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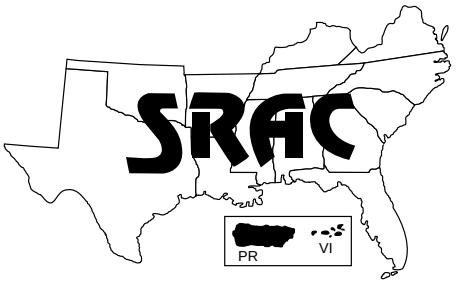

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Species Profile
Southern Flounder

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Flounder are known for their unique and spectacular transformation from a normal-looking fish with an eye on each side of the head to one with both eyes on the same side of the head. This metamorphosis occurs while they are still larvae and is one of the more fascinating transformations among fishes. Southern flounder (*Paralichthys lethostigma*) are in the family Bothidae and the genus *Paralichthys.* Other important cultured paralichthids are the summer flounder (*P. dentatus*) and the Japanese flounder (*P. olivaceous*). There is considerable interest in the culture of southern flounder because of its worldwide market appeal, high market value, and ability to grow in fresh or brackish water. Southern flounder are found throughout the southeastern U.S. and it might be possible to culture them over a large geographic area. Because these flounder appear to grow well in low salinity water, growout operations could be located farther from high-priced coastal areas, reducing the fixed costs associated with flounder farming. However, research on southern flounder culture only began about 5 years ago. Most of this work has concentrated on the hatchery phase of production. Definitive information is not yet available on growout methods or the economic feasibility of southern flounder culture.

Natural history

Range

Southern flounder are found in rivers and estuaries along the Atlantic Coast from North Carolina to northern Florida, and from Tampa Bay, Florida along the Gulf coast into southern Texas. Their distribution is discontinuous around the southern tip of Florida, leading some biologists to wonder if there are two genetically separate natural stocks. Southern flounder are found in a wide range of salinities; adults have been captured in a range of 0 to 36 ppt salinity, and it is not uncommon to catch them by hook and line far inland on coastal rivers.

Life history

Adult southern flounder migrate offshore during the fall to spawn in marine waters. The spawning season begins in December in the northern extreme of their natural range, and in late January to February in the southern extreme. Adults return to estuaries and rivers immediately after spawning. Larval flounder feed on zooplankton in offshore waters for 30 to 60 days; then metamorphosis begins and the larvae are washed through inlets into estuaries. After metamorphosis, juvenile southern flounder begin migrating up the rivers.

Some researchers hypothesize that juvenile and young adult flounder remain in low salinity water to overwinter for the first 2 years of life, migrating out to the ocean when they reach sexual maturity at 2 years of age.

Appearance

Adult flounder are asymmetrical in appearance. Instead of swimming through the water column like other fish, flounder rest on the bottom with a dark pigmented side facing upwards and a white, unpigmented side facing down. Both eyes and nostrils are on the upper side of the head. The mouth is also slightly twisted toward the upper side.

Larval flounder look like other fish until they reach metamorphosis. During metamorphosis, which begins about 30 to 40 days post-hatch, the right eye slowly migrates to the left side of the head, the jaw twists slightly, and the fish changes from a side-to-side swimming motion to an up-and-down motion. When metamorphosis is complete in about 2 to 3 weeks, the fish resemble adults and thereafter rest on the bottom most of the time.

Feeding habits in the wild

Flounder feed by ambushing passing prey in a rapid upward lunge, accompanied by a vacuum action of the mouth, to capture and ingest the food in one swift

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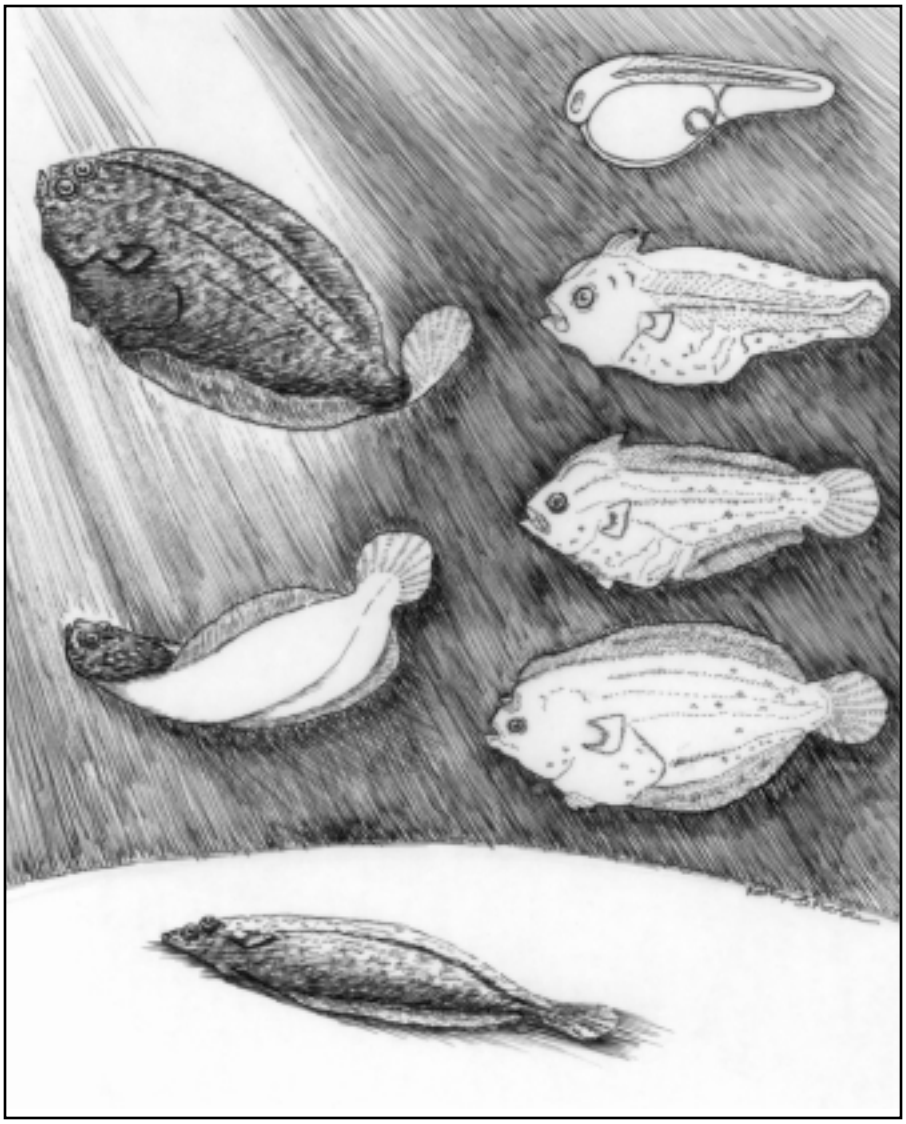

Figure 1. Southern flounder life cycle.

motion. Wild flounder consume mainly shrimp and small fish. After feeding, they immediately glide back down to the bottom. Cultured flounder feed in the same way as wild fish, but can be trained to come to the water surface to eat dry, pelleted feed.

Reproduction in the wild

Adults migrate out of rivers and estuaries in late fall and spawn in the warmer offshore waters of the Gulf stream from November to February. Fertilized eggs have been found at depths of 100 to 650 feet (30 to 200 meters). When southern flounders reach sexual maturity at 2 years of age, the males weigh 300 to 400 g (250 mm, 10 inches) and the females weigh 800 to 1,000 g (350 mm, 14 inches). Females spawn small batches of about 100,000 eggs per kg (45,000 eggs per pound) over several days. Although the number of eggs released per female at any one time is relatively low compared to other types of fish with the same weight, total egg production is similar if all egg batches are combined. Eggs are about 1 mm in diameter, nearly transparent with a single oil droplet, and highly buoyant.

Culture techniques

Broodstock procurement

Because adult flounder migrate at certain times of the year to spawn, they can be easily caught in pound nets at the mouths of inlets or along the shoreline of estuaries. High quality fish can be obtained this way as the fish are out of water for only a short time and can be transported in specially constructed live wells placed on the deck of a boat. Some researchers have obtained broodstock caught by hook and line, from either commercial or recreational fishers, but this method is stressful to the fish and may lead to mortality or poor reproductive performance.

Artificial spawning

Because southern flounder spawn during fall and winter, the environmental conditions required to induce spawning are a short photoperiod of 9 to 10 hours and a water temperature of about 61 ºF (16 ºC). Photothermal conditioning should be started several months in advance of the planned spawning date. Daylength and temperature should be reduced gradually and reach target levels at least 2 weeks before spawning to allow the females sufficient time to begin the process of egg development. Broodstock maintained under these conditions can continue producing eggs for several months.

Most researchers currently working with southern flounder broodstock use some form of hormone intervention to promote final egg maturation and spawning. Cellulose/cholesterol implants containing a synthetic analogue of gonad releasing hormone (GnRHa) are placed into the muscle about midway between the dorsal fin and the lateral line. A dosage of 50 to 100 micrograms/kg is used on female flounder with maximum oocyte diameters of 500 micrometers. Eligible females will have a marked swelling in the abdominal area. Females with smaller egg diameters cannot be forced to maturation with hormone implants. Generally, eggs will reach final maturation and ovulation about 48 hours after implantation, and can be easily stripped and mixed with sperm from running males. Eggs are released from the ventral or blind side. Sperm is released from the dorsal or eyed side. Viable eggs float high in the water column but not all viable eggs are fertilized. The fertilization rate of floating eggs can be determined at

6 hours post-fertilization. At this time the embryos are in a multicell stage that is easily identified at 100 x magnification on a compound microscope.

Researchers have used strip-spawning to produce fertilized eggs for larvae culture. Although strip-spawning requires handling the fish and is stressful to them, this method has the advantage of producing a sufficient number of eggs in a short period of time, which is more convenient for stocking larviculture tanks. Recently, tank spawning without hormone intervention has produced a significant number of fertilized eggs, but this method has not yet reached the level of reliability needed for commercial-scale larval rearing. Tank spawning is clearly the least stressful method on the fish, as handling and anesthetizing are eliminated. This method also produces the highest quality eggs.

Male flounder produce a very small volume of sperm compared to other fish. Spermiating males normally produce less than 0.5 mL of sperm when gentle pressure is applied to the abdomen. Implants or injections of human chorionic gonadotrophin (HCG) have been ineffective in increasing sperm volume or initiating spermiation. Proper environmental conditioning well in advance of the planned spawning date appears to be the most effective method of obtaining spermiating males among captive broodstock.

Larviculture

Eggs hatch after a 55-hour incubation period at 63 ºF (17 ºC). Recently hatched larvae do not have fins, eyes or mouths, but develop them during the 5 days before first-feeding. Larvae are stocked before first-feeding at 75 to 115 / gallon (20 to 30 / L) in 250- to 1,000-gallon (1- to 4-cubic meter) tanks. Most culturists add algae to the tank water at a density of 570,000 cells / gallon (150,000 cells / L). By first-feeding the yolk is completely absorbed, but the oil drop will remain for several days. Rotifers are fed at about 5 / mL until about 15 to 20 days post-hatch, when they begin to eat *Artemia* nauplii (Fig. 2). *Artemia* are fed at 1 / mL initially, then up to 5 / mL through metamorphosis until the start of weaning at day 55 post-hatch. Metamorphosis begins around day 30 at 63 ºF (17 ºC) and takes about 2 weeks to complete. The entire larviculture period takes place in full-strength seawater (33 ppt) at temperatures between 63 and 70 ºF (17 and 21 ºC). Egg hatch and larval survival and development are optimized at 63 ºF (17 ºC), while survival and time to completion of metamorphosis are optimum at 70 ºF (21 ºC). Pond rearing of larvae also appears to be feasible, but suitable harvest methods are still being developed.

Recently metamorphosed flounder can be weaned to dry feeds by gradually reducing the *Artemia* ration from 5 / ml to 0 / mL over a 2- to 3-week period. Weaning feeds should have particles that range from 250 to 500 micrometers and have an orange or reddish color similar to the *Artemia*. Once they are successfully weaned, flounder are graded by size to reduce cannibalism and stocked into nursery tanks. At this time, the fish are about 1 inch (2.5 cm) long.

Growth rates

Little is known about southern flounder growout rates and feed conversion values, but it has been determined that southern flounder females grow approximately three times faster than males. As with other flatfish, the sex of the fish is not determined until after metamorphosis; the precise time is not known for southern flounder. In Japanese flounder, the sex of the fish can be influenced by temperature. The optimum temperature for producing the highest percentage of females is approximately 70 ºF (21 ºC). Temperatures significantly higher or lower than that likely will result in a higher percentage of males in the overall population. High stocking densities may also shift the population towards males. To achieve optimum growth and profitability of cultured flounder, hatcheries should produce all female fingerlings.

Southern flounder are cannibalistic and feed aggressively at the surface. This aggressive behavior leads to uneven growth rates, so they must be graded often to increase survival. Fingerlings may need to be graded three or four times during the few months it takes them to grow from 2 g to 10 g. Larger fish do not require such frequent grading.

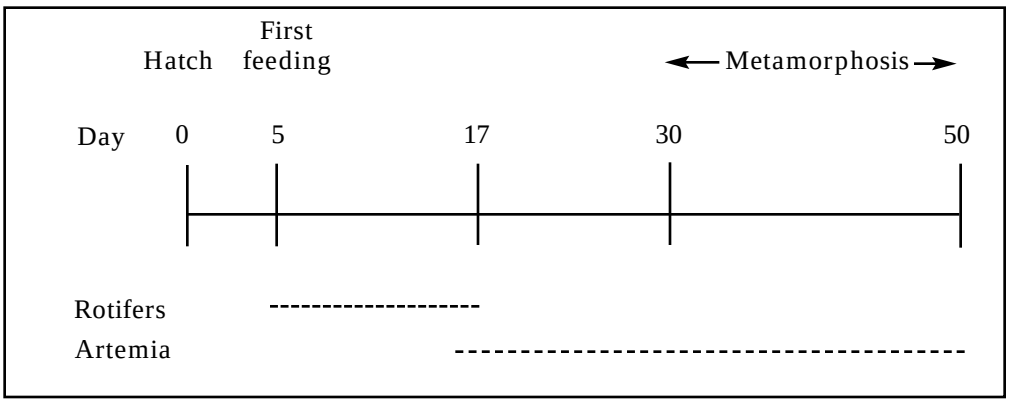

Figure 2. Summary of southern flounder larval rearing.

Little work has been done on the environmental requirements for southern flounder growout. Recently metamorphosed flounder are extremely tolerant of low salinity and can be raised in freshwater with high hardness and alkalinity (both greater than 200 ppm). Twelve-week studies have shown that southern flounder growth rates are not significantly different at 0 ppt versus 20 ppt up to a size of 2 ounces (60 g). However,

longer term studies are needed before attempts are made to grow flounder to market size in freshwater. Based on the conditions of their natural environment, it is likely that these particular flounder will tolerate water temperatures in excess of 82 ºF (28 ºC) during growout. Anecdotal evidence from commercial and recreational fishers indicates that southern flounder are routinely caught in shallow waters that exceed 86 ºF (30 ºC) during the summer months. Tolerance to water temperatures below 39 ºF (4 ºC) can be improved by increasing salinity to full strength seawater (33 ppt).

Other flatfish, such as turbot, halibut and Japanese flounder, are cultured in outdoor land-based tanks or in indoor recirculating systems. Tank sizes and shapes vary considerably but are usually about 20 to 30 feet (6 to 9 meters) in diameter and have some protection from the sun, such as black shade cloth. With a water depth of only 1.5 to 3 feet (.5 to 1 meter) and constant water inflow, the entire tank volume is exchanged every 2 to 3 hours. Tanks are stocked to obtain a final density of 120 to 680/square feet (10 to 30 kg/square meter) of 2.2-pound (1-kg) fish. It is likely that a southern flounder growout facility would use these same tank growout systems and stocking densities.

Diets

Juvenile flounder have a protein requirement of about 50 to 55 percent—similar to other flatfish. Flounder diets typically contain 6 to 14 percent lipid and less than 17 percent ash. Fingerlings are fed three or four times a day, while larger fish are fed only once or twice a day. Feeding rates should be about 6 to 10 percent of body weight during the juvenile stage, 0.4 to 2.2 percent at 8 inches (20 cm), 0.3 to 1.8 percent at sizes larger than 12 inches (30 cm), and less than 0.2 percent during the winter when water temperatures fall below 54 ºF (12 ºC). Although growout feeds will likely be expensive because of the high price of protein, flounder are very efficient feed converters, with feed conversion values below 2:1. Therefore, the high price of the feed will be offset by the smaller amount needed to produce each pound of fish.

Diseases

Although no specific diseases have been reported for southern flounder, it is likely that they will be susceptible to the full range of bacterial infections (*Aeromonas*, *Staphlococcus*, Vibriosis etc.) that infest other cultured flounders. *Edwardsiella tarda* is a persistent pathogen of Japanese flounder. Viruses such as epidermal hyperplasia (herpes virus) and nervous necrosis (striped jack nervous necrosis virus) also are found in cultured Japanese flounder and may cause similar problems in cultured southern flounder. Wild broodstock frequently import a host of parasites into the hatchery and should be quarantined and treated for at least several weeks before they are introduced into the main water system. External parasites such as *Argulus* (sea lice) and leeches have been reported, and intestinal worms also are common in wild broodstock.

Marketing

Flatfish have an established market worldwide. Southern flounder are nearly identical in appearance to Japanese and summer flounder and, therefore, would be sold to the same markets. Southern flounder and summer flounder are not reported separately in fisheries statistics, so the total U.S. southern flounder catch is not known. The commercial catch of flounder in general has declined from 20,000 metric tons (MT) in the mid 1980s to a mandated quota of approximately 5,000 MT in 1998. Most flounder are sold as processed fillets, but a substantial amount, as much as one-third the volume, are now marketed whole (bled), fresh-killed for the Asian (principally Japanese and Korean) markets. High quality fish bled on ice are sold at $4.00 to 6.00 per pound for 1- to 2-pound fish, $8.00 per pound for 2-to 4-pound fish, and $10.00 to 12.00 per pound for 4-pound fish.

Economics

No studies have been done on the economics of southern flounder culture. A stochastic economic model has been developed for the related summer flounder, but actual results of costs and returns for commercial scale production facilities are not yet available. Given the close biological similarities to Japanese flounder, some assumptions about the expected economic performance of southern flounder are possible.
In Japan, cultured flounder rank third in importance with annual production of approximately 7,000 MT. This level of production has been achieved in a relatively short span of about 20 years. Based on this production increase in Japan, a country with notoriously high fixed and variable costs, it is logical to assume that the economics of culturing southern flounder in the U.S. are promising.

Conclusions

Southern flounder culture is still in its infancy. Fundamental information about growout and economics is still lacking. Hatchery production of southern flounder fingerlings has been researched and significant strides have been made in this field. Further research is needed on methods of mass producing monosex female fingerlings, because females grow three times faster than males. Production of all-female fingerlings will require highly specialized hatcheries with captive broodstock and temperature controlled environments during the sex determination stage. Environmental and nutritional requirements for growout have not yet been well-defined, but growout systems will likely be similar to those already used in the culture of other flatfish such as summer and Japanese flounder.

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