Production of Spot as Live Bait for Recreational Angling

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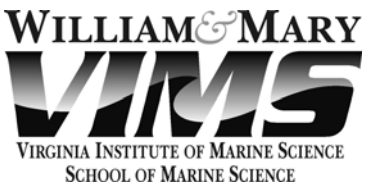


Introduction

In Virginia alone, there are over 100,000 licensed saltwater recreational anglers, who make over four million fishing trips each year and spend in excess of $550 million in pursuit of their elusive prey. These anglers use all sorts of lures, rigs, and baits in hopes of landing the "big one" or to produce a tasty dinner. The use of live bait is one popular method employed by recreational anglers. Popular live baits include bull minnows (*Fundulus heteroclitus*), eels (*Anguilla rostrata*), and spot (*Leiostomus xanthurus*), to name a few. In order to obtain these baits, the angler either purchases them from a bait dealer or spends time catching wild fish. Many times, the availability of live bait is constrained due to environmental or seasonal factors.

Aquaculture of marine finfish is expanding in the United States. New techniques to culture different species are being developed by researchers and industry participants. While much of this development has focused on the production of high-valued food fish, such as flounder, grouper, and snappers, the highest value for a cultured marine finfish may not be as a "food" fish. The production of marine finfish for use as live bait for recreational angling provides an opportunity to capitalize on this expanding industry.

For more information on the potential for marine baitfish culture, refer to: "Marine Baitfish Culture: Workshop Report on Candidate Species and Considerations for Commercial Culture in the Southeast U.S.," compiled by Michael J. Oesterling, Charles M. Adams, and Andy M. Lazur (2004, Virginia Institute of Marine Science, Marine Resource Advisory No. 77, 27 pp).

In this publication the procedures utilized by the Virginia Institute of Marine Science (VIMS) finfish culture program within the Virginia Sea Grant Marine Advisory Program to produce live spot (*Leiostomus xanthurus*) for use as live bait for recreational angling are described. In the fall of 2002, spot were spawned for use in a trial marketing program during the following year. Production information from that project, as well as results of the trial marketing of cultured spot as live bait, will be included as illustrations on the culture process.

Basic Spot Biology

The spot (Figure 1) is very common from Cape Cod south, through the Gulf of Mexico. 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. While the commercial importance of spot cannot be discounted, its value as a recreational target species and bait species likely exceeds that of the commercial fishery.

Spot tolerate wide variations in water temperature and salinity. The lower lethal temperature for spot is thought to be ap-

Figure 1. The spot, *Leiostomus xanthurus*.

proximately 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 (ppt). They 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 offshore. 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 throughout their range, 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. Sexual maturity is generally reached by the second year. While larval spot are planktivores, juveniles and adults are predators of infaunal and epibenthic invertebrates (worms and small crustaceans, for example).

Why Culture Spot? - Trial Marketing

While the spot is an important commercial species, it is also a relatively low-valued one. At times, the value returned to commercial harvesters for spot drops as low as $0.33 per kg ($0.15/lb). With most commercial spot in the 0.2 to 0.3 kg (0.5-0.75 lb) size range, this places individual fish value under $0.10 each. However, similarly sized spot sold as recreational angling bait can command prices approaching or exceeding $1.00 per fish, depending upon size and season. In order to evaluate the potential for cultured spot in the live bait market, a trial marketing project was initiated in the fall of 2002.

Prior to the actual test marketing of cultured spot as live bait for recreational angling, information was gathered about the use of live bait by anglers. To collect this information, two different user evaluations were conducted. The first was a personal interview of recreational anglers to assess live bait usage, identify species most commonly used and how anglers obtain the bait, bait size preferences, and use patterns. Over a three-day period at the end of February and beginning of March, 2003, recreational anglers attending a Sports Fishing Expo in Virginia Beach, VA, were questioned regarding their use of live bait. The anglers were first asked if they used live bait; if they answered in the affirmative, more questions were asked regarding their usage patterns. They were asked to identify:

1. All species of live bait they used.
2. The prices they normally paid for individual species, if they purchased them.
3. The preferred bait size (length) for the different species utilized.
4. An estimate of their annual use, in numbers of animals, for each species.
5. Their impression of a cultured spot as a live bait.

An aquarium with 100-day old cultured spot was on site for the anglers to inspect.

Here are summaries of the responses to the above questions:

Live Bait Species Used

Eels	79% of respondents
Croaker	84% of respondents
Mudminnows	84% of respondents
Spot	100% of respondents

Preferred Bait Sizes

Eels	8 to 14 inches
Croakers	3 to 7 inches
Mudminnows	1.5 to 3 inches
Spot	3 to 7 inches

Prices Paid for Individual Species

Eels	$1.00 to $1.50
Croaker	over $1.00
Mudminnows	$0.10 to $0.15
Spot	$0.75 to $1.00

Estimated Annual Usage Per Angler

Eels	43
Croaker	116
Mudminnows	253
Spot	80

There was overwhelming support from the recreational anglers interviewed for the concept of cultured spot as live bait. Many individuals "volunteered" to test the effectiveness of cultured spot during the angling season.

The second evaluation entailed a mail survey of bait dealers in the Virginia portion of Chesapeake Bay. This survey served two purposes: first, to characterize the live bait business; and second, to solicit participation in trial marketing of cultured spot. The bait dealer survey was not designed to provide a full economic evaluation of the live bait business, but was used to help develop the culture goals and trial marketing parameters of the overall project.

A short, one-page questionnaire was developed to better elucidate the existing live bait business and to alert bait dealers to the potential availability of cultured spot for a trial marketing project. Participants in the survey were identified by their participation as official weigh stations for the Virginia Salt Water Fishing Tournament program, through listings in telephone books for the region surrounding the Chesapeake Bay and by personal knowledge. A total of 94 bait dealers were ultimately sent the mail survey. Only responses from bait dealers who indicated that they sold live bait will be reported here (30 respondents, 31.9% of total).

Live Bait Species Sold (% of respondents)

Mudminnows	93%
Eels	67%
Spot	33%
Mullet	10%

Sourcing of Live Bait (number of responses)

Catch their own	3
Purchase	13
Catch and purchase	14

When Purchasing, Amount Paid per Individual Fish (number of responses by price class)

Eels	Mudminnows	Spot
$0.25 - $0.50 = 2	Less than $0.05 = 9	Less than $0.25 = 1
$0.50 - $0.75 = 5	$0.05 - $0.10 = 5	$0.25 - $0.50 = 3
$0.75 - $1.00 = 10	$0.10 - $0.15 = 1	$0.50 - $0.75 = 3
Over $1.00 = 1	$0.15 - $0.20 = 1	$0.75 - $1.00 = 2
Over $1.00 = 1		

Sizes of Bait Carried (number of responses by size class)

Eels	Mudminnows	Spot
6 - 10 inches = 17	Under 2.0 inches = 23	Less than 3 inches = 8
10 - 14 inches = 24	2.0 to 3.0 inches = 19	3 - 4 inches = 8
14 - 18 inches = 14	Over 3.0 inches = 12	4 - 5 inches = 6
Over 18 inches = 5		5 - 6 inches = 6
Over 6 inches = 2		

Finally, the bait dealers were asked that if they had been available during the 2002 fishing year, could they have sold more live bait.

Yes = 27 No = 2

From the user interviews and the bait dealer surveys, it was decided that the target market size for cultured spot should be over 3 inches in length. Additionally, it was determined that for the marketing trial, wholesale

prices would be $0.25 per fish for spot measuring between 3 and 4 inches, and $0.50 per fish for spot measuring over 4 inches.

In the fall of 2002, spot were spawned and raised according to the protocols described later in this publication. As a result of the bait dealer surveys, five businesses were chosen to participate in the market trials during 2003. Participants were chosen based upon an expressed interest during the survey and their business location and size. The chosen participants were: a high-end dealership located in Virginia Beach (VB); an urban, low-end dealership on the James River (JR); a rural, upscale dealership located on the Middle Peninsula (MP) in an area of heavy recreational fishing; a combination seafood market, bait and tackle shop in Deltaville (D); and a small, new business located on the Rappahannock River (RR).

In order to obtain committed participation, the bait dealers had to agree to supply certain economic information and to provide follow-up information at the completion of the project. Additionally, they agreed to purchase the spot, but were free to charge whatever they felt appropriate for their business. No delivery charges were assessed. All deliveries were made on Thursday in advance of heavy recreational angling on weekends.

The project solicited some advance media exposure through news releases and appearances on radio fishing programs, but the dealerships conducted their own advertising as well. One business advertised on their billboard, "Live Cultured Spot - Striper Candy!"

Almost 7,000 cultured spot were distributed. During this time the JR dealership sold live spot for $6.00 per dozen, the VB dealership charged $8.00 per dozen, and the remaining three dealers all charged $9.00 per dozen. Table 1 presents market value conversions for both wholesale and retail fish.

Table 1. Wholesale and Retail Market Value Conversions.

Wholesale Value (mean weight of 3-4 inch cultured spot = 10.6 g)

10.6 g/fish = ~43 fish/lb @ $0.25/fish = **$10.75/lb**

Retail Value

10.6g/fish X 12/dozen = 122.4 g/dozen (0.27 lb/dz) = 3.7 dozen/lb
At $6.00 per dozen = $22.20/lb
At $8.00 per dozen = $29.60/lb
At $9.00 per dozen = **$33.33**

All market trial participants were asked six questions in a follow-up to the project. The first question was to estimate how many cultured spot they thought they could sell in one year. The responses were: VB - ~1,000 per week over a 6-month season (~24,000); JR - 10,000; MP - 10,000 to 15,000 (depending upon weather); D - no response; RR - 4,800. They were asked whether their prices were too low, too high, or just right. All replied that they felt that their prices were just right for their clientele.

Since the delivery charges had been subsidized by a research grant during this trial, they were given two different scenarios and asked what they would be willing to pay for 3 to 4-inch fish. The first scenario involved having the fish delivered to their business; the second involved having to drive within a 50-mile radius of their business to pick the fish up themselves. Here are their responses:

	Delivered	Pick-up
VB	$0.45	$0.15
JR	$0.25	$0.17
MP	$0.35	$0.25
D	$0.60	$0.00
RR	$0.65	$0.50

The next question dealt with the frequency with which they would like to obtain live spot. The responses varied with the clientele base of the different dealerships: VB - twice per week; JR - weekly; MP - weekly; D - twice a month; RR - every 3 weeks.

The final questions asked about a need for aquaculture-produced spot for live bait angling and general comments. All participants strongly agreed that there was a definite need for cultured live spot. Here are the participants' comments:

VB: It's not cost effective to try and catch them for resale. It's a great idea. I hope you can work it out.
JR: Perfect bait! Do it. It is a needed product!
MP: Simply not available by any other means at that size. Great program. I just hope it resumes. Would like to see similar mud minnow program.
D: Needed for fall striper season; spring cobia. Fish works. Sold great.
RR: Lack of caught live bait and availability. There is a market for raised bait.

Based upon user interviews, bait dealer surveys and a trial marketing project, there is tremendous potential for the production of cultured spot for recreational angling. Angler and dealer acceptance is high. The economics of production, while not totally evaluated, seem favorable for an expansion of spot culture for live bait.

Culture Technology

Since spot spawn offshore during the winter months, to culture them in Virginia, recirculating water systems must be utilized in order to be able to manipulate temperature and salinity within the culture system. These systems must be located within a building, with some temperature control. Facility descriptions are based upon the culture systems in place at VIMS and represent one option for a production system. The technology for recirculating water culture systems is rapidly improving. ***Prior to making any investments in culture facilities, it would be prudent to investigate the current technology of various components within an individual system.*** For the novice, there are several very good explanatory fact sheets available from the Southern Regional Aquaculture Center (SRAC) which provide introductory information on recirculating water systems: SRAC Publication 451, 1998 (revised), by Losordo, Masser and Rakocy, "Recirculating Aquaculture Tank Production Systems: An Overview of Critical Considerations," 6 pp; SRAC Publication 452, 1999 (revised), by Masser, Rakocy and Losordo, "Recirculating Aquaculture Tank Production Systems: Management of Recirculating Systems," 12 pp; SRAC Publication 453, 1999 (revised), by Losordo, Masser and Rakocy, "Recirculating Aquaculture Tank Production Systems: A Review of Component Options," 12 pp. SRAC publications can be accessed at http://www.msstate.edu/dept/srac/ , by writing SRAC at Mississippi State University, P.O. Box 197, Stoneville, MS 38776, or by contacting aquaculture extension agents in your home state.

A recirculating system is essentially a large aquarium where water is continually reused. In order to maintain adequate water quality, different filtration strategies must be employed. In general, there are three different types of filtration, all of which are used within a single recirculating system. These are mechanical, biological, and chemical filtration. A brief description of each type of filtration follows as an introduction to the different components included within any recirculating culture system.

Of the three types of filtration, biological is the most important. Biological filtration is the conversion of potentially toxic nitrogenous waste products into less harmful compounds by bacterial action within a filter bed. This occurs in a step-wise process called the nitrogen cycle. The first step in this process is the conversion of organic nitrogen (waste products, proteins, amino acids, and uneaten food) into ammonia. Ammonia is then further processed by bacteria into nitrite, and nitrite to nitrate. Both ammonia and nitrite can become toxic to fish; nitrate is much less toxic than ammonia or nitrite. The goal of a biological filter is to provide a favorable environment for bacteria to convert all entering nitrogenous waste materials into nitrate.

Chemical filtration does not refer to a reaction such as occurs between acidic and alkaline compounds. Rather, it refers to a complex process known as adsorption. Adsorption is the concentration of dissolved organic substances at a surface or interface; in this case, the interface is between air and water. Bubbles passed through

a column of water will accumulate dissolved substances as well as fine suspended particles on their surface, resulting in a foam. The foam can be skimmed off the water and discarded (known as foam fractionation, protein skimming, or air stripping). Certain chemicals such as proteins, fats, and sugars are released in feces and urine. These compounds can also act as parent sources for other nitrogenous wastes. They can dissolve in water and may build up to critical levels even when a biological filter is in operation. Besides the benefits derived from direct removal of these dissolved organic materials, foam fractionation has additional value. Since much of the organic material being removed is acidic in nature, there is an added benefit of maintaining a stable pH. Also, because of the way these units operate, they are excellent means of ensuring a well-aerated water supply to the culture tanks.

Finally, mechanical filtration can be thought of as a "strainer" to remove solids within the culture water. An important function of the mechanical filter is to prevent solid organic material from entering the biological filter. A mechanical filter also may reduce the transmission of disease vectors, help in maintaining the biological oxygen demand within the entire system, and lower the incidence of gill problems of sensitive fish species. It is important to have a proper functioning mechanical filter and to service this piece of equipment on a regular basis.

While these different filtration units are critical to the operation of any recirculating system, there are additional pieces of equipment which also should be included. One such piece of equipment is some sort of disinfection unit, employing either ultra-violet light or ozone sterilization. Additionally, an external source for aeration should be included. In some cases, pure oxygen should be provided, although in the following system descriptions simple aeration is utilized.

The aquaculture of spot can be broken down into three distinct phases: 1) Brood stock holding and spawning; 2) Larval culture; and, 3) Grow out to bait size. Each of these different stages can require separate culture techniques and equipment.

Brood Stock Holding And Spawning

The spot brood stock holding and spawning system at VIMS is centered around a 4,560-liter (1,200 gallons) culture tank (Figure 2). A single 1/8-HP centrifugal pump circulates water through the entire system, with the exception of the foam fractionation unit which is on a side-stream positioned within a sump with dedicated pumps. The commercially-purchased foam fractionation unit is sized to the water volume in the culture tank. Outflow from the foam fractionation unit provides additional water flow and aeration within the culture tank. Water exits the culture tank either from a bottom drain or a surface drain, depending upon whether egg collection is ongoing. Regardless of where the water exits, it all goes through the egg collector/sump before the pump. The egg collector/sump is constructed from a 55-gallon plastic barrel with one end cut off. The barrel is 51 cm (2 feet) in diameter and 89 cm (35 inches) tall. Water is drawn from the egg collector/sump into the pump and then to a commercially purchased bead filter (rated for a maximum flow of 100 gpm and up to 700 pounds of fish). From the bead filter, water flows through a 1-HP heat pump, fitted with a digital temperature control unit. Exiting the heat pump, the water stream splits with a small portion of the total water flow directed through two 40-watt ultraviolet light sterilizations units and the remaining volume entering the biological filter. The flow rate through the ultraviolet light units is restricted in order to obtain the maximum impact from the sterilization units. For biological filtration, a non-pressurized, low-head, bubbled kaldness media configuration is utilized. Approximately 0.14 cubic meters (5 cubic feet) of filter media are contained within the 51 cm (2 feet) diameter by 127 cm (50 inches) tall biofilter. Aeration within the biofilter keeps the filter media churning in suspension. The biofilter has two entrance ports to accommodate water from the ultraviolet light sterilization units and from the heat pump, and one exit port that empties into the culture tank. Water flows into the culture tank at a rate of 30 liters per minute (7.9 gallons per minute), resulting in a total culture volume replacement approximately every 2 hours (assuming effective water volume of ~3,800 liters within the culture tank). Aeration to the biofilter and to supplemental air stones within the culture tank is provided by a 2-HP regenerative blower. This regenerative blower also powers additional aeration systems within the entire finfish culture facility. As an

added precaution, the pumping system, aeration, and foam fractionation units are on separate electrical circuits within the finfish culture building. This was designed in order to have at least one life support system on line should a circuit fail or a ground fault protector trip when culture personnel were not present.

Prior to their exit from Chesapeake Bay, brood stock spot must be collected. An accepted (and enjoyable) method for collecting spot brood stock is by hook-and-line angling. Since spot tend to congregate in the lower Bay prior to their movement to the offshore shelf, a single day of angling can produce all the brood stock necessary for the spawning season. Arrangements can also be made with local commercial fishermen who use live-capture harvesting gear (pound nets or haul seines) to obtain sufficient numbers of live spot. It will be necessary to have the appropriate equipment to hold and transport live spot back to the brood stock holding facility.

In order to determine the number of brood stock needed, it will be necessary to first set a target production number for market-sized spot. This can also be used to predict the size of production facilities necessary to produce the desired number of fish. Two assumptions must be made for this calculation: number of eggs pro-

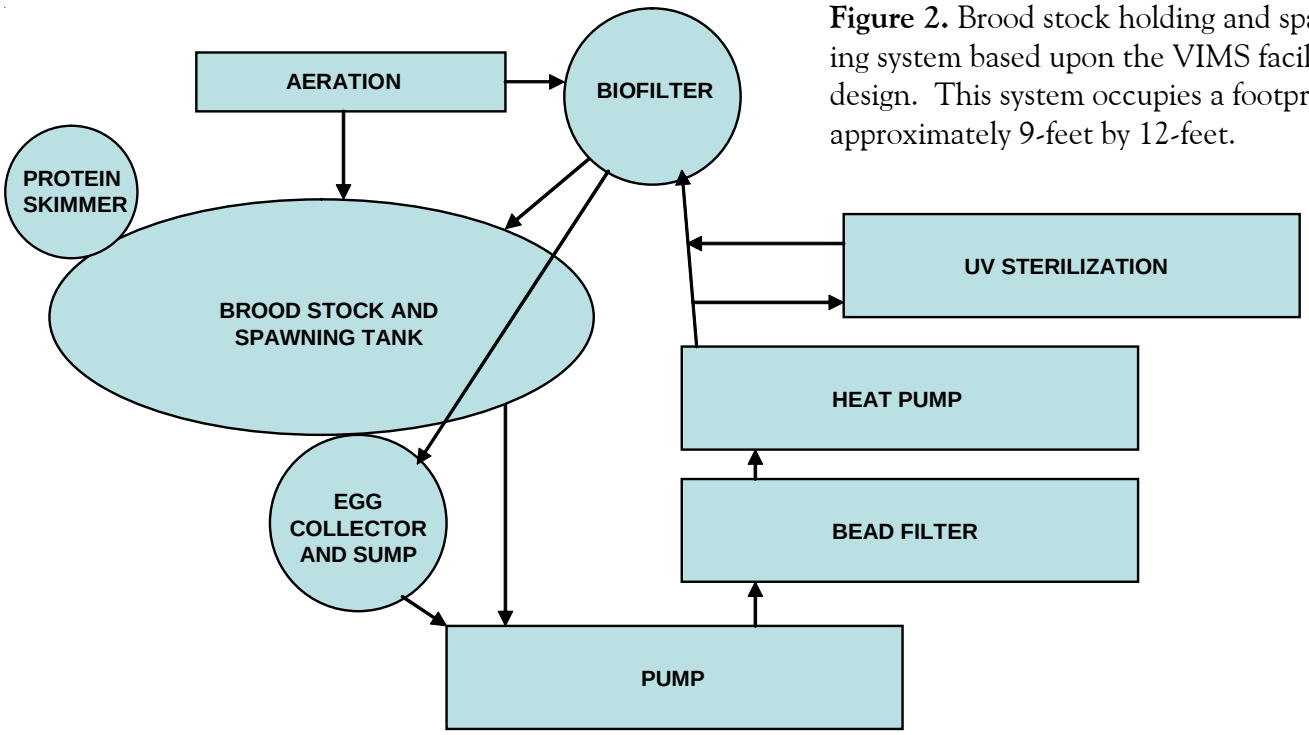


Figure 2. Brood stock holding and spawning system based upon the VIMS facility design. This system occupies a footprint of approximately 9-feet by 12-feet.

Estimated Component Costs

Pump = $320
Bead Filter = $569
Heat Pump = $2,100
UV Sterilization = $354
Biofilter = $490
Aeration = $425
Brood Stock/Spawning Tank = $2,500
Protein Skimmer = $1,000
Egg Collector = $50
Egg Collector Net = $100

TOTAL = $7,908

Estimated Plumbing Component Costs

1.5" 90 (6) = $8
1.5" bulkhead (3) = $22
2" bulkhead (2) = $20
1.5" fernco = $4.25
2" fernco = $4.50
1.5" ball valve (6) = $60
1.5" quick release with cap = $13
1.5" wye (4) = $18.50
1.5" male 90 hose barb = $6
1.5" female threaded = $1.25
1.5" male threaded = $1.25
1.5" flexible PVC pipe (50' roll) = $50.50
Flex PVC cement = $5

TOTAL = $214.25

duced per female spot and survival from egg to market-size. Literature reports that an individual spot female is capable of producing between 30,000 and 60,000 eggs per spawning season. From experiences at the VIMS finfish culture facility, a conservative approach assumes that an individual spot will produce ~4,000 eggs per day over a 7-day spawning event. While survival from egg to market-size spot at the VIMS facility has been as high as 10%, for the novice fish culturist, a more conservative estimate of 3-5% should be utilized; for this exercise, 3% will be used. If a target goal of 10,000 market-size spot is assumed, at 3% survival from egg to market-size, approximately 333,333 eggs must be produced. A total of 12 females would be needed to provide the total number of eggs. However, a larger number of females could potentially provide the required eggs in a shorter time frame, reducing size variation in larvae and synchronizing culture efforts. Once the total number of females necessary is determined, it should be doubled to represent the total number of brood stock spot to be collected. Male numbers should be equal to or exceed that of females.

During the harvest of brood stock, it is often not practical to try to determine the sex of the fish captured. Fish sex can be determined after the brood stock fish have been collected and acclimated to the holding tank. It is advisable to anesthetize the brood stock before handling them for sex determination. An approved anesthetic, such as MS-222 (tricaine methanesulfonate), should be used. Proper dosage can be determined through trial-and-error. However, a good starting point is a concentration of ~125 ppm (0.5 gram MS-222 per gallon of water). There are two steps to determining the sex of the spot. First, gently squeeze the abdomen, moving from anterior to posterior towards the genital opening. If the fish is a "ripe" male, whitish milt (sperm) will be easily expressed. If after a couple of squeezes no milt is visible, the next step is to ascertain if the fish is an immature male or a female. This is done via cannulation. Cannulation involves inserting a small tube into the genital opening of the fish and taking a biopsy of the gonad (Figure 3). Gross visual inspection will identify whether or not the sample contains ovarian material. However, examination under a microscope will be necessary to determine the stage of ripeness of the eggs. Eggs which are developing towards ovulation will exhibit a distinct separation between the external egg covering and the internal nucleus.

After an initial determination of sex, the fish should be marked so that males and females may be readily identified. An easy method of marking is to clip the tail fin. For instance, clip a portion of the upper tail fin if the spot is a male; clip the lower portion if the spot is a female. Fish may also be tagged with uniquely numbered tags for identification purposes.

Once brood stock have been collected, it will be necessary to hold the fish for several weeks to months, depending upon the stage of ripeness and spawning schedule decided upon. During this time they must be conditioned to "think" that they have moved offshore to their spawning grounds and they must be fed an appropriate

FIGURE 9.1 General anatomy of a teleost (*Perca*): *A* angulo-articular bone, *AF* anal fin, *AN* anus, *B* bulbus arteriosus, *BR* branchiostegal rays, *C* caudal fin, *D* dorsal fin, *DFR* dorsal fin ray, *DFS* dorsal fin spine, *DN* dentary bone, *E* ectopterygoid bone, *G* intestine, *GA* gill arches, *H* a hypural bone, *HS* hemal spine, *I* an interneural bone, *K* kidney, *L* liver, *LL* lateral line, *MX* maxillary bone, *N* neural spine, *NO* anterior and posterior nares, *O* opercular series and preoperculum bones, *OV* ovary, *PC* pyloric caecum, *PF* pectoral fin, *PMX* premaxillary bone, *PVF* pelvic fin, *Q* quardate bone, *R* ribs, *S* stomach, *SB* swimbladder, *SC* scales, *SM* symplectic bone, *U* urostyle bone, *UG* urogenital opening, *V* vertebral centrum. (Modified from Dean, 1895.)

Figure 3. Cannulating spot to assess gonadal development.

brood stock conditioning diet. Natural food items must be used. Squid, chopped clams, marine worms, or chopped fish have all been used previously as food items and should be provided in a mix. Feeding should occur at least once daily. Besides feeding, environmental parameters (temperature, salinity, and light if the culture system is housed in a building without natural sunlight) must be manipulated to mimic conditions found in the natural spawning grounds. Initially, spot will have been captured in Chesapeake Bay, where salinity will be lower than that encountered over the continental shelf. Salinity within the culture system should be slowly raised over a couple of weeks to approximately 30-32 ppt. Spot will spawn at lower salinities; however, below 28 ppt the eggs are not buoyant and will require a different collection strategy than described below. While the salinity is being raised to approximate the offshore location, water temperature should be lowered and stabilized around 20° C (68° F). If ambient natural lighting is not provided, such as in a greenhouse setting, then a 12-hour light, 12-hour dark cycle should be maintained.

While it is possible to obtain a "natural" spawn within the brood stock holding tank, the use of a spawning hormone to initiate the process will simplify egg collection. Once visual inspections have identified that egg development has proceeded to a point where the eggs are close to fully developed, a hormonal injection can be used to stimulate spawning (Figure 4). Prior research by the National Marine Fisheries Service documented the efficacy of using the compound HCG (human chorionic gonadotropin) for this purpose. It will be necessary to obtain a prescription for HCG from a licensed veterinarian. To use HCG as a spawning stimulus, the weight of individual fish must be known so that proper dosage can be calculated. Once again, the use of MS-222 to anesthetize the fish will facilitate weighing the fish and administering the proper HCG dosage. It will not be necessary to inject ripe-running male spot. For females, the proper dosage is 0.5 IU (international units) per gram of fish. There are 1,000 IU per milliliter. So for a female spot which weighs 350 g (~0.75 pounds), dosage would be 175 IU or ~0.175 ml. Approximately two days after injection with HCG, spawning and egg collection should begin. Spawning generally occurs after sunset.

Figure 4. Injecting brood stock spot with HCG to initate spawning.

Newly spawned and fertilized spot eggs measure approximately 80 microns in diameter (Figure 5). It will be necessary to have a means to collect these small eggs. The easiest way to accomplish this is to incorporate an egg collector within the design of the culture system. Since spot eggs are buoyant in waters over 28 ppt salinity, they can be removed via a surface flow pattern into a collector fitted with a net with smaller diameter openings than the diameter of the eggs (Figure 6). This collector should be easily accessible and removable. After female spot have been injected with HCG, the egg collector should be checked every morning for the presence of eggs.

Unfortunately, all eggs collected will not be fertilized. It will be necessary to separate the "good eggs" from the "bad eggs" before stocking them in the egg-hatching/larval culture system. This can be done by washing all eggs from the collector and concentrating them in a container with clean seawater over 28 ppt salinity. The size of the container will depend upon the number of eggs collected. Once eggs have been consolidated, the container should be set on a stable surface and not disturbed for 10-15 minutes. During this time, the "good" eggs

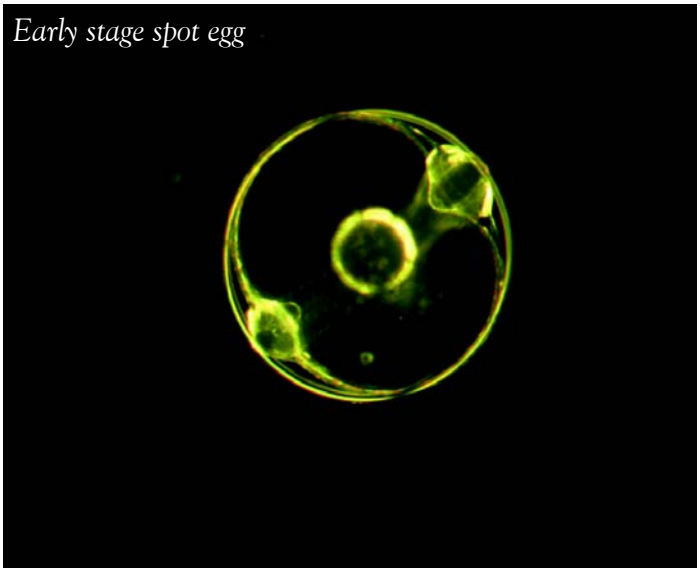


Figure 5. Spot eggs.

(fertilized) will rise to the surface where they can be easily removed by surface skimming with a fine net or gently decanting them to another container.

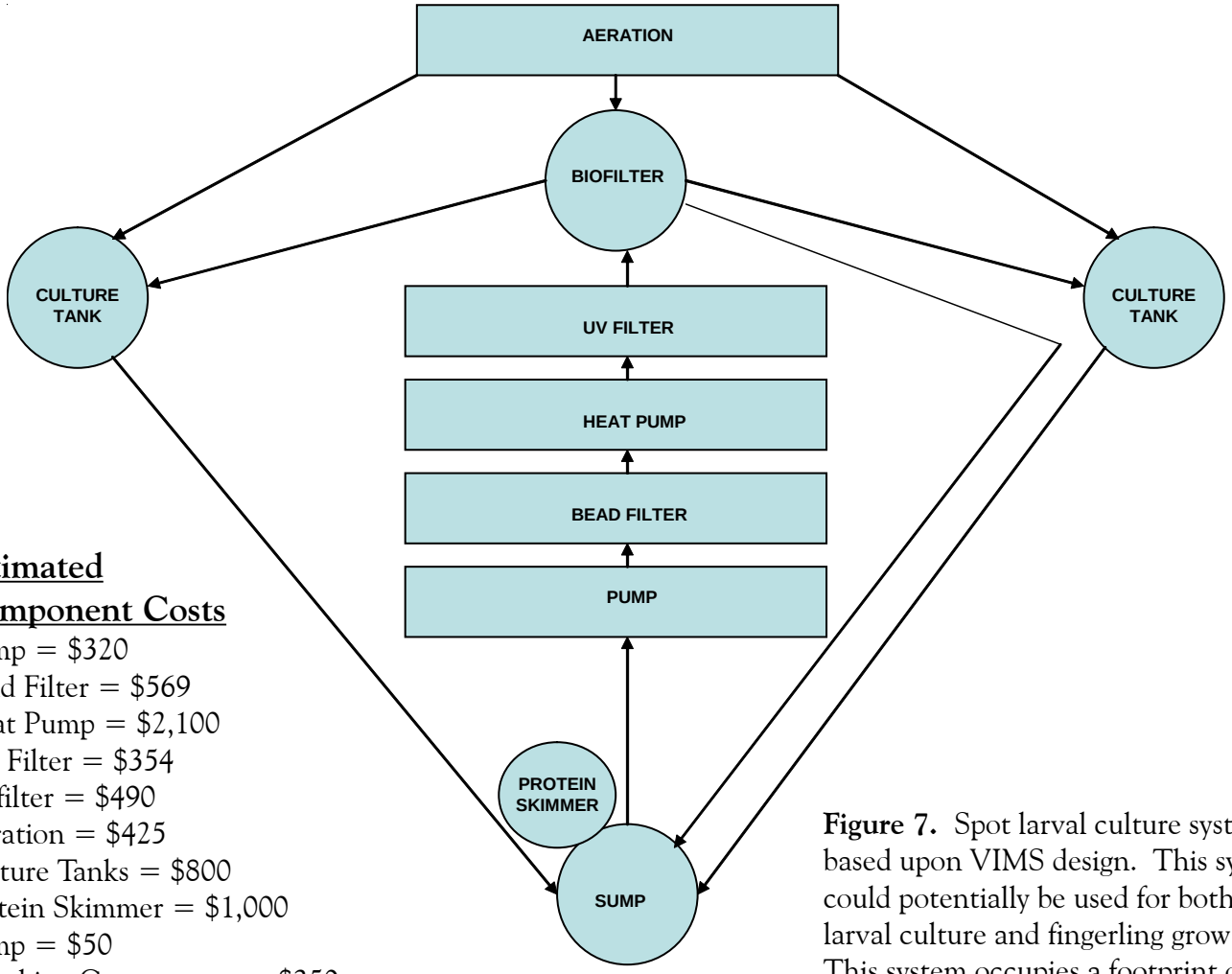
In order to stock the larval systems at the appropriate density, it will be necessary to enumerate egg production. This is most easily done by a volumetric method. After good eggs have been separated, a small sub-sample of known volume should be taken and the number of eggs counted. This should be done several times and an average number determined for a unit volume of eggs. The total volume of eggs can be measured and a calculation done to determine the approximate number of eggs produced. The appropriate number of eggs to be stocked in larval culture systems can be determined based upon the volume of water in the culture tanks and the number of eggs per unit of volume.

Figure 6. Fine-mesh net egg collector suspended above egg collector/sump.

Larval Culture

Larval culture of spot is the most labor intense period of the entire culture period. In addition to caring for the larval spot, one must also culture their food items. So, besides growing spot, it will be necessary to grow the rotifers and brine shrimp necessary to feed them.

Egg hatching and larval culture must be accomplished in a system separate from the one used to hold brood stock and for spawning. A very similar equipment lay-out can be used (Figure 7). In the VIMS finfish culture facility, instead of a single culture tank, two culture tanks each of 1,900-liter (500 gallons) capacity are utilized for egg-hatching/larval culture. Additionally, flow patterns must be changed for the



Estimated Component Costs

Pump = $320
Bead Filter = $569
Heat Pump = $2,100
UV Filter = $354
Biofilter = $490
Aeration = $425
Culture Tanks = $800
Protein Skimmer = $1,000
Sump = $50
Plumbing Components = $250
TOTAL = $6,358

Figure 7. Spot larval culture system based upon VIMS design. This system could potentially be used for both larval culture and fingerling grow out. This system occupies a footprint of approximately 9-feet by 16-feet.

initial culture period as heavy water flow will damage or kill early juvenile spot. A "by-pass" system from the biofilter to the sump will enable the water to continually flow through the biofilter to maintain filter bacteria, as flow is gradually increased to the culture tank. Diffuse lighting (approximately 12 hours light, 12 hours dark) should be provided within the larval culture area, with high intensity overhead lighting kept to a minimum.

At 20° C (68° F) spot eggs will hatch in approximately 24 hours. Newly hatched spot larvae are less than 2 mm (0.08 in) in length, with a large yolk sac/oil globule (Figure 8). The yolk sac/oil globule is able to sustain the larval spot for approximately

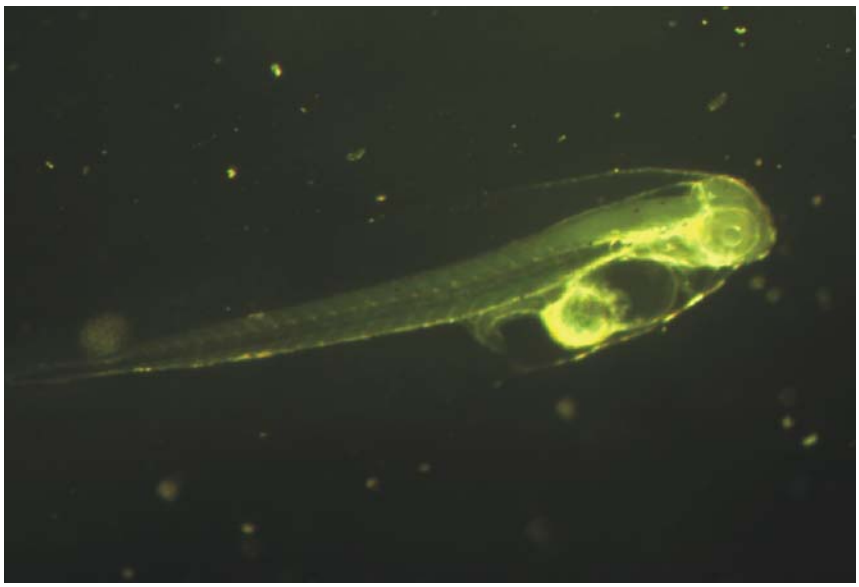


Figure 8. 1-Day Post Hatch spot larvae – note large oil drop and that the mouth is not opened.

five days, at which time the mouth has fully developed and live foods must be provided. Water temperature within the culture system should be maintained at the same temperatures as the spawning temperature or a few degrees centigrade higher. For the first couple of weeks of larval culture, salinity within the culture system should be 30 to 32 ppt. Once the larvae have grown, salinity can be slowly reduced, but should not be dropped too quickly.

Egg/larval stocking density should approximate 20 animals per liter of culture water (approximately 38,000 eggs per 1,900-liter tank). Stocking densities higher than this will require more attention to water quality parameters and will likely result in higher larval mortality or wide size variation among juveniles. Stocking densities below 20 animals per liter may result in better overall survival, but is an inefficient use of water volume, which may necessitate increased culture capabilities to achieve the desired number of market-sized spot.

During the first 21 days of the larval culture period, water within the culture tank should be static with light aeration, just enough to gently keep the larvae moving within the water column. Standard "green water" culture protocol should be followed to help maintain water quality and to provide a food supply for the live prey items to be added to the culture tank. Tank bottom cleaning using narrow-gauge siphon tubes should be conducted on an as-needed basis to remove unhatched eggs, egg sheaths, dead larvae, or fecal matter. Water quality within the culture vessel should be monitored on a regular basis, with water replacements performed if ammonia or nitrite levels approach 1 ppm levels. A separate algal culture system will be required to provide live algae for the "green water" culture. Additionally, live algae when used in conjunction with an algal paste, will enhance the quality of the live prey items to be fed to the larval spot. A description of algal culture systems is beyond the scope of this publication.

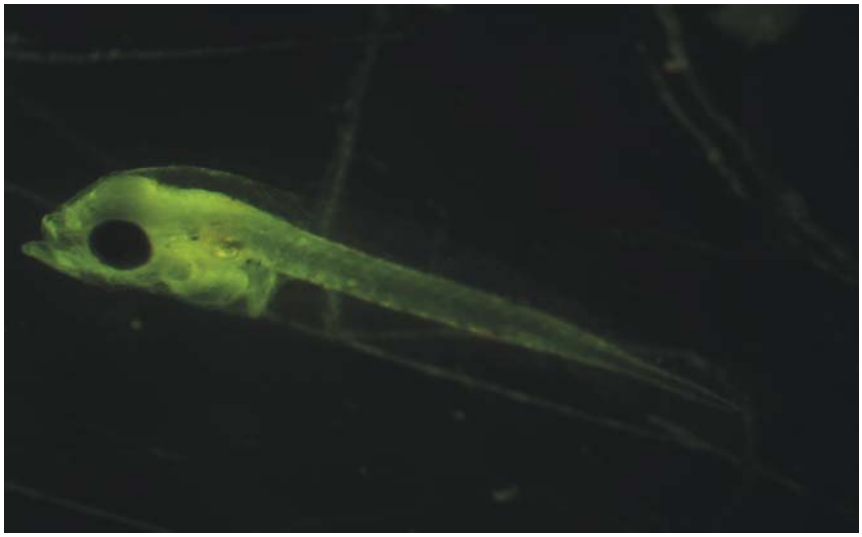


Figure 9. 3-Days Post Hatch spot larvae – note opened mouth, developed digestive system, and small oil droplet.

At 3 days post-hatch (dph), rotifers (*Brachionus plicatilis*) should be provided to the culture tank at a density of 1-2/ml as live prey for the developing spot larvae. Larval spot mouth parts are fully formed around 4 dph and, despite the presence of the yolk sac/oil globule until 5-dph, food items need to be present when spot are first able to begin feeding (Figure 9). The small size of rotifers, 120-300 microns in length, makes them ideal first foods for small marine finfish larvae. Following 5 dph, the concentration of rotifers should be increased to >7/ml. Rotifers are fed to the larval spot through 24 dph. As the larval spot age, their dependency on rotifers as a prey item will decrease, and similarly, the prey concentration can be reduced. It is critical, however, that high quality, algae-enriched rotifers be provided during the entire time when rotifers are utilized as food items.

Rotifer production systems are available for purchase from aquaculture supply companies or can be assembled by the culturist. The rotifer production system used at VIMS consists of a 500-liter (~130 gallons) culture vessel, two peristaltic pumps (one to deliver food, the other for pH control), a pH probe, 300-watt quartz immersion heater and aeration (not oxygen). Both live algae (*Tetraselmis*, *Isochrysis*, and *Nannochloropsis*) and commercially available algal paste (*Nannochloropsis*) are fed to the rotifers. Ammonia neutralizing compounds are used to counter any potential toxic effects from metabolic products within the culture system. This culture system can produce volumes of rotifers approaching 500 animals per ml. Intensive rotifer production systems employing oxygen can generate volumes of rotifers several times higher than straight aeration systems. An

excellent reference publication on rotifer culture is F.H. Hoff and T.W. Snell, 2004 (6th edition), *Plankton Culture Manual*, available from aquaculture supply companies or book stores.

As the larval spot increase in size, additional prey items must be introduced to the culture system. Brine shrimp (*Artemia sp.*) are fed beginning at 18 dph, maintained at a density of 1-2 nauplii per ml. Initially, unenriched, newly hatched nauplii (approximately 400 microns in length) are fed. As the larval spot grow and their mouths are able to accommodate larger prey items, 1-day old nauplii which have been enriched to a docosahexanoic acid to eicosapentanoic acid (DHA/EPA) ratio of 2:1 are fed to the larvae. Commercial enrichment diets with detailed instructions are available from aquaculture supply companies. Brine shrimp cysts and hatching cones are also readily available from commercial sources.

Prey counts within the larval culture tanks should be performed at least twice a day and prey density adjusted according to how many prey items are being consumed by the spot larvae. This must be done to ensure a supply of fresh, high quality prey items.

Larval spot must be weaned from live prey items to an inert diet for continued grow-out. Beginning at 22 dph, very small quantities of a high quality "weaning diet" are introduced to the culture vessel. Initial particle size of the inert diet should be <212 microns and size should be increased as the spot grow. Both the ration size and amount fed should be based upon feeding observations and measurements of the mouth opening. A general rule of thumb is that prey items or food particle sizes (width) should be between 25 and 50% of the fish mouth width. Larvae should be fed multiple times per day (up to 6 times) to satiation. As larvae begin accepting inert food, the volume of live prey items provided should be decreased and ultimately eliminated. By 45 dph all spot should be weaned off of live prey and onto an inert diet. During the weaning process it is not unusual for some larvae to never transition to inert diet and die. Once the weaning process is complete, larval spot should be approximately 2.5 cm (1 inch) in length and can now be considered juveniles or fingerlings, ready for the grow-out process to a marketable size (Figure 10). At this point, there should be very little additional attrition; the juvenile spot are very hardy, except in extreme cases when water quality deteriorates.

Figure 10. Fully-weaned juvenile spot ready for grow-out.

Grow Out To Bait Size

It's possible to use the same system for larval culture and for grow-out production. Likewise, the system which was used for brood stock holding and spawning could also be used for juvenile grow-out, after brood stock have been removed and the culture water re-conditioned. Or, if the production strategy calls for multiple spawning runs, separate culture facilities can be built exclusively for juvenile growth to market size. A system design as described for brood stock holding and spawning can be constructed for grow out to market size (Figure 2).

A variety of grow-out plans can be developed in order to prolong the period of time during which marketable spot would be available or to speed up the production cycle. Culture at lower water temperatures around 18° C (~64° F) will slow growth, while warmer temperatures around 24° C (~75° F) will accelerate the growth rate. Adjusting stocking densities can also impact the length of time to market size. Combining a lower stocking density (~0.5 fish per liter) with a higher culture temperature will result in spot reaching market size more quickly. Conversely, combining a higher stocking density (~1.5 fish per liter) with lower water temperatures will lengthen the time until market size is achieved. Both of these strategies may be employed, depending upon when bait-size spot are desired in the market. As the culturist gains experience, spot could be "conditioned" to spawn during other times of the year, expanding culture opportunities.

One of the VIMS grow-out systems used during the 2002-2003 production season was the original brood stock holding and spawning tank. This system was originally stocked at a density of 1.5 fish per liter of water (~7,000 fish). Culture water salinity was gradually decreased from 26 to 16 ppt, in order to reduce the reliance on salts needed to augment ambient salinity of source waters. Water quality was monitored on a regular basis. If ammonia/nitrite concentrations approached 1.0 ppm, corrective measures were taken. Depending on the situation, this was either a partial water exchange, the addition of an ammonia-neutralizing compound, or a combination of the two. When water alkalinity levels fell below 100 ppm, baking soda was added. This is necessary to maintain proper biofilter function. Oxygen concentrations were normally between 3.45 ppm and 7.3 ppm just with aeration, not requiring the use of pure oxygen to provide adequate oxygen levels. Culture water temperature was maintained at 24° C (~75° F) during the entire grow out period.

Juvenile spot were initially fed four times a day by hand, to satiation. Ration size was adjusted as fish grew, with the maximum size fed a 3.0 mm pellet. In retrospect, the maximum size necessary would be 2.0 or 2.5 mm. The ration was a high protein and high fat diet, more suited to a highly carnivorous fish like a cobia (*Rachycentron canadum*). At this time the proper protein-fat diet formulation for spot has not been identified. However, a lower protein-fat content food will reduce the food costs associated with grow-out. As the fish grew, hand feeding was reduced to once daily, usually in the morning in order to observe fish feeding behavior, and automatic belt feeders were added to the culture systems. Fish were still fed to an estimated satiation based upon prior feeding experience. Since the length of the fish was the determining harvest parameter, no calculations were performed for percentage of body weight fed per day. During the 2002-2003 production season, a total of 10,000 fish were produced. Table 2 presents the total amount of food fed during the entire culture period and a cost estimation based on feed costs at the time.

Table 2. Spot food consumption and costs, 2002-2003 production season.

Ration Size	Amount Fed	2003 Cost/gram	Food Cost
0.7 grain	1,439.9 g	$0.0024	$ 3.45
1.0 - 2.0 mm	5,515.2 g	$0.0012	$ 6.61
1.5 mm	78,908.6 g	$0.0010	$271.80
2.0 mm	16,096.0 g	$0.00079	$ 12.77
2.5 mm	16,437.0 g	$0.00077	$ 12.68
3.0 mm	10,590.0 g	$0.0009	$ 9.85
TOTALS (284.4 lb)	128,986.7 g		$317.16

10,000 fish produced = $0.032 food costs/fish

At 130 dph a sub-sample of juvenile spot was taken for length and weight measurements, primarily to assess whether market-sized fish were present in sufficient numbers to begin the market trials. Of the fish measured, 70% were greater than 76.2 mm (3 inches), the minimum market size identified previously. The mean weight for the spot over 76.2 mm was 10.6 g (0.4 ounces), or approximately 43 fish per pound.

The first spot were distributed for market trials at 160 dph. Market-sized spot were hand graded, with smaller fish being re-distributed to culture systems for continued growth. There were no adverse effects noted from this handling.

Bait-sized spot were transported to participating dealerships in a 1,100-liter (300-gallon) tank with aeration. This tank would fit within the bed of a pick-up truck. The tank was never filled with more than 550 liters (150 gallons) of water for transport. As many as 1,000 bait-sized spot were transported at one time with no ill effects.

Summary

The production of spot as live bait for recreational angling shows promise. The basics of spawning, larval culture and grow-out have been demonstrated. There is no doubt that cultured spot are productive baits and are readily accepted by recreational anglers. Preliminary economic evaluations suggest that spot culture can be profitable, even in small-scale production.

Suggested Reading

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