MARINE BAITFISH CULTURE

Workshop Report on

Candidate Species & Considerations for Commercial Culture in the Southeast U.S.

December 2004

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P.O. Box 1346
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Workshop Report on Candidate Species & Considerations for Commercial Culture in the Southeast U.S.

Compiled and written by

Michael J. Oesterling
Virginia Sea Grant Marine Advisory Program
Virginia Institute of Marine Science
College of William and Mary
Gloucester Point, Virginia

Charles M. Adams
Florida Sea Grant Extension Program
University of Florida
Gainesville, Florida

Andy M. Lazur
Maryland Sea Grant Extension Program
Horn Point ENvironmental Laboratory
University of Maryland
Cambridge, Maryland

This document is the result of a workshop on research, outreach, and policy needs which could lead to the expansion of marine finfish culture for use as recreational angling bait along the coasts of the eastern United States. The workshop was convened in February 2004 in Ruskin, Florida.

The list of potential species and the identification of impediments discussed in this document were developed through consensus of the workshop participants.

December 2004

Investigations of new finfish species targeted for marine aquaculture production should involve critical evaluations for culture potential based upon biological, marketing, and financial criteria. A recent trend in marine finfish aquaculture has been to target candidate species which occupy upper trophic levels of the food chain (e.g., dolphin, snappers, groupers, flounder, tuna, and cobia). These species are very desirable food fish that command high market prices, with the potential to offset production costs and yield considerable profits. However, the highest value for a cultured marine finfish may not be as a "food" fish. One example would be the culture of marine ornamental species. Another example of recent, growing interest would be the culture of marine finfish for use as live bait for recreational angling. And yet, little focused attention has been directed to alternative culture species and market strategies for live, marine baitfish.

This document summarizes the results of a workshop convened to identify opportunities for and challenges to the successful culture of marine baitfish in the eastern United States. The workshop was held February 2-3, 2004 at the University of Florida, Tropical Aquaculture Laboratory in Ruskin, Florida. The workshop was convened by the Sea Grant Programs of Maryland, Virginia, and Florida to bring together knowledgeable individuals with an interest in marine baitfish culture. (See Appendix 1 for a list of participants.) It is important to note that attendees included research scientists, extension personnel, and industry members from Maryland, Virginia, North Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Arkansas.

Due to the large geographic area represented by attendees, the diverse recreational angling bait needs found throughout the region, and the different species of baitfish currently in use, all potential species of marine baitfish could not be adequately addressed. For this reason, the attendees first attempted to identify the many species of marine finfish currently being used as live bait by the recreational angling community throughout the Southeast. The next task was to narrow that list to the species which, in the collective opinion of the attendees, offered the most potential for commercial aquaculture development. This in no way means that these are the only species of marine finfish that are candidates for culture as baitfish. Rather, the species chosen were those that currently are being used by recreational anglers and for which some science-based information is already available about biology, culture, or economic/market potential of the species. Additionally, only finfish indigenous to the eastern United States were considered.

The decision-making process for inclusion of a considered species was facilitated by the use of a "knowledge matrix" (shown here). The matrix identifies factors which should be taken into account when investigating the culture of any new species of finfish. A consensus of the attendees then determined whether sufficient information was "known," "partially known," or "not known" about each factor in order to proceed with culture development.

Once the primary candidate species were chosen, the next step was to further identify impediments to the development of viable culture activities. Four broad categories were selected to represent different impediments to culture development:

1. *Regulatory* - regulatory concerns could include existing wild-harvesting regulations (size limits, seasons, etc.) that would impact brood stock acquisition or market distribution of wild-caught bait-size fish, natural history regulations (for example, non-native species rules), or other permitting concerns.

2. *Technical* - these concerns deal primarily with the production technology of culturing a specific species, including information needed to close the life cycle of the candidate species, culture methods, information regarding different

Knowledge Matrix:

TOPIC	KNOWN	PARTIALLY KNOWN	NOT KNOWN
Regulatory issues/permits			
Brood stock availability			
Spawning biology			
Larval nutritional needs			
Larval environmental requirements and ranges			
Juvenile nutritional needs			
Juvenile environmental requirements and ranges			
Growth rates			
Disease susceptibility and control methods			
"Hardiness" to handling and water quality stress			
Culture methods			
Equipment requirements for grow-out			
Previous culture attempts			
Market analysis - demand, seasonality, location			
Secondary markets (aquarium trade/food)			
Competition (other growers/wild harvest)			
Economic analysis - production versus returns			
Number of crops per year			
Multi-cropping/polyculture opportunities			
Technical support available			
Demonstration projects conducted			

culture stages (larval, juvenile, etc.), nutritional needs for all life stages, and disease/therapy.

3. *Economic* - this relates primarily to production costs (land, capital cost, labor, feed, energy, etc.) needed for the culture of the candidate species, as well as the necessary market conditions for that species, both in its "local" area and other potential market locations.

4. *Environmental Impact* - while somewhat similar to the Regulatory category, this category refers to how the culture technology will be applied (ponds, nets, recirculation, etc.), discharge issues, and the potential conflict of cultured species being used in the natural environment.

For each candidate species, these four categories were evaluated to determine which posed the greatest impact to further development, based upon the knowledge matrices and experiences of the assembled participants.

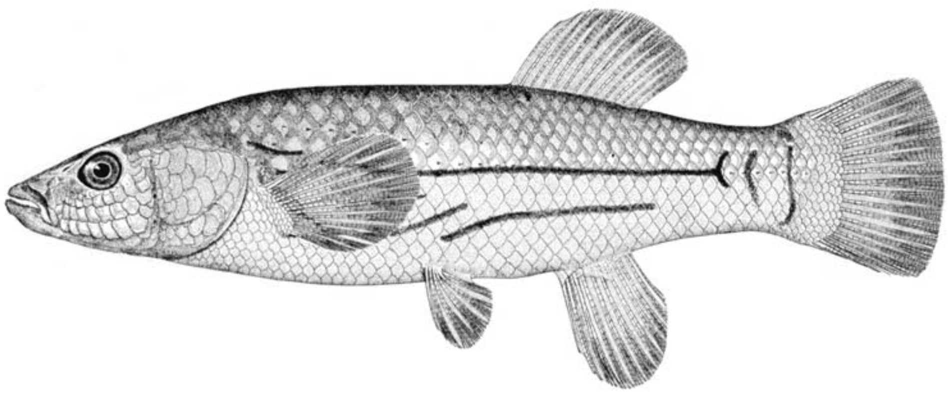
Throughout the course of the discussions, the need for strong, coherent outreach programs was stressed, regardless of the species of choice. Without clear demonstrations of economic potential and culture technology feasibility (or lack thereof), marine finfish bait aquaculture will either not move forward, or it will attract unwise investment. Along with demonstration projects, user-friendly communications must be initiated to transfer the information garnered from experimental culture activities. For each candidate species, a well planned outreach program must proceed concurrently with any research, market evaluation, or development activity. The importance of industry-academic partnerships was emphasized as a critical component to all development activities.

The candidate species (or species group) which participants felt demonstrate the greatest potential for successful development as a live bait for the recreational angling community are listed in order of highest priority as reached by a consensus of workshop participants:

1. *Fundulus* species - minnows
2. *Leiostomus xanthurus* - spot
3. *Lagodon rhomboides* - pinfish
4. *Orthopristis chrysoptera* - pigfish
5. *Micropogonias undulatus* - croaker
6. *Mugil* species - mullet
7. *Bairdiella chrysoura* - silver perch
8. *Morone americana* - white perch
9. *Dormitator maculatus* - fat sleeper

The following sections address each candidate species and provide brief background information, as well as perceived impediments to continued development. A list of selected publications for each species is included in Appendix 2.

CANDIDATE SPECIES



Fundulus grandis, F. similis, and *F. heteroclitus*

The *Fundulus* complex includes species commonly used as live baits by recreational anglers along the Gulf of Mexico and Atlantic Coast. Throughout their ranges, these species are known by a variety of local names, including: minnows, bull minnows, mudminnows, marsh minnows, tiger minnows, killifish, mummichogs, gudgeons, and cacahoes. More information is available about *Fundulus* species and their potential for culture than any other species considered. A strong consensus of workshop participants found that *Fundulus* species offer the most potential for further development as a cultured species. Indeed, several farms throughout the region are host to research projects that are addressing this potential.

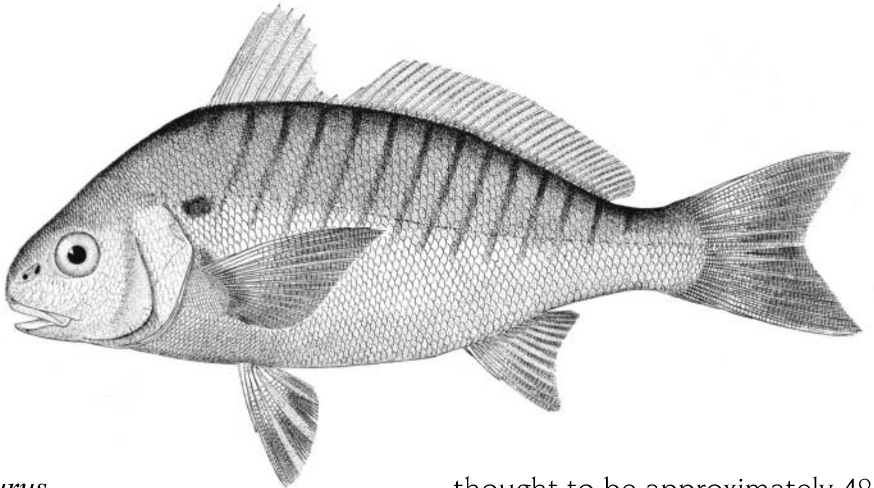
Fundulus are recognized as hardy fish that tolerate a wide range of water temperatures and salinities, traits that make them very popular with recreational anglers. These minnows generally do not exceed 15 cm (6 in.) in length, with bait sizes typically ranging from 5 to 10 cm (2 - 4 in.).

Fundulus species are oviparous, and the size of the fish influences the number of eggs produced. The timing and duration of the spawning seasons for the different species will vary based upon geographic location and water temperature parameters. Multiple spawns can be expected over the course of a spawning season. Eggs are attached to solid substrates for the incubation period, which may span 7 to 21 days, depending upon water temperature and salinity.

Because fecundity of *Fundulus* is relatively low (100-300 eggs per day over a 3-5 day spawning period for *F. heteroclitus*), larger numbers of brood stock fish will be needed for commercial operations. Previous studies on the growth rate of minnows in pond culture settings indicate a strong inverse relationship to stocking density. This needs to be taken into account when formulating any culture strategy for *Fundulus* species. Market-size minnows can be obtained as early as three months after spawning. As opportunistic feeders, *Fundulus* adapt readily to prepared diets.

Considerable information is available on the Technical aspects of *Fundulus* culture. In addition, limited perceived Regulatory concerns or Environmental Impacts are associated with continued development. However, economic issues appear to be a major impediment to commercial expansion. Wild-harvested *Fundulus* currently supply the live bait market and generally do not command premium prices, making culture expenses a major concern for prospective producers. Despite limited previous study, a need exists for projects which would demonstrate *Fundulus* culture technology in ponds, including less regulated, affordable inland sites, as well as recirculating water systems. This work could provide a comparison of the financial characteristics of *Fundulus* culture via detailed production budgets. A comparison of production costs based on current market prices would also provide insight into the break-even wholesale price needed to achieve commercial feasibility.

TOPIC	KNOWN	PARTIALLY KNOWN	NOT KNOWN
Regulatory issues/permits	X		
Brood stock availability	X		
Spawning biology		X	
Larval nutritional needs		X	
Larval environmental requirements and ranges		X	
Juvenile nutritional needs		X	
Juvenile environmental requirements and ranges		X	
Growth rates		X	
Disease susceptibility and control methods		X	
"Hardiness" to handling and water quality stress		X	
Culture methods	X		
Equipment requirements for grow-out	X		
Previous culture attempts	X		
Market analysis - demand, seasonality, location		X	
Secondary markets (aquarium trade/food)		X	
Competition (other growers/wild harvest)		X	
Economic analysis - production versus returns		X	
Number of crops per year		X	
Multi-cropping/polyculture opportunities		X	
Technical support available	X		
Demonstration projects conducted	X		



Leiostomus xanthurus

The distinctive dark spot above the pectoral fin of *Leiostomus xanthurus* accounts for the most common name given this species, "spot," although it is also known by lafayette, goody, or Norfolk spot. The spot is very common from Cape Cod south, through the Gulf of Mexico. It is considered both a valuable commercial and recreational species throughout its range. Because of its abundance, the spot is important to the functioning of estuarine ecosystems. As such, a great deal of literature is available regarding the spot's importance in nutrient fluxes, predator-prey relationships, estuarine ecology, and larval transport mechanisms. Spot has also been called the "estuarine white rat" because of its extensive use as a bioassay animal and in contaminant studies. Despite a relatively small size, usually not exceeding 250 mm (10 inches) in length, spot are highly sought after as a food fish by both commercial and recreational fishermen. Its abundance in near-shore oceanic, coastal embayments, and estuarine areas makes spot readily available to all anglers. While the commercial importance of the spot cannot be discounted, its value as a recreational target species, bait species, and bioassay subject likely exceeds that of the commercial fishery.

As with other estuarine fish, spot tolerate wide variations in water temperature and salinity. The lower lethal temperature for spot is thought to be approximately 4° C (~39° F), while the upper lethal temperature is over 35° C (95° F). Spot have been found at salinities of 0 to 60 parts per thousand. Spot are catadromous fish that spawn in offshore, higher salinity waters and utilize inshore estuarine areas as nursery grounds. As estuarine water temperatures begin to drop, spot congregate and move to moderately deep waters. Spawning activity begins in the fall and continues into winter months.

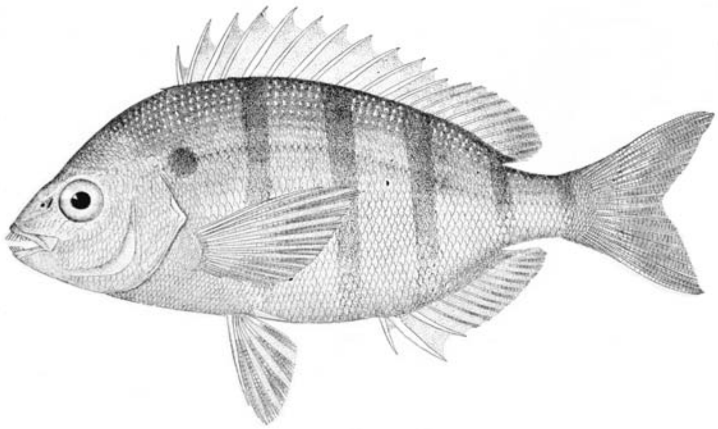
Fecundity of spot is reportedly between 30,000 and 60,000 eggs per female; individual females are capable of spawning multiple times during a single spawning season. Eggs are buoyant and at 20° C (68° F) hatch within 48 hours. Literature suggests larvae are passively carried back toward shore and estuarine areas soon after spawning. Times of arrival vary depending upon geography and onshore currents. Because of an extended spawning season, larval and juvenile spot continue to enter many estuaries throughout the spring and early summer months. Seagrass beds and tidal creeks appear to be important nursery areas for juveniles.

As they grow, juvenile spot disperse over a wider area of an estuary. During their first year of life, spot can reach 80 mm to 200 mm (~3 to ~8 inches) in length. Those in more southerly portions of their range reach larger sizes. Sexual maturity is generally reached by the second year. While larval spot are planktivores, juveniles and adults are predators of, primarily, infaunal and epibenthic invertebrates. Culture demonstrations have successfully raised spot to bait size on commercially available fish diets.

Like *Fundulus,* sufficient Technical information exists for spot culture to proceed. Recent projects have demonstrated a viable culture technology within recirculating water systems. Additional studies are necessary on extensive pond production -- especially in the southern portion of their range -- to further delineate critical culture parameters in all production systems. Research that couples recirculating technology for spawning, larval production, and juvenile culture with extensive pond production methodology is warranted.

The Economics of production and marketing need to be more adequately addressed. Any study of the Economics of production must take into account competition from the expanding wild harvest of spot for recreational angling bait, as well as alternative markets, such as bioassay animals or live food fish for ethnic outlets. Additional demonstration efforts will allow for a more thorough assessment of the economic characteristics of the various culture options. Environmental Impacts and Regulatory considerations do not, at this time, appear to be a major impediment to the expansion of spot aquaculture technologies.

TOPIC	KNOWN	PARTIALLY KNOWN	NOT KNOWN
Regulatory issues/permits			X
Brood stock availability	X		
Spawning biology	X		
Larval nutritional needs		X	
Larval environmental requirements and ranges		X	
Juvenile nutritional needs		X	
Juvenile environmental requirements and ranges		X	
Growth rates		X	
Disease susceptibility and control methods			X
"Hardiness" to handling and water quality stress		X	
Culture methods		X	
Equipment requirements for grow-out		X	
Previous culture attempts	X		
Market analysis - demand, seasonality, location		X	
Secondary markets (aquarium trade/food)			X
Competition (other growers/wild harvest)		X	
Economic analysis - production versus returns		X	
Number of crops per year		X	
Multi-cropping/polyculture opportunities			X
Technical support available	X		
Demonstration projects conducted	X		



Lagodon rhomboides

Lagodon rhomboides, generally referred to as pinfish, sailor's choice, or pin perch throughout its range, is one of the most common inshore fish. Its extensive range from Massachusetts through the Gulf of Mexico makes the pinfish known to coastal anglers as a notorious "bait stealer," but also as a good bait for other larger, more desirable food species.

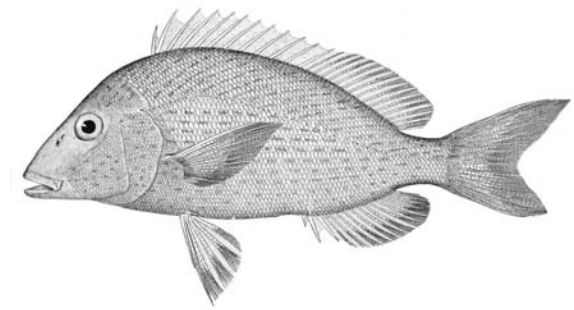
Pinfish are an estuarine dependent fish, abundant through most of their range, especially from Virginia south. As such, they occur over a wide variety of bottom types but prefer vegetated bottoms. Pinfish can tolerate wide variations in temperature and salinity conditions. The maximum size of pinfish has been reported at 400 mm (15.7 inches), although finding pinfish of that size is very rare. While larger pinfish can be consumed, it is most often considered as a baitfish or for use in bioassays.

Spawning occurs offshore in higher salinity waters during the fall and winter months. Pinfish eggs usually have a single oil globule and are semi-buoyant. At 18° C (64.4° F) eggs hatch after about 48 hours; newly hatched larvae are approximately 2.3 mm long (0.9 inches). Fecundity of pinfish has been reported as averaging approximately 21,600 eggs per female (111 to 152 mm standard length/4.5 - 6.0 inches).

After hatching in offshore waters, larval pinfish migrate into estuaries where they grow though the summer months. Most pinfish become sexually mature at 80 mm to 100 mm (3 to 4 inches) total length, either late in their first year or in their second year of growth. A late fall migration to offshore spawning grounds is most likely triggered by a drop in water temperatures below 10° C (50° F). Throughout its life history, pinfish demonstrate planktivory, omnivory, strict carnivory, and even strict herbivory, depending upon times, locations, and stages of development. Along with spot, pinfish are reported to be one of the most abundant fish species in estuarine icthyofaunal assemblages.

Because of the importance of pinfish within the estuarine community, a great deal of information is available on its natural history and environmental requirements. However, there is a paucity of information regarding culture criteria for this species. For this reason, Technical aspects of pinfish culture were identified as the most important need for development of pinfish as a potential aquacultured bait species. Included under this category would be appropriate culture system choices and nutritional needs. Of equal importance are the Economic parameters for pinfish culture. A major concern relates to the availability of wild pinfish and the willingness of anglers to purchase cultured pinfish as opposed to catching their own in the wild. Studies regarding the market acceptance of cultured pinfish and the pricing necessary to access the bait market are needed. Regulatory and Environmental Impacts were considered to be of minor importance for pinfish culture development.

TOPIC	KNOWN	PARTIALLY KNOWN	NOT KNOWN
Regulatory issues/permits			X
Brood stock availability		X	
Spawning biology	X		
Larval nutritional needs		X	
Larval environmental requirements and ranges		X	
Juvenile nutritional needs		X	
Juvenile environmental requirements and ranges		X	
Growth rates		X	
Disease susceptibility and control methods			X
"Hardiness" to handling and water quality stress	X		
Culture methods		X	
Equipment requirements for grow-out			X
Previous culture attempts			X
Market analysis - demand, seasonality, location		X	
Secondary markets (aquarium trade/food)		X	
Competition (other growers/wild harvest)	X		
Economic analysis - production versus returns			X
Number of crops per year			X
Multi-cropping/polyculture opportunities			X
Technical support available			X
Demonstration projects conducted			X



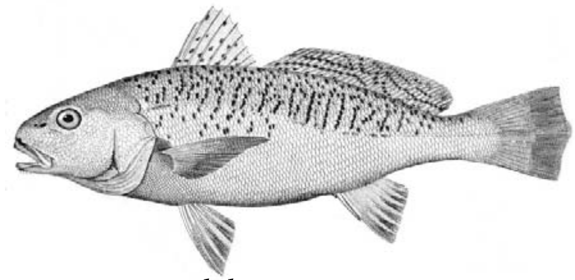
Orthopristis chrysoptera

Despite the unattractive common name "pigfish," *Orthopristis chrysoptera* is a very colorful member of the grunt family, with a bluish upper and a silvery lower body. Each scale has a blue center and bronze edge, which forms a series of yellow-brown stripes on the sides and sometimes exhibits orange bands on the snout and head. While the full range of pigfish extends from Massachusetts through the Gulf of Mexico, it is uncommon to see one north of Virginia. Pigfish are frequently taken by recreational anglers and considered to be a good quality food fish. The fish are of limited commercial importance, and most commercial landings are aggregated with other grunt species. Pigfish are popular live bait, especially in Florida and Gulf of Mexico waters. Yet, little information is available on this species or its potential for culture.

Limited information is available on pigfish growth. Reported maximum length is approximately 460 mm (18 inches), with a maximum weight of about 0.9 kg (2 pounds). Pigfish three years of age are rare along the Atlantic coast and four-year-old fish are very rare. With such a short life span, pigfish mature by their second year. Throughout their range, pigfish spawn in the late winter to spring. It is believed that spawning occurs in the early evening hours. Larval and early juvenile pigfish are planktivores and become, primarily, benthic carnivores as they mature. Pigfish are abundant in more saline coastal waters and around offshore reefs. They tend to avoid salinity levels under 15 parts per thousand. Similarly, they apparently avoid low temperature waters, migrating instead to deeper water during winter months.

With the paucity of information available on life history parameters and culture activities, it is not surprising that Technical unknowns were identified as the primary impediments to pigfish aquaculture. However, recent reports in trade magazines indicate that some progress has been made by private individuals in pigfish culture. While this may be true, there have been no demonstration projects or economic studies to document pigfish culture. The lack of information on Economic characteristics and potential for pigfish culture was therefore found to represent a significant gap in existing knowledge. There remains a need for detailed production economics information today. In addition, an evaluation of the market potential for pigfish as a live, marine bait needs to be conducted. Environmental Impact and Regulatory constraints were deemed of less importance to pigfish culture development.

TOPIC	KNOWN	PARTIALLY KNOWN	NOT KNOWN
Regulatory issues/permits			X
Brood stock availability		X	
Spawning biology		X	
Larval nutritional needs			X
Larval environmental requirements and ranges		X	
Juvenile nutritional needs		X	
Juvenile environmental requirements and ranges		X	
Growth rates		X	
Disease susceptibility and control methods			X
"Hardiness" to handling and water quality stress		X	
Culture methods			X
Equipment requirements for grow-out			X
Previous culture attempts			X
Market analysis - demand, seasonality, location		X	
Secondary markets (aquarium trade/food)			X
Competition (other growers/wild harvest)			X
Economic analysis - production versus returns			X
Number of crops per year			X
Multi-cropping/polyculture opportunities			X
Technical support available			X
Demonstration projects conducted			X



Micropogonias undulatus

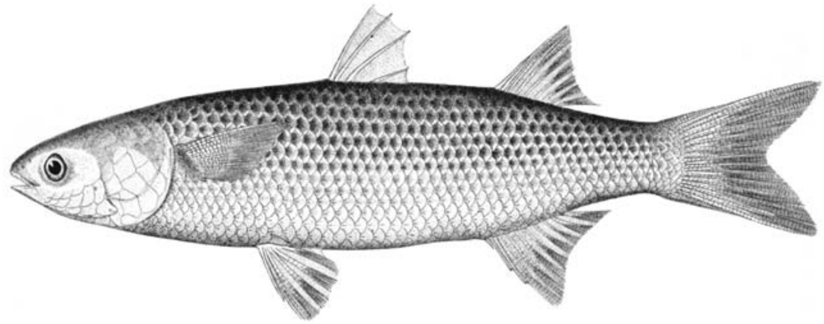
The Atlantic croaker, ***Micropogonias undulatus***, also referred to as croaker and hardhead, belongs to the family Sciaenidae and is an abundant species ranging from Cape Cod, Massachusetts, to the Campeche Bank, Mexico. Significant commercial groundfish and recreational fisheries exist in many states. Live croaker are a common bait for grouper and speckled sea trout. This demand as bait and preliminary success in rearing of early life stages of the fish suggest promise as a desirable candidate for culture.

At two years of age, croaker spawn well offshore (20-50 km) in waters ranging from 8 to 80 meters in depth from August to May. Peak spawning activity occurs in September in mid-Atlantic latitudes and in November for southern locations. Fecundity ranges from 42 to 180,000 eggs for a 39-cm female. Eggs are pelagic and hatch within one week. Upon hatching, larvae are demersal and are carried into coastal bays and estuaries where they stay until migrating to the ocean in preparation for spawning. Larvae are primarily zooplankton feeders, and detritus is a key diet source for juveniles in addition to benthic micro-invertebrates. Adults are capable of feeding on larger invertebrates and small fishes. Croaker are found in a wide range of salinities, (1-32 ppt), with largest catches occurring in 15-19 ppt waters. Soft bottoms associated with sea grass beds are preferred habitat.

A limited amount of information is available on Technical or culture issues for croaker. Preliminary tank culture of croaker juveniles showed good growth (>400% weight gain) and excellent survival over a 7-week period at 28° C and at 28 ppt. Larval feeding regimes similar to red drum have been used with relatively good success and juveniles have responded well to higher protein diets. Other Technical information, such as recommended stocking densities and adaptability to various culture systems, is needed.

Marketing and Economics are the greatest issues needing to be addressed to assess the potential of this species as a baitfish. Though used extensively by anglers for several recreational fish species, information on demand and supply is critical for future development. Because of its wide range, the issue of Regulations and Environmental Impacts may not be as critical as other potential marine bait species.

TOPIC	KNOWN	PARTIALLY KNOWN	NOT KNOWN
Regulatory issues/permits		X	
Brood stock availability	X		
Spawning biology	X		
Larval nutritional needs		X	
Larval environmental requirements and ranges		X	
Juvenile nutritional needs		X	
Juvenile environmental requirements and ranges		X	
Growth rates		X	
Disease susceptibility and control methods		X	
“Hardiness” to handling and water quality stress		X	
Culture methods		X	
Equipment requirements for grow-out			X
Previous culture attempts		X	
Market analysis - demand, seasonality, location			X
Secondary markets (aquarium trade/food)	X		
Competition (other growers/wild harvest)	X		
Economic analysis - production versus returns			X
Number of crops per year			X
Multi-cropping/polyculture opportunities			X
Technical support available		X	
Demonstration projects conducted			X



Mugil cephalus and *M. curema*

Mullet are one of the most widely distributed food fishes in the world, occurring in tropical and subtropical coastal waters. They are not only prized for their flesh and roe, but also as live bait. *Mugil cephalus* is commonly known as striped mullet, grey mullet, or flathead mullet. *M. curema* is referred to as white or silver mullet. Because of their leaping abilities, both are referred to as "jumpers" or "jumper" mullet. With a worldwide distribution and commercial importance, it's not surprising that a great deal of information exists on mullet. A literature search reveals literally thousands of articles about mullet, many with aquaculture implications.

M. cephalus is the larger of the two species and more important as a food fish. This is reflected in the volumes of information on *M. cephalus* commercial fisheries, life history aspects, and aquaculture. *M. cephalus* has been cultured for centuries in many countries. While *M. cephalus* is an established food fish already being cultured, *M. curema* is recognized as a prized bait fish, especially for large game fish (sailfish, marlin, etc.). Currently, wild-harvested mullet used as bait either originate from commercial harvesters or are captured by recreational anglers for their own use.

With the focus on mullet as food, both as a commercial fishery and as a cultured species, a great deal is known about their life history. This is especially the case for the grey mullet. Mullet are generally euryhaline, occurring in salinities ranging from strictly fresh water to over 35 parts per thousand. While preferring warmer water temperatures, they have also been found at water temperatures from 0 to 35° C (32 - 95° F). Mullet feed at a low trophic level, primarily consuming detritus and algae. A migration from inshore, lower salinity waters to offshore, higher salinity waters occurs in the fall and winter as mullet prepare for spawning.

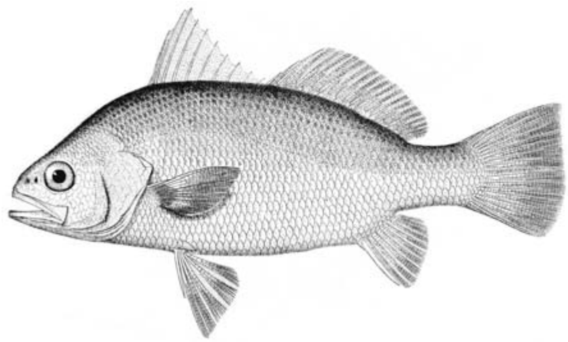
While induced spawning has been perfected for hatchery production of mullet fingerlings, natural production within a controlled setting has not been successful. It has been suggested that the interruption of the spawning migration prevents final maturation and spawning in captive mullet. Information on induced spawning of mullet is readily available in the literature, and entire volumes of the journal *Aquaculture* have been devoted to mullet culture.

Mullet eggs are positively buoyant and hatch after approximately 48 hours of incubation. Like other marine finfish, larvae hatch with many body parts undeveloped and rely upon a yolk sac for the first several days of life. Larvae/juveniles migrate to inshore waters and estuaries at an early size (~20 mm) and spend the majority of their first year in coastal inshore, lower salinity waters. When older mullet begin their offshore spawning migration, fish less than one year old generally overwinter in deeper portions of the estuary. Following their first year, mullet can be found over wide areas with salinities ranging from open ocean to fresh waters. Most mullet sexually mature in their third year of life. The maximum size for grey mullet is reported to be approximately 8 kg (17.5 pounds) and the maximum age is reported at 16 years. White mullet have a reported maximum size of about 0.7 kg (1.5 pounds).

Despite a large number of publications addressing the culture of, primarily, grey mullet, Technical aspects of culture were identified as the primary impediment to implementation for bait culture of mullet. This is reflected in the reliance on induction for the production of seed stock and the lack of experience in the culture of the white mullet, which is the preferred live bait in the Gulf and South Atlantic regions. Because of the importance of mullet as a food fish, Regulatory issues were also seen as potentially delaying the development of the culture of mullet for use as live bait. Finally, Economic issues were viewed as being more important than Environmental Impacts to the overall development of mullet culture. Not much is known about the economic characteristics of mullet culture in the United States.

As with other potential live bait species, demonstration culture efforts would help provide estimates of the production costs associated with producing a bait-sized mullet. In addition, studies on the existing market for live mullet as bait would provide insight into the production cost levels that regional and local markets would allow. The viability of mullet culture would, necessarily, depend upon the volumes and prices that the live bait market could accommodate.

TOPIC	KNOWN	PARTIALLY KNOWN	NOT KNOWN
Regulatory issues/permits		X	
Brood stock availability	X		
Spawning biology	X		
Larval nutritional needs	X		
Larval environmental requirements and ranges	X		
Juvenile nutritional needs	X		
Juvenile environmental requirements and ranges	X		
Growth rates		X	
Disease susceptibility and control methods		X	
"Hardiness" to handling and water quality stress	X		
Culture methods	X		
Equipment requirements for grow-out		X	
Previous culture attempts	X		
Market analysis - demand, seasonality, location		X	
Secondary markets (aquarium trade/food)	X		
Competition (other growers/wild harvest)	X		
Economic analysis - production versus returns		X	
Number of crops per year		X	
Multi-cropping/polyculture opportunities		X	
Technical support available		X	
Demonstration projects conducted	X		



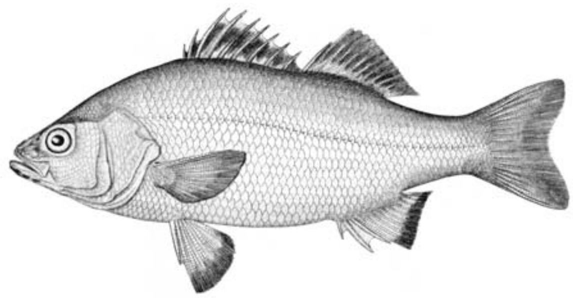
Bairdiella chrysoura

Bairdiella chrysoura, also known as a silver croaker or silver perch, is another member of the large family of Sciaenids prevalent from New York southward through the Gulf of Mexico to northern Mexico. Because of its relatively small size (maximum adult size ~30 cm/12 inches, total length), the silver perch has limited commercial value as a food fish. It does, however, have potential as a live bait species and is occasionally used as such by anglers who harvest the fish for their own use. Commercial harvesting for bait purposes is very limited.

The silver perch is found in coastal waters during warmer months in the northern portion of its range and moves offshore during cooler months. In the southern portion of its range, silver perch will spend longer periods of the year in the inshore nursery and feeding grounds of an estuary. The diet of silver perch consists mainly of crustaceans, worms, and occasionally fish. Spawning occurs during the late spring and early summer months; taking place earlier during the year in the southern portion of its range. Juveniles settle in nearshore sea grass beds. The larval and juvenile phases are very similar to those of other Sciaenids.

It's not surprising that Technical aspects of silver perch culture were identified as the primary constraint to development. Virtually no literature exists on the growth, nutrition, and sexual maturation of silver perch. Almost all basic life history and nutritional parameters must be determined before this species can be cultured. Equally important for the initiation of culture activities is an understanding of the Economics of culturing silver perch as bait. And, virtually nothing is known on the potential market for this fish as a live bait. Environmental Impacts and Regulatory issues were deemed of minor importance for consideration of this species.

TOPIC	KNOWN	PARTIALLY KNOWN	NOT KNOWN
Regulatory issues/permits			X
Brood stock availability		X	
Spawning biology			X
Larval nutritional needs			X
Larval environmental requirements and ranges			X
Juvenile nutritional needs			X
Juvenile environmental requirements and ranges			X
Growth rates			X
Disease susceptibility and control methods			X
"Hardiness" to handling and water quality stress			X
Culture methods			X
Equipment requirements for grow-out			X
Previous culture attempts			X
Market analysis - demand, seasonality, location			X
Secondary markets (aquarium trade/food)			X
Competition (other growers/wild harvest)			X
Economic analysis - production versus returns			X
Number of crops per year			X
Multi-cropping/polyculture opportunities			X
Technical support available			X
Demonstration projects conducted			X



Morone americana

The white perch, *Morone americana*, is a smaller cousin of the widely cultured striped bass and related hybrids. White perch is also an important commercial species in most of its range, which extends from the Canadian maritimes to South Carolina. Because of their importance as a target species for recreational anglers and their ability to readily adapt to fresh water, white perch have been introduced into many inland lakes, reservoirs, and streams throughout the Midwest and eastern United States. As a voracious predator, white perch can become problematic in areas where introduced. With all that is known about the culture of other, related *Morone* species, the white perch is well positioned as a potential candidate for culture as a live bait fish.

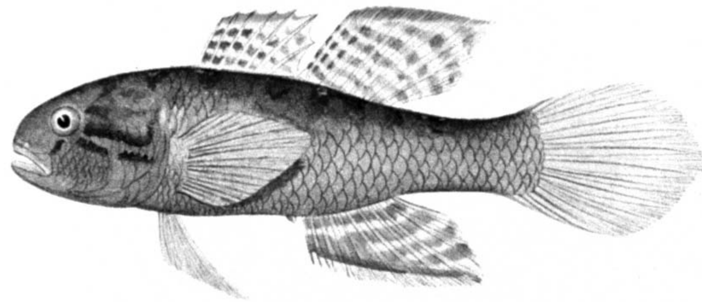
The natural range of white perch is from the coastal maritime provinces of Canada to South Carolina. However, the largest populations of white perch are located in the mid-Atlantic states, including the Chesapeake and Delaware bays. White perch have been introduced extensively into fresh waters of New England, the Great Lakes, and midwestern states, where it has readily adapted and reproducing populations now exist. Based upon life history studies, white perch are very adaptive to different habitats. They occur from fresh water to full-strength seawater. White perch are found over various bottom types. Most of the information known about the white perch is based upon life history studies in their natural range.

Spawning begins with warming water temperatures in the late winter/early spring and continues into early summer. Over its range, white perch spawn at water temperatures between 11° and 21° C (52° to 70° F). White perch may or may not undergo migrations to spawning areas, in which estuarine populations move to fresh

TOPIC	KNOWN	PARTIALLY KNOWN	NOT KNOWN
Regulatory issues/permits		X	
Brood stock availability	X		
Spawning biology	X		
Larval nutritional needs	X		
Larval environmental requirements and ranges	X		
Juvenile nutritional needs		X	
Juvenile environmental requirements and ranges	X		
Growth rates	X		
Disease susceptibility and control methods		X	
"Hardiness" to handling and water quality stress	X		
Culture methods		X	
Equipment requirements for grow-out		X	
Previous culture attempts			X
Market analysis - demand, seasonality, location			X
Secondary markets (aquarium trade/food)		X	
Competition (other growers/wild harvest)			X
Economic analysis - production versus returns			X
Number of crops per year		X	
Multi-cropping/polyculture opportunities			X
Technical support available		X	
Demonstration projects conducted			X

water. Spawning aggregations containing hundreds of individuals have been reported. Fecundity is related to fish size (age) and can range from 20,000 to over 300,000 eggs per female. Fertilized eggs may attach to substrate or adhere to each other, drifting freely downstream. Hatching can occur as soon as 30 hours after spawning in water temperatures of ~20° C (68° F), with time requirements increasing as water temperatures decrease. Larvae are generally transported downstream from the spawning location, usually in waters of 0 to 8 parts per thousand salinity. Upper estuaries and creeks are nursery areas for juveniles throughout their first year of life. With decreasing water temperatures, juveniles seek deep pools in tidal creeks or deeper waters of rivers to overwinter. By the end of their second year, most white perch have sexually matured.

Given the large amount of information available on the culture of related temperate basses, Economic issues were perceived as the most important ones for developing white perch as a live bait species. Because the fish occur in a fairly well defined geographic range, market issues must be addressed if expansion is to be considered. Technical aspects of culture need to be refined or adapted for white perch, but should not be too limiting. Because of its adaptability to a wide range of habitats, Environmental Impacts must also be addressed when considering culture technology. Culture systems without potential for release (such as, recirculating) may be necessary in regions where white perch are currently not established. Regulatory concerns tying together Environmental Impacts and Technical issues must be addressed as well.



Dormitator maculatus

Fat sleepers are found throughout coastal environments from the Carolinas, southward through the Americas, to lower Brazil. In the coastal areas of the northern Gulf of Mexico, these fish (locally known as "storm minnows") are seasonally available to recreational anglers during the late summer/fall when vast numbers of sexually mature individuals school in response to rain events. Harvest from the wild temporarily inundates bait shops before the availability of the minnows abruptly ends. Thereafter, these highly prized baitfish are scarce, and bait dealers rely solely upon stockpiled individuals. The reputation of these minnows for being effective and hardy is near-legendary among red drum and seatrout anglers of the Gulf of Mexico.

As a member of the sleeper family, Eleotridae, the fat sleeper, is reported to have very similar — if not identical — karyotype with the Pacific sleeper, *D. latifrons*. In coastal areas along the Gulf of Mexico, ***D. maculatus*** is keyed to the variations in salinity caused by tidal flux and rain events. Adapting to the variations of marsh life has made the "storm minnow" very resistant to low oxygen and rapidly changing water quality. Reported as reaching 26 - 30 cm in length, mature animals are more often in the 5 to 8 cm size, with reproduction in response to freshwater flushes possible after one year. Small eggs hatch within 11 to 25 hours. Best larval survival is reported in areas with slowly increasing salinity. A voracious omnivore, the fat sleeper will quickly adapt to a flexible diet, including plant and animal matter dead or alive.

Although most of the information on the fat sleeper has been generated by the aquaria trade or through field ecology studies, a considerable bank of information is available to apply to the large-scale culturing of this species as a baitfish. It is thought that the aggressive behavior of the fish will warrant a need for hatchery facilities where fish can be satiated by prepared food. Growth is expected to be rapid, with annual crops (such as with ***Fundulus grandis***) in the year following spawning. Technical information on captive spawning, intensive culture, and general water quality parameters will be necessary to further the use of the fat sleeper as a cultured bait fish. Regulatory issues could be limited to karyotypic fidelity for areas within its range or for use in areas outside its normal range. While marketability is expected to be strong wherever there is a native population of fat sleepers, a more thorough investigation of the Economics of both culture and market issues is required. Wild harvest could be impacted by cultured animals, and vice versa, but could be tempered by seasonal pricing strategies. Demonstration grow-out projects coupled with economic studies are warranted for this species.

TOPIC	KNOWN	PARTIALLY KNOWN	NOT KNOWN
Regulatory issues/permits		X	
Brood stock availability	X		
Spawning biology			X
Larval nutritional needs			X
Larval environmental requirements and ranges			X
Juvenile nutritional needs			X
Juvenile environmental requirements and ranges			X
Growth rates			X
Disease susceptibility and control methods			X
"Hardiness" to handling and water quality stress	X		
Culture methods			X
Equipment requirements for grow-out			X
Previous culture attempts		X	
Market analysis - demand, seasonality, location		X	
Secondary markets (aquarium trade/food)		X	
Competition (other growers/wild harvest)		X	
Economic analysis - production versus returns			X
Number of crops per year			X
Multi-cropping/polyculture opportunities			X
Technical support available		X	
Demonstration projects conducted			X

APPENDIX 1
Workshop Participants

Chuck Adams
University of Florida
P.O. Box 110240
Gainesville, FL 32611-0240
352-392-1826
<cmadams@ifas.ufl.edu>

Lee Brothers
Carolina Fisheries
2207 Idalia Road
Aurora, NC 27806
252-322-7117
<carolinafisheries@yahoo.com>

Leroy Creswell
Florida Sea Grant Extension Program
University of Florida
8400 Picos Road, S-101
Ft. Pierce, FL 34945
772-462-1660
<lcreswell@ifas.ufl.edu>

Albert "Rusty" Gaude
Louisiana State University
AgCenter
479 F. Edward Hebert Blvd., Suite 201
Belle Chasse, LA 70037
504-433-3664
<agaude@agctr.lsu.edu>

Ron Hodson
North Carolina Sea Grant College Program
North Carolina State University
Box 8605
Raleigh, NC 27695-8605
919-515-2454
<ronald_hodson@ncsu.edu>

Andy Lazur
Horn Point Environmental Laboratory
University of Maryland
P.O. Box 775
Cambridge, MD 21613
410-221-8474
<alazur@hpl.umces.edu>

Frank Leteux
1203 Governors Square Blvd.
Suite 200
Tallahassee, FL 32301
850-414-0200
<leteuxf@doacs.state.fl.us>

Carlos Martinez
Tropical Aquaculture Laboratory
University of Florida
1408 24th Street, SE
Ruskin, FL 33570
813-671-5230
<cvmartinez@ifas.ufl.edu>

Mike Oesterling
Virginia Institute of Marine Science
College of William and Mary
P.O. Box 1346
Gloucester Point, VA 23062-1346
804-684-7165
<mike@vims.edu>

Peter Perschbacher
University of Arkansas at Pine Bluff
P.O. Box 4912
Pine Bluff, AR 71611
870-575-8145
<pperschbacher@uaex.edu>

Mark Peterman
Coastal Aquaculture Unit
Mississippi State University
P.O. Box 4079
Gulfport, MS 39502
228-896-5778
<map7@ra.msstate.edu>

Ben Posadas
Mississippi-Alabama Sea Grant Program
Mississippi State University
2710 Beach Blvd., Suite 1-E
Biloxi, MS 39531
228-388-4710
<benp@ext.msstate.edu>

Claude Reeves
Alabama Cooperative Extension System
Auburn University
P.O. Box 217
Headland, AL 36345
334-693-2010
<creeves@aces.edu>

Dan Sennett
Virginia Institute of Marine Science
College of William and Mary
P.O. Box 1346
Gloucester Point, VA 23062
804-684-7669
<dans@vims.edu>

Thomas “Frito” Shierling
University of Georgia Marine Extension Service
715 Bays Street
Brunswick, GA 31520-4601
912-264-7268
<shierlin@uga.edu>

John Stevely
Florida Sea Grant Marine Extension
1303 17th Street, West
Palmetto, FL 34221-5998
941-722-4524
<jmstevely@ifas.ufl.edu>

Leslie Sturmer
Florida Cooperative Extension Service
P.O. Box 89
Cedar Key, FL 32625-0089
352-543-5057
<lnst@ifas.ufl.edu>

Don Sweat
Florida Sea Grant Marine Extension Service
University of South Florida
830 First Street, South
St. Petersburg, FL 33701
727-553-3399
<dsweat@marine.usf.edu>

Craig Watson
Tropical Aquaculture Laboratory
University of Florida
1408 24th Street, SE
Ruskin, FL 33570
813-671-5230
<caw@ifas.ufl.edu>

APPENDIX 2
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Sea Grant Communications
Virginia Institute of Marine Science
Post Office Box 1346
Gloucester Point, VA 23062