossing a female striped bass with a male white bass. They were called the "original cross" or "Palmetto Bass." The following year, a female white bass was crossed with a male striped bass, known as "reciprocal cross" or "Sunshine Bass." Both crosses have become very popular for recreational stocking programs and for use in aquaculture. Heterosis (hybrid vigor) occurs in these crosses and results in rapid early growth rates, greater disease resistance, improved survival and general hardiness.

Ovulated eggs are transparent and hexagonal in shape.



Spawning of ripe striped bass is accomplished by injecting the broodfish with hCG and or administration of a GmRHa (gonadotropic-releasing hormone analogue) pellet implant and then either stripping the sperm and eggs (gametes) and artificially mixing or by letting fertilization occur naturally via tank spawning. With the artificial method, the female's eggs are stripped at the time of ovulation and artificially fertilized with sperm (milt) stripped from the male. This technique is labor intensive and can cause damage to broodstock.

With the tank spawning method, hormone-treated males and females are place in tanks at a ratio of one female to three males. Tank spawning requires larger facilities to house spawning tanks but is less labor intensive and less damaging to broodstock.

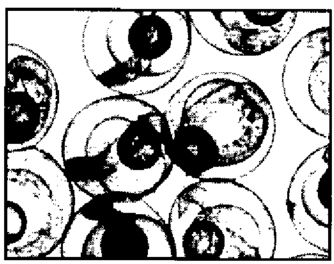
However, manual stripping and artificial mixing of gametes is required at the present time to produce hybrids because striped bass and white bass will not naturally tank spawn together even when injected with hormones. Historically, hCG was injected intramuscularly at a rate of 500 to

1,000 International Units (IU)/lb. for white bass females, 150 IU/lb. for female striped bass, and at about 75 to 200 IU/lb. for male striped bass and white bass, respectively. However, recent findings suggest that similar or improved spawning performance can be achieved with use of lower dosages (≤150 IU/lb) of hCG. Similarly, use of GnRHa implants with striped bass is an area of current focus. Present results suggest that a dose of about 5-10 µg/lb provided in a 95% chloresterol + 5% cellulose implant will induce ovulation in ripe striped bass. Such implants release GnRHa for up to several weeks.

Sometimes eggs from several females are simultaneously obtained and mixed with milt from several males. At other times, eggs from a single female are mixed with milt from one to several males. Currently, the sunshine bass is more commonly produced because female white bass are more readily available than female striped bass.

The eggs of striped bass and its hybrids are incubated in McDonald hatching jars at a density of approximately 100,000 to 250,000 eggs/jar (100-250 ml eggs/jar). Oxygenated water is injected through a center tube which causes continuous upwelling. The eggs hatch in about 48 hours depending on water temperature. Temperatures of 64° to 68°F are usually used to incubate the eggs. After the eggs hatch, fry swim up with the upflowing water and are collected in an adjacent tank.

Eggs hatch within 48 hours.

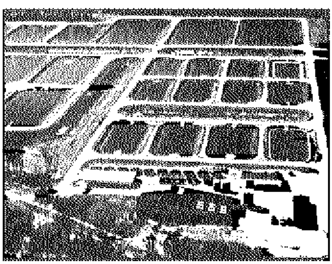


Striped bass eggs are semi-buoyant and easily kept rolling in the jars. White bass eggs, however, are highly adhesive and will form large clumped masses. This clumping is undesirable and can be prevented by adding a solution of 150 mg/1 (0.57 g/gal) tannic acid to the McDonald jars. The fertilized eggs are then added and vigorously aerated in the tannic acid solution for seven to 10 minutes before clean freshwater is flushed through the jars. The tannic acid solution reduces clumping and results in a higher hatch rate for reciprocal cross hybrid bass eggs. After this procedure, the same incubation technique is used as for the striped bass. More detailed hatchery procedures are provided in references listed in the suggested reading section at the end of this manual.

Pond Design & Preparation.

Pond size and shape are based on a variety of considerations including specific site characteristics, construction cost and management preference of the farmer. Rectangular ponds typically are about twice as long as they are wide: one to three acres for Phase I and Phase II nursery work and from one to five acres for final grow-out are recommended. Water depth should range from five to six feet at the deep end to a minimum of three to four feet at the shallow end. Pond banks should be sloped at about a 3:1 ratio depending on soil characteristics. Pond bottoms should be free of debris and sloped toward the drain.

Rectangular ponds utilize area more efficiently than other configurations and are preferred by farmers.



A harvest basin will reduce handling stress during harvest of Phase I and Phase II fish. A concrete basin which is two to three feet deep is suitable for holding fish produced during these phases. The pond outlet pipe should be large enough to drain the pond in a 24-hour period and must be below the level of the harvest basin or pond bottom so that complete and rapid pond drainage is possible. The main water inflow pipe should be at the shallow end to maximize water circulation during production. During harvest, clean water should be added from a water inlet pipe located at the harvest structure as well. The water discharge structure should be double screened to prevent escapement. For additional layout and construction information, contact your local Natural Resources Conservation office.

To prepare a pond for culturing hybrid bass, certain parameters must be tested. Soil pH is very important and should be at least 5.8. If the pH is lower than 5.8, agricultural limestone should be added to increase the pH to this level. Soil pH can be determined by collecting samples of pond soil from different areas, mixing them together and sending a subsample to the local county agent or land grant institution for analysis. Organic and inorganic fertilizers should be added to pond water of nursery ponds to induce unicellular algal blooms and zooplankton production. The zooplankton serve as the fry's initial food source. At the proper pH level, unicellular algal growth and reproduction can take place. These organisms are necessary to produce oxygen and shade out undesirable macrophytes (rooted vegetation) and are eaten by the zooplankton (small aquatic animals).

Ponds that are reused after a Phase I nursery harvest may not need fertilizers during filling as there is usually enough organic material remaining in recently harvested ponds to produce an algal bloom. Prior to filling any ponds, screens should be put in place and inspected to make sure that they have been installed properly and that no fish can escape.

Filling the ponds with water should be conducted over several days to initiate algal blooms; this technique is referred to as "puddling." Rapid filling can cause growth of rooted aquatic weeds which are difficult to control after they are established. When surface water is used for filling, it should be filtered through a mesh bag (400 micron) to prevent the introduction of predators and competitors. Pond filling should be completed before fish are stocked to prevent predation by wading birds.

Dissolved oxygen and temperature are two parameters that should be monitored prior to stocking the pond. Minimum oxygen concentration necessary for normal striped bass development is 3 ppm. However, oxygen concentration between 4 and 5 ppm is considered the minimum acceptable level for culture. In hybrid bass culture, dissolved oxygen often can reach low critical levels, especially during warm weather. Therefore, it is recommended that each pond be provided with electricity in case supplemental mechanical paddlewheel aeration is necessary. Alternatively, aeration can be provided by air blowers or, in emergencies, by tractor-powered paddlewheel aerators. Pond water temperatures between 58° and 70°F are recommended for stocking larvae. Once stocked, pond temperatures of 65° to 88°F are considered satisfactory for rearing. Optimum growth occurs at water temperatures of 75°-80° F.

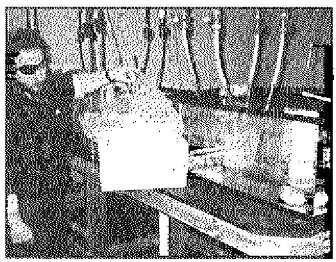
During the winter months, it is best to dry and disk the soil in ponds which are not holding fish. This kills various parasites and helps break down organic materials that may have accumulated in the pond bottom. Rye grass is sometimes planted to prevent erosion and serve as a source of organic fertilizer once the pond is refilled.

Stocking & Management of Nursery & Grow-Out Ponds.

Production of yearling hybrid bass is divided into two distinct nursery phases. Phase I lasts about 30 to 60 days, during which time newly hatched fry are stocked in the pond and reared to 1.5 to 2 inch fingerlings. Phase II requires about eight to 10 months, during which the 1.5 to 2 inch fingerlings are reared to a larger size (4 to 8 inches). These larger juveniles or yearlings are used to stock the final grow-out ponds where the food-sized fish are produced. Smaller ponds are generally used during the Phase I and Phase II nursery and larger ponds for production of food-sized fish. However, some farmers use the same ponds for all production phases.

Stocking density is established based on the size of fish and production level desired at harvest. Often economic risk and management capabilities are considered in determining stocking densities. Generally, higher stocking densities will yield smaller fish (e.g., 1000 fish/lb.), while lower stocking densities will yield larger fish (e.g., 500 fish/lb.) The recommended stocking rate for a Phase I pond is about 100,000 to 200,000 fry/acre.

Larvae are typically shipped in plastic bags containing oxygenated water.



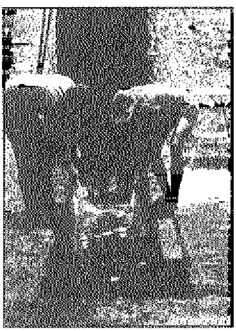
Fry should be transported from the hatchery in plastic shipping bags that are inflated with oxygen and placed in styrofoam shipping boxes. Fry can be shipped for up to eight hours at densities of 100,000 three-day old fry per three gallons of water.

Fry should be acclimated prior to being stocked in Phase I ponds. To do this, place the transport box containers with the fry on the pond bank. Next, slowly add pond water to the bag for a minimum of 20 to 30 minutes prior to releasing the fry. Fry should be stocked at or near sundown to avoid exposure to direct sunlight, which has been reported to cause significant mortalities.

Phase I juveniles should be fed a prepared ration at frequent intervals for at least two weeks prior to harvest, as the zooplankton population has usually been grazed to a low level. This may also help train the fish to eat prepared feeds.

Typical stocking density for Phase II ponds ranges from 10,000 to 25,000 1.5 to 2 inch fingerlings/acre. Survival rates among facilities will vary depending on many factors but should be in the range of 20 to 40 percent for production of Phase I fingerlings and about 60 to 80 percent for production of Phase II juveniles.

Harvest basins greatly reduce stress associated with fingerling harvest.



The supplemental feed used during the Phase I nursery should be small enough (#1 or #2 starter or crumbles) for the young fish and should be provided at least two times per day (early morning and afternoon). Supplemental feeding should begin about the third week or when the natural food in the Phase I pond is depleted. Often it is best to delay harvest of the Phase I fingerlings until they weigh 300 fish/lb. or measure 2 inches. Although 50 to 60 days may be required to produce fish of this size, these fish are more tolerant of handling stress and are more easily trained to eat artificial feed than smaller fingerlings. This is an important consideration when fish are used for aquaculture purposes, as compared to releasing them in the wild to support recreational fisheries.

Harvested Phase I fingerlings should be acclimated to Phase II pond or holding tank conditions before stocking if there are differences in pH, temperature, salinity or hardness between the hauling tank water and the pond water. Acclimation can be accomplished by exchanging water in the hauling tank over a one- to two-hour period. Fish should be stocked from the tank by a quick release system that discharges through a large pipe directly into the pond. Handling stress increases when fish are dip-netted from the tank. Transferring fish to soft waters (alkalinity <50 ppm) from hard water can result in significant mortalities up to one week after stocking. To reduce such losses fish are sometimes held in tanks containing hard water for three or four days after hauling and then slowly acclimated to the soft-water conditions.

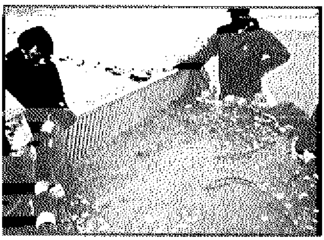
It is desirable to size grade fish and train them to accept prepared rations before stocking them into Phase II ponds. To accomplish this, fish are mechanically graded and stocked into tanks, cages or a netted-off section of the pond and fed frequently over a one- to two-week period. During this time, most fish will become accustomed to eating prepared feeds. This additional step in the production cycle will improve feed use and reduce population size variation of Phase II fish at harvest. However, there may be some increased mortality due to the additional handling stress during harvesting and stocking as well as cannibalism while in confined conditions.

Numbers of fish harvested and stocked should be estimated by weighing and counting several samples of fish. This will give you an average number of fish per unit of weight. As other fish are removed from the pond, group weights can be taken and used to estimate the total number harvested. All fish should be handled gently and weighed in water to reduce stress.

If fish are stocked directly in Phase II ponds, it is useful to estimate stocking mortality. Mortality can be estimated by walking the pond banks at sunrise for several mornings after stocking and counting dead fish. Alternatively, a small number of the fish to be stocked can be placed in a floating cage in the pond and their survival monitored for several days. Either way, be aware that birds will eat dying and dead fish; they also can remove fish from uncovered cages. If losses are higher than 5 to 10 percent, it is desirable to restock similar-sized fish to supplement the population.

Juveniles should be graded to improve uniformity in growth.

At harvest, the Phase II juveniles can range in weight from about 1/16 to 1/2 lb. Usually there is a considerable size range in the harvested population and it is often beneficial to grade the fish into at least two size groups and stock similar-sized fish in the grow-out ponds. Stocking densities for grow-out ponds should range from 2,500 to 4,000 fish/acre. The preferred time for grading and stocking is December to February when water temperatures are low (<59°F). As described for Phase I and II, fish should be acclimated to pond conditions before stocking. With proper pond management, a survival rate of 90 percent can be expected.



This final rearing phase of producing food-sized fish is practiced only by commercial aquaculture operations. State and federal hatcheries focus on the production of Phase I and II juveniles for stock enhancement purposes. General pond management techniques used during Phase I and II are applicable to the final grow-out phase as well.

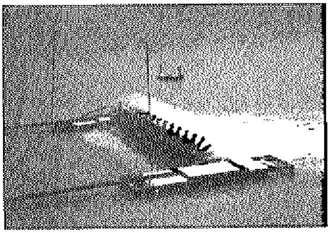
Monitoring Water Quality. Certain water-quality parameters should be regularly monitored throughout the complete culture cycle. Most water-quality parameters can be monitored with simple-to-use test kits or with more expensive electronic meters. Dissolved oxygen (D.O.), pH, temperature, carbon dioxide, ammonia-nitrogen, nitrite-nitrogen, hardness, alkalinity and light penetration are of primary importance.

Dissolved oxygen is defined as the amount of oxygen that is in solution in the water. Oxygen is produced via photosynthesis by phytoplankton during the day and often reaches its highest concentration late in the day near the surface; it generally decreases with depth. Oxygen also is transferred to the surface water through atmospheric exchange, especially on windy days. During the night, phytoplankton and the cultured fish consume oxygen and produce carbon dioxide. Dissolved oxygen should be monitored each morning at sunrise and in the late afternoon if dense algal blooms are apparent.

■ **Table 2.** Oxygen Content, at Saturation, of Fresh Water at Various Temperatures.

Temperature (°F)	Oxygen Content (ppm)
40	12.5
50	10.9
60	9.8
70	8.7
80	7.9
90	7.3

The amount of oxygen that can be dissolved in water decreases as temperature increases. Therefore, it may be necessary to aerate up to 24 hours per day or pump in highly oxygenated water during the summer (June to September) when dissolved oxygen concentrations tend to be low. Preferred D.O. levels are 5.0 ppm or higher throughout a well-mixed water column. D.O. should be measured at sunrise when levels are lowest. If the D.O. levels are 4.5 to 5.0 ppm with a dense phytoplankton bloom, it is advisable to closely monitor levels and be prepared to aerate, replace water and reduce feed as needed. Because oxygen is the most critical water-quality parameter, it is recommended that a dependable meter be used to monitor concentrations. Light penetration (a rough estimate of phytoplankton density) is measured with a Secchi disk. When readings are less than 16 inches, oxygen levels should be regularly monitored. Desirable Secchi disk depth readings are in the range of 18 to 25 inches taken when the sun is overhead.



Farmers should use aeration devices to maintain satisfactory dissolved oxygen concentrations.

Thermoclines are areas of steep temperature gradients which are the result of stratification of the water column into layers between which little or no mixing occurs. Thermoclines are usually recognized by an abrupt change in temperature at a certain depth. The danger of a thermocline in a pond is that the denser bottom water is often low in oxygen due to organic decomposition of uneaten food, feces, and dead or dying phytoplankton. A sudden mixing of the nutrient-rich low D.O. bottom water with the rest of the water column may result in a fish kill. Sometimes a strong wind or heavy rain will cause a "pond turnover" which also can result in a low oxygen induced fish kill.

Temperature should be measured daily both at the surface and the bottom to check for the formation of a thermocline. It is best to measure temperature at about the same time each day (e.g., at sunrise along with the D.O. check). The rate of organic decomposition increases as temperature increases; so does oxygen consumption. Thus, it is important to avoid the formation of a thermocline by keeping the pond water well mixed and aerated.

The pH is the measure of alkalinity or acidity of the water. This should be measured at least two days per week, preferably both at sunrise and at sunset. The pH is at its lowest level in the morning due to the formation of carbonic acid during respiration and increases due to photosynthesis throughout the day. The pH levels are best maintained at 6.5 to 9.0. Fish growth may slow with pH levels less than 6.5, and 4.0 is lethal for many species. Organic acids and carbon dioxide can cause the pH to decrease (i.e. increase in acidity). It may be necessary to buffer the water to reduce fluctuations in pH. To control the pH, limestone, which contains calcium carbonate ($CaCO_3$), is often used as a buffering agent. As pH decreases, calcium carbonate slowly dissolves and maintains the pH level. An increase in pH especially above 9.5 - 10.0 also is undesirable because it results in higher levels of un-ionized ammonia which is highly toxic to fish. High and low pH levels in the water can lead to serious stress and even death of the fish.

Ammonia is a by-product of waste produced by the fish and decaying feed. It is composed of un-ionized ammonia (NH_3), which is highly toxic to fish at levels of about 0.2 to 0.6 ppm, and ammonium ion (NH_4^+), which is not very toxic. The amount of un-ionized ammonia is calculated from the total ammonia levels. The percent of un-ionized ammonia increases with increasing pH and temperature levels. If the un-ionized ammonia level becomes a problem, feeding should be greatly reduced or discontinued and water exchanged until conditions improve. Total ammonia-nitrogen levels usually increase slightly for several hours after feeding.

Nitrite-nitrogen (NO_2) is the result of bacterial action on ammonia. Nitrite is slightly toxic to fish, especially when it occurs in conjunction with high ammonia levels. This parameter should be checked, along with total ammonia, at least twice a week and more often if the levels exceed 0.3 ppm. Addition of NaCl (sodium chloride salt) reduces nitrite toxicity in catfish ("brown blood disease") and may also be suitable for use with hybrid bass if nitrite toxicity becomes a problem.

Carbon dioxide (CO_2) should be tested at least two times per week during the summer months. It will be at its highest level at sunrise and should be maintained at concentrations below 5 ppm. High concentrations of CO_2 interfere with respiration, therefore the minimum concentration of oxygen that fish need to survive and grow increases with increasing CO_2 levels. High levels of CO_2 can be particularly detrimental in the hatchery phase where well water is often used. CO_2 levels in ground water may exceed 45 ppm. These high concentrations should be reduced by aeration and circulation of the water in a storage tank to allow the CO_2 to dissipate into the atmosphere before the water is used in the hatchery. In ponds, spraying or splashing the water as it enters the pond will help remove CO_2 and add oxygen.

Table 3. Percentage Un-ionized Ammonia in Solution at Various pH and Temperature Levels

pH	Temperature (°F)				
	50	60	70	80	90
7.0	0.2	0.3	0.4	0.6	0.9
8.0	1.8	2.8	4.1	5.9	8.8
9.0	15.7	22.5	29.9	38.7	49.0
10.0	67.6	74.4	81.0	86.3	90.6

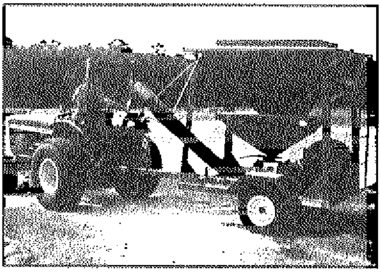
Water hardness is a measure of alkaline earth minerals, primarily calcium and magnesium in water. A hardness of 125 ppm or greater is desirable, but culture success also is being achieved at much lower levels. If hardness must be increased, lime ($CaCO_3$) and other calcareous materials (CaCl) can be added if short-term increases in calcium are needed or relatively small volumes of water are involved. Quick lime [$Ca(OH)_2$] is not recommended to increase hardness because it usually makes the water too basic, overcoming the buffer system in many cases. Gypsum ($CaSO_4$) can be used to increase water hardness without increasing pH in areas with high alkalinity and low hardness. Limestone also can be used to increase hardness, but is not effective in waters of high pH because the limestone will not dissolve. Attempts to increase water hardness after the addition of phosphate fertilizers should be conducted cautiously since the calcium released will combine with the phosphate, making the fertilizer treatment ineffective in producing algal blooms.

The alkalinity, or the amount of bicarbonate (HCO_3^-) and carbonate (CO_3^-) ions that are available in the system, should generally be between 30 and 200 ppm (as equivalent $CaCO_3$) in freshwater. Calcium and magnesium are generally associated with the carbonate ions which are the principal sources of alkalinity in water. Alkalinity is often characteristic of the carbonate contents of rocks and soils of the watershed. Waters with high alkalinity tend to be more strongly buffered against sudden changes in pH than waters with low alkalinity. Natural water which contains 50 ppm or more total alkalinity (as equivalent $CaCO_3$) is considered as hard water for biological purposes, while water of lower alkalinity is referred to as soft water. Typically hard water is preferred for aquaculture purposes.

Feed & Feeding Techniques.

Success in the production of Phase I fingerlings is usually directly related to the types and abundance of zooplankton available during the early growing period and to water quality and feed-management practices. Reciprocal cross hybrid bass fry begin to feed as soon as their digestive tract is developed at three to five days of age. Reciprocal fry require small zooplankton such as rotifers, protozoans and copepod nauplii as their initial food; they cannot eat large zooplankton.

Feed blowers evenly distribute food over a large area.



Thus, timing of broodstock spawning and filling and fertilization of ponds is critical to ensure that these small zooplankters are available at the onset of initial feeding by the fry. Depending on a number of factors, including temperature, water source and previous pond use, pond filling and fertilization is usually performed within one week of the planned spawning date. Original cross hybrids and striped bass fry are larger than reciprocal cross fry and are usually stocked at five to 10 days of age. They can be fed brine shrimp (Artemia) nauplii in tanks if necessary while a proper zooplankton population is established in the pond. Also, these larger fry are more versatile in their feeding behavior and can eat larger zooplankton including adult copepods. For these fry, ponds are normally filled one to two weeks prior to stocking.

During Phase I, zooplankton abundance will become limiting after three to four weeks due to grazing by the fish. Therefore, it will be necessary to supplement the diet with commercial starter rations (meals to crumbles) beginning the second or third week or when natural foods are reduced. A high protein (≥50 percent protein) sinking ration is recommended. Feed can be provided by hand, feed blowers, timer-activated feeders and demand feeders. Hand feeding and blowers allow the manager to visually assess the health and responsiveness of the fish by observing feeding activity. Blowers reduce competition for feed by spreading it over a broad area of the pond. To increase feed efficiency and availability, the daily ration should be divided and fed several times a day, especially when fish are small.

During the first month after stocking Phase I juveniles (1.5 to 2 inch fish) into Phase II nursery ponds, fish are fed several times a day, a total of 25 to 50 percent of the estimated initial biomass to provide the fish maximum opportunity to become accustomed to dry feed. As the fish grow, the percent biomass fed per day is reduced while feed size and quantity are increased. Feed rates are based on estimated biomass in the pond. Population sampling by seining may be done periodically during the growing season to determine fish size so that necessary adjustments in pellet size and daily rations can be made. A general feeding guide is provided in Table 4.

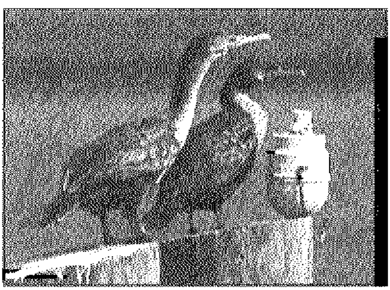
■ **Table 4.** Recommended Feed Sizes & Daily Rates for Hybrid Striped Bass.

Fish Size		Feed	
Weight #/lb.	Total Length (inches)	Size	Rate (% Biomass)
<500	1.75	#3	15.0
300	2.0	#4	10.0
50	3.5	3/32"	7.5
20	5.0	1/8"	5.0
6	7.5	1/8"	3.0
3	9.4	5/32"	2.0
2	9.8	3/16"	1.5
<1	>11.8	1/4"	1.0

Salmon and trout feeds which are high in protein (35 to 50 percent) have been commonly used for all production phases. However, feeds formulated specifically for hybrid bass have recently been developed and should be available from most major feed suppliers. Sinking feeds are less expensive; but floating feeds are preferred as they allow more accurate assessment of feeding activity. However surface feeding activity and feeds attract avian predators and competitors.

When feeding, REMEMBER it is always better to underfeed than to overfeed fish if in doubt of feeding response. Also, DO NOT FEED if the dissolved oxygen concentration is less than 3.0 ppm. Feeding activity is minimal in the winter months (January and February) when water temperatures are below 55°F. Feed ration should be decreased at water temperatures at or below 60°F.

Double-crested cormorants are one of the primary hybrid striped bass predators.



Predators & Competitors. Insects, birds, fishes, reptiles and mammals are all potential predators. During the larval stage, the fry are especially vulnerable to predacious insects. Large mortalities of stocked larvae may be avoided by filling the ponds as close to stocking time as possible or using EPA-registered chemicals to control insects. Ponds should be sampled with a 500 micron mesh plankton net prior to stocking larvae to assess the abundance of predaceous insects (e.g., backswimmers, diving beetles, water boatman, dragon fly nymphs).

Of the vertebrate predators, birds usually are the most significant and they should be actively discouraged from entering fish-rearing ponds.

Wading and diving birds can cause serious mortality to pond-reared fish, especially juveniles. Water snakes, turtles and alligators also should be removed as quickly as possible. Otters, minks and other small mammals can be controlled by trapping to prevent fish loss. The accidental introduction of other fish species can cause competition for feed and predation on cultured fish.

Management techniques such as proper pond design, screening inflow waters, and installation of lighting and fencing may reduce predation. Many devices are available for discouraging predators; however, the best defense is early discouragement techniques. Once predators learn about the "captive meal," it is very difficult to keep them away. Killing protected species is against the law, so before killing any predators, contact local wildlife enforcement officials and the USDA animal control officer to obtain a depredation permit.

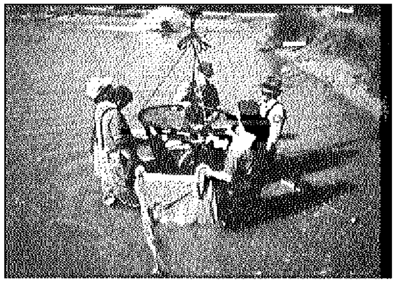
Diseases & Parasites. Diseases and parasites can kill, and infections often occur as a result of improper handling of fish or poor water-quality conditions. The most common bacterial infectious agents encountered in hybrid bass culture are *Flexobacter columnaris, Aeromonas,* and *Vibrio. F. columnaris* is the most serious bacterial disease that infects striped bass in freshwater culture systems. Diseases caused by marine forms of *Pseudomonas, Chromobacter,* and *Flexibacter* are difficult to cure because these organisms are more resistant to commonly used therapeutic drugs. Vaccination with *Vibrio anguillarum* bacterin seems to be an effective way of preventing this disease.

Regular population sampling and inspection may allow detection of potential disease outbreaks before they become serious. Changes in normal feeding response may indicate problems with disease. Fish are more susceptible to disease when they are stressed by handling and poor water quality. Maintenance of good water quality will reduce the incidence of disease. Also, salinity appears to be a barrier to the spread of some organisms, and fish tend to handle better in slightly saline water. Only chemicals registered for use on hybrid bass foodfish may be used to treat diseases.

A variety of parasites also may infect hybrid bass. Parasites may occur on the gills, fins and skin of hybrid bass and can interfere with respiration or cause lesions on the skin or fins which makes the fish vulnerable to secondary infections by bacteria. The major external parasites include: *Amyloodinium ocellatum, Ichthyophthirius multifiliisich, Epistylis sp., Trichodina sp., Ichthyoboda (Costia),* monogenetic trematodes and *Ergasilus sp.* Other parasites may exist in muscle tissue, eyes and the intestinal tract. These parasites include: digenetic trematodes, nematodes and acanthocephalans.

The best method for controlling severe infestations of parasites is to avoid conditions which induce stress, such as poor water quality, overcrowding, malnutrition, etc. Other steps to reduce risk of infestation include avoiding use of water sources containing wild fish populations, reducing the presence of snails which are intermediate hosts for some parasites and avoiding use of raw fish as a supplemental feed as it may contain parasites. For more details on parasites and diseases and control techniques, consult "Culture and Propagation of Striped Bass and its Hybrids" listed in the suggested reference section.

Harvesting Techniques. Harvesting of Phase I fish occurs when water temperatures are increasing (April to June), and great care should be exercised to minimize stress of these small fish. The harvest of Phase II fish is usually conducted at temperatures between 50 to 58°F. When temperatures are higher, mortality due to handling stress may occur. At lower temperatures, fish may be sluggish and not move toward the drain with the water. As the pond water level is lowered, any internal harvest basins should be cleaned of accumulated mud and debris. It is advisable to add clear, low-turbidity, high-oxygen water to the harvest area or basin at the time of fish removal if pond water is excessively muddy or low in oxygen. This will help concentrate the fish and reduce stress.

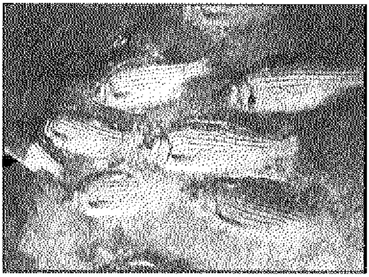


Harvest techniques range from seining and lift baskets to fish pumps.

If the pond does not have a basin, then seining should begin when water depth is about two feet in the deep end. After fish have been captured in the seine bag, the bag should be kept in the water and washed of mud and debris. The fish can then be removed from the seine by nets or other types of harvesting equipment. Phase II and market-size fish also may be removed by special fish pumps and sorted by size with mechanical grading equipment. This later approach is much more time-and cost-efficient as compared to manually harvesting and grading and is actually less stressful to the fish. It is the preferred approach if the farmer can afford to purchase or rent the equipment.

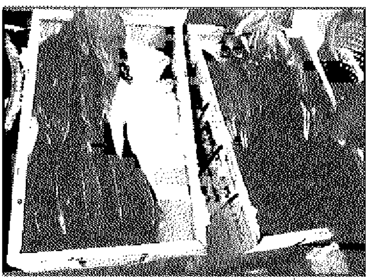
Handling, Processing & Shipping.

To provide a high-quality product, the harvested food fish should be chill-killed as soon as possible after removal from the pond. This is usually accomplished by placing large tanks containing a water and ice slurry next to the ponds. As the fish are harvested, the market size fish are immediately placed in the tank and held in this chilled state until they are packaged for shipping or further processing. The higher the temperature difference between the pond water and the ice water, the quicker the fish will die.



Harvested fish should be immdiately chill-killed in an ice bath.

If the fish are handled roughly, they can bruise and become unsightly. This also will occur if the fish are allowed to thrash around before dying. If this occurs and the fish were properly iced, the product still will be of high quality, but filleting, skin removal and washing may be necessary to remove the unsightly hemorrhagic areas.



Currently, most farmers ship whole iced fish. However, new product forms are being developed.

The current market uses primarily whole fish. These fish are usually packed in ice in boxes in 50 to 70 lb. lots and shipped by truck to market. In some cases, gilled and/or gutted fish have been shipped. Depending on the specific market, fish also have been air shipped in waxed or plastic containers containing frozen gel packs or ice. In some cases, producers seal the shipping boxes with bands to prevent tampering and theft. Test marketing of live fish indicates that there is also a specialty market for this type of product.

As production and availability increases, it is expected that hybrid bass will be marketed in a variety of product forms including fresh and frozen fillets. To date, "off-flavor" fish have not been identified as a problem among pond-reared hybrid bass. However, it may occur and the farmer should test his product before harvesting and marketing to ensure that only high-quality fish are sold. Any occurrence of "off-flavor" hybrid bass in the marketplace will have a deleterious effect on all cultured hybrid bass offered for sale.

Economic Considerations. Many factors are involved in determining the economic feasibility of hybrid bass farming. Such factors include site selection, management expertise and objectives, type and scale of operation, production plan, marketing approach, source of funding, etc. Based on pilot-scale production trials, hybrid bass aquaculture appears economically attractive. Major costs are associated with feed and labor. Detailed cost and return budgets for different-sized farms are provided in "Raising Hybrid Striped Bass in Ponds" listed in the suggested reading section.

As the industry matures, a number of changes are expected. Foremost, the price for hybrid bass in wholesale markets should decline from its current level and become more competitively priced with other products. However, specialty markets and direct marketing should still result in premium prices. Development of hybrid bass formulated rations and improvement in the farmer's management experience should help increase production levels and overall farm economics. These factors, when combined with new developments in broodstock selection, domestication and spawning, genetic manipulation of hybrids, use of remote waterquality sensing and control systems, and availability of juveniles throughout the year, etc., should result in the establishment of a large-scale industry. Nevertheless, growers should precede cautiously and consider phasing in facility expansion as their culture skills and management experience is developed.

Summary. Pond aquaculture of hybrid bass is a growing industry, especially in the southern United States. This industry is in an expansion stage but there are still many issues which are the subject of both public and private research. Such issues include domestication of broodstock, year round production of juveniles, feeds for different life stages, disease control and drug clearance, identification of new products and marketing outlets.

Besides food-fish production, hybrid striped bass will continue to be used to enhance recreational fishing opportunities through public stocking programs. In addition, these fish can be used in private fee-fishing operations where they will generate revenues from a select fishing sector. In S.C., use of fish in this later activity has increased substantially.

In summary, hybrid bass culture shows promise as a new industry capable of producing a wholesome aquafood product for the seafood consumer. With proper guidance and nurturing by both the public and private sectors, hybrid striped bass should form the basis of a large-scale aquaculture industry.

Acknowledgements. We greatly appreciate the efforts of Diana DuBois Alford who helped prepare the initial draft of this manual.

Much of the technical information contained herein was obtained from cooperative research studies supported by the S.C. Sea Grant Consortium and the State of South Carolina and conducted at the Waddell Mariculture Center. Dawn Alessi, May Baird and Joe Hoats assisted in the conduct of these studies. Special thanks to Rick DeVoe for his encouragement and guidance and to Sea Grant's Communications and Information Services division, which edited and published this manual. The S.C. Department of Natural Resources and the S.C. Sea Grant Consortium provided support for preparation of this manual.

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Natural Resources Conservation Service
U.S. Department of Agriculture
Thurmond Mall
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(803) 765-5681

Suggested Reading.

Culture and Propagation of Striped Bass and Its Hybrids. 1990. Reginal M. Harrell, Jerome H. Kerby, and R. Vernon Minton (editors), American Fisheries Society, 5410 Grosvenor Lane, Suite 110, Bethesda, Maryland 20814. 323 pp.

Raising Hybrid Striped Bass In Ponds. 1990. Ronald G. Hodson and Jennifer Jarvis, UNC Sea Grant Publication #UNC-SG-90-05, UNC Sea Grant College Program, Box 8605, North Carolina State University, Raleigh, North Carolina 27695. 44 pp.

Hybrid Striped Bass Culture: Status and Perspective. 1987. R. Hodson, T. Smith, J. McVey, R. Harrell, and N. Davis (editors), UNC Sea Grant Publication # UNC-SG-87-03, North Carolina State University, Raleigh, North Carolina 27695. 106 pp.

The Aquaculture of Striped Bass: A Proceedings. 1984. Joseph McCraren (editor), University of Maryland Publication # UM-SG-MAP-84-01, Bethesda, Maryland. 262 pp.

Tank Culture of Striped Bass : Production Manual. 1981. W.M. Lewis, R.C. Heidinger, and B.L. Tetzoff. Illinois Striped Bass Project 1DC F-26-R Fisheries Research Laboratory, Southern Illinois University, Carbondale, Illinois. 115 pp.

Water Quality in Warm Water Fish Ponds. 1979. Claude E. Boyd, Auburn University Agricultural Experiment Station, Auburn, Alabama. 359 pp.

Guide to Oxygen Management and Aeration in Commercial Fish Ponds. 1988. G.L. Jensen and J.D. Bankston, Louisiana Cooperative Extension Service, Louisiana State University, Baton Rouge, Louisiana. 27 pp.

Handbook for Common Calculations in Finfish Aquaculture. 1988. G.L. Jensen, Louisiana Cooperative Extension Service, Louisiana State University, Baton Rouge, Louisiana. 59 pp.

Third Report to the Fish Farmers: The Status of Warmwater Fish Farming and Progress in Fish Farming Research. 1984. H.K. Dupree and J.V. Huner (editors). U.S. Fish and Wildlife Service. Washington, D.C. 270 pp.

Estimated Annual Production of Commercial Hybrid Striped Bass Growers in the United States. 1991. R.J. Rhodes and B. Sheehan. Striped Bass Growers Association, P.O. Box 11280, Columbia, South Carolina 29211

Magazines & Journals of Interest.

Aquaculture Magazine. Kay Homer (editor). Achill River Corporation, 31 College Place, Asheville, North Carolina 28801

The Progressive Fish-Culturist. Robert Piper (editor). American Fisheries Society, 5410 Grosvenor Lane, Bethesda, Maryland 20814

Proceedings of the Southeastern Association of Fish and Wildlife Agencies. Arnold Eversole (editor). Copies of proceedings may be ordered from D. McCor-mick, Kentucky, Department of Fish and Wildlife Resources, 1 Game Farm Road, Frankfort, Kentucky 40601

Journal of World Aquaculture Society. Ronald Thune (editor). World Aquaculture Society, 16 E. Fraternity Lane, LSU, Baton Rouge, Louisiana 70803

Water Farming Journal. Carroll Trosclair (editor). Carroll Trosclair and Associates Inc. 3400 Neyrey Dr., Metairie, Louisiana 70002

Trade Organizations.

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National Aquaculture Association
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World Aquaculture Society
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This manual focuses on the pond culture of hybrid bass, providing the reader with general guidelines and procedures associated with growing these fish. As with any business, success is a function of many considerations including site selection, technical expertise and marketing opportunities. A list of recommended reading materials, as well as in-state sources of assistance, can be found in the back of this manual. In South Carolina, the culture of hybrid striped bass is regulated by the S.C. Department of Natural Resources. For a permit application or specific permit requirements, the reader should contact the Aquaculture Permit Office, S.C. Department of Agriculture, P.O. Box 11280, Columbia, S.C. 29211, phone (803) 734-2210.