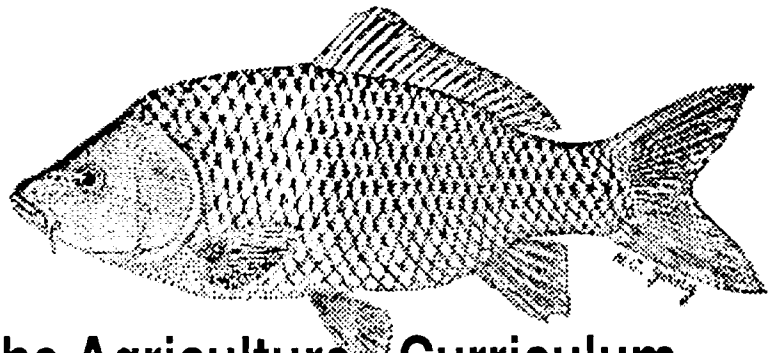
Aquaculture:



A New Component of the Agriculture Curriculum

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Aquaculture is a booming business in the United States. This article discusses the need for agricultural programs in colleges and universities to develop research programs and curriculums that include aquaculture. A status report of the aquaculture industry in the U. S. is included along with a discussion of the increasing demand for aquatic plants and animals. The article also reports on how Illinois State University (ISU) is attempting to meet the demand for information and training in the aquaculture industry.

Introduction

Although an ancient profession in other parts of the world and a dynamic enterprise in the southern states, aquaculture is only now emerging as a substantial industry throughout the United States. Indoor aquaculture is still a fledging industry in the United States but many scientists agree with Buttner when he states that aquaculture "... may soon be on par with dairy, grain, and horticulture industries as a prevalent form of agriculture" (Buttner, 1988). Recent changes in the eating habits of many Americans have increased the demand for fish and other aquatic products to the point that adequate quantities can no longer be harvested from the wild. "Diet-conscious consumers are creating many opportunities for aquaculture. In recent years, the U.S. per capita consumption of fish products has increased from 4.6 kg/person/year in 1960 to 6.5 kg/person/year in 1985 ... Imports have supplied most of the need for increased domestic consumption ... Today's aquaculture provides only about 10% of the world's aquatic-grown protein To give a sense of magnitude, the world's 1984 commercial catch of fishery products was 82.8 million metric tons. Aquaculture could provide 50% of the aquatic protein by the beginning of the 21st Century. Meeting this goal will require major basic and applied engineering research efforts" (Fridley et al., 1988, p. 13). Many forecasters contend the catch of wild fishes is currently beyond "maximum sustainable yield" while global population is expected to approximately double by the year 2000. This population swell, coupled with gains in per capita consumption of aquatic products, necessitates further developments in the domestic production of various fish, shellfish, crustaceans, and aquatic plants to a level capable of meeting growing consumer demands. While many southern states such as Mississippi, Louisiana, and Texas have established huge aquaculture industries, they have been unable to meet the rapidly increasing demand for aquaculture products other than catfish and crawfish. The U.S. is therefore presently forced to import nearly 90 percent of all the aquatic products it consumes, even though surplus grain production and adequate supplies of water and space make it very feasible for the U.S. to produce, and even export, many of these same items.

The inexperience of most potential "fish farmers" in culturing aquatic plants and animals is creating an urgent need for information. The responsibility for developing and disseminating the necessary materials on producing aquatic species must fall on American colleges and universities. Several institutions, including Illinois State University, are already actively striving to fill this void, and others must become involved. Just as with terrestrial plant and animal production, different regions of the country will require different types of information. Universities in the midwestern and northern states, for example, may need to concentrate their efforts on indoor tank culture systems, while the southern states continue to concentrate on outdoor pond systems. In addition, because of the many diverse types of aquatic plants and animals, some institutions will need to concentrate on certain species while different institutions experiment with others. To date, catfish has been the major aquatic product of the southern states, but alternative species may turn out to be better suited for other regions.

Curriculum Needs

Most aquaculture curriculum in the U.S. is in one of two specialized areas: coastal marine aquaculture or freshwater production of catfish in low-density, outdoor ponds located in the southern states. Little curriculum has been developed for intensive indoor production in northern climates. However, aquaculture appears to be following the historical trend of most forms of animal agriculture; evolving from extensive, outdoor production to intensive, indoor con-

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trolled production environments. "During the transformation of agriculture, land-based operations moved from being extensive, laborious, and of low productivity to being intensive, mechanized, and of high productivity. In contrast, water-based agriculture -- or aquaculture -- has undergone minimal change. Although exceptions exist, aquaculture has generally remained an extensive, low-technology business. Therefore, aquaculture offers many opportunities for exploiting the experience of agriculture and developing rapidly into an important segment of agriculture" (Fridley et al., 1988, p.12). In the northern states, such as Illinois, indoor production not only allows for greater control over production inputs but it also provides protection from cold weather. Many aquaculture species do not grow at the low water temperatures found in Illinois during most of the year. For example, "the main constraint on the (tilapia) industry is that tilapia are warmwater fish and will not survive at temperatures much below 12°C (55°F)..." (Brown, 1980, p.347). Indoor producers require training in efficient production. "In many instances, aquatic farmers have the knowledge to produce a specified amount of food, but production is not carried out in a technologically efficient manner" (National Academy of Sciences, 1978, p.61).

Illinois, like most of the midwestern states, imports more than 97% of the aquatic products consumed in the state, and, as discussed earlier, the U.S. as a whole imports over 90% of what it consumes. If indoor production systems for fish and crustaceans can be developed to the point that they are mechanically feasible and economically sound, Illinois and other midwestern and northern states could produce most, if not all, of the fish and seafood needed in their regions. Many midwestern states have an abundance of water, feed, and in some locations, vacant farm buildings; the only limiting factor is the current lack of reliable information. Though it appears that most of Illinois and the upper midwest cannot compete favorably with southern states in outdoor production of warm water fish such as catfish, indoor systems may prove quite profitable. Mississippi produces enough catfish in outdoor ponds to generate over a billion dollars annually in economic activity, and Louisiana produced 100 million pounds of crawfish in 1987 (McClinic, 1988, p. 10-13). Midwestern states could conceivably achieve similar results with indoor systems. As an example, one Kroger store in central Illinois that has been selling hybrid tilapia fillets produced in a California tank culture system for $6.49 per pound cannot meet the demand for the fillets; many other species of fish and crustaceans may prove as important to aquaculture in the U.S.

The diversification provided by aquaculture may greatly assist a nationwide movement toward a more sustainable agriculture. Indoor tank aquacultural systems could provide an additional enterprise for many farm operations in the upper midwest. Several aquatic species could become consumers of surplus grain and soybeans as well as provide a means for utilizing available family labor and otherwise unused farm buildings. If the aquaculture industry develops like other confinement livestock industries in the U.S. (i.e., poultry and swine), it will demand the development of expertise in producing aquatic species. Universities will need to meet this demand for more information and provide appropriate educational opportunities for individuals engaging in aquacultural operations. It is conceivable that, in the very near future, confinement aquaculture buildings will become just as common as confinement swine buildings on midwestern farms.

Where Does Aquaculture Belong?

Occasionally universities discuss whether aquaculture belongs in a biology department or in an agriculture department. Biology, zoology or ecology programs have been the traditional home for "fisheries program". Fisheries programs emphasize the sport fishery industry, commercial fisheries and the management of wild fish populations and their environments. But just as managing a wild deer herd is not the same as producing beef cattle, producing fish fillets on a farm is not the same as setting creel limits for largemouth bass. Agriculture programs are the traditional home of the business of plant and animal production. In the early 1900's a new plant, the soybean, was introduced and accepted as part of agriculture. Now, in the late 1900's, a new form of animal agriculture, aquaculture is being brought into the fold. Indeed, the slogan heard throughout the aquaculture industry, and the slogan used in federal legislation is that "aquaculture is agriculture". At the same time, aquaculture programs will continue to rely on the basic research conducted in biological, chemical and physical science programs.

At Illinois State University, we have developed an interdisciplinary program which draws from the strengths of both the biology and agriculture programs. The agriculture program provides expertise in production economics, systems engineering, fish processing (meat handling), animal nutrition and breeding. The biology department provides expertise in basic genetics, limnology, fish pathology, and crustacean endocrinology.

The aquaculture program builds on the foundation courses for the other agriculture programs at ISU. Students take introductory courses in agribusiness management, agricultural engineering technology, animal science and agronomy. The principles taught in these foundation courses are applicable to all agricultural applications, including aquaculture.

ISU is currently exploring the possibility of a joint masters degree in aquaculture between the departments of biology and agriculture. This program would be oriented towards those students interested in the advanced study of aquaculture with a basic science orientation. Graduates from this program would be employed at "wet-lab" jobs - for example, hatchery managers, pathologists, nutritionist, or breeding specialists. A second option for advanced study is in the ISU Agribusiness Management Masters Degree program. Students enrolled in this program find employment such as facility managers, farm operators, production specialists, loan officers, or managers of the service industries that support aquaculture (feed, equipment, health products, real estate, etc.).

Students interested in aquaculture are finding excellent employment opportunities upon graduation. Most students find employment on the home farm where they see aquaculture as a method of generating income from under-utilized assets such as empty livestock confinement building or ponds used only for recreational and wildlife purposes. A growing number of students seek employment with established, full-time aquaculture enterprises. Students seeking to escape from the harsh Illinois winters are finding many job opportunities in Southern Florida, Texas, and even the Caribbean Islands. A limited but growing number of full-time aquaculture enterprises in the midwest are seeking graduates with an aquacultural orientation to their agriculture degrees. For example, a large midwestern livestock equipment manufacturing firm now employs specialists who design, manufacture or sell automatic fish feeding equipment; the cooperative extension services are producing specialists for the growing aquaculture industry (most of these are current employees being retrained); a large aquacultural engineering firm in Springfield, Illinois is seeking a fisheries biologist to assist in their facilities design work; a tilapia farm at Urbana, Illinois is seeking a farm manager; a "livehauler" (a fish trucking firm) in Central Illinois recently employed additional managers and drivers; a fish processing business on the Illinois River has increased its staff; a large multi-national grain company headquartered in Central Illinois has hired aquaculture personnel for its new aquaculture facility. In addition, many cornbelt universities are increasing the number of technician-level staff devoted to aquaculture.

ISU's Aquaculture Program

Illinois State University has been studying aquaculture as an alternative to traditional enterprises undertaken on Illinois farms. In 1987, construction and renovation of an aquaculture facility began on the University's laboratory farm. The current facility consists of a 2 hectare lake, two research ponds of one-tenth hectare each, a new combination aquaculture production building and laboratory, and a fish hatchery building which has been used for the past four years to produce fish, freshwater prawns, and crawfish. The new building houses the latest recirculating fish production units available. This building and the new equipment are being funded through a combination of state, federal and private sources.

ISU has been experimenting with both an indoor system and a combination indoor tank culture/outdoor pond culture system for producing prawns (Macrobrachium rosenbergii) and hybrid tilapia (Tilapia mossambica x Tilapia hornorum). Tilapia is a warm-water fish species produced extensively for food in outdoor ponds, lakes, and streams in Africa and other tropical/subtropical countries. Hybrid tilapia were chosen because of their ability to grow rapidly in tank culture systems, tolerance for low water quality, excellent market potential and because there is little danger of their surviving in the northern waterways should they escape. Moreover, tilapia are very efficient converters of feed to meat, exceeding even the efficient catfish; they have been known to produce one kilogram of gain on as little as one and one-quarter kilograms of feed. Studies have reported that tilapia grew more than twice as fast as channel catfish under similar conditions (Lovell, 1987).

Tilapia (mossambica) cannot survive water temperatures below, approximately 11°C (50°F) and therefore cannot live outdoors through winter in the upper midwest. The water temperature of outdoor ponds in central Illinois is typically only warm enough for tilapia and prawns from early June through late September, not a sufficiently long season to grow these animals to market weight. One possible production option is to start them indoors and finish them outdoors. They can be marketed in August and September, a time when wholesale fish dealers (in the Chicago area) have had difficulty obtaining enough wild fish for their markets. A second possibility, which seems to hold the most promise for producers in the upper midwest, is a completely indoor system that can be developed to produce fish on a regular weekly basis for a year-round fresh fish market. Five hundred gram tilapia can be produced indoors in seven to ten months under typical growing conditions, including water temperatures of 24 to 28°C. (It should be noted that indoor fish production suffers from many of the same or similar problems experienced by confinement swine operations, i.e., diseases, environmental conditions, and waste handling).

Since beginning its aquaculture production five years ago, Illinois State University's Department of Agriculture has been deluged with requests for information on indoor tank culture systems. Though an abundance of materials is available on catfish farming in the southern states, very little exists on indoor systems in the northern states. Reliable data on commercial scale production systems was simply not available to satisfy the constant stream of requests for information on equipment needs, start-up costs, profit potential, species selection, labor requirements, and marketing methods. To meet industry demand, ISU offers a new course, "AGR200: Aquaculture Technology and Management". The course is now in its third year and has proved popular with students and local industry personnel (see Appendix A for course syllabus). This course covers the breadth of the aquaculture industry. Students are exposed to the scope and economic significance of the various segments of the industry. Each significant fish species is discussed but the course is oriented towards tilapia, catfish, walleye and trout production. Students learn the applicability of the various forms of fish "housing systems" - tank culture, pond culture, raceway culture and cage culture. In-depth design analysis is conducted for tank and cage culture systems.

Water quality measurement and management is a major segment of the course. In lecture and laboratory activities students learn the range for major water quality parameters, various methods for measuring water quality, the impact of adverse water quality on fish production, and techniques for adjusting water quality variables to a desired level. Students learn to calculate the impact of fish loading, feeding rates, or water flow rates on water quality. The course is very

skills oriented. Upon completion, students know the practical techniques of many aspects of fish production including those involved with feeding (formulations, feeding rates, protein levels, feeding equipment), breeding (sex reversal, induced spawning, fish sex identification, spawning practices), pond construction (mapping, surveying, water inflow), filter design, business plan development, etc. Students leave the course with skills necessary to begin a small aquaculture business or to be a valuable addition to an existing aquaculture enterprise.

Conclusion

Aquaculture has tremendous potential in the U.S. Besides providing a big boost to the rural economies of many states, it can help to correct the negative trade balance between the U.S. and other countries. Furthermore, it can help in the development of a sustainable agriculture by providing opportunities for greater diversification on some farms. Colleges and universities must take the lead in developing this country's aquaculture industry by establishing more aquaculture programs in their curricula and providing the personnel, equipment, and facilities necessary to conduct the desperately needed research and development activities. Illinois State University's Department of Agriculture has already begun development of an aquaculture program and hopes to provide guidance to others interested in initiating programs of their own in aquaculture.

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Appendix A – Course Syllabus

AGR 200: Aquaculture Technology and Management
3 credits, 2 hours of lecture, 2 hours of lab

Course Overview and Objectives:

This course covers both scientific principles and hands-on training in commercial aquaculture with emphasis on the engineering of indoor production systems. The course is designed to give students exposure to the rapidly expanding aquaculture industry especially as it pertains to conditions in the midwest. Specifically, upon completion of this course, students will be able to:

1. describe the scope and potential of the aquaculture industry
2. explain the anatomy and physiology of aquaculture plants and animals
3. describe water quality parameters crucial to aquaculture production systems
4. adjust water chemistry to produce proper culture conditions
5. describe the culture systems commonly used in the United States
6. describe culture techniques used to economically produce common aquaculture species
7. design and construct aquaculture equipment and facilities using a variety of construction materials
8. describe methods for processing aquaculture products
9. describe methods for marketing aquaculture products

Lecture Requirements:

Students are responsible for all announcements and lecture material discussed during class periods. To receive the most benefit from the course students are strongly encouraged to participate in all lectures. All exams and quizzes will be announced. Test material will be derived from lecture discussions, assigned readings, and laboratory activities.

Students are required to complete an introductory course in animal science or biological science before enrolling in this course.

Laboratory Requirements:

Attendance is required for all laboratories. Due to the complexity of the labs, make-ups are not possible. Some labs will be held outdoors or in the mechanization laboratories. Wear clothes which can tolerate these environments. Students are required to supply their own dissection kit.

Lecture Topics

1. Introduction to the Aquaculture Industry
   a. per capita consumption trends
   b. industry history, current production levels, growth trends
   c. aquaculture legal constraints (species permits, hormone use, etc.)
   d. aquacultural engineering impact on industry
2. Fish Biology
   a. morphology
   b. physiology
   c. endocrinology
   d. esoteric behavior patterns
3. Aquaculture Products
   a. animals produced for food
      1) catfish
      2) trout and salmon
      3) tilapia
      4) eels
      5) freshwater shrimp
      6) striped bass
      7) crayfish
      8) lobsters and bluecrabs
      9) clams and oysters
      10) carp, other species
   b. animals produced for sport
      1) trout and salmon
      2) walleye
      3) bass
      4) bluegill
      5) catfish
   c. baitfish
   d. ornamental fish
   e. aquatic vegetation
      1) water chestnuts
      2) water cress
      3) hyacinth
   f. hydroponically produced terrestrial vegetation
4. Environmental Variables in Aquaculture
   a. Nonconservative Aspects of Water Quality
      1) photosynthesis
      2) plant nutrients
      3) nitrogen derivatives
      4) pond fertilization
      5) the carbonate buffer system
      6) dissolved oxygen
   b. Conservative Aspects of Water Quality
      1) temperature
      2) salinity
      3) light
      4) turbidity
      5) pH