Current Status and Opportunities for Marine Stock Enhancement and Aquaculture in Florida

This report has been prepared in response to the 2005 Florida House Bill 1855 and a request from the Florida Ocean and Coastal Resources Council to review the potential for inland, recirculating aquaculture technology to produce marine species and to recommend and implement a multi-institutional pilot project for marine stock enhancement and aquaculture initiatives. While the Florida Fish and Wildlife Conservation Commission (FWC) is currently evaluating the efficacy of using stock enhancement as a management tool for helping replenish depleted fish stocks in the future, this work is underway with red drum and common snook, there is a clear and critical need to search for and test additional species that have the potential to be economically viable (cost effective) target species for future enhancement and for future farming activities in the State of Florida.

With **increasing seafood demand** and declining wild fisheries, U.S. marine aquaculture production must greatly expand. A decade ago global fisheries reached maximum yield at 2.2 billion pounds. The urgent need to develop sustainable aquaculture production of high-value marine fishes was further substantiated by the November 3, 2006, paper in the journal *Science* in which lead author Boris Worm warned "if the long-term trend continues, all fish and seafood species are projected to collapse within my lifetime -- by 2048." Earlier studies predicted that aquaculture's contribution to seafood needs must rise from 30% to 50% in the next 25 years to meet the increasing seafood demand and ease harvest pressure on wild fish stocks.

The **expansion of Florida's aquaculture industry** is challenged by the high cost and limited availability of coastal land and water resources, environmental impact concerns, high production costs, and lack of sufficient quality fish seedstock. Expanding marine aquaculture will reduce the U.S. trade deficit, increase employment opportunities for inland rural sectors and displaced farmers, increase crop diversity, and enhance food biosecurity.

In the past ten years, there have been three **aquaculture industry workshops** in Florida addressing marine food fish opportunities. The first workshop, Marine Aquaculture Industry Development was held in 1998 at Harbor Branch Oceanographic Institution. Industry, government and research leaders evaluated and ranked 35 potential marine food fish species for culture based on production, marketing, and regulatory constraints. In 2003 and 2005, Harbor Branch and the USDA/ARS held the International Sustainable Marine Fish Culture Conference with the goal to bring together researchers, industry and stakeholders to identify and address constraints currently limiting marine fish production in Florida and the U.S. (www.sustainableaquaculture.org).

The Florida Oceans and Coastal Resources Council recommends: The pilot project will proceed in concert with the State of Florida's strategic plan to use aquaculture technology for marine stock enhancement and to investigate the biological and economical efficacy of potential species for stock enhancement and aquaculture. Year one (2007-2008) and year two (2008-2009) of the pilot project will focus on developing the inland, recirculating and aquaculture technology needed for stock enhancement research, and on establishing stock enhancement capabilities for new species in Florida.

Demonstrate economically feasible production and marketing of high-value marine fish species that can be farmed in land-based recirculating production systems

Culture of marine fish in Florida is an emerging sector of Florida's aquaculture industry. In 2006, marine fish culture activities in Florida were taking place at private non-profit and university research institutions, a government hatchery, and private commercial farms (Figure 1). Three research institutions have been investigating the potential for multiple high-value marine fish species for food production, stock enhancement (i.e., cobia, pompano, common snook, southern flounder, black sea bass, and mutton snapper), and for a variety of marine ornamentals for the aquarium trade. Commercial hatcheries have been producing and marketing juvenile marine fish (i.e., cobia, pompano) to farms located outside of the state (i.e., Puerto Rico, Bahamas) for growout in offshore cages. A recently established commercial farm has reported results of growout trials using pompano in ponds and tanks; however, farmed pompano are not yet available through Florida wholesale markets. At least two marine ornamental farms in Florida have been producing and selling a wide variety of fish species into U.S. and international markets.

Figure 1. Florida marine fish facilities (2006).

Experimental and pilot-scale production of **marine fish for stock enhancement** in Florida is underway. Husbandry techniques are being developed for common snook and experimental stock enhancement trials have been ongoing for approximately 10 years. Recent breakthroughs in captive maturation and spawning of snook may provide an opportunity to expand the stock enhancement research from experimental to pilot-scale level. Another experimental aquaculture and stock enhancement program was conducted by a team of Florida, Mississippi and Hawaii researchers using cultured red snapper that were stocked on offshore artificial reefs in southwestern Florida. This program was terminated in 2005 due to lack of funding. The State of Florida is conducting a large-scale prototype evaluation of red drum stock enhancement. Plans are underway to develop a network of saltwater hatcheries to expand the aquaculture production for red drum to include multiple hatcheries on the west and east coasts of Florida.

Most marine aquaculture commercial and research facilities in Florida are producing fingerling and market-size fish in land-based tanks and ponds. Although there are currently only a small number of marine fish farms in Florida, there is interest in the private sector to diversify land-based agriculture and aquaculture operations to include marine fish farming. In order to expand Florida's aquaculture industry, Harbor Branch Oceanographic Institution and Mote Marine Laboratory are developing techniques to expand the use of underutilized agricultural land through the culture of marine species that are adaptable to fresh water and low salinity environments.

Another technology for production of marine fish that has gained momentum in recent years is offshore aquaculture. Farming marine fishes to market size in submerged offshore cages is expanding around the world. Florida has yet to capitalize on these technological advances because of an intricate, complex, lengthy and expensive permitting process. ~~Recently, the Florida Department of Agriculture, Division of Aquaculture, in collaboration with a large group of experts developed Best Management Practices (BMP) for cage aquaculture. The goal of the BMPs is to simplify the permit application process and provide opportunities for offshore aquaculture in Florida.~~ To be striken:

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Consensus achieved

Offshore farms will continue to rely on land-based facilities for particular life stages (i.e., maturation, spawning, larval rearing, early nursery) **of marine fishes**. Thus, the need to develop recirculating systems to accommodate the reproductive, larval and nursery stages will still play an important role in the successful implementation of offshore aquaculture.

Land-based marine farms are utilizing a range of culture system technologies from open (flow-through) tank and pond systems to recirculating tank systems to maintain the required water quality conditions to farm fish. The water quality requirements are determined by the different life stages of marine fish (e.g., larval versus growout stage) because the biological and water quality requirements often change with different life stages. Most marine fish farms and research laboratories using recirculating technology are located adjacent to estuarine or marine

coastal environments and exchange 10-30% of the system water through a series of water treatment ponds. At least one inland marine farm is trucking saltwater in and out of their facility to exchange and maintain appropriate water quality conditions for the cultured species. Although the ornamental farms recycle a large portion of the culture system water, the systems tend to be lightly loaded (in terms of total biomass), which simplifies the filtration systems required to maintain water quality. Mote Marine Laboratory's Aquaculture Research and Commercial Demonstration Park, which is located nearly 20 miles away from the coastal marine ecosystem, is in the process of developing the technology to recycle 100% of the water from their live food and marine fish culture systems.

A number of biotechnical issues need to be resolved in the development of commercial-scale, land-based recirculating farms to produce marine fish. Reliable systems that allow farmers to maintain and monitor water chemistry parameters, strategies to conserve limiting water resources, and economic feasibility will all factor into the success of Florida's marine aquaculture industry.

Finally, it is necessary to evaluate the market potential for candidate marine species targeted for food or ornamental outlets. A marketing-oriented approach suggests that candidate species only have commercial development potential if, in addition to biotechnical feasibility, there is a ready market at prices that provide a reasonable profit. The first step in this approach is to identify marketing opportunities by estimating the total market demand, growth, and profit potential of a market.

Develop and demonstrate marine stock enhancement and stock restoration using recirculating marine aquaculture technology

The Economic Output of Florida's saltwater recreational fishing industry was $5.4 billion dollars in 2001 (latest data), the greatest economic output from saltwater sportfishing in the world, and three times greater than in any other state or territory in the U.S. The Florida Fish and Wildlife Conservation Commission (FWC) has made it a high priority to develop adequate measures to protect this resource. Much emphasis is now given by FWC to developing and implementing effective and responsible stock enhancement technology to rapidly replenish depleted high-value sportfish and to boost productivity of those fisheries.

Saltwater fishery management in Florida is mandated to include user-supported hatchery-based stock enhancement. The FWC's Marine Stock Enhancement Program, led by Fish and Wildlife Research Institute (FWRI), is developing saltwater stock enhancement technology in partnership with Mote Marine Laboratory (MML) in order to develop a viable approach to restore U.S. fisheries. This public-private partnership has established a multidisciplinary approach to developing effective strategies for integrating stocking into traditional fishery management. FWC and MML have established that stocking red drum into Biscayne Bay and Tampa Bay can affect fishery landings near release sites, and that small-scale stocking of common snook can affect fishery landings in Sarasota Bay. FWC is planning a large-scale release of red drum in Tampa Bay, and MML continues to make progress toward developing

effective strategies for stocking snook into Sarasota Bay and resolving impediments to large-scale production of snook in recirculating systems.

The focus of FWC's stocking program has shifted emphasis over the past decade from a program that had become by the mid-1990s largely driven by stakeholder demand for primarily "production-oriented stocking" (essentially, stock fish and hope that it works) to using best management practices to develop economical stock enhancement based on assessments of stocking effects on fishery yields for various stocking-strategy scenarios. This approach will provide economically successful and ecologically sound stocking technology for replenishing high-value fish stocks that fuel the multi-billion dollar fishing industry in Florida. **Stock enhancement can potentially provide rapid response disaster relief, increase fishing opportunities and maintain economic value, supplement weak year classes, and recover endangered and threatened species.**

Using the framework in FWC's Strategic Plan for Florida Stock Enhancement (see Appendix II), red drum and snook were identified as the target species for developing stock enhancement technology in Florida. Included in the top 5 species for enhancement were spotted sea trout, flounder and pompano. **The FWC/MML team developed and implemented protocols to protect genetic diversity, health, and ecological attributes of target stocks.** These genetic and health policies apply to the release of cultured fishes statewide and provide the foundation for legislative rule-making and activity permitting.

By incorporating adaptive pilot-release experiments, with state-of-the-art tagging technologies, the FWC/MML team made rapid progress in designing and improving stocking technology to enhance red drum and snook stocks in coastal bays and estuaries (see Appendix II). With the clear and unambiguous results gained from these studies, Florida is now poised to lead the nation in demonstrating the value of stock enhancement in saltwater sportfish restoration.

Marine Species Candidates for Florida

Since the 1998 Marine Aquaculture Industry Development workshop evaluation of 35 candidate marine fish species, Florida's research and commercial community has focused their efforts on the development and evaluation of husbandry and system technologies for seven marine fish species or species groups. These species are targeted for food, stock enhancement and ornamental production and include: cobia, Florida pompano, black sea bass, southern flounder, mutton snapper, spotted sea trout, common snook, red drum, and marine ornamentals. The Florida Keys National Marine Sanctuary and Mote Marine Laboratory have recently partnered to examine the potential to culture hard corals for reef restoration. A brief review of the species characteristics, research and commercial status is presented below.

Cobia

Other Common Names: ling, lemonfish, bacalo
Scientific Name: *Rachycentron canadum*

Cobia is a highly sought after food fish found in tropical and subtropical waters around the world. This pelagic species is found in a variety of habitats and prefers water temperatures between 20 to 30°C. This exciting new aquaculture species can reach 6-7 kg in one year. There are numerous research programs underway in Gulf of Mexico and southeastern Atlantic U.S. Until recently, the only commercial hatchery was located in the Florida Keys. The Keys hatchery is closing down operations and the only Florida hatchery producing cobia is the University of Miami Experimental Hatchery. A commercial growout farm for cobia is located in Puerto Rico where cobia are being grown out in offshore cages. Research trials are also underway in Florida in ponds and will be evaluated in recirculating systems in 2007 at Harbor Branch. Stock Enhancement research trials have been conducted in South Carolina.

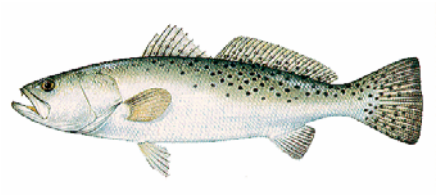
Florida Pompano

Other Common Names: pompano, common pompano, Atlantic pompano, sunfish
Scientific Name: *Trachinotus carolinus*

Florida pompano are one of the highest priced marine food fish in U.S. The species ranges from Massachusetts through Gulf of Mexico, in Central and South America to Brazil, and in the West Indies. Pompano are found in coastal waters (bays, estuaries, sandy beaches) where they form small to large schools along the beaches. Aquaculture efforts with Florida pompano were initiated in the late 1960s and were stopped in the early 1970s because of limitations in growth using commercially available diets. Research was initiated again in 2002 at Mote Marine Laboratory and in 2004 at Harbor Branch with USDA/ARS and two commercial farms began hatchery production in 2002/2003 at Mariculture Technologies, Inc. and Dyer Aqua. Maturation and spawning research trials have documented successful larval production using hormone and environmentally induced spawning techniques. Commercial-scale larval, nursery and growout protocols for inland recirculating systems are being developed. Research trials to evaluate opportunities for inland, low-salinity aquaculture of Florida are underway. The market for Florida pompano looks very promising. There is a limited supply in the market and a high ex-vessel price, ranging from $7 to $13 per kg for whole fish.

Spotted Sea Trout

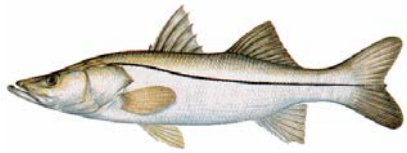
Other Common Names: spotted weakfish, speckled trout
Scientific Name: *Cynoscion nebulosus*



Spotted sea trout occur from Massachusetts to Mexico in estuaries, bays and lagoons and can be grown in fresh or salt water conditions. Aquaculture efforts have mainly focused on culture of juveniles for stock enhancement in Texas and South Carolina; experimental stock enhancement efforts have also been initiated in Mississippi. This popular sport fish may be a good candidate for farming. Spotted sea trout will spawn in captivity with environmental and hormonal manipulation. Cannibalism seems to be the main problem but can be minimized if the fish are weaned early, fed well, and graded.

Common Snook

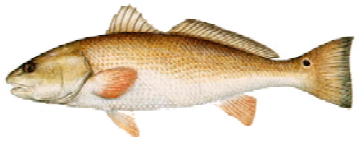
Other Common Names: robalo, thin snook
Scientific Name: *Centropomus undecimalis*



The geographic distribution of common snook includes Florida, South Texas, the eastern coasts of Mexico, Central and South America (to Brazil), and the Caribbean. Common snook are found in estuarine and near-shore environments and attain weights up to 27 kg and lengths of 1.3 m. This prized game fish is cultured experimentally in Florida at Mote Marine Laboratory as part of the stock enhancement research program with FWC. Approximately 1.8 million snook are caught by anglers annually in Florida. Food production of common snook in Florida is currently prohibited. Aquaculture research has been ongoing since the 1970s. Spawning efforts have focused over the past 10 years on field strip spawning, which can be successful. The inconsistent results from field spawning efforts led to a recent shift to captive maturation and spawning research. In 2006, Mote Marine Laboratory demonstrated that wild broodstock could be acclimated, matured and spawned in large tank systems.

RED DRUM

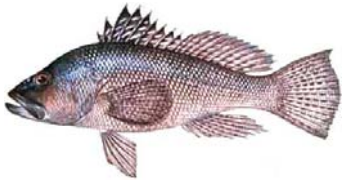
Other Common Names: redfish, channel bass, spottail bass
Scientific Name: *Sciaenops ocellatus*



Red drum are found in coastal environments from Maine to Mexico. Red drum are an extremely popular sport fish in Florida. Aquaculture production efforts have primarily focused on culture of juveniles for stock enhancement in Florida, Texas, and South Carolina. Captive red drum broodstock are conditioned to spawn at FWC's fish hatchery and grown to stocking size in ponds at Port Manatee. Over 4 million red drum have been released in the pilot-scale stock enhancement studies conducted by the FWC/MML team.

Black Sea Bass

Other Common Names: sea bass, black fish, black bass, rockfish, talywag
Scientific Name: *Centropristis striata*



The geographic distribution for black sea bass range includes western Atlantic inshore areas from Maine to northeastern Florida and the eastern Gulf of Mexico. They inhabit reef and rubble areas offshore. Aquaculture research programs are underway in Florida as part of the Harbor Branch and USDA/ARS collaborative program and in North Carolina. Preliminary market analyses indicate there is potential for a cultured black sea bass industry, given the small current market, relatively high dockside prices, and excess demand for the species.

Southern Flounder

Other Common Names: flounder, mud flounder, doormat, halibut
Scientific Name: *Paralichthys lethostigma*

The geographic distribution for southern flounder includes the western Atlantic, from North Carolina to Texas. Southern flounder occur in brackish water bays and estuaries and occasionally in freshwater areas. Aquaculture research programs are underway in North Carolina, South Carolina and Florida. There is a lot of interest in this species because of the potential for fresh or low salinity culture. A recent market analysis was done for Southern Flounder by University of Florida, IFAS, in Ft. Pierce, Florida, as part of the Harbor Branch and USDA-ARS collaborative project. The conclusion of the study is that unless niche markets are targeted, the outlook for Southern Flounder aquaculture in the U.S. is not promising due to current low dock side prices, which equal farm gate prices, and the excess supply from fisheries and imports.

Mutton Snapper

Other Common Names: mutton fish, king snapper, virgin snapper, and snapper
Scientific Name: *Lutjanus analis*

The geographic distribution of mutton snapper includes the western Atlantic, from Massachusetts to southeastern Brazil, the Caribbean, and the Gulf of Mexico. They occur in inshore estuarine habitats (seagrass beds, mangroves) and occasionally in offshore reefs. Mutton snapper can reach 0.5-1.0 kg in 1 year. Aquaculture research and commercial efforts have been carried out in Florida (University of Miami, Harbor Branch, and Aquaculture Center of the Florida Keys) Puerto Rico and the Bahamas.

Marine Ornamental Fishes

Common Names: Clownfish, etc.

The roots of the U.S. marine ornamental tropical fish culture began in St. Petersburg, Florida, in the early 1970s with the culture of clownfish. In the 1980s and early 1990s, a few small companies began producing multiple ornamental fish species in the Bahamas, Florida, and California. In the late 1990s, Oceans, Reefs and Aquariums began operations in Ft. Pierce, Florida at Harbor Branch, and they have made great strides in advancing the propagation of clownfishes and other reef fishes, adding many new species to the list of commercially cultured marine ornamentals. A few other Florida companies (Florida Aquatics, Maritech) have begun producing and marketing marine ornamentals in the past few years. The primary constraint to expansion of ornamental species is the small eggs that hatch into planktonic larvae, which require small live zooplankton feeds.

Hard Corals

Culturing corals to restore damaged and declining reef systems represents a promising opportunity to provide the diversity of coral species required to recreate the reef environment following a disturbance event. Numerous factors limit coral growth in the ocean, including erosion, predation, and chemical acids from certain animals that dissolve limestone coral. Culturing corals in a controlled environment can eliminate many of these factors and allow corals to grow up to three times their normal growth rate. Replanting reefs with cultured coral fragments may greatly reduce the time required for successful reef restoration. Mote Marine Laboratory's Tropical Research Laboratory (MML-TRL) in Summerland Key partnered with the Florida Keys National Marine Sanctuary (FKNMS) to culture more than 20 species of hard corals beginning in 2003. A consortium of coral research laboratories (University of Florida's Tropical Aquaculture Laboratory, Florida Aquarium, MML-TRL, MML, FKNMS) are working together to develop aquaculture and stock enhancement strategies for disturbed reef ecosystems in the Florida Keys.

APPENDICES

Appendix I: HISTORICAL INFORMATION ON FOOD FISH CULTURE IN FLORIDA

Appendix II: BACKGROUND ON FLORIDA STOCK ENHANCEMENT

Appendix III: PRIVATE PRODUCTION EFFORTS

Appendix IV: SUMMARY OF MARINE AQUACULTURE PROGRAMS, PARTNERSHIPS AND COOPERATIVE PROJECTS