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Trout Culture in the North Central Region

K. Cain
Michigan State University

D. Garling
Michigan State University

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Abstract

Trout have been raised in the United States for about 150 years. Initially, trout were raised to replace wild stocks that were declining because of over fishing, loss of habitat and pollution. United States trout farming began in the North Central Region with the establishment of Ackley's Farm near Cleveland, OH. This farm was run by Theodatus Garlick, M.D., and H.A. Ackley, M.D., who developed ways to spawn brook trout and incubate the eggs in glass jars. Today, trout are still raised in the North Central Region in state, federal and private fish farms to stock lakes, ponds and streams. Trout are also raised and sold through fee fishing operations and as food fish through restaurants and supermarkets. Rainbow trout are the most commonly raised trout followed by brook and brown trout. Private commercial trout farms range from small owner/ operator farms to large farms with many employees.

Disciplines

Aquaculture and Fisheries

Comments

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North Central Regional
Aquaculture Center

In cooperation with USDA

Trout Culture in the North Central Region

by K. Cain and D. Garling, Department of Fisheries and Wildlife, Michigan State University, East Lansing, MI

Introduction

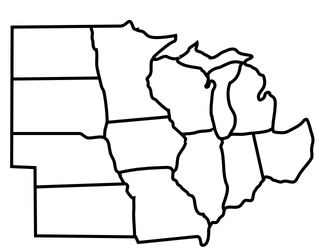
Trout have been raised in the United States for about 150 years. Initially, trout were raised to replace wild stocks that were declining because of over fishing, loss of habitat and pollution. United States trout farming began in the North Central Region with the establishment of Ackley's Farm near Cleveland, OH. This farm was run by Theodatus Garlick, M.D., and H.A. Ackley, M.D., who developed ways to spawn brook trout and incubate the eggs in glass jars.

Today, trout are still raised in the North Central Region in state, federal and private fish farms to stock lakes, ponds and streams. Trout are also raised and sold through fee fishing operations and as food fish through restaurants and supermarkets. Rainbow trout are the most commonly raised trout followed by brook and brown trout. Private commercial trout farms range from small owner/operator farms to large farms with many employees. The states of Michigan, Wisconsin, and Missouri had a total of 114 trout farms which had a combined total sales of approximately 6.8 million dollars in 1991. Further expansion of trout farming in the region is constrained by the scarcity of adequate supplies of high quality water at appropriate temperatures.

The information in this fact sheet is intended to provide an overview of basic trout culture practices used in the region. Water quantity and quality are discussed along with hatchery design, spawning and rearing, incubation, production, feeding, general fish health management and marketing. This material can be applied to any size fish culture operation. Additional information on state permits, regulations, business planning, finance, and economic data will be necessary to plan and start a successful trout farm.

Water Quantity

Before any plans to begin a commercial trout farm are initiated, a thorough study of the water supply should be completed. Trout can be raised in areas where a constant supply of high quality water is available year round. Most trout farms and hatcheries use springs, wells, or streams as the source of their water. Production of food-sized fish requires the largest volumes of water. Water flows of at least 500 gallons per minute (gpm) are needed for small operations, while flows exceeding 2,000 gpm are commonly used at large commercial operations. Smaller water flows are required for fee-fishing operations, however at least 50 to 100 gpm is still desirable.



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Water Quality

In addition to abundant quantity, high quality water is essential for a commercial trout hatchery. Dissolved oxygen, tempera ture, suspended solids, dissolved gasses, pH, mineral content, hardness, and alkalinity of the water supply should be analyzed before any site specific facility plans are initiated to assure that they are in the desirable range for trout production (Table 1).

If any types of ground water contamination are known to occur in the area, the water should also be tested for those specific toxic chemicals. Potential water sources for a hatchery site should be observed throughout a full season.

Water temperature is usually the most critical water quality factor. Temperature effects survival, growth and egg production (Table 2).

The most desirable water supplies provide water temperatures within the optimum growth range year round. Trout hatcheries should have an adequate supply of high quality water that ranges from about 45-65˚F. Water supplies with temperatures that are outside the range for optimum growth for significant periods of time during the

Table 1. Water quality parameters for trout hatchery water supplies (Piper et al. 1982). Variable	Trout
Dissolved oxygen	5 ppm to saturation
temperature	45-65˚F
pH	6.5-8.0
Total alkalinity ($CaC0_3$)	10-400 ppm
Calcium	4-160 ppm
Magnesium	Needed for buffer system
Manganese	0-0.01 ppm
Iron (total)	0-0.15 ppm
Phosphorus	0.01-3.0 ppm
Nitrate	0.3.0 ppm
Zinc	0-0.05 ppm

year should be avoided since growth will be slowed by both higher and lower temperatures. Although trout can withstand a wide range of temperatures, the extreme upper temperature limit can only be tolerated for very short periods of time.

The best source of water for hatcheries is generally groundwater from springs or wells because they tend to have minimal seasonal temperature fluctuation. Springs and artesian wells are more economical than wells that have to be pumped. However, groundwater sources may be low in dissolved oxygen, high in hydrogen sulfide, and may require supplemental aeration. Rivers and streams can be used as a water source; but, temperature fluctuations, flow fluctuations, silt, diseases, and unwanted fish make them less desirable. Trout are not usually reared in water recirculation systems because of their low tolerance to marginal water quality.

Since trout require high levels of oxygen, the oxygen content of the water supply must be high. Oxygen levels should never fall below 5 parts per million (ppm) in the hatchery effluent. In general, dissolved oxygen concentrations of incoming water should be above 90% saturation. Proper aeration of the incoming water and control of numbers of fish raised in the rearing system can be used to overcome low oxygen problems. However, hatcheries that depend on supplemental aeration can loose many fish to oxygen depletion if a failure in the aeration system occurs.

Supersaturated nitrogen levels in the hatchery water supply may cause potential fish health problems. If nitrogen and oxygen remain at supersaturated levels, gas bubble disease may occur. This disease is similar in effect to a diver with the bends. Small nitrogen bubbles can form in the blood and block free blood flow. In sever cases, significant numbers of trout may die. Aeration using a packed column can reduce nitrogen levels to below saturation. Packed columns usually consist of a tube "packed" with screen or other loose material to break up and aerate the incoming water.

General guidelines for the concentrations of dissolved gasses in hatchery water supplies are found in Table 3.

Hatchery Design

Hatchery rearing facilities may include areas of egg incubation, fry rearing, grow out tanks, raceways, broodstock ponds and a waste treatment pond. There also should be areas for feed storage, chemical storage for disease treatment, and an office area. Hatchery managers need to keep accurate production, sales and other business records.

Take advantage of gravity and choose a location for your hatchery that is downstream from the water source, otherwise the water will have to be pumped. Also choose a site with impervious soil to hold water with little seepage and an area with a gently sloped gradient to provide drainage and to allow raceways to be arranged in series for partial water reuse.

Production raceways for trout grow our are typically linear earthen or cement structures built with a width to length ratio or 1:10, generally between 6'x10' to 10'x100'. Raceways are also typically 3 to 4 feet deep. Linear raceways are easy to clean and fish are easily harvested. These design features also help maintain water quality by minimizing waste build up and warming of the water. In areas where the water supply is hard and has a neutral to basic pH (greater than 7), three raceways can be built in series to re-use the water. A fall of 18 inches between each raceway will help re-aerate the water; but, ammonia levels will

Table 2. Effects of water temperature on spawning, survival and growth of trout (Piper et al. 1982)

Species	Spawning Frequency	Survival (˚F)	Optimum Growth (˚F)	Optimum Spawning (˚F)	Eggs per pound of fish
Rainbow trout	Annual	33-78	50-60	50-55	1,000
Brook trout	Annual	33-72	45-55	45-55	1,200
Brown trout	Annual	33-78	48-60	48-55	1,000

Table 3. General guidelines for the concentrations of dissolved gasses in hatchery water supplies (Source: (Piper et al. 1982)	
Oxygen	5 or more ppm
Nitrogen	less than 100% saturation
Carbon dioxide	10 ppm or less
Hydrogen sulfide	0.1 ppb or less
Hydrogen cyanide	10 ppb or less

continue to increase, making a fourth raceway impractical. Two basic rules of thumb apply when planning the actual size of a 3 pass raceway system: approximately 100 lbs. of fish can be raised per gallon per minute of water flow and about 2-4 pounds of fish can be reared per cubic foot of water.

Recently, there has been growing concern over the impact of waters discharged from fish hatcheries on the receiving waters. These discharges are called effluents. Discharge permits are required in most areas to insure that hatchery effluents meet all State and Federal regulations.

The types of wastes that may be discharged from fish hatcheries include bacteria and parasites, drugs and chemicals used in disease treatment, and metabolic wastes such a phosphorus, ammonia, feces, and uneaten feed. Phosphorus from fecal waste and uneaten feed is of the highest concern due to it's role in nuisance aquatic plant growth and accelerated lake aging. Settling basins have been used to collect suspended solids before the water is discharged into a lake or stream. A settling basin is usually a pond or the last section of a raceway.

At larger hatcheries, the fecal material and uneaten feed are pumped into a hauling truck. The sludge is transported to nearby farmer's fields or other areas for disposal. In the future, regulations may further limit the levels of phosphorus which can be discharged from hatcheries. Development of formulated feeds that contain lower levels of phosphorus may also help meet stricter phosphorus effluent limits.

Spawning and Rearing

Many trout hatchery operators have their own broodstock (adult fish for spawning). However, due to the high cost of maintaining broodstock and the skill and amount of labor involved in spawning, many private and state hatcheries purchase eyed eggs or fingerlings from other sources. Eggs are often purchased from suppliers outside the North Central Region. For example, 92 percent of all purchased rainbow trout eggs came from outside the region, predominantly from western states. These eggs should be "certified disease free" to avoid the potential of introducing new viral and bacterial diseases. Some states require that all imported eggs are obtained from hatcheries certified as disease free.

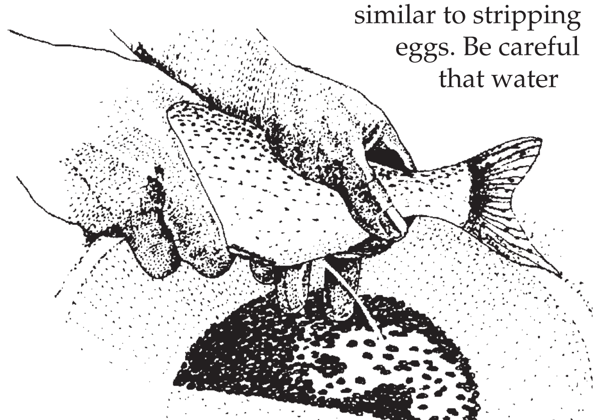
Most native North America trout populations spawn in the spring or fall. Through many years of selective breeding, hatchery strains have been developed that can spawn throughout the year. A continuous egg supply promotes year-round production of fish at appropriate marketable sizes.

Most trout over 10 inches can be used for spawning. Artificial spawning involves manually stripping and combining eggs from the female with milt from the male.

Rainbow trout will generally produce about 1,000 eggs for every pound of fish. Handling of the fish should be kept at a minimum during the spawning process. Anesthetics such as MS-222 or carbon dioxide should be used to reduce stress to the fish and simplify the spawning procedures. The easiest hand spawning method uses two people. One person gently grasps the trout near the head with one hand and just above the tail with the other hand. Point the vent (the opening on the underside of the fish) downward toward a pan. The second person massages the belly beginning just above the vent working back toward it. If the female is "ripe" then eggs will flow very easily from the vent. The eggs should initially be collected in a dry pan and kept dry to improve fertilization.

A better method of egg removal is air spawning. A hypodermic needle is connected by a hose to a low pressure (about 2psi) air compressor or air cylinder. The needle is inserted about 1/2 inch into the females body cavity just in front of the pelvic fins. The gentle air pressure will expel the ripe eggs with minimal handling and stress to the fish. After air spawning, the air must be removed from the female by gently massaging the sides of her body.

After the eggs have been collected. milt can be added. The procedure for removal of milt is similar to stripping eggs. Be careful that water



Eggs are fertilized artificially by experienced spawn takers.

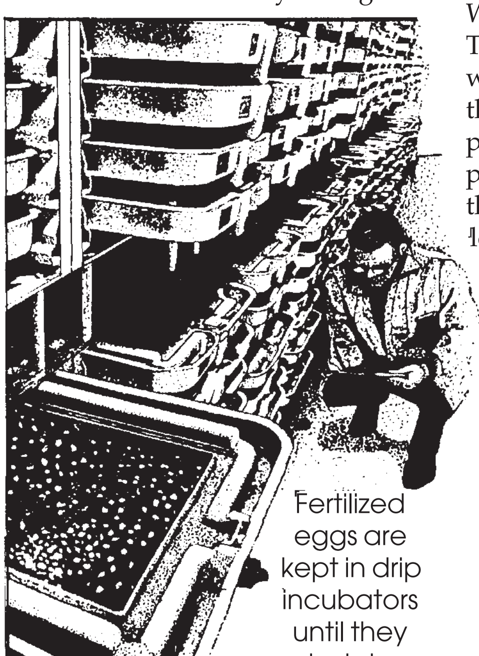
and urine does not mix with eggs or milt because they interfere with fertilization. Collect the milt into a plastic wash bottle or directly over the eggs. Sperm from at least two males should be used to fertilize the eggs from each female to insure good hatching success.

After thorough mixing of the eggs and milt, water should be added to activate the sperm. Water activation increases the number of eggs fertilized. Eggs must be water-hardened before handling and transport. Water-hardening occurs when water is absorbed by the eggs and fills the perivitelline space between the shell and yoke. Water hardened eggs can be transported from 1 to 48 hours after fertilization, but after 48 hours eggs should not be moved until the eyed stage (eyes can be seen through the egg.)

During the spawning and incubation process, eggs should not be exposed to direct sunlight or intense artificial light. Intense light will kill developing trout embryos.

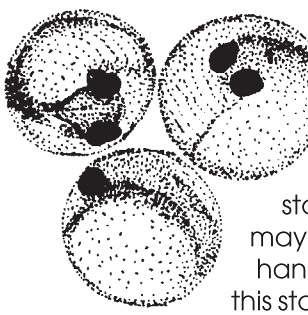
Incubation

Once fertilization, water-hardening and transport to incubation systems are completed, eggs are incubated undisturbed until the eyed stage (about 14 days at water temperatures of 50 degrees F). Handling eggs before the eyed stage will damage and kill the sensitive developing trout embryos.



Fertilized eggs are kept in drip incubators until they hatch.

Trout eggs can be incubated by various methods. Eggs can be placed in wire baskets or rectangular trays placed in existing hatchery troughs. Water is passed through the trays or baskets. Newly hatched fry drop through the mesh to the bottom of the trough. This method is used to save space and reduce costs; but fewer eggs will generally survive. Other methods typically use jars or vertical trays to incubate trout eggs.

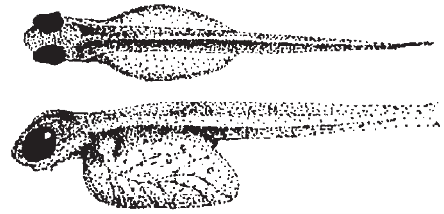


Once eggs reach the eyed stage they may be safely handled. At this stage, any dead eggs are white in color and may be removed.

Specially designed hatching jars are placed in rows in hatchery troughs. Water is passed through the jars. The jars are designed to introduce water at the bottom and flow out the top. A layer of gravel may be placed in the bottom of the jar to provide a gentle upward flow through the eggs. This method allows eggs to remain undisturbed and stationary during incubation.

Hatching "jars" can also be made from two 5 gallon plastic pails. One pail is modified by removing the bottom while leaving a 1/4 to 1/2 inch rim. Two pieces of fiberglass window screen are cut to cover the opening. A piece of screen is silicone cemented to the inner and outer surface of the lip. The second bucket is modified by drilling a hole on the side of the bucket near the bottom edge. A male hose adapter is silicone cemented in the hole and piece of hose attached. The screen bottomed pail is placed into the other pail and water is gently added through the hose. Water flows up through the eggs and out over the top of the inner bucket. Up to 50,000 eggs can be incubated in this inexpensive incubator system.

Newly hatched sac fry rely on their yolk sac for nourishment

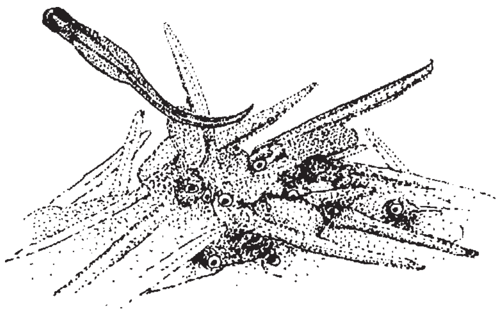


Vertical trade drip incubators are widely used for trout and salmon eggs. Eggs will hatch in the trays and the fry can remain there until ready to feed. The trays are designed to allow water to flow up through the eggs. Up to 16 vertical trays may be stacked in special racks, using a single water source, which allows large numbers of eggs to be hatched in a minimal amount of space and water.

Another important aspect of egg incubation is the control of fungal growth. Fungus treatment of eggs is most often done in formalin (a 37% solution of formaldehyde) at a concentration of approximately 1 part formalin to 600 parts water for about 15 minutes, every 1 to 3 days. When the eggs reach the eyed stage they can be shocked by addling. Addling is a procedure used to identify weak and undeveloped eggs. The eggs are siphoned from the incubators and allowed to drop about 18 inches into a bucket of water. Weak or undeveloped eggs will rupture, turn white and can easily be removed.

Production

When fish begin to swim-up to the surface, thin yolk sac has been ab-



When the yolk sac is almost entirely absorbed, the trout become swim-up fry and must be fed artificial feeds.

sorbed. They should immediately be transferred to tanks and fed appropriate sized feeds. Most facilities have shallow tanks for swim-up fry, intermediate depth tanks for fingerlings, and larger outdoor raceways for final grow-out. Outdoor raceways are normally constructed of concrete to facilitate cleaning and fish handling.

In order to manage a hatchery efficiently, proper feeding practices, growth projections, and keeping and up to date inventory are essential. Detailed descriptions of the following methods can be found in Piper et al. (1982). Every trout farmer should have a copy of this book.

An easily measured index of growth is the length-weight relationship, often referred to as condition factor (C). C is the ratio of fish weight to the length cubed. Since C may vary between species, strains, diet and feeding levels, water quality and hatchery management, it should be calculated for each hatchery. C is calculated by weighing a sample of 50-100 fish together. The fish are anesthetized to take individual lengths. Measurements are taken in standard English units (inches and pounds). After the average weight and the average length are measured, values are used in the formula $C=W/L^3$. A high condition factor would indicate a well fed fish, while a low condition factor may indicate a poorly fed fish of the same length. Once C is established for the hatcher, a standard length-weight table can be used to estimate the average weight of the fish.

In order for fish to survive and grow, water flow must be sufficient to keep oxygen levels high and to dilute and remove ammonia and other metabolic products. The carrying capacity of a hatchery is the maximum weight of fish which can be raised at any given time. Carrying capacity varies based on a number of factors including: water flow, volume, exchange rate, temperature, oxygen content, pH, size and species of fish being reared, and accumulation of metabolic products. Carrying capacity is based on loading (the weight of fish per unit of water flow) and density (the weight of fish per area of raceway).

The Flow Index can be used to estimate the maximum loading (maximum weight of fish at a given size and water flow rate that can be raised at a specific hatchery). The formula for Flow Index is F=W/(LxI), where F=Flow Index; W=Known permissible weight of fish; L=Length of fish in inches; I=Water inflow in gallons per minute. Standard Flow Index Tables have been calculated at various temperatures and elevations based on an optimum Flow Index of 1.5 at 50˚F and 5,000 feet. F can be used to estimate how many pounds of fish/gallon/minute water inflow can be reared at these flow levels providing the water supply is at or near 100% oxygen saturation. The formula can be rearranged to find the permissible weight at a given flow index: W=FxLxI.

The maximum weight of fish per area of raceway can be determined by using the Density Index (DI). The DI takes into account the spacial relationship of fish to one another. Crowding increases the risk of disease transmission and oxygen depletion dramatically. DI can be calculated by the formula: W = D x V x L, where: W = Permissible weight of fish; D = Density index (0.5 suggested trout); V = Volume of raceway in cubic feet; and L = Fish length in inches.

C,F and DI are important because even though there may be enough flow to support a given number of behavioral or physical problems. These calculations can be very helpful and informative for anyone involved in fish culture. Overloading of fish, high water temperatures, or decreased oxygen and higher ammonia levels resulting in reduced growth and disease outbreaks.

Feeding

Proper feeding practices are very important. Inadequate feeding practices result in higher expenses, reduced production, degradation of water quality, and possible disease problems. There are many trout feeds on the market today and most supply the needed vitamins, minerals, and amino acids required for growth. Feeding rates should be followed carefully. Standard feeding tables (see Piper et al. 1982) can be used to estimate the amount of *dry* pelleted feed needed for rainbow trout. These tables are a good basic guide to follow; but, hatchery managers must observe the feeding habits of their fish. At certain times of the year, feeding levels can be increased while at other times they may need to be decreased. For example, in the spring as water temperatures are increasing the fish often become much more active and feeding rates should be increased to higher levels. In winter, when water may be cooler, feeding rates should be decreased. The percent of feed fed per body weight decreases as trout grow larger.

Another aspect of feeding that should be monitored regularly is feed conversion. Feed conversion is the amount of dry feed fed divided by the amount of weight gain: FC=dry weight of feed fed/weight gain. If fish are feeding poorly, cut back on the feeding rate. Generally feed conversions of between 1.0 and 2.0 are acceptable. This should be monitored regularly, once every month or two weeks. If the FC fluctuates significantly then feeding practices should be adjusted accordingly. A change in FC can also indicate disease or stress problems before physical signs appear.

Fish Health Management

Disease outbreaks can be devastating to any fish farm. Knowing how to deal with disease outbreaks can mean the difference in a successful business or going broke. Good management practices involve providing a healthy environment for fish while minimizing stress and meeting proper nutritional requirements. Selecting an appropriate site and using the production techniques described above will help minimize stress. Many disease problems can be prevented as long as levels of stress are kept at a minimum.

If disease problems do occur, it is important to administer treatments immediately. By becoming aware of the signs of many diseases, a manager can diagnose a problem quickly and administer treatment before it gets out of hand. If fish are acting abnormally and the cause is unknown, an affected fish should be sent to a fish pathology laboratory as soon as possible.

Viruses, bacteria, fungi, protozoans, and many invertebrate animals can cause diseases in fish. These disease-agents may be present in a water supply and not cause serious problems as long as the trout are not stressed by poor water quality or overcrowding.

Another factor that may cause disease problems is poor quality or old feed. Trout can be stressed by using feeds that do not contain adequate amounts of proteins, amino acids, fats, carbohydrates, vitamins, and minerals. Fish fed an inadequate diet may be more susceptible to disease agents. Remember that stress, above all else, can lower resistance and increase susceptibility to disease outbreaks.

All equipment used should be disinfected after use to avoid transferring bacteria between tanks. Nets should be dipped in a disinfectant solution that is approved for food dish after use. Also, workers and visitors should be made well aware of the possibilities of transferring disease.

The types of trout diseases and their treatments are beyond the scope of this bulletin. Individuals involved in trout farming should become knowledgable in fish disease identification and treatment through short courses offered by the United States Fish and Wildlife Service and many universities or through appropriate trout disease textbooks. Before administering any recommended drug treatment be sure that the drug is currently approved by FDA and EPA for trout use. Follow all label recommendations. Check with your aquaculture extension specialist, state diagnostic clinic, or state veterinarian before using any fish disease treatment.

Marketing

As with any business venture, a trout farm cannot be profitable unless there is a market for the product. Whether fish are raised for human consumption, fee-fishing or for stocking purposes, some basic questions need to be answered:

Yes	No	
❑	❑	Is there a market for eyed eggs?
❑	❑	Is there a market for fry or fingerlings?
❑	❑	Is there a demand locally for live trout for stocking purposes?
❑	❑	Is it possible to contract with fish and game agencies for production of fish or eggs?
❑	❑	Are there competing fee-fishing operations in the area?
❑	❑	Would local supermarkets, restaurants, or hotels be willing to buy this product?

Make sure that these types of markets exist for trout in your area before attempting to build a trout farm. Also make sure that you can provide a product to meet the specific needs of your market, in part, by answering the following questions:

Yes	No	
❑	❑	Is there an established market for your fish?
❑	❑	Can you produce your fish at a price that is competitive with other available fish products?
❑	❑	Is there a market for your fish when you plan to sell them?
❑	❑	Can you produce marketable sized fish year-round if so required by the market?
❑	❑	Can you produce enough fish to meet market needs?
❑	❑	Can you process the fish to meet local market requirements?

To have a good probability of success, most of your answers should be in the "yes" column. Always remember, careful planning is the key to success. **GOOD LUCK!**

Suggested Readings

Garling, D.L. 1992. Making plans for commercial aquaculture in the North Central Region. North Central Regional Aquaculture center, Fact Sheet Series #101. 10p.

Kinnunen, R.E. 1990. Salmonid egg and fingerling purchases, production and sales. North Central Regional Aquaculture Center, Technical Bulletin Series #103. 18p.

Kohler, S.T. 1992. Choosing an organizational structure for your aquaculture business. North Central Regional Aquaculture Center, Publication #103. 4p.

Leitritz, E., and R.C. Lewis. 1980. Trout and Salmon Culture. Division of Agricultural Sciences. University of California.

Piper, R.G., I.B. McElwain, L.E. Orme, J.P. Leonard. 1982. Fish Hatchery Management. United States Department of the Interior. Fish and Wildlife Service. Washington, D.C. 1982.

Roberts, R.J., and C.J. Shepherd. 1974. Handbook of trout and salmon diseases. Fishing News Books Ltd. Farnham, England. 172p. (Some treatment recommendations listed in this book are not approved by the FDA or EPA for use in the United States. Only treatments approved by the FDA and EPA can be used to treat fish diseases.)

Thomas, S.K., R.M. Sullivan, R.L. Vertrees, and D.W. Floyd. 1992. Aquaculture law in the North Central States: A digest of state statutes pertaining to the production and marketing of aquaculture Products. North Central Regional Aquaculture Center, Technical Bulletin Series #101. 76p.

Contact your state extension specialist(s) for the above information sources and other pertinent information regarding channel catfish culture.

Series Editor: Joseph E. Morris, Associate Director, North Central Regional Aquaculture Center.
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