PREFACE

A MESSAGE FROM INDIANA'S COMMISSIONER OF AGRICULTURE

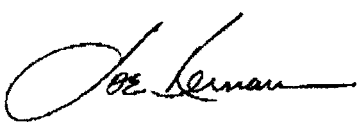
As Indiana's new Commissioner of Agriculture, I am proud to support a growing aquaculture industry in the State of Indiana. The Office of the Commissioner of Agriculture has been pleased to promote this industry through sponsorship of value-added research, a series of "think tanks" to address pressing issues and by providing staff support for the advancement of the industry throughout the state.

Aquaculture has tremendous, long-term opportunities for Indiana's farms and businesses. More and more people are eating fish and seafood in the United States. At the same time, in other parts of the world, export opportunities are expanding as many countries look for new sources of food.

Indiana is in an excellent position to capitalize on aquaculture opportunities. The Hoosier state is near many major markets, has an abundance of natural and agricultural resources, and boasts a dedicated network of aquacultural specialists and entrepreneurs throughout the state. Indiana also has many high quality businesses that are actively involved in support services such as transportation, marketing and feed manufacturing.

It is with great pleasure that I present to you this **Indiana Aquaculture Plan**. The plan presents the current status of aquaculture in the state of Indiana and planning for its development in the future.

Sincerely,



Joseph E. Kernan
Lieutenant Governor and
Commissioner of Agriculture

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The Indiana Aquaculture Plan was compiled and edited by Casey Reed and David Isaacs with Aquatic Control, Inc., Seymour, Indiana.

EXECUTIVE SUMMARY

A survey of Indiana's fish culturists shows the diversity present in today's aquaculture industry. Fish and plants are grown for human consumption, recreational fishing, ornamental display, and use in scientific research. Culture methods vary from low density pond production to high tech, intensive recirculating systems that more closely resemble assembly lines than farm ponds. Indiana fish farmers are growing cold water species, such as trout, as well as fish imported from the warm tropical waters of Africa. If there is a demand for an aquacultured species and a viable method for producing it, Indiana farmers are doing their best to meet the demand.

People realized thousands of years ago that fish could be propagated for human consumption. Recent technological advancements in culture techniques have allowed the aquaculture industry to achieve levels of sophistication never before seen. Scientific research in the public and private sectors in areas such as genetic manipulation, hormone induced spawning, sex reversal, water reuse, and nutrition have made it possible to consistently produce a wide variety of species on a commercial scale. As wild fish stocks decline due to over fishing and habitat destruction, the contribution made by fish culturists will become increasingly evident. Fish produced as a protein source for humans and for stocking to enhance wild fish populations are allowing the aquaculture industry an opportunity to contribute to the preservation of the world's natural environment.

The Indiana Aquaculture Association (IAA) recognizes the potential impact the aquaculture industry could have on the world's food supply, as well as the benefits associated with captive fish production as an alternative to removing fish from the wild. Working with funds provided by the Indiana Department of Commerce, Office of the Commissioner of Agriculture under the Value-Added Program, the IAA has taken the lead in determining the status of aquaculture in the state of Indiana and planning for its development in the future. The Indiana Aquaculture Plan is the first step in this assessment.

The Indiana Aquaculture Plan is not meant to be a “How To” guide for the production of aquatic plants and animals, rather it was designed to offer insights to the aquaculture industry in the state of Indiana. Its contents describe the current methods of production used, species suitable for culture, regulatory considerations, marketing strategies employed, and gives information on financing aquaculture operations and the management of fish culture facilities. Technical support and educational opportunities available in the state are described, along with information on current and future research in the field of aquaculture. The final chapter, entitled “Aquaculture Growth in Indiana,” recommends a course of action for developing and monitoring the aquaculture industry in the state. The IAA hopes the Indiana Aquaculture Plan demonstrates the viability of aquaculture in the state and elicits support for its development from lawmakers and the public.

1 INTRODUCTION

National Aquaculture Act

The passage of the National Aquaculture Act of 1980, P.L. 96-362, gave formal recognition of the National policy "to encourage the development of aquaculture in the United States", while stating "the principle responsibility for the development of aquaculture in the United States must rest with the private sector." The Act also recognizes that government must participate by providing "encouragement and support through programs and services that cannot reasonably be expected from private sources." In response to P.L. 96-362, the Joint Subcommittee on Aquaculture prepared the National Aquaculture Development Plan (NADP). The NADP describes technologies, problems, and opportunities associated with aquaculture in the U.S. and its territories; contains in-depth discussions of important selected aquaculture species; analyzes the social, environmental and economic impacts of growth in aquaculture; recommends actions to solve problems; and provides an extensive bibliography. The NADP is being revised at the time of this writing.

The NADP, however, does not address issues specific to individual states. As a consequence, many states have taken it upon themselves to address these issues. In all, nearly half of the states have completed or are currently investigating/writing aquaculture plans. Since the list of active states includes all of Indiana's sister states, and since the largest inland seafood market (Chicago) is on Indiana's door step, it is imperative that Indiana, likewise, become involved.

History of Aquaculture

Although aquaculture in the U.S. has a history as old as the country itself, aggressive expansion did not become evident until the early 1960's. By 1975, aquaculture production in the U.S. was estimated at about 130 million pounds; by 1994 production had grown to 651 million pounds. Although the industry was not formally recognized until the 1980 National Aquaculture Act, support from Federal and State agencies, academic institutions, and a strong entrepreneurial spirit in the private sector were already providing for a major expansion in production. This expansion was fueled by: 1) the recognition that traditional commercial fish stocks had reached or exceeded their sustainable harvest capacities as witnessed by the adoption of the Magnuson Fishery Conservation and Management Act, P.L. 94-265, 2) an increasing per capita consumption of seafood (10.3 pounds per capita per year in 1960; 13.0 pounds in 1980, National Fisheries Statistics Program, 1984; 14.5 lbs in 1985, 15.2 pounds in 1994), and 3) an increasing contribution to the National trade deficit by fish products ($5.6 billion in 1985; National Fisheries Statistics Program, 1986). Finfish and shellfish products are the greatest agricultural contributor to our nation's annual trade deficit, ranking second only to petroleum among natural products. It was observed by the National Research council the "constraints on orderly development of aquaculture tend to be political and administrative, rather than scientific and technological."

In recognition of the regional nature of many of the aquatic products, the National Agriculture Act of 1985 provided for the establishment of regional aquaculture centers. These centers are to coordinate regional research efforts for the most efficient use of research money ($4 million appropriation annually). The industry quickly responded and regional associations of leaders in governmental, institutional, and private sectors were established. These ultimately led to the creation of the Northeast, Southern, Western, and North Central Regional Aquaculture Centers, along with the Center for Tropical and Subtropical Aquaculture.

Aquaculture in Indiana

Aquaculture in Indiana dates to the late 1800's when a substantial goldfish industry developed in Martinsville. The farms produced goldfish for the bait industry which were shipped via rail throughout the Midwest. By 1994, the aquaculture industry in the state had grown to a total product volume of $3.5 million. The greatest emphasis, in terms of acres devoted to fish production, has been in the production of game fish (bass, sunfish, and catfish) for private stocking, minnows for baitfish, and ornamental fish on one large farm. In recent years, a number of fee fishing operations have been established in the state creating a demand for large fish. Some of these fish are supplied by local producers, but a number are imported from out of state.

Indiana Aquaculture Association

In February 1987, fish farmers (active and potential) together with representatives from education, government, and the aquaculture service industries met and formed the Indiana Aquaculture Association (IAA). This meeting came about due to concern that Indiana was going to be left behind in aquacultural development if action was not taken quickly. The aquaculture industry had been growing at approximately 20% per year, Indiana's neighboring states were becoming increasingly active, and potential market shares could be lost if an organized effort wasn't established. Of the 56 million pounds of trout and 495 million pounds of catfish, not to mention dozens of other products which are produced in the U.S. today, probably a third or more is delivered and redistributed/consumed out of Chicago markets. The potential for jobs in agriculture, either directly or from value added, and in recreation appears to be staggering.

The intent in forming the IAA was primarily to assist in promoting the production and marketing of aquaculture products. However, it was recognized that the industry could not develop competitively if IAA did not also provide for the educational advancement of its members (and potential members), encourage scientific research, promote an exchange of information among members, and extend/develop public interest in the discipline. These are the primary goals of the Indiana Aquaculture Plan.

2 REGULATORY CONSIDERATIONS

Indiana Aquaculture Act

In 1989 the Indiana Legislature passed State Senate Bill 143, known as the Indiana Aquaculture Act. This Bill officially recognized aquaculture as a form of agriculture and not an offshoot of the sport fishing industry as it was previously considered. As with any industry that provides food for human consumption or whose activity might have an effect on the environment, aquaculture has specific state and federal regulations that dictate how facilities are operated and how products are handled and sold. Laws are also in place to regulate how natural resources such as ground water are used and to ensure that waste products are not disposed of in a way that could damage the environment.

Below is a list of the state and federal agencies that are currently involved with regulating aquaculture facilities and operations in the state of Indiana. The list should be used by aquaculturists as a guide to gathering information on the permits required for aquaculture production and to indicate which agencies are responsible for the various types of regulation. Each agency should be contacted to determine exactly what is required for compliance.

STATE AGENCIES

Indiana Department of Environmental Management (IDEM)

NPDES Permit

Office of Water Management- The IDEM regulates point source discharges of pollutants into national waters as part of the Clean Water Act. A National Pollutant Discharge Elimination System (NPDES) permit is required if IDEM determines your facility “is a significant contributor of pollution to the waters of the United States." Specific criteria have been established to determine if an aquaculture facility must posses an NPDES permit before discharging waste water. These criteria deal mainly with the number of days you plan to discharge, total weight of fish produced, and total pounds of feed input. The criteria are different for coldwater and warmwater facilities. The IDEM may also be involved with permitting, in conjunction with the U.S. Army Corps of Engineers, and the Indiana Department of Natural Resources Division of Water, in cases that involve the development of wetlands for use in aquaculture.

Indiana Department of Natural Resources (IDNR)

Division of Fish and Wildlife- The IDNR Division of Fish and Wildlife is required by law to protect and properly manage the fish and wildlife resources of the state. This requires the Division to make determinations of the legal ownership of certain animals as well as the conditions under which these animals may be collected, held, produced, or sold. The Division of Fish and Wildlife also protects the native wild animals of the state by determining appropriate methods for safe importation, culture, sale, and release of non-native animals. Permits are required in most cases if a person wishes to raise, hold, transport, stock, import, export, sell, or collect fish in the state of Indiana.

Division of Water- Prior to construction of an aquaculture facility it should be determined if any of the three aquaculture-related permits administered by the IDNR Division of Water are required. The first permit is mandated by the Flood Control Act and is required of any person proposing construction (including buildings, culverts, utility lines, etc.) in or on a stream or river or in its floodway. The second permit also deals with construction and is required of persons wishing to undertake a construction activity in or on Lake Michigan. The permit most often required for aquaculture production, however, is the one involving water supply and withdrawal. Any wells or surface water intakes that individually or in combination are capable of withdrawing more than 100,000 gallons of water daily must be registered with the IDNR. Water withdrawal must be reported on an annual basis. There may also be local ordinances to be considered especially with regard to flood plain construction. For this reason the Division of Water highly recommends contacting local officials to assure compliance.

High Volume Wells

Indiana Department of Commerce

Office of the Commissioner of Agriculture (OCA)- The OCA develops policy and encourages efforts to facilitate the growth of aquaculture and other forms of agriculture in the state of Indiana. It was instrumental in getting the Aquaculture Act authored and passed in the General Assembly and has provided funds, through the Value-Added Program, for critical projects in the development of aquaculture in the state. The office also works closely with Purdue University, USDA, FFA, and others in providing a strong voice for the support of aquaculture in Indiana and the Midwest. The OCA does not have any regulatory control over aquaculture activities and does not require any permits.

Indiana State Department of Health (ISDH)

Division of Wholesale and Manufactured Foods**-**The ISDH Division of Wholesale and Manufactured Foods is responsible for the implementation of the Wholesale Food Protection Program. The intent of this program is to ensure a safe, wholesome food supply for the citizens of the State of Indiana, as well as ensuring the quality of food products shipped into other states and countries. It is also designed to reduce the risk of food borne illness outbreaks which could be associated with the improper storage and handling of food items introduced into channels of commerce. This division regulates fish processing establishments and requires they be registered with the ISDH for inspection. County health agencies may also require regular inspection of processing facilities and should be contacted to ensure compliance with their regulations. The ISDH Sanitary Engineering Division may be involved with the investigation of waste water discharges if it is deemed necessary.

Seafood Processing

Division of Meat and Poultry**-** The ISDH Division of Meat and Poultry is only involved in aquaculture if fish are being processed in one of its official meat processing plants. In these cases the only requirements are that fish are kept separated from other products and that the fish processing area is maintained at the same level of cleanliness as the rest of the plant. The fish processed are not inspected and do not leave the plant with any type of certification of inspection. If a federal fish inspection program is implemented in the future and it is handled by the United States Department of Agriculture (USDA) this Department of ISDH will be involved. At this time it is not known if such a program will be required or which agency will be responsible for its enforcement.

Indiana Department of Revenue

Commercial aquaculture must follow the same guidelines as any agricultural business venture with regard to sales and income tax. The Indiana Department of Revenue administers these taxes as directed by State Government.

FEDERAL AGENCIES

United States Army Corps of Engineers

Wetlands and Flood Plains

Regulatory Branch- The majority of Indiana falls under the jurisdiction of the Corps of Engineers Louisville District, with the exception of a few counties in the northern part of the state which are in the Detroit District. The Corps of Engineers has been given the authority to regulate certain activities under two Federal Laws: the 1899 Rivers and Harbors Act and the 1977 Clean Water Act. The Rivers and Harbors Act requires a Corps permit for any structures or work over, in, or affecting the navigable waters of the United States to what is called the Ordinary High Water Mark (OHWM). The Clean Water Act requires a Corps permit for the discharge of dredged or fill material into waters of the United States including adjacent wetlands. The USFWS Division of Ecological Services may act as a review agency in some cases.

United States Fish and Wildlife Service (USFWS)

Division of Law Enforcement**-** The USFWS Division of Law Enforcement is responsible for enforcing laws that govern the import and export of wildlife to and from the United States. Protection from the importation of "injurious wildlife" is also provided by this department and may apply to fish or fish products that may carry pathogens. The USFWS Division of Ecological Services may also be consulted in cases involving exotic species. Any imported or exported wildlife must pass through one of twelve USFWS designated ports. Many species require permits prior to transportation and inspection upon arrival. The USFWS Division of Law Enforcement also enforces laws pertaining to threatened and endangered species.

Division of Hatcheries and Fishery Resource Management**-** The functions of the USFWS pertaining to aquaculture have changed substantially in recent years in response to changing priorities established by Congress, the President, the Secretary of the Department of the Interior, and the Director of the USFWS. The USFWS supports the development of private aquaculture if the development is managed in an environmentally responsible manner. Although the USFWS no longer has an active, coordinated program for the support of aquaculture, technical support is available through individual fish hatcheries, fish health centers, or fish technology centers at the discretion of the Director of each facility. The USFWS maintains they are still committed to the principles and goals established in the National Aquaculture Act of 1980, and amendments thereto.

Division of Migratory Bird Permits- All bird species that are responsible for depredation of cultured fish stocks are protected under provisions of the Migratory Bird Treaty Acts. An aquaculturist may be able to obtain permits to kill limited numbers of fish-eating birds if he or she can demonstrate depredation is causing a significant economic loss and that the control measures used will not seriously impact the populations of birds. The USFWS Division of Migratory Bird Permits is the agency that issues these permits through their Regional Offices. No permit is required to merely scare or herd depredating migratory birds with the exception of threatened or endangered species such as bald eagles or golden eagles. The United States Department of Agriculture Division of Animal Control is a non-regulatory agency that offers support to the aquaculture industry by researching and suggesting methods of non-lethal predator control. This agency should be contacted if information on this type of predator control is desired.

Bird Depredation

United States Food and Drug Administration (FDA)

FDA's regulatory programs are intended to ensure compliance with laws pertaining to the safety, wholesomeness, and proper labeling of food products; ensuring the safety and effectiveness of human and animal drugs; and protecting consumers from economic fraud. The Federal Food, Drug, and Cosmetic Act (FFDCA) is the basic food and drug law of the United States and includes provisions for regulating the manufacture, distribution, and use of new animal drugs and animal feed.

United States Environmental Protection Agency (EPA)

Statutory authority for the aquaculture industry is found in the Clean Water Act and is enforced at the federal level by EPA. In cooperation with IDEM Division of Water, EPA is responsible for inspecting aquaculture facilities and determining if permits are required for NPDES and Concentrated Animal Feeding Operations and Aquatic Animal Production Facilities. As stated in the IDEM section, only operations that exceed certain discharge and feed input criteria are required to obtain these permits.

NPDES Permit

Conclusion

Leroy Hushak reports in the "North Central Regional Aquaculture Industry Situation and Outlook Report" that Indiana has one of the most favorable regulatory climates in the region. There are, however, a number of regulations enforced by State and Federal agencies that present and prospective aquaculture producers should be aware of. It is the responsibility of the producer to contact each regulatory agency to determine what regulations are applicable and to obtain all permits that are required. The permitting process can often be complicated and time consuming, but it is a necessary evil that must be endured.

3 PRODUCTION SYSTEMS

There are four basic types of fish culture systems: ponds, flow-through systems, cages, and recirculating systems. Each system is designed to provide the animals being cultured with an environment which promotes good health, rapid growth, and in some cases, reproduction. Each system has advantages and disadvantages, but all have proven to be viable fish rearing systems. The aquaculturist must choose the system that works best for their particular geographical region, topographical layout, or species being cultured if he or she hopes to be successful.

There is a basic set of environmental criteria that must be met regardless of the culture system used. These criteria are discussed below and a general description of each type of system is provided. Particulars of the physical structures and construction may be found in numerous reference books and extension publications beyond the scope of this chapter. Instead, each system is briefly described with emphasis on design principles which contribute to the uniqueness of a particular system. All of these production systems are in use in Indiana and throughout the world. Their status and future potential in aquaculture are discussed.

ENVIRONMENTAL CRITERIA

A fish culture system must provide the animal being grown with an environment which facilitates growth. The amount of labor, care, and managerial expertise required to operate the system is directly correlated to the extent that water quality and environmental parameters are controlled. For example, a lightly stocked farm pond will produce fish with little or no attention while a heavily stocked pond, tank, or raceway would require constant water quality monitoring, manipulation, and adjustment. Major factors that must be considered when designing a fish culture system are temperature, light, space, protection from predators, and water quality.

Water quality is the term used to describe the chemical and physical properties of water. The water quality parameters that are generally of most concern are temperature, dissolved oxygen, nitrogenous waste compounds, pH, alkalinity, and salinity. Fish are cold blooded animals that require an external heat source to regulate their body temperature. The body temperature of a fish greatly influences its metabolic rate. Fish which grow optimally at temperatures below 65°F are classified as coldwater species, between 65°F and 80°F as coolwater, and greater than 80°F are considered warmwater. Temperatures that fall below the optimum range for a cultured species cause the fish to become lethargic, resulting in lower feed consumption and decreased growth. Higher than optimum temperatures increase the fish's metabolic activity and its susceptibility to disease. Species from each classification are currently being raised in Indiana.

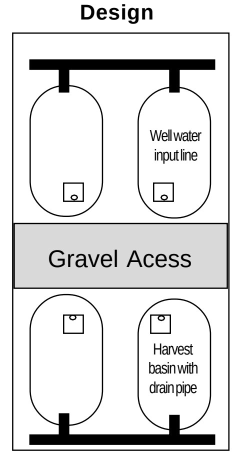
Light, space, and protection from predators are important to all cultured fish but especially to those fish being raised for spawning and fry production. In general, these variables must mimic the fishes natural environment if successful spawning is to occur. Protection from predators is crucial if fry produced are to have high survival.

Fish held in artificial environments provided by aquaculture systems depend entirely on the culturist to provide adequate water quality. In most intensive systems, dissolved oxygen and nitrogenous waste management are the factors most likely to limit fish production. Alkalinity, pH, and salinity must also be consistently maintained at levels acceptable to the species cultured. Poor water quality causes stress in fish which can lead to increased susceptibility to parasites and disease.

PONDS

Pond culture is the most commonly used method of fish production in commercial aquaculture. Worldwide, pond aquaculture produces the majority of carp, tilapia, sportfish, catfish, baitfish, crayfish, and shrimp. Three of the four largest aquaculture industries in the U.S. (catfish, crayfish, and baitfish) use ponds as their primary culture systems. Catfish farming is the largest aquaculture industry in the U.S. with over 495 million pounds of production annually. Most production catfish ponds are greater than 10 acres in size and have stocking densities that range from 2,000 to 6,000 pounds per acre. Recently, some producers have claimed stocking densities as high as 12,000 pounds per acre. Increased stocking densities require the operator to closely monitor the critical water quality variables in ponds, especially with regards to dissolved oxygen levels. The demand placed on the oxygen carrying capacity of a pond is most evident during the summer months when fish and algae respiration combined with high feeding rates and warm temperatures result in oxygen levels dropping to critically low levels. At these times the operator must recognize the problem and provide supplemental aeration or risk losing some or all of the pond production.

Typical Pond System Design



Pond Design

There are two general types of pond structures; hill or watershed ponds, and levee ponds. Hill or watershed ponds are commonly used as recreation and farm ponds but rarely in commercial aquaculture. Levee ponds are the pond of choice for aquaculture due to their uniform dimensions and depths. They are usually rectangular in shape with sizes ranging from 0.1 acre to greater than 50 acres. Fish production ponds in the southern U.S. typically have a maximum depth of 6 feet or less. Culture ponds in northern states are usually somewhat deeper to avoid winter fish-kills. The top of at least one levee is usually designed with the necessary width to allow vehicle travel and is often covered with crushed stone. Most ponds are built side-by-side or in a block to take advantage of shared common levees, thereby reducing construction costs. Fish production ponds are typically equipped with a good source of high quality well water plumbed to each pond. A drain is positioned in the deepest section to facilitate harvest drain down, complete emptying, and recovery of animals produced.

Pond Advantages

Ponds have many advantages that account for their popularity as production systems. Natural biological processes resolve many water quality problems. Nitrogenous wastes are oxidized by bacteria in the water and pond bottom, and naturally occurring algae provide much of the dissolved oxygen for the cultured animals. Ponds are a cost effective way to convert large acreages into aquaculture production; even land with marginal value for traditional agricultural crops, thus greatly increasing its productivity. Ponds may also be used in double cropping, such as the rice and crayfish ponds common in Louisiana. In this double cropping scheme, rice is grown in the summer months and crayfish are harvested in the winter. Another form of double cropping is the culture of warmwater species in the summer, followed by the culture coldwater species in the winter. This seasonal double cropping is currently being done by Indiana fish farmers to raise catfish and trout, thereby attaining year-round pond production.

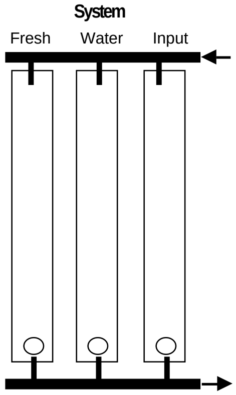
Pond Disadvantages

Ponds are also not without certain disadvantages. Large ponds require expensive equipment for feeding and harvesting. Tractors are required to pull harvest seines and cranes may be needed to lift fish from the ponds onto transport vehicles. The large size of ponds may also hinder the observation of fish or the treatment of diseased fish. Some water quality problems may necessitate flushing the pond with fresh water, requiring enormous quantities of fresh water, and an area to accept the drained water. Predation is also a problem in many aquaculture ponds. Large farms often operate noise makers or cover their ponds with nets in an attempt to deter fish-eating birds. Finally, there is little control of temperature in most pond systems. In the U.S., there is usually a period of time where production efficiency is greatly decreased due to low temperatures. For example, in Mississippi, the heart of the U.S. catfish producing region, catfish are usually dormant and do not grow for 2-3 months during the winter season.

Ponds are currently the most widely used fish production system in Indiana.The majority of fish produced in Indiana ponds are sport fish used for stocking, ornamentals, and bait fish. Fishing has always been popular in Indiana and there is no reason to believe sportfish will not continue to be in high demand for stocking into recreational bodies of water.

FLOW-THROUGH SYSTEMS

FlowTrough RaceWay System



Flow-through systems are broadly defined as any production system which receives a constant input of fresh water. The water source for these systems is usually spring water that flows by gravity through the production units. Some state and federal hatcheries employ ponds or tanks to raise trout, salmon, and other game fish for stocking into public waters. Raceways, however, are more commonly used by private producers. This is evident in the large number of raceway systems employed by the Idaho trout producers in the Snake River Valley. This group of producers make up the second largest aquaculture industry in the country, thereby proving the viability of flow through aquaculture systems.

Raceways are long, narrow, rectangular systems with a source of fresh water at one end that flows swiftly through the system and is then discharged through a water outlet at the other end. Raceways may be earthen, fiberglass, or more commonly, concrete. Commercial scale raceways are typically 20 to 80 feet in length and 6 to 12 feet wide. Raceways are often built in a stair step series through which water flows by gravity from one raceway to another until the water quality is no longer suitable for fish production. Many different species of fish are produced in raceway systems but the trout industry utilizes them to the greatest degree.

Flow Through Advantages

The advantages of flow-through systems are numerous. Raceways enable much greater stocking densities than static ponds with a stocking rate of 10 to 14 pounds of fish per cubic foot of water common. This contrasts sharply with the 0.07 pounds per cubic foot in even the most densely stocked catfish pond. Another benefit of raceways is the ease with which fish are fed, handled, and harvested in the confined space. Water quality is rarely a problem in properly designed raceways as the constant influx of water maintains high water quality and optimum temperature, allowing for maximum growth.

Flow Through Disadvantages

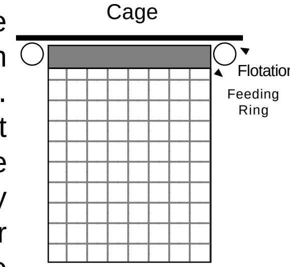
The problems most commonly associated with flow-through systems arise from the massive volumes of water used. Pumping is not economical; therefore, flow-through systems must be located where large quantities of water with appropriate quality and temperature flow naturally. In Indiana there are very few areas where these geographical rarities exist for private development. The large volumes of water flowing through these systems produce an equally large volume of effluent for disposal. Most large commercial producers using raceways have installed expensive effluent treatment systems in an attempt to counteract environmental concerns. Government owned hatcheries must also be concerned with the effluent produced by flow-through systems.

Indiana does not have the natural resources required for large scale, privately owned, flow-through aquaculture systems. Some small naturally flowing springs do exist and at least one small Indiana trout farm is using a flow-through system. The only large flow-through systems currently operating in Indiana are located at state fish hatcheries.

Cages

Most bodies of water not specifically designed for fish culture are either too large, deep, or irregularly shaped to facilitate successful fish culture. In these situations cages can be used to confine fish in a manageable area. Indiana has over 40,000 acres of ponds that potentially could be used for cage culture. Cages typically float at the waters surface and are anchored to prevent loss of the structure. The most common cage design incorporates a plastic or aluminum frame that is either round or cubical and covered with nylon or plastic mesh. The mesh should be as large as possible to maximize water exchange without allowing fish to escape. The size of the cage is dependent on its intended use and the size of the water body in which it is to be used. Cages that are heavily stocked often require supplemental aeration or a method of circulating water through the cage to maintain water quality. Stocking densities typically range from 3 to 15 pounds per cubic foot (0.4 to 2 pounds per gallon). While these stocking densities appear to be very high, the total biomass in the cages cannot

Typical Aquaculture Cage



exceed the carrying capacity of the body of water containing the cage, which is usually 1,000 to 2,000 pounds per acre.

The largest commercial utilization of cages is in the salmon farming industry. Almost half of the salmon on the market today are farm-raised and the majority of those salmon are raised in cages. The cages used in commercial salmon farming are called “net-pens” and may be 30 feet deep and 40 to 100 feet in length and width. Net-pens are usually located in protected areas of the sea, such as the fjords of Norway, but are employed by the salmon industry worldwide. Although the salmon industry is the largest commercial industry using cages, just about any fish which can live in the body of water to be used can be raised in a cage.

Cage Advantages

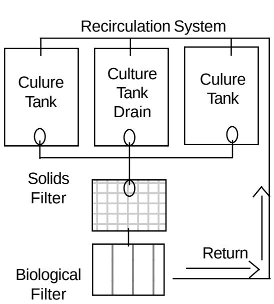
The primary advantage of cage culture is that existing bodies of water can be used for aquaculture. Whether the body of water is a 1.0 acre watershed pond or an ocean, a cage allows confinement of the cultured animal. The confinement provided by the cage allows the fish to be easily fed, observed, and harvested. Another advantage of cage culture is that small cages are a cost effective option for the beginning aquaculturist or the hobbyist who wishes to produce his or her own fish.

Cage Disadvantages

Disadvantages of cage culture include all the problems associated with the confinement of fish. Fish in confinement are not able to seek out better quality water when needed and therefore may be more susceptible to disease. Fouling of the mesh from algal growth reduces water flow through cages and requires regular maintenance to keep cages clean.

Catfish, hybrid striped bass, tilapia, yellow perch and trout have all been raised in Indiana by small producers and hobbyists using cages. Most successful beginners and hobbyists stock very lightly which allows for fish production with no supplemental aeration and very little effort. Most cage culturists stock advanced fingerlings so the fish are large enough to be harvested at the end of one growing season. Some cage culturists in Indiana raise warmwater fish, such as tilapia or catfish, from May through September followed by coldwater fish, such as trout, from October through April. The popularity of cage culture in Indiana has increased in recent years and should continue to expand.

Recirculating Systems



Recirculating systems derive their name from their operation. Water contained in the production system is continually recycled or reused in an endless loop. Large scale, completely enclosed systems do not exist as water is inevitably lost through filter cleaning and evaporation. In practice, most commercial aquaculturists using recirculating systems replace 5 to 25% of the total water volume per day. The most basic recirculating systems have three key components: the culture tank, the solids filter, and the biological filter.

The culture tank is usually the largest component of the system and contains the animals being raised. Culture tanks may be any size and vary in commercial operations from a few gallons to 20,000 gallons or more.

The solids filter is responsible for removing feces and uneaten feed from the culture water. There are many different designs currently being used, with settling chambers (also commonly referred to as sumps or clarifiers) being the most common. The settling chamber is designed to reduce the flow rate of the water and allow solids to precipitate out of the water column. Screen and mesh filters are also commonly used. They function by trapping solids larger than the screen or mesh pore size while allowing the filtered water to pass through.

Solids Filter

The biological filter is responsible for oxidizing the highly toxic nitrogenous waste products ammonia and nitrite to the less toxic compound nitrate. This is done through the biological process known as nitrification by the bacteria *Nitrosomonas* and *Nitrobacter*. Nitrification occurs when water containing nitrogenous waste is allowed to come into contact with biofilter media which is colonized by countless nitrifying bacteria. Biofilter media is designed to provide a maximum amount of surface area for bacterial growth in a minimum amount of space. There are a wide variety of biofilter designs: rotating biological contactors, trickle filters, fluidized beds, and bead filters. Each biofilter type performs the same basic function. Much of the solids and biofilter technology utilized in recirculating systems has been modified or borrowed directly from the municipal waste water industry.

Biofilter

There are several advantages to recirculating systems. A well designed system allows for total control of all water quality and environmental parameters. This allows the operator to provide near optimum growing conditions, thereby maximizing fish growth and attaining year-round production. Environmental control is best achieved indoors which is where most recirculating systems are maintained. Producers have been able to achieve stocking densities greater than 7.5 pounds per cubic foot using recirculating systems which is comparable to flow through systems but higher than any other culture system. Finally, water consumption is minimal and very little effluent is produced.

Recirculation Advantages

Although the technology exists to control water quality, total artificial control of a fish production system can be problematic. The operation of recirculating systems is labor and management intensive. A trained operator must be available at all times to solve any problem that may arise. Water quality must be carefully monitored on a continuous basis as the control of all variables is dependent on the design and mechanics of the system and the expertise of the manager. Catastrophic fish losses can occur within minutes of a power outage due to the extremely high stocking densities used in recirculating systems. Because of the high density and potential for stress from even minor water quality deficiencies, diseases can be a problem resulting in high mortality. These systems are also extremely expensive to build and have operating expenses that are considerably higher than most other systems. Recirculating systems generally require a great deal of gas and electricity to heat and move water, and many producers use liquid oxygen (rarely seen in other systems) to maintain adequate dissolved oxygen levels in their densely stocked tanks.

Recirculation Disadvantages

Recirculating systems are used throughout the U.S. to culture both fresh and salt water species of cold, cool and warmwater fish. A few aquaculturists in Indiana use recirculating systems to culture hybrid striped bass, yellow perch, and tilapia. There are also several small producers of ornamental fish for the pet trade using recirculation technology. The high production costs incurred by producers using these systems requires a premium price be paid for their products. Selling to high scale speciality markets such as restaurants that demand a small but continuous supply of very high quality living or fresh fish may be an option. Predictions of massive indoor farms using recirculating systems have been made for many years. There are very few systems in operation, however, that have run long enough to offer a proven successful track record. In fact, most recent attempts at large scale aquaculture using this type of system have been unsuccessful. It appears more research and technological advancement is required before large recirculating systems are economically viable.

Conclusion

Aquaculture production systems vary greatly in size, shape, materials, location, stocking densities, construction, and operational costs. Ponds currently provide the majority of the world's aquacultured products. Flow-through systems are relatively easy to manage, are very productive in terms of output for the space dedicated to fish production, but are dependent on enormous quantities of high quality free flowing water. Cages are excellent production systems and usually the only option when existing bodies of water are to be used for aquaculture. Finally, recirculating systems represent the latest in technological advancement in aquaculture, capable of tremendous production in terms of the quantity of water used. Recirculating systems are, however, difficult to manage and failures in the industry outnumber successes.

SPECIES SUITABLE FOR AQUACULTURE IN INDIANA

There are currently over 23 species of finfish cultured in Indiana. Finfish are grown for a variety of markets, including sportfish, foodfish, baitfish and ornamentals, with several species falling under more than one of these categories (Table 1).

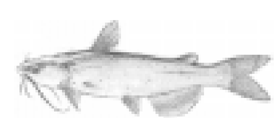
Historically, the majority of species cultured in Indiana have been for the sportfish and fingerling markets. The thousands of acres of farm ponds and lakes in Indiana coupled with expansion in fee-fishing operations have given stability and fueled the growth of the state's sportfish industry.

The number of food fish producers in Indiana has increased in recent years with continued growth expected in this area. The relatively short growing season in Indiana has limited the current number of food fish producers. Seasonal temperature fluctuations limit pond production, making it difficult to compete economically with growers in the southern half of the United States. Potential remains, however, for pond producers to focus on niche markets where great demand exists for species such as channel catfish, hybrid striped bass, and yellow perch. Indoor production of foodfish has increased with the development of recirculation technology. As systems become more efficient, Indiana farmers will be able to compete by raising species with high market values such as tilapia and hybrid striped bass.

Several factors must be considered before selecting a species for culture. The producer must first gather as much information as possible on the species being considered. If a species is relatively new to the industry it may be discovered that culture methods are not well developed. Regardless of the experience of the aquaculturist, culturing new species can involve significant problems with a high potential for failure. Demand for the product must be determined and a marketing plan developed before the first fish is stocked. This will target customers and identify the competition. Harvestable size fish are worth nothing if there is no market for the product or if competition forces sales at a loss. Finally, the culturist must determine if the environmental requirements for the cultured species can be met at the facility to be used.

Indiana has great potential for the production of a wide variety of aquaculture crops. The following section provides a brief overview of several species with current and future potential for aquaculture production in Indiana.

Channel Catfish

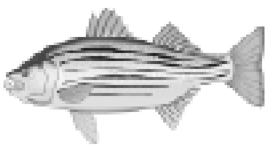


Channel Catfish

The channel catfish (*Ictaluris punctatus*) is the most commonly cultured fish in the United States, representing nearly half (455-465 million pounds in 1995) of the total production in the U.S. aquaculture industry. Most of the catfish produced in Indiana are reared in ponds or cages, with limited production in recirculating systems. Catfish are well accepted as food fish throughout the

Midwest and continue to grow in popularity in many markets. Catfish are well suited for Indiana's climate and grow well under a variety of conditions. The availability of extensive documentation on production techniques and economics makes the catfish a good choice for those just starting in the industry. The largest drawback to catfish culture is the relatively low price received by the producer and the short growing season in Indiana by comparison to southern states. Several markets exist, however, with growers selling to pond owners, fee-fishing operations, live-haulers, and restaurants.

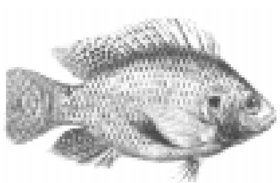
Hybrid Striped Bass



Hybrid Striped Bass

The hybrid striped bass, a cross between the striped bass (*Morone saxatilis*) and white bass (*M. chrysops*), has gained significant support throughout the U.S. aquaculture industry in recent years. The hybrid exhibits faster growth rates, increased disease resistance, and higher survival than either of its parental species. The hybrid striped bass is a relatively new aquaculture species in Indiana, but its adaptability to a wide range of culture environments gives it good potential for Indiana producers. The Indiana Department of Natural Resources has maintained a striped bass and hybrid striped bass fingerling production and stocking program throughout the state for several years. Private producers in the state have had success raising hybrids in several culture systems including ponds, cages, and recirculating systems. Good potential for growth exists in both the food fish and fingerling markets. Fingerling production is more difficult than many other aquaculture species. With a large native population of white bass, however, fingerling production is possible if a supply of striped bass broodstock can be obtained. The hybrid demands a higher market price than channel catfish and can reach market weight (1.5-2.0 lbs) in approximately the same length of time, which may make production economics more viable for some producers. The largest markets continue to be in the northeast and along the Atlantic coast. Hybrid striped bass can be marketed as fingerlings, whole fish, fillets, or alive to markets in larger metropolitan areas.

Tilapia

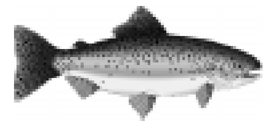


Tilapia

Tilapia (*Tilapia sp., Sarotherodon sp., Oreochromis sp.*) are one of the most widely produced food fish in the world and have become the United States fastest growing aquaculture commodity. The U.S. currently imports more tilapia (48 million lbs. in 1995) than it produces (16 million lbs. in 1995) which should warrant a strong growth potential for this industry. Tilapia are tropical, warmwater fish that require temperatures above 80^oF to flourish. This water temperature requirement makes it an unlikely candidate for most Indiana aquaculturists. There is a potential, however, for indoor production in recirculating systems and limited cage production during summer months. Many producers throughout the U.S., including Indiana, are currently raising tilapia in recirculating systems. Tilapia are a very hardy species that exhibit a high tolerance to varying water quality conditions. They are easy to reproduce, grow to market weight (1-1.5 lbs.) in less than twelve months, obtain feed conversion rates of about 1.5:1, and exhibit extraordinary disease resistance. Tilapia can be raised on a grain based diet with the bulk of the protein provided by soybean meal, possibly grown in Indiana. Tilapia can be marketed as fingerlings to other producers, fillets, or alive to markets in cities such as Chicago, Toronto, and New York.

Trout and Salmon

Trout and salmon production is limited to areas in Indiana with an abundant supply of good quality cold water. Rainbow trout (*Oncorhynchus mykiss*) are the most commonly cultured trout species. Some producers have been successful in culturing rainbow trout in fall and winter months when pond temperatures drop to desired levels for the species. This has allowed producers to expand their outdoor operations by making use of idle production ponds. Rainbow trout are one of the most completely documented species in production. Market demand is good and prices tend to stay high. Larger producers in the western United States tend to dominate the farmed trout market; however, the potential exists for niche markets to local restaurants and fee-fishing operations. Very few producers have attempted salmon production in Indiana due to the lack of an adequate cold year-around water supply.



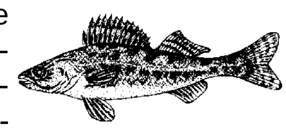
Rainbow Trout

Baitfish

The most commonly cultured baitfish species include: fathead minnows (*Pimephales promelas*), golden shiners *(Notemigonus crysoleucas)*, and goldfish *(Carassius auratus)*. Crayfish, an invertebrate shell fish, is also included in this classification as a bait species and discussed later (see Crayfish). All are relatively easy to raise and considerable culture information is available. The fathead minnow is the most commonly cultured baitfish in Indiana and has good potential for sale to both the bait and forage fish markets. Fluctuating demand for certain sizes of minnows can be a challenge to producers marketing their crops. Crayfish are also commonly cultured in Indiana for the baitfish market. Crayfish can be cultured in ponds with other species, allowing the producer to maximize pond production with little additional labor. Some producers are utilizing systems to rear soft-shell crayfish which are coveted by recreational fisherman and can demand high market prices. Goldfish sold to the baitfish market are generally comprised of culls (fish not suitable for the ornamental market). Much of the baitfish sold in Indiana is imported from other states such as Arkansas, which is the largest U.S. producer.

Walleye

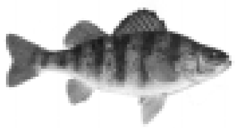
The walleye (*Stizostedion vitreum*), a highly prized food fish, is one of the most sought after game fish in the United States. For these reasons, the walleye has attracted significant interest in the aquaculture industry. Walleye are a cool water fish that could have excellent potential for Indiana producers once the production cycle has been fully developed. Current research into the production techniques of fingerlings has proven successful and encouraging. Fingerlings for the sportfish market have been cultured for many years . Producers have been able to train walleye fingerlings to accept artificial feeds but the continuation of the production cycle to food size fish has met with limited success. Current availability of fingerlings is limited which has impacted price. The walleye shows great promise as an aquaculture species and should command a high market price.



Walleye

Yellow Perch

The yellow perch (*Perca flavescens*) is another cool water fish which has aroused interest on many Midwestern fish farms. Once commercially harvested in large numbers from the Great Lakes, populations have declined in recent years and severe restrictions have been placed on harvests. This has significantly reduced the availability of perch fillets to well established markets throughout the Great Lakes region. Production of yellow perch by Indiana aquaculturists may potentially supply this demand. Yellow perch have been successfully produced for many years for stocking as gamefish. Spawning and fingerling production techniques are relatively well developed but production techniques for food size fish have only recently been researched. There has been some success raising perch to market size in ponds and it may be possible in recirculating systems. Yellow perch are often marketed at weights of three to five fish per pound which receive high market prices.



Yellow Perch

Paddlefish

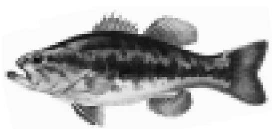
Paddlefish (*Polyodon spathula*) culture has only occurred in the United States over the past two decades. This primitive species is native to Indiana and has been commercially harvested from the Ohio River since the late 1800's. Commercial harvest is now limited to only a few states, as wild populations have declined in most regions of the country. The primary market for paddlefish products is caviar, but the meat also has market potential as it is white and has a firm texture. Market acceptability for these products is uncertain, however, and the seven years required for paddlefish females to mature requires a significant investment of time and labor to obtain eggs for the caviar market. Paddlefish have been successfully cultured in both tanks and ponds, with the latter being the most common. Under ideal conditions, they are able to reach five pounds in their second year and they can be trained to accept artificial feeds. As with many new species to the aquaculture industry, production methods are not yet well developed.

Sturgeon

Similar to the paddlefish, the sturgeons appeal to aquaculture has been primarily for caviar production, although the firm white flesh is also being marketed. Several countries, including the U.S., are conducting extensive research on sturgeon culture. The white sturgeon (*Acipenser transmontanus*) has received the most attention in the U.S. with the majority of sturgeon farms located in California. The development of sound culture techniques will determine the future potential of this species. The outlook for Indiana production seems limited. The largest markets exist on the Atlantic and Pacific coasts along with the majority of research and farm production.

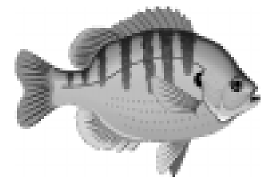
Sunfish and Black Bass

The centrarchid family of fish comprise a large number of species which have current and future potential for production. The most important species for culture include the largemouth bass (*Micropterus salmoides)*, smallmouth bass *(M. dolomieui)*, bluegill *(Lepomis macrochirus)*, redear *(L. microlophus)*, hybrid sunfish *(M. macrochirus X M. cyanellus)*, and black and white crappie *(Pomoxis nigromaculatus and P. annularis)*. The largemouth bass, bluegill, redear and hybrid sunfish have been cultured in the state for many years and continue to be popular with many producers. These species comprise the most frequently



Largemouth bass

stocked sportfish in farm ponds and lakes throughout the state. The market for these species has remained stable and it should continue. Smallmouth bass, black crappie, and white crappie are not as commonly cultured due to their limited performance in farm ponds when stocked in combination with the previously mentioned species. These three species are better suited for market to larger private lakes which contain adequate forage, habitat, and specific environmental conditions. Interest in the production of crappie as a foodfish has also increased as it too is a superb tasting fish. Production methods are being developed and appear promising, however, this species is more difficult to raise and transport than bluegill. Market potential appears to be similar to bluegill but remains uncertain.

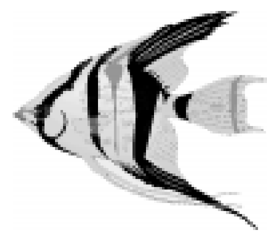


Bluegill

The popularity of the bluegill as a sportfish and favored eating fish throughout the Midwest could lead to the development of a strong foodfish market for this fish or a hybrid of the species. Hybrid sunfish exhibit hybrid vigor, expressed through faster growth rates and increased willingness to accept artificial feeds. These traits combined with frequent spawning and ease of culture may fuel their production as a foodfish. Some supermarket chains are now selling bluegill at the seafood counter.

Ornamentals

The warm climates required by most ornamental species limits their production in Indiana. Two species which do have significant potential in the state are the goldfish (*Carassius auratus*) and koi (*Cyprinus carpio*). Both of these species tolerate a wide range of water quality conditions and are capable of over wintering in outdoor ponds and tanks. Indiana has a long history of goldfish culture; one company in the state is among the world's largest and oldest producers of goldfish. Production methods for both species are well documented and relatively easy. The potential for these species will depend on the producers ability to enter this highly competitive market. The recent interest in small ornamental ponds has resulted in an increased number of goldfish and koi producers. Koi are very popular for this market and receive premium prices.



Angelfish

The growth and popularity of the aquarium fish industry has increased the number of small-scale tropical fish producers in the state. Many species such as angelfish (*Pterophyllum spp.*), African cichlids (*Haplochromis spp., Melanochromis spp., Lamprologus spp.,* etc.), discus (*Symphysodon aequifasciatus*), guppies (*Poecilia reticulata*), mollies (*Poecilia spp.*), and swordtails (*Xiphophorus spp.*) are capable of being reared in indoor systems for sale to the aquarium market. Large numbers of tropical fish can be raised in a relatively small area utilizing various configurations of aquariums and small tanks. As with goldfish, market competition is great. The success and future of production will depend on the individual producers ability to penetrate larger markets and develop niche markets.

Crayfish

Aquaculture production and wild harvest of crayfish of several species has remained stable (200-280 million lbs.) over the past few years. Crayfish farmers have met with competition from domestic and foreign wild harvest and the importation of cultured crayfish meat from China. Popularity of the crayfish as a seafood product in the Midwest has increased but the primary market remains in the southern United States. Pond production of crayfish has potential in Indiana. Production methods are well established and labor requirements are minimal compared to most finfish. Producers in the state would most likely produce crayfish on a small scale as a secondary species and sell to local niche markets. Crayfish are beginning to appear in local supermarkets and can be marketed in a variety of forms. Live marketing is the most common and it appears to make most sense economically.

Freshwater Prawns

The United States is the world's largest consumer and importer of shrimp. Freshwater prawns (*Machrobracium rosenbergii*) may offer a domestically produced alternative to imported shrimp in the future. The effects of cool water temperatures on growth must be determined, and nutritional requirements more fully understood. If production is possible in the Midwest, the future for this species could be excellent for Indiana. Markets are well established, with both shrimp and prawn consistently commanding high market prices.

Grass Carp

Grass carp *(Ctenopharyngodon idella)* have been used extensively throughout the country as a means of biological control of aquatic macrophytes in ponds and lakes. The Indiana Department of Natural Resources requires a permit to produce, sell, and transport any form of grass carp within the state. Most states allowing the introduction of grass carp to any water, public or private, require that they be triploids. Triploid grass carp are sterile, thus ensuring overpopulation can not occur. Overpopulation of grass carp could lead to the loss of wetland vegetation and essential habitat for many aquatic species. This species effectively controls a variety of nuisance aquatic plant species and has significant market potential in Indiana from numerous private pond and lake owners. Grass carp may also be marketed live as a food fish to ethnic markets in large U.S. cities, however, demand and market price tends to fluctuate.

Bullfrogs

Bullfrogs

Bullfrog (*Rana catesbiana*) culture appeals to many producers because of the high market prices for frog legs and live frogs. The majority of production has occurred in small-scale pond systems, although some indoor producers have also been successful. The complex life cycle of the bullfrog makes commercial production difficult. One of the biggest problems with bullfrog culture is the relatively low meat production of harvest size frogs. Frog legs are popular in Indiana and niche markets are available. A large portion of cultured frogs are also sold to the biological supply market as research animals. Improvements in culture techniques may make production more efficient and profitable. Small scale polyculture with non-predatory finfish species may be a favorable and economical option.

Aquatic Plants

The culture and marketing of aquatic plants has become more popular in recent years following the increased popularity of small garden ponds with homeowners and landscaping firms. Some sportfish producers in Indiana raise aquatic plants in their rearing ponds and use them as a source of supplemental income with virtually no labor involved. The plants establish themselves naturally and, as they mature, can be sold to private pond owners. Cattail (*Typha spp.*), waterlily (*Nymphea spp.),* and arrowhead (*Sagittaria spp.*) are some of the more common aquatic plant species cultured for this niche market. Plants can also be cultured for the aquarium industry, with a potential market for aquarium fish retailers and wholesalers.

Cattails

CONCLUSION

What species can be cultured in Indiana and sold at a profit? This seemingly basic question is the only one that should be considered when deciding which species to produce. Of course, this question will cause the producer to begin questioning culture methods and marketing strategies. A fish that is easy to raise but has no market is as useless as a fish with unlimited market potential but is impossible to produce. The aquaculturist that successfully comes up with the correct answer is the one who will have an opportunity to succeed in the industry.

Table 1. Production, marketing potential and selected culture requirements of species suitable for culture in Indiana.

Species	Production Potential	Ease of Culture	Marketing Potential	Market* Type	Temperature Requirements		Protein Feed Requirements	Most Common Production Systems
					Growout	Spawning		
Atlantic Salmon *Salmo salar*	Moderate	Easy	High	F	50-62ºF	42-50ºF	45-50%	Raceways, Net Pens
Bluegill *Lepomis spp.*	Excellent	Easy	Moderate	S,F	55-80ºF	75-80ºF	36-44%	Ponds
Channel Catfish *Italurus punctatus*	Excellent	Easy	High	S,F	80-85ºF	72-82ºF	28-30%	Ponds, Cages
Coho Salmon *Oncorhynchus kisutch*	Moderate	Easy	High	F	48-58ºF	45-55ºF	45-50%	Raceways, Net Pens
Crayfish *Orconectes, Procambarus, spp.*	Good	Easy	Mod.-High	F,B	75-85ºF	75-80ºF	20-30%	Ponds
Fathead Minnow *Pimephales promelas*	Excellent	Easy	High	B	70-80ºF	65-70ºF	30-38%	Ponds
Freshwater Prawn *Macrobrachium rosenbergii*	Moderate	Difficult	High	F	83-85ºF	NA	35-40%	Ponds
Goldfish *Carassius auratus*	Excellent	Easy	Moderate	O,B	70-80ºF	>60ºF	30-38%	Ponds
Golden Shiner *Notemigonus crysoleucas*	Moderate	Easy	Moderate	B	50-80ºF	70-8º5F	30-38%	Ponds

*Market Type: F = Foodfish, S = Sportfish, B = Baitfish, O = Ornamental

(Table 1. continued)

Species	Production Potential	Ease of Culture	Marketing Potential	Market* Type	Temperature Requirements Growout	Temperature Requirements Spawning	Protein Feed Requirements	Most Common Production Systems
Grass Carp *Ctenopharyngodon idella*	Good	Difficult	Mod.-High	S	70-77ºF	68-80ºF	41-43%	Ponds
Hybrid Striped Bass *Morone saxatilis x Morone chrysops*	Excellent	Moderate	Moderate	F,S	77-80ºF	60-68ºF	45-50%	Ponds, Cages, Recirc.systems
Largemouth Bass *Micropterus salmoides*	Excellent	Mod.	High	S	55-80ºF	60-65ºF	40%	Ponds
Rainbow Trout *Oncorhynchus mykiss*	Good	Easy	High	F,S	50-60ºF	50-55ºF	45-50%	Raceways, Net Pens
Smallmouth Bass *Micropterus dolomieui*	Moderate	Easy	Moderate	S	50-70ºF	58-62ºF	45%	Ponds
Tilapia *Tilapia, Sarotherodon, Oreochromis, spp.*	Good	Easy	Moderate	F	80-84ºF	80-84ºF	28-32%	Recirc. systems, cages
Walleye *Stizostedium vitreum*	Moderate	Difficult	High	S,F	72-77ºF	48-55ºF	40-50%	Ponds
White Sturgeon *Acipenser tranmontanus*	Poor	Difficult	High	F	57-63ºF	NA	45-50%	Ponds, Tanks
Yellow Perch *Perca flavescens*	Poor	Moderate	High	F,S	70-77ºF	50-60ºF	40-50%	Ponds, Recirc.systems

*Market Type: F = Foodfish, S = Sportfish, B = Baitfish, O = Ornamental

5 MARKETING

Americans continue to be health conscious consumers. Consumption data compiled by the United States Department of Commerce (USDC) showed a steady increase in the annual per capita consumption of seafood through the 1980's. This demand leveled out during the 1990's, mainly as a result of high seafood prices, but is expected to increase 30% by the year 2000. This rise in consumption can be attributed to Americans realizing the health benefits that can be obtained by choosing seafood products as a significant source of dietary protein. Seafood is generally lower in fat and calories than red meat and contains Omega 3 fatty acids, shown to reduce cholesterol levels. While the population as a whole is interested in better health, it may be the aging "Baby Boomer" generation that is most concerned with leading a more healthy lifestyle.

Seafood products have traditionally been obtained by commercial fishermen harvesting the world's surface waters. Commercial fishing is the only food procurement industry which still harvests wild animal populations. The vastness of the oceans has given many people the impression that there is an endless supply of fish available to feed the world's population. This has proven to be a false assumption, as wild fish stocks show signs of serious depletion. The demands placed on the natural productivity of the world's oceans has simply outgrown its production capability. Just as agriculture replaced the hunting and gathering techniques employed by our ancestors to obtain food, so too will aquaculture eventually replace commercial fishing as a means of supplying seafood to the world's population.

Aquaculture not only provides fish for consumption as food, but also for recreation. Gamefish are stocked into lakes and ponds to establish and supplement recreational sport fisheries. These fish are produced in private and government owned fish hatcheries. Baitfish are also raised as forage for sportfish and for use as bait by fishermen. Ornamental fish production helps supply the demand of aquarium hobbyists and has become an established industry in many parts of the country. While foodfish production will surely increase in the future, non-food fish species are currently the largest aquacultural commodity in the state of Indiana.

Sound marketing practices must be employed by those in the aquaculture industry if it is to expand. Aquaculture products possess many attributes that can be exploited by those responsible for marketing. These attributes are discussed below, as well as marketing strategies commonly used for aquaculture products.

Characteristics of Aquacultural Products

Aquaculture production offers a variety of benefits that are not available through wild-caught fisheries, but are attractive to consumers. The primary benefits to controlled production include sustainability, decreased seasonal fluctuations in supply, proximity to the marketplace, and increased quality assurance.

Aquaculture is Agriculture

Aquaculture is agriculture. Just as row-crop farmers cultivate seeds to produce edible products, aquaculturists take eggs and fry to produce marketable size fish. By controlling the production cycle, fish culturists are able to ensure seed stock for future production. Recent advancements in reproductive technology have produced animals with increased disease resistance, higher feed conversion and growth rates, and improved dress out percentages that are available in a nearly constant supply.

Growout systems are being refined that allow fish to be produced year around, thereby reducing seasonal fluctuations in supply to the consumer. Commercial fisherman are normally restricted to specific fishing seasons and burdened with selling all of their catch at one time to avoid loss due to spoilage. Fish produced in aquaculture facilities can be harvested on a continuous basis, thereby ensuring freshness.

Another problem associated with commercial fishing is the time required and cost associated with delivering fish to the marketplace. Oceangoing fishing vessels are often at sea for weeks, requiring all or part of the catch to be stored on board. The catch is then delivered to coastal ports for distribution throughout the United States. Aquaculture facilities, on the other hand, can be located in close proximity to populated areas. In fact, as recirculation technology advances it should become possible to locate fish farms in cities, thereby greatly reducing shipping costs.

Raising fish in controlled environments allows producers to ensure the quality of their products. Consumers have been justifiably concerned with the quality of seafood products in recent years. These concerns are based on reports of contaminated fish and the pollution of the world's aquatic ecosystems. Water quality and feed inputs can be controlled in aquaculture production, thereby enabling fish culturists to provide a high quality product with improved taste and no possibility of heavy metal or pesticide contamination.

As with any business, aquaculture producers will be faced with competition. Commercial fishing will continue to be a major source of seafood products. Fishing practices will likely be modified to allow a sustainable harvest from the world's oceans, thereby providing competition for aquaculture producers. It is highly unlikely that all of the fish species currently harvested will be candidates for aquaculture production. Difficult culture requirements and limited adult reproductive stock availability will make this an impossibility. The greatest competition for aquaculturists, however, will likely come from the producers of other types of livestock, such as pigs and cattle, and from other aquaculturists.

Marketing Strategies

Choosing an appropriate marketing strategy is often the difference between success and failure for most aquaculture ventures. Aquaculture products can be sold by a variety of different methods, each requiring different levels of involvement and investment by the producer. Production levels, cash supply, and the talents of the producer must all be considered when choosing a marketing approach. Examples of some possible marketing strategies are given below with an explanation of the good and bad points of each.

Mainstream Marketing

Mainstream marketing strategies are employed by many small and medium sized producers, and are used almost exclusively by large scale aquaculture operations. These strategies include direct sales to retailers or consumers and wholesale sales.

Direct Sales Advantages

Direct Sales- Direct sales allow the producer to realize a greater profit for their product by taking responsibility for the promotion and distribution, thereby "cutting out the middle man." Money that would otherwise be paid to a wholesaler or shipper is kept by the producer, thus increasing the profit margin. Direct sales also allow the producer total control of the quality of the product sold. This is especially important if the producer is marketing a product which is identified by the producers name. Selling directly can offer the producer a degree of independence not possible when selling to a wholesaler. The producer has more control over the product's price and is not at the mercy of one large customer, the wholesaler, who may find another source of fish. The producer is often more enthusiastic about the product than a wholesaler who may be marketing a number of different species and who may not be pushing any one product. Harvest scheduling is controlled by the producer and not the wholesaler, which can have a significant impact on profitability.

Direct Sales Disadvantages

There are a number of problems associated with direct sales. The promotion and distribution done by the producer costs money and may not be done as effectively as by a wholesaler whose entire business is the buying and selling of fish. Most food fish producers raise a single species of fish which may not be attractive to retailers or consumers looking for variety. Those who are willing to buy a single species are often not interested in buying in large quantities, requiring the producer to establish a number of small accounts to sell all of the product.

Wholesale Sales Advantages

Wholesale Sales- Selling to wholesalers allows the producer to concentrate time, effort, and cash resources on fish production. The wholesaler is responsible for purchasing the expensive refrigerated trucks and storage equipment needed for product distribution, and for paying the maintenance costs, insurance, and taxes involved with such equipment. Wholesalers generally have a broad customer base which allows them to purchase large amounts of a single species for resale. They are equipped with the office space and sales force required to move large quantities of product.

Wholesale Sales Disadvantages

The main drawback to selling wholesale is the price the producer receives for the product. Wholesalers are in the business of buying fish at low prices and reselling them at higher prices. To do this they must be able to buy fish at prices considerably lower than the selling price to the retailer.

Niche Marketing

Niche marketing is the method by which the producer finds a market that can accept their product and offer a return that provides an acceptable profit. The high rate of return usually achieved in niche marketing provides many small producers with an opportunity to compete. Niche markets are usually limited in size and ability to accept large amounts of product.

Live Fish Sold for Food

This market exists primarily in large cities such as New York and Chicago where customers are capable of taking several thousand pounds each delivery. There are opportunities in smaller communities as well and some supermarkets have live tanks that hold fish and crayfish. Producers may also sell fish directly to consumers at the production facility.

Bait Suppliers and Distributors

Most of the bait sold to Indiana anglers is produced out of state. Indiana aquaculturists may be able to break into this lucrative market if they can lower production costs and offer bait dealers fish at prices that are competitive with current suppliers. Baitfish are often a secondary product for game fish producers or fish that are not suitable for the ornamental fish trade, as with the fish culled in goldfish farming. This should not take away from the fact there is a profit to be made by selling to this market.

Pay Fishing Operations

These operations stock their lakes with large fish then charge a fee for admission and for the weight of fish harvested. Many operations also offer processing at an additional cost. It is estimated there are 50-100 of these fee fishing operations in the state of Indiana, with the majority purchasing their fish from out of state suppliers. Catfish, sunfish, crappie, and bass are the species of choice consumed by pay lake operators and anglers. These species could be produced by aquaculturists in our state.

Lake and Pond Stocking

There are thousands of private lakes and ponds in the state of Indiana, many of which are stocked with the same species listed above. Indiana producers are currently supplying the majority of fish stocked into privately owned bodies of water. The fish most often used for stocking are juvenile gamefish whose small size allows for delivery in small trucks. The Department of Natural Resources (DNR) currently operates hatcheries to supply the fish stocked into public bodies of water. There may be opportunities, however, for producers to raise and sell fish for stocking which are not provided by the DNR. In addition, given the current trend of down-sizing government, it could be the fish stocked in Indiana's public waters may someday come from private producers.

Live Hauling

Live hauling is a vital service required by many fish producers. Indiana live haulers have been transporting fish produced both in state and out of state for a number of years Live haulers pick up fish for transportation in trucks with special water tanks and aeration equipment and deliver them to customers for stocking into lakes and ponds, for pay lake operations, and for human consumption. It is possible for a producer to act as a live hauler for other producers as a means of supplementing income or for a hauler to generate enough business to perform this service as a sole means of support.

Ornamentals

As previously noted, ornamental fish have been produced in Indiana for many years. Most of the ornamentals produced are goldfish and koi, but angelfish and other tropical fish are also produced on a much smaller scale. It may be possible for ornamental fish production to become a more important part of Indiana's aquaculture industry if recirculation technology allows producers to raise fish profitably in indoor systems.

CONCLUSION

There are many methods used to market aquacultured products. Some producers find they are better at growing fish than selling fish. In this case it may be wiser to invest time and money into efficiently producing fish, take a lower price, and sell to a fish wholesaler. Other producers find the additional money received for their products justifies the effort required for selling direct. Niche marketing may be a viable alternative for small scale producers. The marketing method that offers the highest profit margin is the best strategy for the producer.

FINANCE AND BUSINESS

6

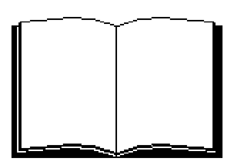
The statement “ aquaculture is agriculture” is commonly used by fish producers. A more accurate statement would read “aquaculture is agribusiness." Those who have been successful in the aquaculture industry learned early on just how important it is to view aquaculture production as a business venture. This fact is usually made abundantly clear during the search for financing. A prospective lender will likely be more concerned with the way their money will be spent and how the operation will be managed than with the species of fish grown or the type of system used. The investor's goal is to make as much money as possible while limiting risk. This is done by investing in people or companies that make decisions based on sound business strategies.

A well thought out business plan, based on realistic projections, provides the producer and the investor with information necessary to determine the likelihood of success. The business plan also acts as a blueprint by which all parties involved can monitor the development of the business. If the business plan warrants construction of an aquaculture facility, it is then up to the producer to implement sound business strategies to ensure profitability. These strategies include the prudent use of resources, monitoring production indicators, and limiting risk.

THE BUSINESS PLAN

Funding for aquaculture development has historically been difficult to obtain. This has been especially true in areas such as Indiana where there is a limited history of fish production information from which conclusions can be drawn. While some state and federal programs are intended to promote agriculture (Farmers Home Administration and the State Treasurer’s Farm Program, for example), they rarely apply to aquaculture ventures. Fish culturists have been forced to acquire financing through other sources; primarily banks or private investors.

As with any business endeavor, a detailed business plan is required before an investor will even consider loaning money for an aquaculture venture. Gathering the information necessary for formulation of the business plan may be the most challenging task the aquaculturist faces. Aquaculture is a relatively new industry, and those who have been successful are understandably reluctant to provide information to a potential competitor. Regardless, the aquaculturist must put together a plan that accurately reflects the financial requirements of the operation, shows how the money will be spent, and projects an adequate return on the investment.



Business Plan

“Preparing a Business Proposal for Aquaculture Loans” by Engle and Stone recommends the following elements be included in the business plan:

Description and characterization of the proposed site

Describe the site you have chosen for your facility, including details on soil characteristics and water supply. Proximity of the site to feed mills, processing facilities, and disease diagnostic laboratories should also be included. It is your responsibility to prove the site you have chosen is suitable for a successful aquaculture operation.

Description of the intended production system

Information should be provided on the system you plan to use for fish production (see chapter on Production Systems). Include information such as stocking rates, expected growth rates, and harvesting methods and give justification for each.

A detailed marketing plan

You don't make money raising fish, you make money selling fish. Give a description of the marketing strategy you will employ to sell your product (see Marketing). Offer information on distance to market, historical prices paid, and any other factors that could affect your ability to sell fish and make a profit.

Estimated cost and returns

A table of annual cost and returns should be estimated for the proposed production system. The table will compare all fixed and variable production costs with the total expected harvest weight and price per pound to project annual profits.

Estimate of the financing required

This section should clearly state the financial requirements for the operation and be divided into the following categories: operating loan, equipment loan, and real estate loan. A repayment schedule should be provided to indicate how revenues will cover the debt payments. Obtaining adequate operating capital is crucial to the success of the venture. If there is no money available to purchase fish feed or operate aeration equipment, the farm will surely fail. It should also be noted that most aquaculture operations do not generate a positive cash flow until the second or third year of production, thus extending the payback period of the loan.

A current appraisal of the site

The lender will require a current appraisal that reflects the value of the proposed site before and after ponds and facilities are constructed. This will be used to determine the loan to appraisal value ratio.

Pro forma balance sheet

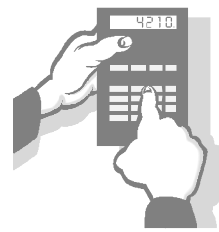
The term "Pro Forma" is used when projected performance figures are used for accounting purposes. The pro forma balance sheet lists all of the assets and liabilities for the entire operation. From the balance sheet, net worth can be calculated as well as the following financial ratios: owner equity, net capital ratio, debt/equity ratio, and current ratio.

Pro forma income statement

The income statement itemizes anticipated farm income and expenses. Its primary purpose is to compute profit for a given time period.

Pro forma cash flow budget

A cash flow budget shows cash receipts and cash expenses on a monthly basis. It includes only cash expenses and provides an indication of when cash will be available for loan repayment. Cash flow budgets will need to be prepared for each year of the life of equipment that is financed.



Personal financial statement of the borrower

The borrower must provide three years of tax records as well as three years (including a current statement) of financial statements.

Brief resume of borrower

A resume should be provided listing all aquaculture experience and training, along with any relevant management experience. Include information on key employees and any outside consultants that will be used to make the operation successful.

The formulation of the business plan is a difficult undertaking whose description is beyond the scope of this brief discussion. In many cases it will benefit the aquaculturist to seek professional help when putting together the business plan. The contents of the business plan will determine if financing is received or denied.

BUSINESS STRATEGIES TO ENSURE PROFITABILITY

Domestic aquaculture producers face stiff competition from the commercial fishing industry and foreign fish producers. It is the aquaculturist who combines sound production methods with proven business management techniques that is able to secure funding and make a profit in the aquaculture industry.

Some of the business strategies that should be used by aquaculture managers include:

Prudent use of resources

It is usually a good idea for a prospective producer to install and operate a pilot facility before going into full scale operation. This will test the production methods to be used and ensure that the producer possess the management skills required for the operation of a commercial aquaculture facility. The pilot facility will indicate what resources are required and how they can be used most efficiently. These resources include, but are not limited to; water, production space, operating capitol, aeration equipment, and manpower. Whether the system installed is pilot or full scale, the best results are obtained by keeping the operation "lean and mean." Each employee hired and each piece of equipment purchased must be vital to the success of the operation.

Monitoring and Feedback

It is important to obtain data that reflects the production success of the operation. Information such as feed inputs, growth rates, and harvest yields can give an indication of how well actual production of the farm was predicted by the business plan. Monitoring offers the manager an opportunity to correct problems that may be occurring in the production cycle.

Identifying and Controlling Risk

There are a number of variables that can be perceived as "risks" in the aquaculture industry. Increased feed costs, disease problems, extreme weather conditions, and changes in the marketplace are all examples of factors that, if not considered and addressed, could impact the success or failure of an aquaculture venture. It is the responsibility of the manager to predict any risks and provide a contingency plan for each situation.

CONCLUSION

Proper planning and management are vital to the success of an aquaculture venture. The construction of a detailed and accurate business plan will allow the aquaculturist and the prospective lender to determine if the proposed operation has a possibility of succeeding. Sound management strategies must then be implemented to ensure the facility is run as efficiently as possible. Aquaculture is agribusiness, and it is the well prepared agribusinessperson who will succeed in the industry.

TECHNICAL SUPPORT, RESEARCH, AND EDUCATION

7

If we are to continue eating fish and shellfish, aquacultural development must increase. In response to this need and the demand from citizens of Indiana, the base of technical support for aquaculture has been expanding. Educational, research, and extension programs in Indiana are providing leadership at a time when many programs are downsizing. Expanding technical support, research, and education in Indiana should facilitate aquacultural development in the state.

Sources of Technical Support

Universities

There are a number of sources of technical support in the state of Indiana. Chief among these is Purdue University and specifically the Illinois-Indiana Sea Grant Program Aquaculture Extension Specialist. The Specialist position was created in direct response to needs in the private sector. The position is funded by Illinois-Indiana Sea Grant, Purdue Cooperative Extension Service, and the University of Illinois Cooperative Extension Service. Administrative leadership of the Illinois-Indiana Sea Grant Program is housed in the Department of Forestry and Natural Resources, Purdue University, and the Extension Specialist is physically housed in the Department of Animal Sciences. Thus, there is cooperation among units at Purdue in maintaining the position. The Specialist is the lead person in communicating opportunities, helping solve problems, and communicating needs of aquaculturists to research scientists.

There is a common saying among university personnel, “If you answer your phone, you will provide technical support to Indiana residents.” In addition to the Extension Specialist, all faculty members in Aquatic Biology Programs throughout the state serve as sources of technical support, just as all faculty members in other disciplines serve as sources of technical support in their respective disciplines. Universities with programs in aquatic biology are listed in the education section of this chapter.

One of the more innovative training programs undertaken by the Cooperative Extension Service in recent years was the formal training of established County Extension Educators in aquaculture. This program was initiated by the Aquaculture Extension Specialist, and over the course of 2 years, provided detailed training to 10 Educators in Indiana. The agents volunteered for continuing education in this new area and now serve as the “front line,” answering questions, providing basic information, and directing more detailed questions to specialists. In the past five years, a clear and significant base of technical support developed within the classic extension education system administered by Purdue University.

Indiana Department of Natural Resources (IDNR)

Personnel employed by the IDNR Hatchery Division are some of the most well trained and experienced aquaculturists in Indiana. The IDNR hatcheries propagate and raise virtually all species of fish that are of interest to Indiana aquaculturists. As with university personnel, they also answer their phones and provide technical information to established aquaculturists seeking refinements in their operations. Their base of information and technical support is often limited to propagation (spawning) and early life history, but these are obviously critical stages in fish culture. Without a source of juvenile fish, aquaculturists cannot produce marketable-size fish.

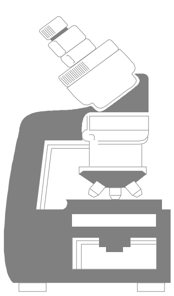
Suppliers

Established aquaculturists and suppliers to the aquaculture industry also provide significant help to Indiana's aquaculturists. There is a general camaraderie among fish producers in the state, particularly toward new culturists seeking information. Aquaculture suppliers in the state are always good sources of information as they are the providers of supplies and materials necessary for cultivation of aquatic species. One of the most important contributions suppliers make to aquaculturists is knowledge and awareness of new pieces of equipment as well as new uses of existing pieces of equipment. Suppliers in Indiana provide an invaluable service to our citizens.

RESEARCH

Current Research

Research programs in aquaculture have been in place for over a decade. These programs began in the more general Aquatic Biology programs identified below and became more specific as the harvest from the world's oceans diminished and the need to develop aquaculture became more immediate.



Research programs in aquaculture, regardless of location, must first ask the simplest question, "Can we grow aquatic animals in our conditions, and, if so, which species and which production system?" Those studies were the logical first steps in Indiana that continue today, but with new species and new culture systems. The first question has been answered with several species and the research programs have become more focused in recent years. We now have disciplinary scientists contributing their expertise to aquaculture. Teams of scientists have coalesced at the universities and those teams have been successful at acquiring large grants from federal research programs. The principal scientists contributing their expertise to aquaculture are listed below.

Paul B. Brown, Purdue University, Department of Forestry and Natural Resources, General aquaculture of fish and crustaceans, Nutrition of fish and crustaceans

M.R. White, Purdue University, Animal Disease Diagnostic Laboratory, Pathology of aquatic animals

Marshall Martin, Purdue University, Department of Agricultural Economics, Economics and marketing of aquatic animals

Bruce Watkins, Purdue University, Department of Food Science,
Lipid chemistry of fish and fish products
Rick Mattes, Purdue University, Department of Foods and Nutrition,
Sensory properties of fish and crustaceans
Bill Muir, Purdue University, Department of Animal Sciences,
Population genetics of aquatic animals
Chris Bidwell, Purdue University, Department of Animal Sciences,
Molecular biology of fish
Paul Collodi, Purdue University, Department of Animal Sciences,
Developmental biology of fish
Dirk Maier, Purdue University, Department of Agricultural and Biological
Engineering, Fish feed manufacturing
Tom McComish, Ball State University, Department of Biology, Aquatic Biology,
and Fisheries, General aquaculture of fish

Research programs are in the listed areas of expertise and all are needed for rapid development of aquaculture. The program at Purdue has become focused on general culture, rapid development of diets for new species of interest in the state, disease conditions encountered in new species, diagnosis of existing disease conditions, economics of producing new species of fish, marketing opportunities and constraints in Indiana, effects of nutrition on shelf life of fish products, incorporating beneficial fatty acids in fish products, consumer preferences for fish and shellfish, and optimum conditions for extruding feedstuffs. These are the basic research foundations necessary for development of new industries in Indiana.

Future Research Needs

Given that aquaculture is relatively new in Indiana, the research needs are simple. We need to continue the lines of research listed above and expand those by incorporating additional disciplinary scientists. In short, virtually all disciplinary scientists in agriculture are needed in this leadership effort. Several research lines will be emphasized below, but these are not the sole needs of a new industry.

Research Needs

Feeds are typically 30-60% of annual variable costs in aquaculture, and without nutritionally adequate diets, fish will not grow to their potential. Producers of traditional commodities (corn, soybeans, and wheat) need new markets for their products and aquaculture needs those products as diet ingredients fed to fish. Use of our high quality, readily available plant feedstuffs decreases the cost of diets for fish and shellfish and provides a local source of ingredients for manufacturing diets. Further, use of diets that contain a high percentage of plant feedstuffs generally improves taste of fish by alleviating the typical “fishy” aroma found in fish fed high levels of fish meal.

Reproduction or propagation of fish is the other critical area in need of research effort. Reproduction and larval rearing are different for the various species under cultivation in Indiana, and those methods must be delineated and refined for successful industrial development. It is impossible to develop a new industry without a continual supply of juvenile fish. New industries must have information on optimum diets and methods of producing juvenile fish for growth to market size.

Most of the research listed above is focused on the biological aspects of aquaculture. However, without the economics and marketing studies that have been ongoing at Purdue, new industrial development would not be possible. New producers must have a thorough understanding of the costs of production and which factors contribute the most to those overall costs. Further, development of a business plan is impossible without a thorough understanding of markets and factors that effect market acceptance of products.

The immediate needs in aquacultural research in Indiana are development of diets for the new species of interest in the state, proven methods of propagating those new species and the economic and marketing studies that will define the potential of industrial development.

EDUCATION

High Schools

Indiana was one of the initial nine states to receive significant federal funding for development of aquaculture training in high schools. Under the direction of the South Putnam Aquaculture Council and the local School Board, South Putnam County High School developed an aquaculture wing on their building that is a state-of-the-art teaching and research laboratory. South Putnam is a midwest training center for high school teachers from Indiana and throughout the midwest. South Putnam's focus on aquaculture training stimulated development of at least 30 other aquaculture programs in high schools across Indiana. These programs serve as important educational service to the state's youth by providing an introduction to aquaculture as a developing new state-wide industry.

Universities

Several university programs in Indiana offer classic aquatic biology training to their students. In addition, Purdue University has developed an aquaculture education program. All are important sources of technical training for citizens of Indiana to prepare for the new aquaculture industry.

Ball State, Indiana State, IUPU-Calumet, IUPU-Ft. Wayne, Notre Dame, Purdue, and the University of Indianapolis all offer classic aquatic biology programs or coursework for their students. Several of these programs are internationally recognized for their contributions to our understanding of animals that continuously live underwater. Although most are not aquaculture programs per se, the importance of these programs should not be diminished. To raise an aquatic animal, aquaculturists must understand the basic biology of the animal. No one living in the terrestrial world can intuitively comprehend the necessities of life underwater. Several of our more active and successful aquaculturists gained their first understanding of life underwater in classic aquatic biology programs. These programs will continue to provide trained students and new aquaculturists.

Following the employment of several key faculty members, Purdue University established an Aquaculture Option within its Fisheries and Aquatic Science degree seeking program in the Department of Forestry and Natural Resources. This new option offers a series of classes mixing classic aquatic biology coursework, including a course in Aquaculture, with the necessary business courses.

Continuing Education

With the development of the Aquaculture Extension Specialist position, continuing education programs for existing and new aquaculturists, consumers, and lending institutions increased significantly. Workshops are now hosted by Purdue University and the Illinois-Indiana Sea Grant Program on a regular basis. These workshops are in direct response to needs within the state. For example, workshops on crayfish, hybrid striped bass, yellow perch, indoor recirculating systems, and cage culture of fish have been regularly hosted in the state. The interest in aquaculture is real and growing. Attendance at these workshops is commonly over 50 people and often over 100. Established aquaculturists in Indiana comprise a steady, but small percentage of those participating; most are new aquaculturists. Representatives of lending institutions also comprise a steady percentage of participants as they are continually receiving requests for loans from new aquaculturists. This interaction is vital for industrial development in the state. Aquaculture tends to be capital intensive, but rewarding for those who are successful. Education of lenders and interaction of lenders with new aquaculturists will provide the climate needed together with the necessary capitol essential for significant development of aquaculture in the state.

CONCLUSION

The necessary groundwork in the areas of technical support, research, and education already exists in the state of Indiana. Support must be given to aquaculture educators on all levels to ensure the industry's survival in the state. The aquaculture industry, while thousands of years old, is undergoing rapid technological advancement in many areas. Education and research, coupled with high quality technical support, will provide Indiana aquaculturists with access to the most current information available and an opportunity to compete on a national and global basis.

8 AQUACULTURE GROWTH IN INDIANA

As the over harvesting of the world's oceans and lakes continues to reduce the availability of fish and shellfish, farm raised production of these commodities will dramatically increase to replace previously wild sources for the marketplace. This projected increase, combined with the opportunities available to non-foodfish producers, provides Indiana's aquaculture industry with an excellent opportunity for significant expansion in future years. The Indiana Aquaculture Plan should be viewed as the framework for the wise and sustainable expansion of Indiana's aquaculture industry well into the 21st century. For this to occur various programs and services need to be developed or expanded that offer the following: education programs to current and future aquaculture producers; education programs for industries providing the infrastructure necessary for aquaculture development; and government programs that support the industry.

Programs Required for Growth of Indiana's Aquaculture Industry

Education

If Indiana aquaculturists are to compete in the industry, they will require support in the form of education. This education must be provided by continuing education programs, employee training and education at the high school and college levels, and technical assistance from university and county educators.

Educational Opportunities

Aquaculturists in the state of Indiana should have access to educational programs that will increase their likelihood of succeeding in the local, national, and world marketplace. Examples of programs that should be offered include: water quality management, intensification of existing farms, best management strategies for aquaculture effluents, alternative culture species, marketing, and business management. As the industry expands and diversifies, so too should the educational opportunities available to fish culturists.

Secondary Education

The educational opportunities provided by vocational agriculture programs at selected high schools in the state should be expanded and made available to many more state high schools. These programs provide basic introductory education and experience required for graduates to begin work in the aquaculture field or continue their education at the university level. Trained aquaculturists at all levels will be needed as the industry expands.

Cooperative Extension Service

Continuing education must be provided to county educators if they are to provide the technical assistance needed to support aquaculture development. County educators are the "front line" of information dissemination. If they are to be effective, they must be kept abreast of recent developments in the aquaculture industry. They must be aware of the resources available to producers and provide access to this information. The University based aquaculture extension specialist has the responsibility to provide continuing education to the county educators.

Adult Education for Producers

Universities

The state's universities should be encouraged to expand their involvement with aquaculture training and base their aquaculture research on the needs of Indiana producers. Currently the Aquaculture Extension Specialist located at Purdue University is shared with the Illinois Cooperative Extension Service. As the Indiana aquaculture industry expands, consideration should be given to expanding this position to full time for Indiana. Support should be given to the Animal Disease Diagnostic Laboratory at Purdue University to further the work being done on fish health issues and disease prevention.

Infrastructural Training

If the aquaculture industry is to expand in Indiana it will require the development of a sound infrastructure comprised of support industries interested in supplying goods and services to fish culturists. These industries include, but are not limited to:

Lending Institutions

Educational programs should be developed to provide lenders with information on the viability of aquaculture in the state.

Feed Manufacturers

Indiana based feed manufacturers must be educated with regard to the potential aquaculture development holds for their industry. Expansion of the aquaculture industry would cause a marked increase in fish food sales in the state. Benefits would be realized by Indiana grain farmers, feed mills, and fish culturists if this feed is manufactured, sold, and utilized by Hoosiers.

Processing Plants

Processing plants that are capable of processing aquacultured products must be built where needed in the state. Existing processing plants along Lake Michigan that have historically processed commercially caught fish from the lake must be modified and updated. Plant operators, along with Cooperative Extension Service Foods and Nutrition Educators, must be educated on the Hazard Analysis Critical Control Point (HACCP) based mandatory seafood inspection which will be required for all seafood products in the near future.

The State Government can have a significant impact on the growth of the aquaculture industry in Indiana by implementing the following programs encouraging expansion:

Financial Programs

The State Government should expand programs that provide low interest loans or loan guarantees to citizens interested in aquaculture production ventures. These loans will provide the financing necessary to fuel the growth of the aquaculture industry in Indiana.

Marketing and Promotion

State funded marketing and promotion strategies will be needed to develop a "state industry" that can compete with states already established in the industry. These programs will be necessary to encourage potential investors to put their money into aquaculture development in the State of Indiana and not another state. The support of Indiana state government for the industry should be evident if development is to proceed and grow.

Monitoring Growth

Monitoring the progress made toward fulfilling the outlined objectives of the Indiana Aquaculture Plan and its impact on the industry will be essential. No single individual has all the necessary resources to ensure that the plan stays on track. It is therefore recommended that a State Aquaculture Team be developed that will meet at least annually to review the progress made toward the growth of Indiana's aquaculture industry. The State Aquaculture Team should be made up of the following representatives:

Develop a State Aquaculture Team

President of the Indiana Aquaculture Association
President-elect of the Indiana Aquaculture Association
Illinois-Indiana Sea Grant Aquaculture Extension Specialist
Indiana's Aquaculture Coordinator (Chair)
Department of Natural Resources' Division of Fish and Wildlife, Fisheries Section
Department of Natural Resources' Division of Water
Department of Environmental Management
Department of Health
Indiana Farm Bureau
Indiana Farmers' Union
Representative from the American Culinary Federation
Representative from the Indiana Society of Agri-Bankers

The team will review the implementation of recommendations made by the plan in light of the current status of the industry. If the team feels that amendments to the plan need to be made, a committee will be appointed for that function.

Continual monitoring by Indiana Agriculture Statistics Service will also provide insight into the status of the state's aquaculture industry. The Illinois-Indiana Sea Grant Program implemented a biannual aquaculture producer survey in 1993. In 1995 the North Central Regional Aquaculture Center (NCRAC), the Illinois-Indiana Sea Grant Program and the Illinois Department of Agriculture worked together to develop a regional producer survey. The survey will be conducted by each state in the North Central Region. Results from the survey will be used to produce a regional Aquaculture Situation and Outlook Report by the NCRAC. Indiana Agriculture Statistics Service agreed to conduct future producer surveys. By having Indiana Agriculture Statistics Service carry out the survey, producers can be confident that information provided will be held in strictest confidence.

Conclusion

The worldwide aquaculture industry is currently in a period of significant growth. If aquaculture in the state is to become an active participant in the growth of the industry, programs must be implemented to further the interests of Indiana fish culturists. The status of aquaculture in the state should be carefully monitored to ensure the programs set forth for aquaculture development are enabling Indiana's aquaculture industry to keep pace with the rest of the country and the world.