Virginia Cooperative Extension

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Freshwater Fish Farming in Virginia: Selecting the Right Fish to Raise

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Introduction

In Virginia and throughout the United States, interest in fish farming for profit or as a hobby has increased in the past few years. Encouraged by the success of trout farmers in western states and catfish farmers in southern states, prospective fish farmers question if similar opportunities exist in Virginia's fresh waters.

The prospects for fish farming in Virginia range from very good to poor depending on the objectives (commercial or noncommercial), the economic and water resources available, and the type of fish selected for growing. In this publication we present basic information on fish farming and discuss some of the opportunities and problems involved with growing certain freshwater fish and other aquatic animals in Virginia.

Opportunities

Many opportunities exist for freshwater fish farming in Virginia.

Virginia is a water-rich state endowed with thousands of miles of flowing rivers and streams and an equal abundance of ponds and lakes. Virginia's standing surface water resources, comprised of more than 80,000 ponds and lakes, provide numerous opportunities for fish farming throughout the state.

In addition, Virginia's three geographic provinces (Mountain Zone, Piedmont Region, and the Coastal Plain) vary strikingly in climate, growing season, rainfall, soil composition, soil fertility, and topography. This natural variation provides a diversity of environmental conditions that allows for the culture of a wide variety of warmwater, coolwater, and coldwater fish and aquatic animals in the state.

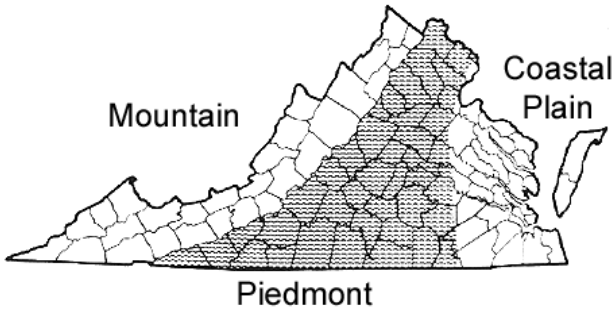

Figure 1.Virginia's three provinces add variety to fish farming potential.

Types/Purposes

Unfortunately, the term "fish farming" often suggests large-scale commercial enterprises directed at the production of food fish for marketing in restaurants and supermarkets. This common misconception of fish farming is misleading in many respects.

First, many successful fish farming ventures are small, family- run, "backyard-type" operations that produce a limited number of food fish for sale in local markets. Second, many fish farms do not grow food fish at all, but instead rear (1) eggs and fingerlings (2-4 inch fish) for sale to food fish producers; or (2) fingerling sportfish for stocking in private ponds and streams; or (3) catchable-sized sport fish for stocking in recreational ponds and fee-fishing waters; or (4) bait minnows, frogs, crayfish, worms, and aquatic insects for sale to anglers as fish bait; or (5) goldfish, tropical fish, turtles, and other aquatic animals and plants for sale as aquarium pets. Finally, many successful fish farms are noncommercial, hobby-type operations that simply grow fish for home use and stocking personal recreational fishing ponds.

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Table 1. Fish Farming Purposes.	
Non-Commercial:	**Commercial:**
Home-Use Food Fish Production	Food Fish Production
Personal Recreation Fishing	Egg and Fingerling Sportfish
Personal Fish Bait Production	Catchable-sized Sportfish
	Fish Bait Production
	Aquarium Pet Production
	Fee-fishing/Fish-out Pond

Of the two major types of fish farming (non-commercial and commercial), growing fish on a non-commercial basis for home-food use or personal recreational fishing is the easiest and least expensive way to begin fish farming. Most fish farmers start small by growing a few fish for fun and expand to large-scale commercial operations only after they gain the necessary skills and experience.

Commercial fish farming is a time-consuming, expensive, high-risk business that requires careful planning, a good understanding of fish biology, and sound business management skills. A careful study of economic considerations, especially product demand, financing, production costs, and marketing should be conducted before investing in a commercial fish farm. A detailed description of important considerations for establishing a commercial fish farming enterprise is provided in Virginia Cooperative Extension Publication 420-012, "Planning for Commercial Aquaculture."

Table 2. Typical Fish Farming Costs.	
Capital Costs	**Operating Costs**
Land	Fish
Pond Construction	Feed
Buildings	Electricity
Hauling Trucks	Fuel
Water Supply	Labor
Plumbing & Pipes	Transportation
Hauling Tanks	Maintenance
Aerators	Chemicals
Oxygen Meter	Drugs
Nets & Seines	Telephone
Waders & Boots	Taxes
Feeding Equipment	Interest
Tractors & Mowers	Insurance
	Production Facilities

Fish can be grown in a wide variety of natural waters or artificial systems. Fish may be stocked and reared free in ponds, lakes, rivers, and streams. They may also be raised in raceways, tanks, pools, and cages constructed of plastic, metal, concrete, wood, glass, or any other materials that will hold water and that are not toxic to fish.

Figure 2 Fish farming in circular cages.

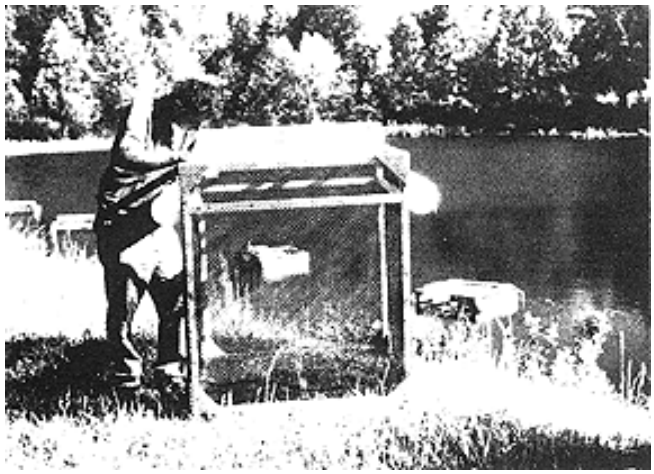

Figure 3 Fish farming in floating cages.

Land and Water Supply

Two fundamental requirements for starting a successful fish farm are sufficient physical space (land) and a good supply of high- quality water. The amount of land and water available limit the type of rearing facilities and number of fish that can be reared. Water quality also restricts the type of fish that can be reared and production rates.

Figure 4 Sufficient land is required.

Ground water from springs, wells, or underground seepage is the best source of water for fish farms. Other sources of water including surface waters, runoff water, and even municipal water can be used to grow fish. Of course, all sources of water must be free of fish diseases and parasites, nuisance fish, predators, silt, pesticides, chlorine, and other chemicals that are harmful to fish life. A good water supply of sufficient quantity and quality is absolutely essential for all fish farms. Before considering developing a fish farm, have your water tested. Your local Virginia Cooperative Extension (VCE) or Soil Conservation Service (SCS) agent can assist in determining the quality of your water.

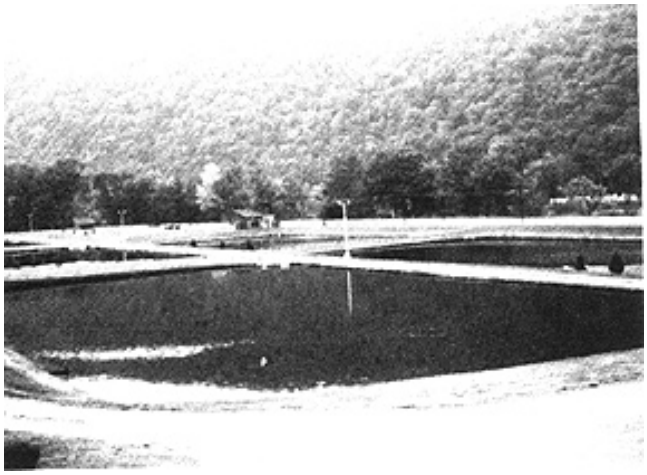

Figure 5 Level land above the flood plain is ideal.

Figure 6 A continuous supply of clean water is required.

The Ideal Fish

Although there is no "perfect" fish for farming, the following are desirable biological and economic attributes when selecting the best fish to farm. The fish species should:

1. be capable of reproducing in captivity;
2. produce numerous and hardy eggs and larvae (young);
3. have well-known culture requirements;
4. be adaptable to many types of culture systems;
5. be adaptable to multi-species farming (polyculture);
6. exhibit rapid growth to a large maximum size;
7. readily adapt to artificial feeds;
8. be tolerant of crowding and high density conditions;
9. exhibit high survival (low mortality) rates;
10. be easy to handle, harvest, and transport;
11. be resistant to disease and parasite infestations;
12. not be cannibalistic or territorial;
13. be readily available as eggs, fingerlings, and adults;
14. have a high market demand;
15. exhibit high feed conversion rates;
16. have good dress-out weight values;
17. have a long shelf life;
18. be easy to process;
19. have a healthy appearance and color;
20. have good eating qualities;
21. have highly regarded fighting abilities;
22. be catchable.

Species Selection

A wide variety of freshwater fish and other aquatic animals can be farmed in Virginia. Table 3 lists types that are most frequently considered and which have particular appeal to citizens of Virginia. Each species listed has been assigned a farming potential rating (good, fair, poor). These ratings represent "best-guess" estimates based on the amount of information available, previous experience of growers, and consideration of the current economic conditions associated with each fish species.

Theese ratings can and probably will change as a result of new reserch, technological advancements, and changing market values.

The opinions range from growing optimism (good) to guarded pessimism (poor). However, do not let these opinions discourage you from trying to grow fish with a poor rating or others not on the list. The ratings represent only general guidelines. Adventurous fish farmers with sufficient land, water, and economic resources can grow all of these and probably several other aquatic species in Virginia.

Table 3. Freshwater fish and aquatic organisms and their potential for farming as food fish, sportfishing stocks, fish bait, and aquarium pets in Virginia.

	Farming Potential Rating			
Species	**Food Fish**	**StockingPonds**	**Fish Bait**	**Aquarium Pets**
Coldwater Fish:				
Rainbow Trout (Salmo gairdneri)	Good	Good	--	--
Brook trout (Salvelinus fontinalis)	Good	Good	--	--
Brown trout (Salmo trutta)	Poor	Poor	--	--
Warmwater Fish:				
Channel catfish (Ictalurus punctatus)	Fair	Good	--	Poor
Other catfish (Ictalurus spp.)	Poor	Poor	--	Poor
Largemouth (Micropterus salmoides)	Poor	Good	--	Poor
Bluegill sunfish (Lepomis macrochirus)	Fair	Good	--	Poor
Redear sunfish (Lepomis microlophus)	Poor	Good	--	Poor
Striped bass (Morone saxatilis)	Fair	Fair	--	Poor
Bait Fish:				
Fathead minnow (Pimephales promelas)	--	Good	Good	Poor
Golden shiner (Notemigonus crysoleucas)	--	Fair	Good	Poor
Goldfish (Carassius auratus)	--	Poor	Fair	Fair
Coolwater Fish:				
Smallmouth bass (Micropdolomieui)	Poor	Fair	--	--
Pikes (Esox spp.)	Poor	Poor	--	--
Walleye (Stizostedion vitreum)	Fair	Poor	--	--
Yellow perch (Perca flavescens)	Fair	Poor	--	--
Others:				
Crayfish	Poor	Fair	Good	Fair
Frogs (Rana spp.)	Poor	Fair	Fair	Poor
Freshwater clams (mussels)	Poor	Fair	Poor	Fair
Salamanders	--	Poor	Fair	Fair
Hellgrammites	--	Poor	Fair	Poor
Aquatic plants	Fair	Fair	--	Fair

Coldwater Fish (Trout) Farming

1. **Rainbow trout** (*Salmo Gairdneri*) Good potential (food & stocking)

Figure 8. Rainbow Trout

Rainbow trout is the most widely grown and preferred coldwater fish for farming. This species possesses a number of desirable traits, including its rapid growth to a large size, high survival, adaptability to artificial feeds, high quality flesh, high market demand and value, well known growth requirements, and ready availability as eggs, fingerlings, and adult stocks.

As a sportfish grown for stocking recreational waters, rainbows are highly regarded as spectacular fighters and leapers, and for their healthy appearance, color, and table quality. Rainbow trout are native to the western United States, but have been widely transplanted in the eastern states. Self-reproducing populations occur in Virginia's coldwater streams.

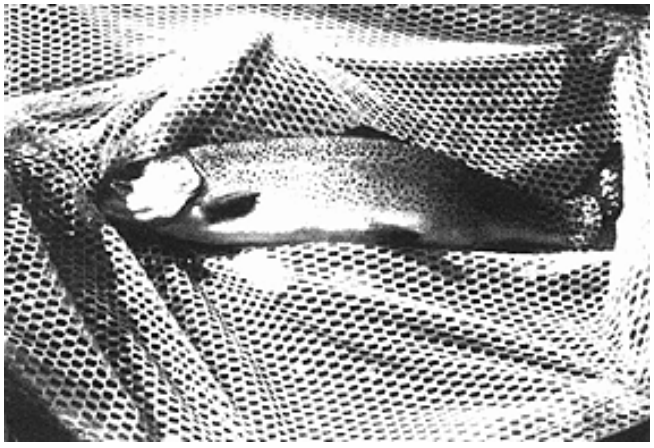

Figure 13. Rainbow trout are excellent food and sportfish.

2. **Brook trout** (*Salvelinus Fontinalis*) Good potential (food & stocking)

Figure 9. Brook Trout

Brook trout is the only salmonid species native to Virginia. This species also has good potential for farming in the state. Brook trout are slightly more sensitive than rainbow trout to temperature, crowding, low oxygen, and other stresses associated with fish farming. They grow more slowly and to a smaller maximum size than rainbow trout.

However, despite these disadvantages, they are also a good species for farming. Brook trout are considered a more colorful fish, have native species appeal, and often are considered a better eating fish than rainbow trout. As a sportfish, brook trout are not as esteemed as fighters as rainbow trout, but they are much easier to catch and, therefore, would be an excellent choice for stocking in fee-fishing or catch-out pond waters.

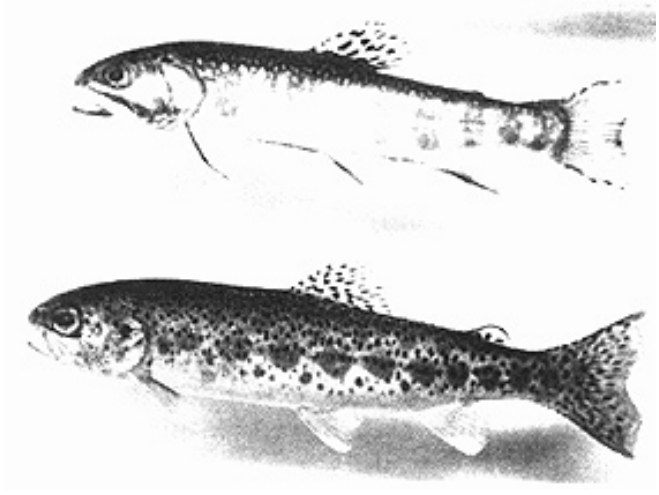

Figure 12 Brook trout and Rainbow trout.

3. **Brown trout** (*Salmo Trutta*) Poor potential (food & stocking)

Figure 10. Brown Trout

Brown trout and other coldwater salmonid species are not recommended for fish farming in Virginia. Although brown trout are commonly reared in state and federal fish hatcheries and are stocked in public waters throughout the state, they are less desirable for farming than rainbow or brook trout.

Brown trout are more territorial, more cannibalistic, more difficult to catch, and often considered a poorer quality food fish than either brook or rainbow trout. Brown trout will grow to a very large size and are tolerant of certain environmental stresses, particularly high water temperatures, but they generally cannot be reared in high densities like rainbow or brook trout. Few private hatcheries rear brown trout and, consequently, eggs, fingerlings, and adult stock are difficult to obtain. Brown trout are native to Europe and were introduced into this country in 1883. Wild, self-reproducing populations occur in some of Virginia's coldwater streams.

Current Status:

Rainbow trout is the leading coldwater food and sportfish farmed in the United States. Private commercial production is estimated at about 48 million pounds annually. Most of these fish are sold for food, but the number of trout marketed for stocking private ponds and streams is increasing each year. An additional 20 million pounds of rainbow trout are produced annually at state and federal hatcheries to stock public fishing waters. Most commercial production of rainbow trout occurs in the western states, primarily Idaho, where an abundance of natural coldwater springs with isothermal 15 degrees C (59 degrees F) water temperatures provide ideal farming conditions for this species. In Virginia, rainbow trout is the major food and sportfish farmed commercially.

Rainbow trout production in the state is estimated at about 500,000 pounds annually. Of this total, about 40% are marketed as food fish and 60% are sold as fingerlings and catchable-sized adults for stocking private recreational waters. In addition, over one million trout are produced at public fish hatcheries in the state and stocked each year into approximately 185 streams in 40 counties of Virginia.

Trout culture in Virginia is restricted to the Ridge and Valley Province (Alleghany and Blue Ridge Mountain Region) where an abundant supply of high-quality, cold, spring water provides good growing conditions. Private commercial trout production in Virginia is based mainly on rainbow trout monoculture (single species). Farming of brook and brown trout is negligible, constituting less than 1% of the total annual production. The predominance of rainbow trout is due largely to the availability of eggs and fingerlings. Although some trout farmers in the state produce their own egg stock, many firms purchase eggs from western hatcheries than specialize in egg production.

The trout farming industry in Virginia consists mainly of well- established, small-scale, family-operated firms. Most trout farmers in the state have been in business for at least 10 years, have a labor force of two full-time and two part-time employees, and have 1.6 acre-feet of raceways with an average flow of 2100 gallons per minute (4.7 cubic feet per second). Commercial trout farms in the state are well managed, producing an average of 16,000 pounds for each cubic foot per second (CFS) of water flow.In comparison, the average annual production of trout farms in the U.S. is about 10,000 pounds per cfs.

Constraints/Problems:

Trout are coldwater fish that exhibit optimal growth at water temperatures ranging between 13 and 18 degrees C (55 to 65 degrees F). Trout are very sensitive to water pollutants and require high-quality water. Traditional raceway trout farming requires large quantities of cold water. Thus, the success of trout farming primarily is limited by the abundance of clean, cold water.

Figure 11 Trout farming in raceways.

Trout farming is an expensive business. The seven major costs are for feed, labor, fish, energy, processing, marketing, and distribution. Satisfying the nutritional requirements of trout is particularly expensive. The cost of trout feed accounts for as much as 55% of the total cost of trout production. Since trout are typically reared at high densities in raceways where natural foods are absent, they must be fed artificial diets. Commercial trout feeds are more expensive than other fish feeds because trout are carnivorous and digest carbohydrates poorly and, therefore, must be fed a nutritionally complete diet. Consequently, artificial trout feeds contain large amounts of animal protein (usually fish meal) which is the most expensive feed ingredient.

Securing financial assistance is also a major problem for prospective trout farmers. The high capital outlay for construction of hatchery facilities, along with the high risk and relatively low rate of return, makes it difficult to obtain a loan for trout farming ventures.

Other problems such as water use and water rights conflicts, obtaining effluent permits, satisfying food and drug standards, controlling disease and parasites, and establishing year-round markets confront trout farmers.

Warmwater Fish Farming

1. **Channel Catfish** *(Ictalurus Punctatus)* Fair potential (food) Good potential (stocking)

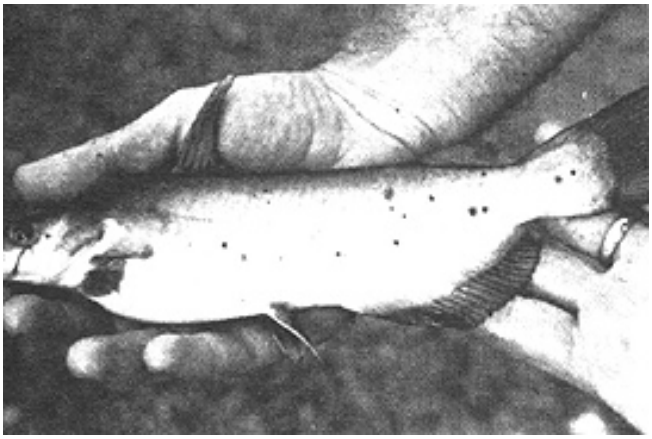

Figure 14. Channel Catfish

Channel catfish is the most widely farmed food fish and one of the most important warmwater sportfish reared in the United States. This species has a number of desirable characteristics for rearing, including its high quality flesh that consists of firm white meat with few intramuscular bones and mild flavor, high tolerance of water temperature variations, rapid growth at water temperatures above 23 degrees C (74 degrees F), high tolerance of crowding, adaptability to a variety of natural and artificial farming systems, high feed conversion values, well- known growing requirements, and ready availability of eggs, fingerlings, and adult stocks.

As a sportfish, this species apparently does not compete drastically with other warmwater fish species and is widely stocked in bass-bluegill ponds--adding variety to anglers' catches.

2. **Other Catfishes** (*Ictalurus* spp.) Poor potential (food and stocking)

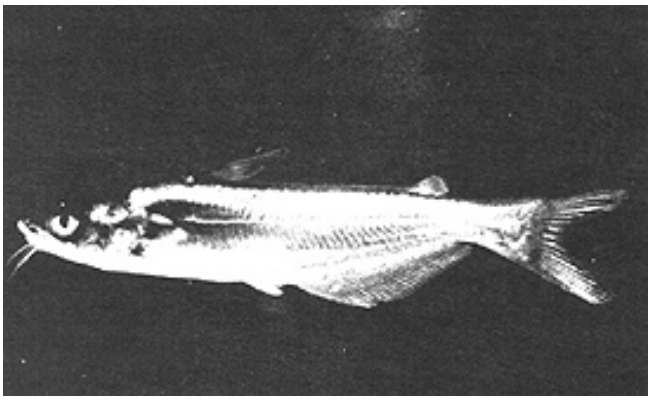

Figure 15. Blue Catfish

The blue catfish (*Ictalurus Furcatus*) and the white catfish (*Ictalurus Catus*) are also reared commercially but to a lesser extent than channel catfish. Blue catfish exhibit slower growth and lower feed conversion efficiencies than channel catfish. White catfish do not grow as rapidly or to as large a size as channel catfish; they also do not dress out as well as other species due to their relatively large head.

Other species of catfish including the yellow bullhead (*Ictalurus Natalis*), brown bullhead (*Ictalurus Nebulosus*), and flathead catfish (*Pylodictis Olivaris*), are not as suitable for farming for a variety of reasons.

Current Status:

Catfish farming is the leading fish farming industry in the United States. Commercial production of food-size catfish totalled about 77 million pounds in 1981. Production and consumption of catfish have increased annually since 1976. Farm- reared catfish now account for about two percent of total U.S. fish consumption.

About 60% of the total crop are marketed as food fish and about 40% are sold to stock private sport-fishing ponds and commercial fee-fishing ponds. Most of the catfish production in the U.S. occurs in the Lower Mississippi Valley where an abundance of water and flat land for pond construction and long growing seasons provide ideal conditions for catfish farming.

In Virginia, there are no commercial catfish farmers producing food fish. Over the past 20 years a number of residents have attempted catfish farming, but have had little success. Major problems associated with developing food catfish farms in Virginia are the relatively short growing season; competition with southern growers; the high costs of suitable land, labor, energy, and fish feed; lack of processing facilities and a well-defined market; and fish kills caused by summer oxygen depletion.

Small-scale catfish farming in Virginia can provide supplemental food and income for small and low income pond owners. However, the potential for large-scale commercial catfish farming directed at food fish production is limited.

In contrast, the potential for raising fingerling (small-sized) and adult catfish for stocking private fishing ponds and fee fishing waters in Virginia appears good. Virginia, with more than 80,000 warmwater ponds and lakes, provides a ready market for catfish for stocking.

In addition, the growing popularity of catfish fee fishing ponds and lakes in the state is expected to provide a steady demand and ready market for catchable-sized catfish. During 1980, only two catfish farmers in the state were growing fish for stocking. At this time, about 50,000 fingerlings were produced in-state, but an additional 400,000 fingerlings were imported from out-of-state producers.

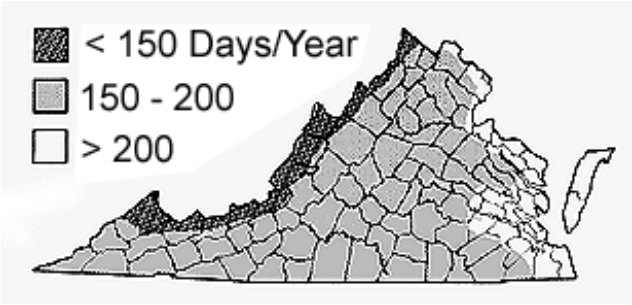

Figure 16 Growing seasons for warmwater fish.

Constraints/Problems:

Two major environmental factors adversely affecting the production of channel catfish in Virginia are the length of the growing season and summer oxygen depletion. The growing season for catfish (water temperatures above 23 degrees C or 73 degrees F) in Virginia ranges from about 200 days per year in the Coastal Plain and some Piedmont counties to about 150 days per year in the Mountain Province. Under these conditions, farm-reared catfish reach edible size in two or three years. Stocking larger-sized catfish (6 inches or more in length) would reduce the growing time for harvestable fish to about 9 months, but larger larger fish are much more expensive to purchase than eggs or small fingerlings.

The risk of fish kills is always present in catfish farming. Algae, stimulated by nutrients from uneaten food and fish excreta, may suddenly die. Their decomposition leads to oxygen depletion and fish mortalities. Aeration is one solution to preventing oxygen-related fish kills.

3. **Largemouth bass** (*Micropterus Salmoides*) Poor potential (food) Good potential (stocking)

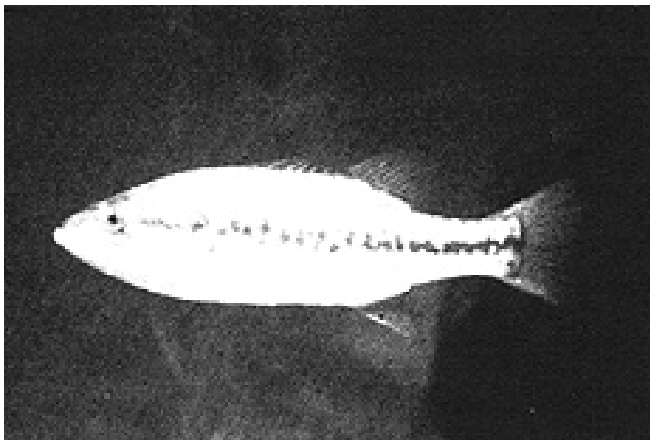

Figure 17. Largemouth Bass

Most of the warmwater sportfish, including the largemouth bass and the sunfishes listed below, have little value for farming as food fish. However, nearly all of these species are extremely popular with anglers. Thus, farming warmwater sportfish to sell for stocking private recreational fishing waters appears to have good potential.

The largemouth bass is probably the most important warmwater sportfish in the United States. About 18 million anglers spend over 300 million days fishing for largemouth bass and sunfish in the U.S. each year. In Virginia, over 700,000 adult and youth anglers fish for this species annually.

To help meet this large and growing public demand, government hatcheries in the U.S. produce and stock into public waters more than 8 million fingerling and adult largemouth bass annually. In many states, including Virginia, fish reared in government hatcheries are stocked only in public waters. Private pond owners must buy fish for stocking from commercial hatcheries.

In Virginia, demand for fingerling and adult largemouth bass for stocking private farm ponds, fishing club waters, golf course ponds, fee-fishing lakes, and for corrective stocking in waters with unbalanced fish populations, is high and exceeds in-state production. Only about 100,000 fingerling bass are produced in commercial hatcheries in the state at present.

Largemouth bass farming is relatively simple. It usually consists of stocking a pond with adults and allowing them to spawn naturally, and then removing the adults or young to prevent cannibalism. Controlling predation and spawning times, producing fertile eggs on demand, training fish to accept artificial feeds or maintaining natural food (usually bait minnows) are the major problems involved with largemouth bass farming.

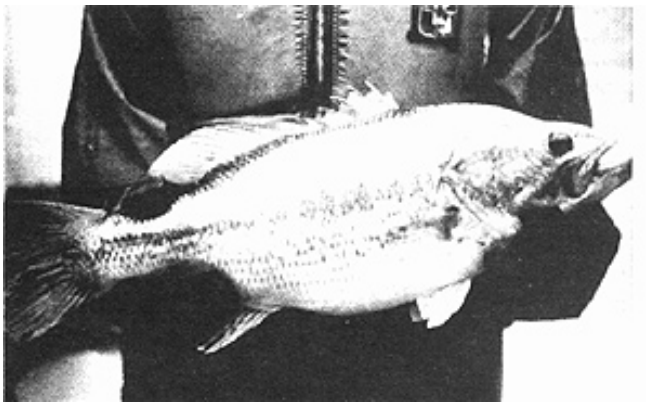

Figure 18 Largemouth bass are popular sportfish.

4. **Sunfishes** (*Lepomis* spp.) Poor potential (food) Fair potential (stocking)

Figure 19. Bluegill (bream) Sunfish

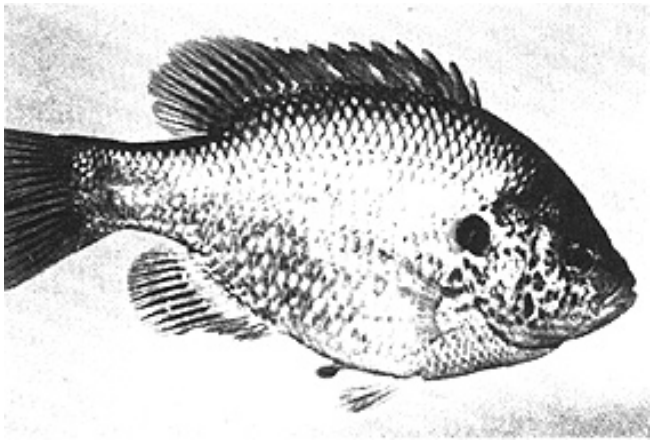

Figure 20. Redear Sunfish

Sunfishes are generally considered unsuitable for commercial farming as food fish. However, they are very popular sportfish, particularly with children. Thus, sunfish often are farmed to stock recreational fishing waters.

The two most commonly stocked sunfish species are the bluegill (*Lepomis Macrochirus*) and the redear of "shellcracker" (*Lepomis Microlophus*). These species are often stocked at high densities.

They add variety to the anglers' catch. The redear is commonly stocked with bluegills since it grows to a larger size, inhabits deeper water, and does not have as high a reproductive rate as the bluegill. A number of other species of sunfish have been used for stocking ponds, but usually with poor results.

In Virginia, at least four commercial growers produce sunfish for sale to pond owners. Annual production averages about 500,000 fingerling sunfish. The major problem associated with sunfish farming involves their high natural reproductive rate. Sunfish spawn readily, producing large numbers of eggs several times during the summer, which often leads to overcrowding and stunting. These unbalanced fish populations provide an opportunity for sunfish farmers to market fish for stocking, since the only realistic solution is to kill all fish in an unbalanced pond by draining and poisoning, and then to restock the pond.

5. **Striped bass** (*Morone Saxatilis*) Good potential (food) Good potential (stocking)

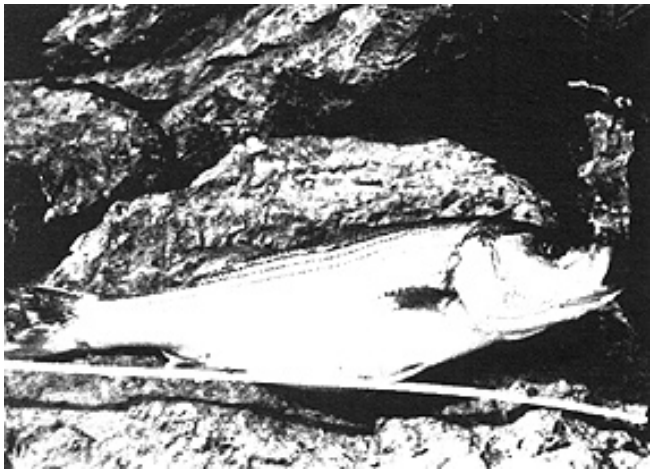

Figure 21. Striped Bass

The striped bass is a major food and sport fish on the Atlantic coast of North America. This species thrives in both salt and fresh water, but must spawn in or near fresh water. Construction of the Santee-Cooper Reservoir in South Carolina and Buggs Island Lake in Virginia trapped some of these anadromous (running up rivers to spawn) fish in fresh water. These landlocked stripers subsequently spawned in the tributary streams of the reservoirs, creating excellent sport fisheries.

Currently, about 10 inland reservoirs in the U.S. support naturally reproducing populations of striped bass. An additional 280 inland reservoirs have striped bass fisheries sustained by stocking fingerlings produced at federal and state government hatcheries.

Striped bass is an extremely important sportfish in the United States. About 4 million anglers spend almost 60 million days fishing for striped bass. To meet this growing demand, government hatcheries produce and stock into public waters about 40 million fingerling striped bass annually. At present, only a few private commercial hatcheries are attempting to produce this species for profit.

A strong demand for striped bass to stock into private recreational waters and for human consumption exists. In Virginia, and most other states, no commercial producers are farming striped bass. The Virginia Commission of Game and Inland Fisheries rears about 1 million fingerling striped bass annually for stocking public waters, but these are not available for stocking private waters.

Unavailability of seed stock is the major problem constraining commercial striped bass farming. Other problems include low survival rates, cannibalism, and disease and parasite infection. But the culture requirements are known and the potential for striped bass farming for food and sportfish production is high. The possibilities of "sea ranching" this species in coastal Virginia adds another opportunity.

Figure 22 Stripers are valuable sportfish.

Bait Minnow Farming

About 100 different species of fish are used by anglers as bait in the United States. As many as 20 species of these fish have been reared commercially and sold as bait minnows in this country. However, only three species are farmed extensively in the southeastern U.S. today.

They are the fathead minnow (*Pimephales Promelas*), the golden shiner (*Notemigonus Crysoleucas*), and the goldfish (*Carassius Auratus*). These fish exhibit desirable characteristics for farming, including a high number of eggs per female, high rate of growth, reproduction at an early age, good marketability, and relatively simple farming methods. One additional freshwater fish, the white sucker (*Catostomus Commersoni*), is reared in northern states as a bait fish. However, since suckers rarely spawn in ponds, they have limited potential for farming in southern states.

1. **Fathead minnow** (*Pimephales Promelas*) Good potential (bait & stocking)

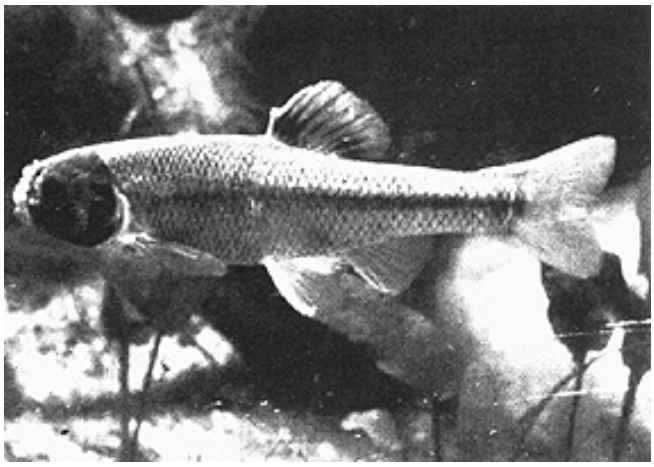

Figure 23. Fathead Minnow

The fathead minnow is probably the most easily grown bait minnow.

This fast-growing species reaches sexual maturity in two years or less and produces an average of 1,000 eggs per female. It can be stocked at high densities, withstands considerable handling stress, and suffers from few disease or parasite problems. Major drawbacks are that this minnow is small (maximum size of 4 inches) and exhibits low over-winter survival and high post-spawning mortality of brood fish.

2. **Golden Shiner** (*Notemigonus Crysoleucas*) Fair potential (bait & stocking)

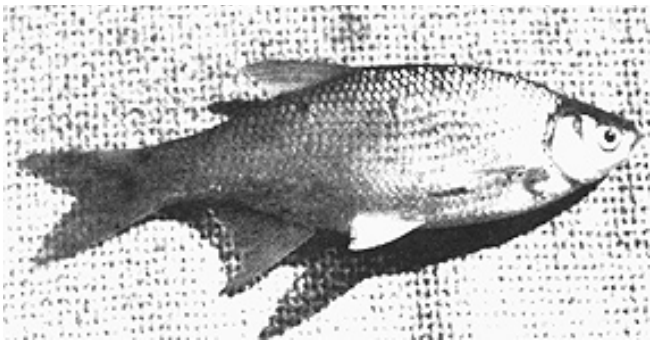

Figure 24. Golden Shiner

The golden shiner, with its bright, flashing coloration, is a very popular bait fish with anglers. Shiner farming requires a little more expertise than fathead minnow farming. Nevertheless, these fish have a rapid rate of growth to a large maximum size (10 inches) and adult females can produce up to 10,000 eggs per fish. Major drawbacks to farming this fish are that they require higher growing temperatures and are less hardy than fathead minnows. In addition, many pond owners prohibit the use of this fish because they grow large enough to compete with sport fish.

3. **Goldfish** (*Crassius Auratus*) Fair potential (bait, aquarium trade)

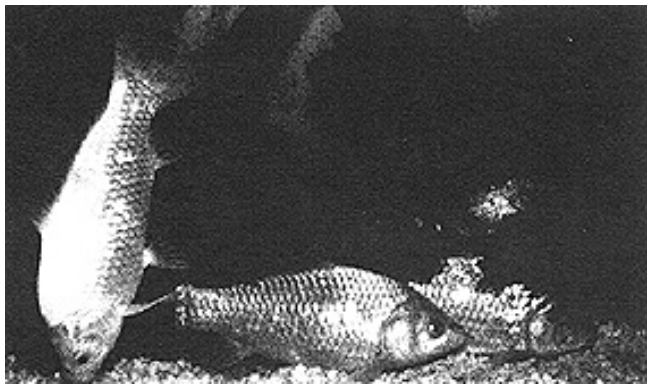

Figure 25. Goldfish

Goldfish are farmed as bait and for the aquarium trade. Goldfish are produced in a wide variety of shapes and colors. The most interestingly colored and shaped fish are sold as aquarium pets; others are marketed as a food fish for aquarium predators or as bait fish for anglers. Goldfish are hardy, easy to handle and transport, and attain a large maximum size. However, the goldfish is not as widely accepted as other bait minnows because of its passive nature on the hook.

Current Status:

Nearly 1,600 bait minnow farms are in operation in the United States. The average bait fish farm produces about 22,000 pounds of fish per year on 44 acres of water. The largest bait farm in the U.S. has about 2,500 acres of water and produces about 3 million pounds per year. Annual yields as high as 4,000 pounds per acre of goldfish and 1,400 pounds per acre of golden shiners have been reported, but average production is much lower. Arkansas is the leading baitfish-producing state, accounting for about half of the nation's supply. Minnesota, Kansas, Louisiana, Mississippi, and Missouri each have over 1,000 acres devoted to bait fish farming.

Commercial bait fish production in Virginia is minimal. Only a few bait minnow farmers, operating on a total of 38 acres, were producing minnows during 1978. During that year, total in-state production was about 15,000 pounds. Bait minnow farming is centered in the Piedmont and Coastal Plain provinces, where the fish are reared in small, heavily fertilized ponds. Despite low in-state production, Virginia provides a ready market for bait fish produced in other states. An estimated 300,000 pounds of bait fish per year are imported from producers in other states. Overall, the bait fish industry in Virginia appears capable of some expansion. Increasing retail prices, angler demand, and transportation costs enhance the profitability of in-state minnow farming.

Constraints/Problems:

Competition with large growers in other states and with commercial harvesters of wild stocks is a major constraint on bait fish enterprises in Virginia. Investment costs, including the price of land, pond construction, brood stock, and spawning facilities, limit minnow farming development. Other costs include seines, vat houses, hauling trucks, feed, fertilizer, aeration equipment, and water pumping. The control of diseases, parasites, and minnow predators such as herons, mergansers, snakes, turtles, and aquatic insects is a constant problem for bait minnow farmers.

Coolwater Fish Farming

Coolwater fish such as the smallmouth bass, the pikes, the walleye, and the yellow perch prefer intermediate water temperature ranges of 20 to 25 degrees C (68 to 77 degrees F). These coolwater conditions commonly occur in a number of recreational ponds and lakes in the mountain region of Virginia. Coolwater ponds generally have summer water temperatures that are too warm for coldwater fish (trout) and too cool for good growth of warmwater fish (largemouth bass, catfish, sunfish). At present, many coolwater ponds contain stunted populations of warmwater fish and cannot sustain trout year-round.

1. **Smallmouth bass** (*Micropterus Dolomieui*) Fair potential (stocking) Poor potential (food)

Figure 26. Smallmouth Bass

The smallmouth bass is a popular sport fish, particularly in the northern United States. Smallmouth bass inhabit cool, clean water, streams, lakes, and reservoirs in the southeastern states, but are more abundant in the northern states. They cannot tolerate the turbid, warmwater conditions characteristic of many southern streams, ponds, and reservoirs.

This species is not commonly farmed, despite its relatively high demand for stocking coolwater ponds and appeal to anglers. Their reproductive habits are similar to largemouth bass and nearly identical farming techniques are used for both species. The availability of high-quality water and egg, fingerling, and adult stocks limit smallmouth bass farming in Virginia.

2. **Pikes** (*Esox* spp.) Poor potential (food & stocking)

Figure 27. Northern Pike

Figure 28. Muskellunge are Prized Trophy Fish

Members of the pike family, especially the northern pike (*Esox Lucius*) and the muskellunge (*Esox Masquinongy*), are prized sport fish often sought by anglers as trophy fish because of their large size. These species have long been cultured by state and federal agencies. Eggs are generally obtained from wild fish in the early spring, hatched and stocked into public fishing waters as fry or fingerlings.

Young pike are voracious carnivores, and cannibalism is the major limiting factor in pike farming. Even under good conditions with plenty of food, low survival is typical. Today, pike are not commonly stocked as pond predators since other fish are more economical to farm.

3. **Walleye** (*Stizostedion Vitreum*) Fair potential (food) Poor potential (stocking)

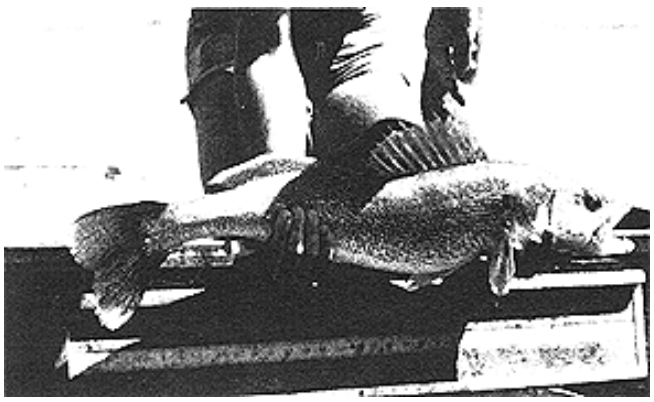

Figure 29. Walleye

The walleye is an excellent food fish primarily sought by anglers for its flesh. This fish is reared by state and federal hatcheries in the northern states to stock lakes and streams. Declining wild stocks and the high market demand for this food fish have prompted interest in farming this species.

Few commercial walleye farms exist and eggs, fingerlings, and brood stock are difficult to obtain. A major problem associated with walleye farming is that this fish does not readily accept artificial food. Demand for walleye to stock ponds is low in the southern states, since this species is very intolerant of turbid, warmwater conditions.

4. **Yellow perch** (*Perca Flavescen*S) Fair potential (food) Poor potential (stocking)

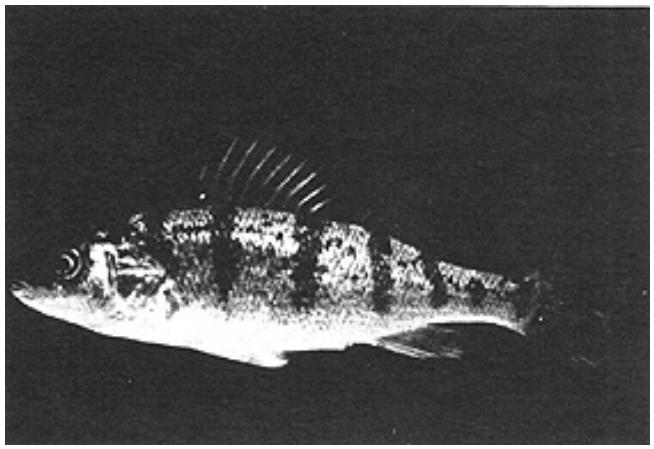

Figure 30. Yellow Perch

The yellow perch is a popular sport fish in the Great Lakes states, avidly pursued by anglers for its high-quality flesh. Declines in the commercial catch of yellow perch in the Great Lakes, particularly Lake Erie, as a result of pollution have prompted interest in yellow perch farming. High market value, often exceeding $5 per pound for yellow perch fillets, provide good economic incentive for considering perch farming.

Currently, culture techniques using heated, recirculated well water are being developed in Wisconsin and Minnesota. Once hatchery methods are perfected, farming perch as food may be profitable. Farming perch for stocking in fishing waters has limited potential. Attempts to establish yellow perch populations in the southeast by stocking ponds, lakes, and reservoirs have been largely unsuccessful. Stocking this species in small ponds in the southern states often results in stunted populations and is generally not recommended.

Figure 31 Yellow perch are tasty food fish.

Other Aquatic Species

1. **Crayfish** Good potential (bait) Poor potential (food)

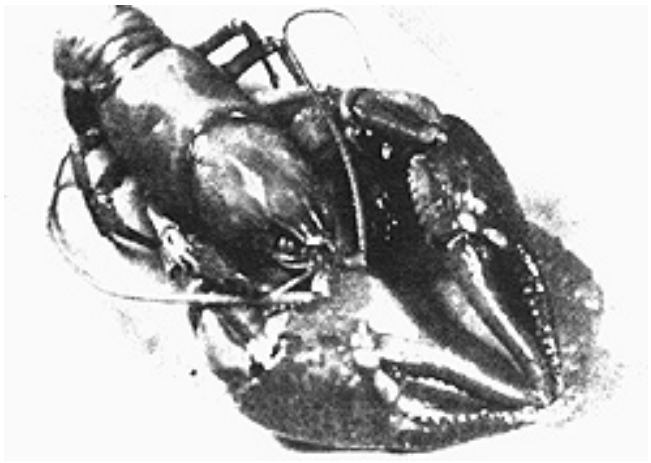

Figure 32. Crayfish

About 300 species of crayfish occur in North America. Virtually every state has native crayfish that can be farmed for food, bait, or both purposes. Most of the crayfish farmed for food in the United States are produced in the southern states, primarily Louisiana, Mississippi, and Texas, where they are farmed in shallow rice ponds and serve as a double-crop of rice/crayfish. Soybeans are also rotated with crayfish in some areas. Crayfish ponds are drained in summer to promote the growth of vegetation (decaying rice and soybean stubble) that serves as a food source for crayfish; the ponds are then flooded in the fall.

About 80 million pounds of farm-raised, food-size crayfish are produced annually in the nation. The food crayfish farming industry centers about two major species: the red swamp crayfish (*Procambarus Clarkii*) and the white crayfish (*Procambarus Acutus*). These crayfish and many other species can be farmed in ponds or tanks for food or as fish bait.

Although profits are not high, production costs are relatively low because (1) only shallow-water (18 to 24 inches) ponds need to be constructed, (2) no special diet is required since crayfish are omnivorous and will eat nearly any protein source including vegetation (millet and rice crops serve as principal food), (3) crayfish will reproduce naturally in ponds, and (4) growth is rapid. Since most crayfish farming occurs on marginal lands, often not suitable for agriculture, these values are particularly attractive to landowners with unused acreage available.

Figure 33 Female crayfish with eggs.

Production is limited for two major reasons. First, of the 20 crayfish species native to Virginia, none reaches a large enough size for commercial production. Second, water temperatures in the state are generally too cool to support optimal growth of the red swamp or white crayfish. Indoor tank culture using heated water may have some potential.

Crayfish farming in ponds and streams in Virginia to produce fish bait has good potential. Most of the small, native crayfish are underutilized by man. Competition by harvesters of wild crayfish may reduce demand, but farming native species for fish bait, stocking ponds, and the aquarium trade has fair possibilities.

2. **Frogs** Poor potential (food) Fair potential (bait & stocking)

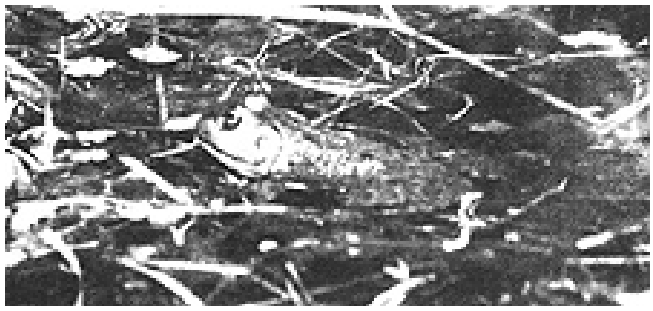

Figure 34. Bullfrog

Farming frogs to obtain leg meat for human consumption has not proven to be economically successful in Virginia or elsewhere in the United States. Frog farms are more myth than reality. Those few individuals who claim to be successful frog farmers generally turn out to be distributors selling adult frogs, tadpoles, or eggs, often harvested from the wild, to misinformed, would-be frog farmers. Beware of frog farming schemes promising a new, quick way to make money.

Many "frog farms" are simply natural marsh areas, swamps, or shallow ponds inhabited by wild, uncontrolled populations of frogs. In most cases, frog farming methods in these areas are limited to increasing shoreline area, erecting fencing to exclude predators and retain frogs, and stocking adults or tadpoles. The frogs are usually left to raise themselves. Indoor frog farming methods have been developed to produce large numbers of small frogs for use in medical and biological research. These methods could be used to rear frogs as fish bait, but it is unlikely that indoor farming can be economically applied to grow large frogs for food.

A number of species of frogs, including the green frog (*Rana Clamitans*), the bullfrog (*Rana Catesbeiana*), and the leopard frog (*Rana Sphenocephala*) are harvested from the wild and sold as frog legs in luxury restaurants. The common bullfrog, or "jumbo frog," is the largest North American species, often reaching 8 inches in body length. Because of its large size, the bullfrog is the most preferred species for food production. Nearly all other small frogs can be farmed as fish bait.

The major problems that limit frog farming for food include: (1) slow growth, often requiring four years to reach a marketable size; (2) food habits of adult frogs largely are restricted to live or moving prey; (3) adult frogs are very territorial, requiring as much as 21 feet of shoreline per frog; (4) adult frogs are cannibalistic and will readily consume their young; and (5) disease, water pollution, natural predators, and competition for markets with harvesters of wild frogs further limit the potential for frog farming.

At present, there is no well established frog farming industry in the United States. Most frogs marketed as food and bait are harvested from wild stocks. Past efforts are frog farming have been largely unsuccessful because of many physical, chemical, and biological problems. The prospects for frog farming are limited.

However, as intensive hunting and drainage of wetlands reduce wild frog populations, demand for frogs for food, fish bait, stocking, and medical research may reach a critical point, permitting profitable frog farming in the future.

3. **Freshwater clams** (mussels) Poor potential (food & bait) Fair potential (stocking & aquaria pets)

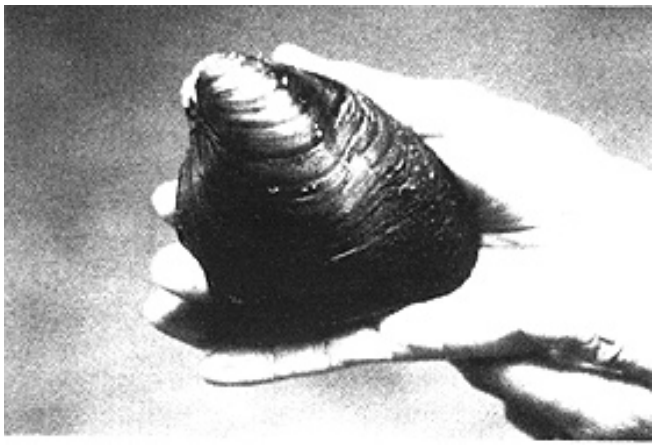

Figure 35. Freshwater Clams

Freshwater clams (mussels), unlike their seafood relatives (saltwater clams and oysters), have little economic importance as human food. Saltwater clam and oyster farming is widespread and well developed, but freshwater clam farming is not currently practiced.

Freshwater clams are edible, but their meat generally is tough and tasteless. Moreover, since clams are filter feeders and tend to concentrate and store toxic chemicals in their body tissue, those clams occurring in polluted waters pose a health risk. Unless you are sure the waters are clean, it is best to avoid eating freshwater clams.

Freshwater clams have been harvested and used as fish bait. However, since clam meat is not a preferred fish bait and better, more readily available baits are marketed, the potential is poor.

Historically, freshwater clams were harvested to make pearl buttons and ornaments. Harvests in the late 1940's and early 1950's exceeded 10,000 tons of shell per year in the Tennessee River. The development of plastic buttons and the decline in wild clam populations as a result of overharvesting, siltation, and other forms of water pollution have eliminated the mother-of- pearl button industry in the United States. The shells of some freshwater clams are still sought for export to Japan as "seed" used to produce cultured pearls.

Farming freshwater clams for sale for stocking ponds and use as aquarium pets has limited potential. There is some evidence that clams, as a result of their filtering ability, can improve water quality and stimulate fish production in ponds. Similarly, certain small species of clams can serve as aquarium pets, cleaning water of suspended particles. Roughly 65 different species of freshwater clams occur in Virginia. Most of these are river species unsuitable for stocking in ponds and aquaria. Only about five native species are suitable for pond and aquarium stocking.

Some of the major problems limiting freshwater clam farming are competition with harvesters of wild clams, the fact that clams are very slow-growing animals that require an abundance of clean water, and gaps in understanding of how to grow clams. New methods for encouraging clams to transform into juveniles without going through the usual parasitic stage on a host fish are currently being developed. New technology and research findings are contributing to promising ways to farm clams. At present, however, this practice is not yet economically feasible.

4. **Salamanders** Fair potential (bait & aquarium pets)

Figure 36. Red-spotted Salamander

Salamanders, often called "spring lizards" because they look like lizards and frequently are found under rocks and logs along spring streams, make excellent fish bait. Unlike lizards, salamanders have moist, non-scaly skin, and no claws on their toes. Of the 32 salamander species found in Virginia, most can be used and sold as fish bait, and some of the more colorful aquatic salamanders are highly desired as aquarium pets.

Most salamanders marketed as fish bait or aquarium pets are captured from wild stocks. At present, there is no salamander farming industry in the United States. The major problems limiting salamander farming are competition from harvesters of wild salamanders and the relatively little-known culture requirements of many species. Beyond the general needs that salamanders, like frogs and other amphibians, need water in which to reproduce; that the eggs hatch into a tadpole-like aquatic stage; that they are scavengers, feeding on insects and a variety of dead materials; and that some species are entirely terrestrial -- little is known about rearing salamanders.

5. **Hellgrammites** Fair potential (bait)

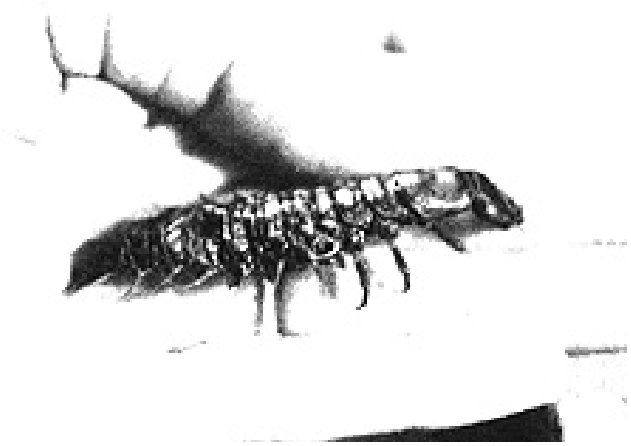

Figure 37. Hellgrammites

Hellgrammites, or "fish flies," are the larvae of a large-winged insect called the Dobson fly. Hellgrammites are found under rocks in stream and river riffle areas. They are collected by turning over rocks and allowing the water current to wash them into a fine net set downstream. They should be handled with care for they are capable of giving a painful nip with their stout pincers. In nature, the adult female Dobson fly deposits eggs in rows of several thousand attached to vegetation, bridges, and other objects overhanging streams. They hatch in 5 or 10 days, and the larvae drop into the water where they prey on aquatic insects for 2 to 3 years.

Hellgrammites are an excellent fish bait and have a high market value. Most hellgrammites sold as fish bait are collected from the wild. The main problem with farming hellgrammites is their cannibalistic habit. Competition for markets with harvesters of wild stocks, and a reliable source of eggs, are limiting factors. Hellgrammites are hardy and can be kept alive for a long time by refrigeration or maintaining them in damp moss or water.

6. **Aquatic plants** Fair potential (food, stocking, aquarium)

Freshwater plants, commonly called water weeds, are used for a variety of purposes including food for humans and livestock; as green manure and soil compost; and for pulp, paper, fiber, and energy production. Freshwater plant farms largely concentrate on growing vegetation for human food, for home aquariums, for scenic water gardens, and for stocking natural wetlands to attract waterfowl.

Figure 38. Water Lily

Figure 39 Plants provide habitat for waterfowl.

Freshwater plants, such as wild rice (*Zizania Aquatica*), watercress (*Nausturtium Officinal*), and water chestnut (*Eleocharis Dulcis*) are widely grown for food. These and other aquatic plants can provide three basic types of food: (1) grain or seeds rich in protein, starch, or oil; (2) green foliage used as leaf vegetables; and (3) underground roots and stems that provide starch.

Wild rice flourishes in marshes and shallow ponds in the northern United States. Once gathered only from the wild, it now has been successfully cultivated and may be possible to farm at high elevations in southern states. Wild rice is easily digestible, rich in vitamin B, and commands high prices as a gourmet food.

Figure 40 Fish nest near aquatic plants.

Watercress is widely cultivated throughout the U.S. in spring streams or canals and channels supplied with cold, clean, flowing water. This plant is rich in iron and vitamins and is highly prized as a fresh-salad herb or as a cooked green vegetable.

Figure 41. Watercress

The Chinese water chestnut root also is a prized vegetable delicacy. It commands high prices as an important ingredient in Chinese meat and fish dishes. This plant is farmed in flooded fields and often rotated with rice in the southeastern United States.

A wide variety of both floating and rooted aquatic plants are sold for home aquarium use. Living plants in fish tanks provide a natural appearance and add to the interest and beauty of aquaria. Moreover, plants improve water quality by absorbing fish waste and harmful gas, and producing oxygen. Plants also offer protective shelter to small fishes and increase the fish carrying capacity of aquaria. An aquarium well established with plants rarely has a serious fish disease or nuisance algae problem.

A large number of freshwater plant species are marketed for stocking scenic garden ponds or planted in waterfowl refuge and hunting areas to lure ducks and geese. Water lilies provide large ornamental flowers in many colors and shapes. These and other species add to the scenic beauty of ponds and lakes, and have a high market demand. Wild game food nurseries produce freshwater plants such as sago pondweed (*Potamogeton Pectinatus*), wild celery (*Vallisneria Spiralis*), arrowhead (*Sagittaria Latifolia*), and wild rice (*Zizania Aquatica*) for establishing feeding grounds for wildlife.

Suggested Readings

General:

Aquaculture: The Farming and Husbandry of Freshwater and Marine Organisms. J. E. Bardach, J. H. Ryther and W. O. McLarney. 1972. Wiley Interscience, New York, NY.

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Reviewed by Michelle Davis, research associate, Fisheries and Wildlife