

**PROJECT NAME:**Current Economic Conditions and Future Market Opportunities for Aquaculture in the Northcentral U.S.

**FUNDING LEVEL:** Year 1 - Grant 1: \$62,900  
Year 2 - Grant 2: \$66,312

**DURATION:** 2 Years

**ADMINISTRATIVE ADVISOR:** Dr. Clarence McNabb, NCRAC, Michigan State University,  
East Lansing, MI 48824-1222

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## JUSTIFICATION

There is growing interest within the north central United States to expand aquaculture production in the region. Increasing numbers of individuals are exploring opportunities to enter the fish growing business. This regional enthusiasm parallels an attitude that exists nationwide. Various government and industry institutions are very optimistic about opportunities for growth within the domestic aquaculture industry. There are two principal reasons for this optimism. First, time series data on consumer demand for fish indicates that per capita consumption is growing. Blaylock and Smallwood (1986) have examined U.S. Department of Agriculture (USDA) consumer survey data to project that per capita seafood consumption of fish may increase from 5 to 17 percent above the 1986 base year (14.7 pounds per capita) by the year 2000. The International Aquaculture Foundation (IAF) meanwhile predicts that U.S. per capita consumption of finfish and shellfish combined may well reach 46.6 pounds in the year 2000, a 40 percent increase over the 1983 level of 33.4 pounds per capita (IAF, 1985). The second reason for high expectations is the apparent inability of the commercial capture fishery to satisfy anticipated future seafood demands. USDA projections indicate that the supply of edible seafood products will need to increase by 18 to 31 percent above 1987 levels in order to meet these needs. With wild stocks currently being harvested at or above sustainable yield levels, commercial fishermen unlikely will be able to provide the desired supplies, thereby providing increased market opportunities for aquaculturally produced fish.

The potential for regional and domestic aquaculture expansion may be greater than consumption projections alone would indicate. The trade deficit for fishfood imports increased from \$1.8 billion in 1980 to \$3.5 billion in 1986. Regional domestic aquaculture production may provide a mechanism for reversing current trade deficit trends. Domestically produced fish may be able to displace foreign supplies in the marketplace. The IAF (1985) forecasts that U.S. aquaculture production of finfish and shellfish may increase 400 percent by the year 2000 (with world production forecast to increase 150 percent). Whether this growth occurs will depend, in part, on the ability of domestic producers to compete with the growing aquaculture industry worldwide. Growth also will depend on the ability of growers to overcome any technological, economic and/or policy constraints that may impede aquacultural development in the region.

A number of factors may constrain growth. For example, growers must be able to find species that can be grown profitably with existing culture techniques and methods. They must be able to acquire sufficient operating capital to finance the operation and any permits needed to raise the fish. Markets must exist for the fish once they are harvested. Producers must have some understanding about how the market will respond to changing fish supplies. Changing market supplies will cause changes in the prices that are received by producers for the cultured fish. Successful enterprise planning and management requires that producers be able to formulate informed price expectations before each growing period. This information is important for those planning to expand or develop new aquaculture operations. Lack of basic economic information both at the firm and market level will impede development and growth of the industry.

Regulatory issues also can play an important role in determining the economic feasibility of an expanded aquaculture industry. Policy institutions can create both impediments and incentives for aquacultural producers. Public policy concerns in aquaculture generally can be classified as regulatory because of a state's interest in managing a common pool resource (fisheries and wildlife), commerce, and public health (environmental pollution and food safety).<sup>1</sup> These issues generally can

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<sup>1</sup>A discussion of policy topology is given in Lowi (1972).

be divided into three broad categories: (1) regulation of commerce in what are traditionally regarded wildlife species, (2) regulation of environmental and health issues, and (3) Great Lakes-specific issues such as competition with sport fisheries and commercially harvested free ranging species.

Whereas there is optimism for the domestic aquaculture industry in aggregate, the outlook by individual species and within regions is quite variable because of potential impediments. Opportunities are not equally bright for all species and all regions. This seems particularly true for species currently being raised or considered for future development in the north central U.S. (hereafter referred to as the North Central Region). The potential varies considerably across those species for which projections exist, both in total pounds and forecasted percentage increases. Future development must be undertaken carefully in order to maximize potential growth opportunities within the industry both across the nation and within the North Central Region. Species to be produced must be selected with great care, giving consideration to the technical, institutional and economic factors that may constrain or impede future development. Unfortunately, projections and information needed to evaluate these factors do not exist for many of the species that might be of interest to producers in the North Central Region. Although economic studies have been done on a few selected species targeted for aquaculture development in the North Central Region, e.g., yellow perch (Lesser, 1978; Lesser and Vilstrup, 1979), these studies are few in number, limited in scope, and lack sufficient information to guide future industry development efficiently. The research proposed here is designed, in part, to bridge the information gap and focus on the economic and policy factors that may constrain future expansion of aquaculture production in the region.

Human consumption of fish has always been high among consumers living in the North Central Region relative to other areas of the country. These consumers seem to have particularly strong preferences for fresh fish (U.S. Department of Commerce, 1981). Strong preferences coupled with the declining catches by sport anglers of such favored species as lake trout, walleye, yellow perch, and salmon have generated substantial interest in producing fresh fish within the region for local specialty and urban markets. Successful development of these markets not only could satisfy increasing regional demands, but also might serve as a springboard for north central producers to establish new market niches in the lucrative east and west coast markets. This would allow regional producers to compete with growers from other regions as well as with foreign suppliers in more well established food fish markets.

Opportunities also exist within the North Central Region for the development and expansion of baitfish aquaculture operations. Sportfishing intensities and values tend to be much higher in the North Central Region than in other parts of the country due to the availability of highly valued coldwater species, e.g., northern pike, walleye, muskellunge, trout, and salmon. The southern part of this region, in contrast, supports highly valued warmwater species like bass (Vaughan and Russell 1982). Recreational use of these fisheries creates a demand for fresh baitfish and fish-for stocking. Although a portion of that demand is satisfied by wild stocks harvested within the region, most of the baitfish supply comes from sources outside the region. Wild stocks are dwindling in supply due to increasing political and environmental constraints, forcing anglers to rely increasingly on the "imported" baitfish. This could change if more baitfish were grown commercially within the region.

The short growth cycle makes the production of baitfish particularly appealing due to the relatively small investment required and the reduced risk associated with being able to produce and market fish in the same year. Development and expansion of commercial baitfish operations not only will provide growers with new financial opportunities, but also can serve the needs of a highly valued recreational fishery that has contributed substantially to the economic growth of many communities in the region.

While all of this points to a potential for rapid expansion in the North Central Region aquaculture industry, information on the economic, social and political constraints are as essential to successful development as are data on scientific and technological advances. Aquacultural producers make many decisions regarding the allocation of resources. They must decide what species to produce and in what quantities. Decisions also must be made as to when to produce, the mix of inputs to be used and the marketing strategies employed. These issues embody economic decision making at the firm level. Firm level decisions made by aquacultural producers, in turn, have direct and indirect impacts on the economy of the entire region.

Planning for economic growth and development, whether at the firm level or within the entire industry, requires an understanding of how producers make decisions, how producer decisions are

influenced by regulatory policies and institutions, how consumers respond to the resulting production, and what the impact will be on regional economies. Data are needed to gain the needed understanding. Unfortunately, sufficient economic data currently do not exist on the North Central Region aquaculture industry. Data systems are not in place to coordinate and compile production and market statistics on the various aquaculture commodities produced in this region. Consequently, there is a lack of basic economic data on production costs, distribution systems and marketing opportunities.

Collection and analysis of these data can mitigate some of the economic factors impeding growth within the industry. Aquaculture firms often are unaware of the most lucrative markets, the most economically efficient production and distribution systems, the trends in consumer tastes and preferences, and the constraints or benefits of government policies on both production and marketing. Improved knowledge on the size and output of existing operations for various species, combined with information on present and projected market demands, can be used to predict how much additional expansion can be supported and how increased competition will affect short- and long-term profitability. This information will contribute to the identification of the most efficient production and processing technologies. It also will assist producers in identifying and developing new market niches and better positioning their products to maximize market share.

Gathering economic information from existing producers, however, may be a difficult task. The reasons for collecting economic information may not be well understood by producers. Aquaculture producers frequently are unaware of the benefits that accurate record keeping can have on their operation and the benefits that might accrue to them through collection and analysis of industry wide data. Producers also tend to be hesitant to provide accurate economic information on their operations because of the competitive nature of the aquaculture industry. Competition is particularly intense among producers of the same product, and where established market outlets exist. Where information is available, it often is derived from reporting forms that aquaculturists are required to file with the state agencies that regulate the industry. Producers frequently are reluctant to supply information that may provide the rationale for stricter regulations or increased licensing and permit costs. An educational effort aimed at shifting this attitude must be directed to producers in this region in order to get the needed economic data. Interest must be stimulated during this educational program to maintain and provide accurate and reliable records so that individual aquaculturists and the industry as a whole can benefit.

The project proposed here is designed to address all these concerns. Initial effort will focus on identifying existing and needed data as well as the development of a regional information management system. This initial activity will provide the needed input to design an educational program for producers on the role of economic data and permit collecting all currently available production, cost, and market data for the regional aquaculture industry. A periodic survey of regional producers will be implemented as part of the educational program in order to develop baseline data for monitoring the growth of the industry. These data not only will support further research on the economic feasibility of aquaculture in the region, but also comprise the first edition of what will become an annual "situation and outlook" report for the region.

Preliminary economic feasibility studies will be performed to identify those species with the highest potential for commercial success. The species groups which have been identified as most in need of supply/demand analysis are hybrid striped bass, walleye, yellow perch, crayfish, salmonids and baitfish (including leeches).<sup>2</sup> However, the rapid growth in the aquaculture of these species indicates the need to identify a broader base of species for commercial-scale aquaculture. In 1983, the National Aquaculture Development Plan identified a total of 36 species groups and developed plans to direct research efforts to close gaps in scientific and technical knowledge for 12 of these species groups (Joint Subcommittee on Aquaculture, 1983). Detailed plans were not developed for many of the species of interest in the Great Lakes region (walleye, northern pike, muskellunge, sturgeon, yellow perch, sunfishes, and Atlantic salmon) but all of these species were viewed to offer

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<sup>2</sup>It is particularly important to assess regional economic conditions for the bait fish and crayfish industries before further biological research should be undertaken. Development of new culture technologies for baitfish and crayfish that are more suitable for use in the North Central Region may not be feasible if economic conditions cannot support the increased production that would necessarily result from new techniques. It is of particular importance to examine the relative costs of baitfish and crayfish culture in the North Central Region relative to costs of importing these species from producers operating outside the region (principally in the south).

commercial potential which could exceed that of the more well-known species groups. Feasibility analysis of these species will be useful in guiding future development of the industry and educating prospective producers on those species with the greatest economic potential for the region.

Existing policy impediments and incentives in each of the twelve states within the region also will be assessed to augment the economic feasibility analysis. The commercial culture of species that occur in the wild raises special problems for state fish and wildlife management agencies. Policy formulation regarding aquaculture development in the North Central Region is likely to be controversial because of the variety of interests and constituencies in several of the north central states. The complexity of issues and probable intensity of public debate suggests that legislative approaches likely will be required in most states before appropriate regulation can proceed by management agencies. Individuals and organizations with interests in expanded aquaculture will need to develop a broad consensus with those having interests in fisheries management, regulation of environmental pollutants and/or food production in order to facilitate appropriate legislation. Early research to identify the interests and concerns of all the parties will foster the development of a policy consensus before the issues reach state legislative bodies in a piecemeal fashion. Investment in research that stimulates a policy dialogue among the various interested groups will facilitate timely production of economically feasible species using environmentally and socially acceptable culture techniques.

### **RELATED CURRENT AND PREVIOUS WORK**

No single agency has exclusive responsibility for tracking U.S. aquaculture statistics. Production, marketing, and economic data are collected and analyzed by the USDA for many agriculture sectors of national importance including commercial aquaculture. USDA coverage of the aquaculture industry, however, has been extremely limited and aggregate in scope. The National Marine Fisheries Service (NMFS) also has attempted to gather industry information, but again, coverage has been extremely incomplete and too aggregate to be useful in analyzing economic feasibility of aquaculture in the North Central Region. Neither agency has produced sufficient economic or marketing information for any aquaculture sector in the North Central Region. The limited information that has been collected is generally recognized to be inaccurate. For example, Warnick (1973) and Van Eeckhout (1976) concluded that figures of production and value from surveys of the bait industry were underestimates. The statistics from the 1986 aquaculture survey of the Steering Committee of the NCR-23 Subcommittee on Aquaculture similarly are known to be underestimates.

If accurate information is to be gathered from aquaculture producers in the North Central Region (via periodic survey efforts), it must be preceded by an educational effort designed to demonstrate the value to aquaculture producers of submitting accurate economic data. Key steps in the education process are legitimation of the survey, effective execution of the survey, and demonstration that the results will be useful to producers. Legitimation is the process of gaining program support through the influence of key individuals in a community. Klein (1983) describes the essential character of legitimation to an effective education program. Organizations in the North Central Region through which legitimation will be most effective include state aquaculture producer organizations, state extension services, Sea Grant programs, and economic development institutions. Many of these organizations have been identified for the North Central Region in the NCR-23 Aquaculture Subcommittee report.

The techniques utilized in developing and delivering a survey are critical to achieving good results. Methods for improving survey response are elaborated in Dillman (1978) and Berdie and Anderson (1979). Additional authors have reported on educational measures that improve survey response (Abramson, 1974; Alwin, 1978; and Miller, 1977). These techniques will be employed in developing appropriate survey designs and questionnaire formats for collecting the data needed to undertake economic feasibility analysis of the regional aquaculture industry.

True economic feasibility analysis requires attention to production economics, marketing analysis, and identification of political and social constraints. Most aquaculture research has focused on each of these aspects individually, leaving many interrelationships undefined and questions unanswered. For example, although a few of the states in the North Central Region have completed "aquaculture plans" (Minnesota, Illinois, Missouri), economic assessment largely has been confined

to breakeven analysis of the production process. Analysis of market opportunities or constraints and legal and social deterrents has been largely descriptive in these "plans".

Production-oriented studies for species of interest to the North Central Region include: Easley (1976) for trout; Smith et al. (1981) for freshwater prawns; Logan and Shigekawa (1980) for sturgeon; and studies by Gates and Mueller (1975) and Gates et al. (1980) on the production of coho salmon in recirculation systems. Two specific regional studies are of methodological interest here. Stechey and Kantor (1988) examined the question of optimal intensity in trout farming using real data from Ontario producers. They found that marginal increases in revenue are offset by disproportionate increases in production costs when production intensity exceeds 15 kg/Lpm/yr. The impact of broodstock source on profitability was addressed by Skurla and MacDonald (1988) in a study of thermally-enhanced walleye production using an engineering-economic approach, i.e., using a number of hypothetical production scenarios. They found egg based operations were more profitable than those using fingerlings.

Several studies have been completed linking both production and marketing into a generalized economic framework. Keenum and Waldrop (1988) incorporated realistic marketing constraints into their production analysis by studying the effects on cash flow of a fixed processing capacity and two scenarios regarding financing (internally capitalized versus partial funding by outside investors). Clardy et al. (1985) used sensitivity analysis to determine the effects of changes in market prices, feed costs, and seed stock costs on the profitability of freshwater shrimp production.

Relatively few marketing studies on aquaculturally produced fish have been done in the North Central Region. Skurla and Van Hale (1987) provide a descriptive analysis for three walleye markets--eggs and fry, fingerlings, and table food. Johnson and Talhelm (1978) and Cole and Stockdale (1985) used largely descriptive methods to identify potential aquaculture opportunities in Michigan and Ohio, respectively. The market demand for yellow perch was studied in the late 1970s (Lesser, 1978; Lesser and Vilstrup, 1979). It was found that market demand for this freshwater species has always been high, in part, due to long standing traditional uses for yellow perch in the region.

The cyclicity of supply, particularly from capture fisheries, and the ability of aquaculturists to supply particular sizes during times when wild-caught supplies are unavailable can have a marked impact on profitability. Gates (1974) provided the initial work on defining the relationship between demand price, fish size, and price of fish (ex-vessel). Up until this study, empirical analyses of the demand for fish ignored fish size. Recent work by Blake (1988) explored the relationship between shrimp size and the amount of annual harvest by size class in the determination of price and shifts in the preferences of restaurant owners. In 1988, an oversupply of medium sized shrimp caused prices to plummet and many retail restaurants that usually prefer larger shrimp (21 to 25 shrimp per pound) switched to the medium size class. For producers of medium sized shrimp, such as Ecuador, prices fell from \$4.48 to \$3.74 per pound showing the importance of quality and size on values and profitability.

North Central Region aquaculture producers are particularly interested in information that will guide marketing strategies. This necessarily requires analysis of consumer perceptions. Only one regional study on consumer attitudes has been identified. Stechey and Okechuku (1988) found that taste was the main determinant in the overall evaluation made by restaurant diners of fresh, tank-versus frozen, and pond-raised tilapia. Fresh tilapia were preferred. Repurchase behavior, however, was found to be dependent on taste, product form, and texture.

Several consumer demand and marketing studies conducted outside the North Central Region provide useful insights about specific cultured species and the methods used to perform socioeconomic research on the aquaculture industry. Studies by Liao et al. (1987) and Liao (1984) provide preliminary marketing intelligence for hybrid bass and crawfish, respectively. Lin and Hermann (1987) and Anderson (1988) have taken the lead in econometric analysis of demand and consumer perceptions for aquacultured Atlantic salmon. Results of studies relying on surveys of wholesale, retail, and end-use consumers are of particular interest. For example, Rackham (1988) found that consumers preferred farm-raised over wild-caught salmon not only on the basis of quality measures such as color and taste, but also because the higher prices charged for cultured fish enhanced the quality image in the eyes of these consumers. Courtney (1988) found that consumers' perception of trout was more favorable if they thought they were eating a wild-caught versus tank-raised fish. Finally, Hatch (1988) evaluated the results from a national survey of U.S. seafood

consumption and found that catfish consumers ranked catfish as superior to other fish on the basis of relative price, few bones, and smell; but was ranked negatively due to inconsistency of supply. The survey also revealed that regional differences in consumer preferences can influence market demand, e.g., New England consumers have much lower per capita demand for catfish than individuals living in the southeastern U.S.

In summary, quality factors clearly are of extreme importance in determining consumer demand for seafood. The quality image of any fishery product includes both conceptual and physical attributes. A true picture of market potential for any species can only be gleaned from the collection of primary data and surveys at all levels of consumer activity. Given the inability to control the quality of most wild-caught species, it is not surprising that consumers' reaction to seafood quality is a relatively unstudied field. Yet, it is in the ability to control quality, to time harvest, and to differentiate products, that the opportunity for profitable development of the aquaculture industry exists.

## **OBJECTIVES**

1. Identify existing and needed economic data; develop statistical reporting methods; design an information management system and prototype annual situation/outlook report on the North Central Region aquaculture industry; begin collecting and compiling a regional database; and prepare the initial situation/outlook report.
2. Develop and implement an extension program designed to educate current and potential aquaculture producers on the need to provide accurate economic information on their operations.
3. Investigate the economic feasibility for species currently being produced in the North Central Region and other species that offer commercial potential.
4. Identify existing policy impediments and incentives for expanded aquaculture development in each participating state within the North Central Region.

## **PROCEDURES**

### **Objective 1**

Dr. Jeffrey E. Hanson, a resource economist in the Department of Fisheries and Wildlife at Michigan State University will be responsible for identifying existing and needed economic data on aquaculture production in the North Central Region. His responsibility will include the design of a microcomputer based information management system and initial collection/compilation of the regional database. Accomplishments made on this objective will be documented in a report to the North Central Regional Aquaculture Center (NCRAC).

Computer assisted and manual literature searches will be used to identify any pertinent published research conducted over the past 20 years on aquaculture in the North Central Region that was overlooked during proposal preparation. Statistical abstracts of federal and state data reports will be examined to locate potential sources of production, marketing and consumption data for the regional aquaculture industry. In addition, federal, state and industry trade organizations will be contacted by mail and telephone as a preliminary step to identify sources of information on aquaculture in the 12-state region.

More complete follow-up on data availability and existing information sources will be accomplished using a mail questionnaire. The questionnaire will be designed according to the Dillman method (1978). It will contain specific questions on current aquaculture data within each state. The questionnaire will be sent to all individuals, agencies and industry organizations involved with aquaculture in the region. Specific names and addresses will be taken from the literature search and from the NCR-23 Aquaculture Subcommittee Report. Respondents will be requested to supply any data that are available on the regional industry. They also will be asked what data are needed to guide future development and expansion of the North Central Region aquaculture industry. This information will be combined with that collected during the previous stages to form an initial

collection of regional aquaculture statistics and data needs for the NCRAC. Data needs also will be based on information requirements of the proposed economic feasibility study. Relevant research and data citations will be acquired and summarized along with the survey results and data needs assessment for inclusion in the accomplishment report.

All data collected during this preliminary phase of research will be compiled and entered into a microcomputer-based data management system. The data management system will be established using existing database software, e.g., LOTUS 1-2-3. Design of the system will be made in consultation with staff at the NCRAC who will be responsible for maintaining the system once it is established. Dr. Judith Maxwell, an economist in the School of Natural Resources at Ohio State University also will be consulted so that the data system can facilitate development and preparation of the annual outlook and situation report on commercial aquaculture activity in the region.

Dr. Maxwell is responsible for developing the format for an annual report describing the current situation and future outlook of aquaculture in the North Central Region. This report will provide a prototype of the document that will be prepared by the NCRAC in subsequent years. The prototype report will contain the data described above and information from the periodic survey of regional producers resulting from Objective 2. The regional report will be tailored after the national situation and outlook report published by the USDA/Economic Research Service. All data will be reported in tabular form with narrative summaries provided as needed.

The regional report will include information from the national report on the current status of world fisheries, price trends for fish products and other major food groups, projections of feed (input) prices, and the situation and outlook for aquacultural species of interest to the region. Emphasis will be placed on reporting regional and statewide statistics. The regional report also will include detailed analysis of those species not given detailed coverage in the national report but of significant local importance.

In general, the regional report will provide information on consumer preferences, consumption trends, production trends, acreages, product prices (at the farm-gate, wholesale, and retail levels), geographic distribution and concentration of producers, processing, sales, imports, and net farm incomes. These baseline data then will be used to project the outlook by species or by market.

This initial prototype report will be completed during the second year of funding. It will be printed and distributed by the NCRAC.

## **Objective 2**

Mr. David J. Landkamer, an aquaculture extension specialist in the Department of Fisheries and Wildlife at the University of Minnesota will develop an educational program following development of a statistical reporting method for fish farmers. The educational program is intended to explain the value to the producer of providing accurate information through the report. The most critical element of the educational program involves establishing credibility through legitimation.

Legitimation will be accomplished by contacting state agencies that have an interest or role in commercial aquaculture (e.g., natural resources, environmental licensing/permitting, and agriculture agencies), state aquaculture associations, state extension services, Sea Grant programs, and economic development groups in each of the states within the North Central Region to seek input and support for the information gathering program. Key individuals respected in the aquaculture industry will be chosen from these groups to facilitate legitimation. The reporting method will be legitimated through appropriate industry publications and other applicable communication channels. Through key individuals, a pre-letter will be sent to each report participant introducing the NCRAC, explaining the goals of the economic survey, and describing the benefits to the producers of providing accurate information.

Presentations will be made at aquaculture conferences and meetings throughout the region to explain the value of economic data reporting and the format for reporting. Requested travel funds will be used to attend at least one meeting in each state within the region during the first year of the project (contingent upon funding availability). Preference will be given to attending those meetings with the largest anticipated attendance by current North Central Region aquaculture producers as travel funds become limited. The cooperation and assistance of state aquaculture extension



specialists will be solicited in order to expand the coverage of producer meetings within each state. Legitimizers will participate in presentations, where possible, to solicit producer participation and cooperation.

Delivery of the reporting form will include a cover letter and a token incentive NCRAC monogrammed pencil to increase response. An assortment of follow-up techniques including letters and telephone contacts will be used to encourage maximum response. Finally, respondents will be sent report results and a copy of the regional aquaculture outlook and situation report (see Objective 1) directly to demonstrate appreciation for their cooperation and to illustrate the usefulness of supplying the requested production information.

### **Objective 3**

A large number of species have been identified as providing aquacultural opportunities in the North Central Region. Some of these, such as trout, are currently being grown commercially in the region but declining profit margins raises the serious question concerning long-term viability of the industry. Other species, such as salmon, probably can be cultured in the region but rapid expansion of salmon aquaculture worldwide indicates that it may be difficult for new entrants to compete. Unique local markets for both food (especially walleye, yellow perch, hybrid striped bass, and crayfish) and baitfish indicate the potential for both the expansion of existing aquaculture and an opportunity to grow species currently not produced in the region.

Dr. Jeffrey E. Hanson (Michigan State University) and Dr. Judith A. Maxwell (Ohio State University) will share equally the responsibility for investigating the economic feasibility objective. They will divide research responsibilities on a geographical basis. The twelve-state North Central Region will be divided into two six-state subregions. Dr. Hanson will focus research activities on the northern subregion (Michigan, Wisconsin, Minnesota, North Dakota, South Dakota, and Iowa) while Dr. Maxwell will concentrate on the southern subregion (Ohio, Indiana, Illinois, Missouri, Nebraska, and Kansas). Both subregions will be studied using the same research protocol. That protocol consists of three sequential phases designed to reduce the large list of potential production species to those that appear to be technically and economically most feasible for the region. The three phases are stated below.

1. Evaluate the market outlook for each species of interest.
2. Assess the technical feasibility for those species found to be most promising from the market evaluation.
3. Determine the preliminary economic feasibility of producing those species for which culturing is technically feasible.

The specific procedures used to complete each phase will be developed cooperatively by Dr. Hanson and Dr. Maxwell. The same procedures will be used for each subregion.

### **PHASE 1**

The market analysis for aquacultured products will focus on individual buyer perceptions based on primary data. Questionnaires will be developed using Dillman's total design method (1978) in order to assess the basic criteria buyers use in making purchasing decisions for fish products in general and to provide a preliminary estimate of the market potential for species in the list of 36 species groups identified in the 1983 National Aquaculture Development Plan (Joint Subcommittee on Aquaculture, 1983). For food fish, the questionnaire will be administered to a sample of retail and wholesale seafood distributors and to restaurateurs in the North Central Region that serve larger metropolitan markets. The baitfish questionnaire will be sent to a sample of baitfish dealers from all of the states in each subregion. The sample will be selected in consultation with fisheries extension specialists from each state. The purpose of this phase is to identify: (1) specific market segments, (2) the most important attributes guiding purchase decisions for each segment, (3) attitudes toward farm-raised versus wild-caught fish in general, and (4) those species and product forms that can be successfully marketed.

Respondents will first be asked to characterize their firm on the basis of four factors to identify market segments for regional aquaculture products. These four factors are: relationship to

the industry (for example, for food fish--restaurants, seafood markets, supermarkets with seafood sections, and wholesalers; for baitfish--customer preferences for sportfish, producer/seller, seller only, percent of sales from live bait, etc.); (2) types of fish purchased; (3) product forms (for food fish--live, fresh, frozen; for baitfish--species and sizes); and (4) whether or not farm-raised fish are purchased.

By asking buyers to assess the relative importance of product attributes in their purchasing decision (price, quality, consistency of supply, and supplier credibility) it will be possible, using conjoint analysis, to identify the most important factors affecting purchasing decisions in general and to assess how the importance of these factors vary across market segments. These results can be used for targeting markets or for developing market strategies specific to each segment.

Respondents from firms that do purchase aquacultured products will be asked to compare wild and farm-raised products, ranking the latter according to quality characteristics (taste, texture, freshness), consumer preferences, prices, and dependability of supply. Factor analysis will be used to assess the degree of substitutability between farm-raised and wild-caught fish. The results will be used to establish the awareness that regional buyers have of aquacultured products and to determine the relative importance of these products in regional seafood and baitfish markets. This information will help identify the need for generic advertising and the form that such advertising should take given the market segment characteristics that are identified above.

Buyers will be asked to rank the likelihood of selling fish and bait that are currently farm-raised in the North Central Region as well as species that have the potential to be cultured in the region in order to identify individual species or species groups that have market potential for the area. These rankings will be used to develop a refined list of potential species based upon market outlook.

Results from Phase 1 will be documented and summarized in a market report for the region. This report will be submitted to the NCRAC early in the second year of project funding.

## **PHASE 2**

The technological feasibility of promising species as identified in Phase 1 will be examined by reviewing cultural practices within the region and in other regions (both domestic and foreign). This assessment will include reviews of the technical literature and informal survey of aquacultural producers, researchers and extension specialists. The NCRAC Technical Committee also will be consulted during this phase of feasibility assessment. It is not within the scope of this study to identify technological breakthroughs or to attempt to attach potential commercial values to production processes still in the experimental stages. Rather, emphasis will be placed on identifying proven (i.e. commercially viable) cultural practices and to relate the application of these technologies to conditions in the North Central Region. This phase will further refine the list of promising species generated in Phase 1 by eliminating species for which no commercial technology currently or likely will exist in the near future. It also will serve to discard certain production systems currently being used in other regions to culture fish that appear infeasible for the North Central Region. Results from this refinement process will include a revised listing of species and production technologies that will be studied in more detail during Phase 3 and subsequent funding cycle proposals. The revised list will be reported in conjunction with the progress report on Phase 3 to be submitted to the NCRAC at the end of the second funding year.

## **PHASE 3**

It is necessary to account for the North Central Region's economic and physical environment in order to assess the economic feasibility of each potential species. Longer growing seasons, prices and availability of productive inputs relative to those in other regions, required economies-of-scale in production and distribution, and the availability of processing facilities all can make a technically feasible operation unprofitable (and therefore, not economically viable). Unfortunately, the economics of production are ill-defined in fledgling industries; this absence of industry standards in itself presents a major deterrent to industry development by restricting the availability of capital from lending institutions and in making it difficult to value fish farms for insurance purposes.

Data collected to fulfill Objectives 1 and 2 can be used to develop cost structures for the production of each species in the revised listing from Phase 2. These data include primary data from the survey of regional producers and published data on existing operations in other regions that are

modified based on local cost estimates. Phase 3 begins the process of developing these cost of production relationships. Production budgets will be developed whenever possible, for a range of firm sizes, cultural intensities, and degrees of self-sufficiency. This will permit an assessment of how the relative importance of operating, fixed and capital costs vary by scale and climatic conditions and how profitability varies with intensity of production and/or with the degree of vertical integration. Complete development of these production budgets will extend beyond the two year time horizon for the current NCRAC funding cycle. Additional research support will be sought from the NCRAC for the funding cycle beginning in FY91-92 in order to finalize the budgets. The general analytical framework and preliminary results in developing the production cost relationships will form the basis for the Phase 3 progress report. This report will be submitted at the end of the second funding year to the NCRAC. The revised species list developed in Phase 2 will be included in the Phase 3 report.

Completion of the production budgets will be contingent upon subsequent NCRAC funding. The completed cost relationships will provide the information needed to identify the most efficient production alternatives for the revised species list. Cost of production estimates can be compared to those in other regions and countries to determine the ability of North Central Region aquaculture producers to compete in the marketplace. These estimates also will provide a useful framework for developing a business plan that will be better able to attract short and long-term financing.

Results from this and all other phases of Objective 3 provide the necessary foundation for the development of individual economic assessment models for those species (most likely including walleye, yellow perch, hybrid striped bass and certain species of baitfish) shown to be both technically and financially feasible for the North Central Region. These models will identify the most profitable species for aquaculture expansion. Since model estimation is contingent upon the results of Phases 1-3, funding proposals for individual species studies cannot be submitted until the currently proposed work is completed. Consequently, these species-specific proposals will be submitted in subsequent NCRAC funding cycles.

### **GENERAL METHODOLOGICAL COMMENTS FOR OBJECTIVE 3**

Two methods widely used in marketing research, conjoint and factor analysis, will be used in Phase I (Green et al. 1988). Conjoint or trade-off analysis permits the decomposition of a purchasing decision into the various attributes of the product which influence the decision; these factors can then be ranked in order of importance. For seafood, such attributes include freshness, ease of preparation, price, color, texture, and consistency of supply. This method has been applied by Stechey (forthcoming) to analyze the technological and economic feasibility of selected species for aquaculture development in Ontario and by Anderson and Brooks (1986) for the salmon market. With factor analysis, interest is centered on defining consumers' perceptions of a total product (seafood or a particular species of fish) as opposed to measuring the trade-offs of individual attributes. For example, Stechey (1988) used this method to assess restaurant patrons' attitudes toward fresh tilapia relative to other species they had eaten and their preferences for product form (fresh, tank-raised versus frozen pond-raised).

The production cost analysis begun Phase 3 will use an engineering-economic approach as described by DeGarmo, et al. (1979) and Thuesen and Fabrycky (1984). This approach will permit the comparison of alternatives since aquaculture for any particular species can be carried out by more than one method. Each alternative will be represented by a "synthetic" firm; technical coefficients for inputs will be synthesized from available data and recommendations from producers researchers. Various production scenarios will be developed to show the feasibility for different levels of investment, input requirements, and project lives. This method has been used by Keenum and Waldrop (1988) for catfish and Clardy et al. (1985) for freshwater shrimp.

### **Objective 4**

Dr. Donald Floyd in the School of Natural Resources at Ohio State University will identify existing policy impediments and incentives for expanded aquaculture development in each state within the North Central Region. The first step will be to develop, implement and report a systematic survey of state governments and other institutions (e.g., grower associations, environmental groups, recreational angler organizations). The purpose of this survey is to identify and classify public policies that positively or negatively impact the potential expansion of the regional aquaculture industry.

A variety of policy issues dealing with the regulation of commercially produced wildlife species, environmental pollution, and food production will positively or negatively affect the ability of each state to sustain efficient aquaculture. In order to deal with these issues on a pro-active basis and to assist production feasibility work, research detailing specific policies on a state-by-state basis is necessary.

In general, this research will detail state policies and regulations that impede and encourage expanded aquacultural production. Examples may include multi-stage permitting, economic incentives to aquaculture, regulations on intra-state movement of species and regulation of commercial species by state fisheries management agencies.

Mail and telephone questionnaires will be used to survey state agencies involved with aquaculture, commercial development or natural resource management. These surveys will identify agencies with regulatory interests in aquaculture, legislation, and permitting procedures as well as the policies that affect establishment or expansion of production. This survey process will be completed during the second year of funding. Preliminary results from the survey will be submitted in a written report to the NCRAC at the end of the second funding year.

Completion of the policy review will require additional resources during FY91-92. A proposal will be submitted to complete the review and prepare a final report. This report will include an overview of the procedures used to identify existing policy impediments and incentives directed toward aquaculture production as well as a state by state description of the relevant policy issues. The material should be useful to current and prospective aquaculture producers, extension specialists, financial institutions, government agencies and lawmakers in the North Central Region.

## **FACILITIES**

### **Michigan State University**

Faculty, staff and students in the Department of Fisheries and Wildlife have full access to the University mainframe computer system as well as numerous IBM-compatible microcomputer workstations within the Department.

### **Ohio State University**

The School of Natural Resources has full access to the University computer facility and both the faculty and research associates have access to IBM PCs. In addition, Dr. Maxwell is affiliated with the Department of Agricultural Economics which employs a full-time computer programmer to assist faculty in research. The Polimetrics Laboratory will provide assistance with various aspects of survey design and questionnaire development.

### **University of Minnesota**

The facilities infrastructure of the Department of Fisheries and Wildlife and Minnesota Extension Service at the University of Minnesota will be used to conduct this work. No special facilities are required.

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## PROJECT LEADERS

<u>State</u>	<u>Name/Institution</u>	<u>Area of Specialization</u>
<b>Michigan</b>	Jeffrey E. Hanson Michigan State University	Resource Economics
<b>Minnesota</b>	David J. Landkamer University of Minnesota	Aquaculture Extension
<b>Ohio</b>	Donald W. Floyd Ohio State Univesity	Natural Resource policy
	Judith A. Maxwell Ohio State University	Resource Economics



**PROPOSED ECONOMICS/MARKET BUDGET SHEET FOR MICHIGAN STATE UNIVERSITY**

**(Hanson)**

**Objectives 1 and 3**

	Year 1		Year 2			
	Yr 1 No.	Yr 1 FTEs	Yr 2 No.	Yr 2 FTEs		
<b>A. Salaries and Wages</b>						
1. No. of Senior Personnel & FTEs <sup>1</sup>						
a. (Co)-PI(s) . . . . .	1	0.05	1	0.05	\$0	\$0
b. Senior Associates . . . . .						
2. No. of Other Personnel (Non-Faculty) & FTEs						
a. Research Assoc./Postdoc . . .						
b. Other Professionals . . . . .						
c. Graduate Students . . . . .	2	0.75	2	0.75	\$18,000	\$18,750
d. Prebaccalaureate Students . .						
e. Secretarial-Clerical . . . . .	1	0.08	1	0.08	\$1,600	\$1,680
f. Technical, Shop, and Other . .						
<b>Total Salaries and Wages</b> . . . . .					\$19,600	\$20,430
<b>B. Fringe Benefits</b> . . . . .					\$400	\$420
<b>C. Total Salaries, Wages and Fringe Benefits</b> . . . . .					\$20,000	\$20,850
<b>D. Nonexpendable Equipment</b> . . . . .					\$0	\$0
<b>E. Materials and Supplies</b> . . . . .					\$2,000	\$2,000
<b>F. Travel - Domestic (Including Canada)</b> . . . . .					\$3,000	\$3,000
<b>G. Other Direct Costs</b> . . . . .					\$0	\$0
<b>TOTAL PROJECT COSTS (C through G)</b> . . . . .					\$25,000	\$25,850

<sup>1</sup> FTEs = Full Time Equivalents based on 12 months.

**PROPOSED ECONOMICS/MARKET BUDGET SHEET FOR UNIVERSITY OF MINNESOTA**

**(Landkamer)**

**Objectives 1 and 3**

					Year 1	Year 2
<b>A. Salaries and Wages</b>	<b>Yr 1</b>	<b>Yr 1</b>	<b>Yr 2</b>	<b>Yr 2</b>		
	<b>No.</b>	<b>FTEs</b>	<b>No.</b>	<b>FTEs</b>		
1. No. of Senior Personnel & FTEs <sup>1</sup>						
a. (Co)-PI(s) . . . . .	1	0.05	1	0.05	\$0	\$0
b. Senior Associates . . . . .						
2. No. of Other Personnel (Non-Faculty) & FTEs						
a. Research Assoc./Postdoc . . .						
b. Other Professionals . . . . .						
c. Graduate Students . . . . .						
d. Prebaccalaureate Students . .	1	0.125	1	0.25	\$2,100	\$4,500
e. Secretarial-Clerical . . . . .						
f. Technical, Shop, and Other . .						
<b>Total Salaries and Wages</b> . . . . .					\$2,100	\$4,500
<b>B. Fringe Benefits</b> . . . . .					\$0	\$0
<b>C. Total Salaries, Wages and Fringe Benefits</b> . . . . .					\$2,100	\$4,500
<b>D. Nonexpendable Equipment</b> . . . . .					\$0	\$0
<b>E. Materials and Supplies</b> . . . . .					\$2,000	\$2,000
<b>F. Travel - Domestic (Including Canada)</b> . . . . .					\$3,600	\$2,000
<b>G. Other Direct Costs</b> . . . . .					\$0	\$0
<b>TOTAL PROJECT COSTS (C through G)</b> . . . . .					\$7,700	\$8,500

<sup>1</sup> FTEs = Full Time Equivalents based on 12 months.

**PROPOSED ECONOMICS/MARKET BUDGET SHEET FOR OHIO STATE UNIVERSITY**

**(Maxwell and Floyd)**

**Objectives 1, 3 and 4**

					Year 1	Year 2
<b>A. Salaries and Wages</b>	<b>Yr 1</b>	<b>Yr 1</b>	<b>Yr 2</b>	<b>Yr 2</b>		
	<b>No.</b>	<b>FTEs</b>	<b>No.</b>	<b>FTEs</b>		
1. No. of Senior Personnel & FTEs <sup>1</sup>						
a. (Co)-PI(s) . . . . .	2	0.15	2	0.15	\$0	\$0
b. Senior Associates . . . . .						
2. No. of Other Personnel (Non-Faculty) & FTEs						
a. Research Assoc./Postdoc . . .						
b. Other Professionals . . . . .						
c. Graduate Students . . . . .	2	1.00	2	1.00	\$25,200	\$26,712
d. Prebaccalaureate Students . .	1	0.29			\$600	\$0
e. Secretarial-Clerical . . . . .						
f. Technical, Shop, and Other . .						
<b>Total Salaries and Wages</b> . . . . .					\$25,800	\$26,712
<b>B. Fringe Benefits</b> . . . . .					\$0	\$0
<b>C. Total Salaries, Wages and Fringe Benefits</b> . . . . .					\$25,800	\$26,712
<b>D. Nonexpendable Equipment</b> . . . . .					\$0	\$0
<b>E. Materials and Supplies</b> . . . . .					\$2,400	\$2,150
<b>F. Travel - Domestic (Including Canada)</b> . . . . .					\$2,000	\$3,100
<b>G. Other Direct Costs</b> . . . . .					\$0	\$0
<b>TOTAL PROJECT COSTS (C through G)</b> . . . . .					\$30,200	\$31,962

<sup>1</sup> FTEs = Full Time Equivalents based on 12 months.

**AQUACULTURE ECONOMICS AND MARKETING**

**Budget Summary for Each Participating Institution at 62.9K for Year 1**

	MSU	U MINN	OSU	TOTALS
Salaries and Wages	\$19,600	\$2,100	\$25,800	\$47,500
Fringe Benefits	\$400	\$0	\$0	\$400
<b>Total Salaries, Wages and Benefits</b>	<b>\$20,000</b>	<b>\$2,100</b>	<b>\$25,800</b>	<b>\$47,900</b>
Nonexpendable Equipment	\$0	\$0	\$0	\$0
Materials and Supplies	\$2,000	\$2,000	\$2,400	\$6,400
Travel	\$3,000	\$3,600	\$2,000	\$8,600
Other Direct Costs	\$0	\$0	\$0	\$0
<b>TOTAL PROJECT COSTS</b>	<b>\$25,000</b>	<b>\$7,700</b>	<b>\$30,200</b>	<b>\$62,900</b>

**AQUACULTURE ECONOMICS AND MARKETING**

**Budget Summary for Each Participating Institution at 62.9K for Year 2**

	MSU	U MINN	OSU	TOTALS
Salaries and Wages	\$20,430	\$4,500	\$26,712	\$51,642
Fringe Benefits	\$420	\$0	\$0	\$420
<b>Total Salaries, Wages and Benefits</b>	<b>\$20,850</b>	<b>\$4,500</b>	<b>\$26,712</b>	<b>\$52,062</b>
Nonexpendable Equipment	\$0	\$0	\$0	\$0
Materials and Supplies	\$2,000	\$2,000	\$2,150	\$6,150
Travel	\$3,000	\$2,000	\$3,100	\$8,100
Other Direct Costs	\$0	\$0	\$0	\$0
<b>TOTAL PROJECT COSTS</b>	<b>\$25,850</b>	<b>\$8,500</b>	<b>\$31,962</b>	<b>\$66,312</b>

**RESOURCE COMMITMENT FROM INSTITUTIONS<sup>1</sup>**

**(Salaries, Supplies, Expenses and Equipment)**

Institution/Item	Year 1	Year 2
<b>Michigan State University</b>		
Salaries and Benefits: SY @ 0.1 FTE	\$4,500	\$4,687
Supplies, Expenses and Equipment	\$11,365	\$12,080
TOTAL PER YEAR	\$15,865	\$16,767
<b>Ohio State University</b>		
Salaries and Benefits: SY @ 0.06 FTE Year 1 & 0.08 FTE Year 2	\$3,588	\$5,071
Supplies, Expenses and Equipment	\$18,054	\$19,008
TOTAL PER YEAR	\$21,642	\$24,079
<b>University of Minnesota</b>		
Salaries and Benefits: SY @ 0.1 FTE	\$3,659	\$3,659
TY @ 0.1 FTE	\$2,500	\$2,500
Supplies, Expenses and Equipment	\$4,500	\$4,500
TOTAL PER YEAR	\$10,659	\$10,659
<b>GRAND TOTAL</b>	<b>\$48,166</b>	<b>\$51,505</b>

<sup>1</sup>Since cost sharing is not a legal requirement and due to the difficulty in accounting for small items, documentation will not be maintained.

### **SCHEDULE FOR COMPLETION OF OBJECTIVES**

- Objective 1: Data collected annually and first compiled in Year 1. Prototype situation and outlook report completed at the end of Year 2.
- Objective 2: Initiated in Year 1 and completed in Year 2.
- Objective 3: Initiated in Year 1 and continued in Year 2. (Completion is contingent upon subsequent funding as described in the procedures for this objective.)
- Objective 4: Initiated in Year 1 and continued in Year 2. (Completion is contingent upon subsequent funding as described in the procedures for this objective.)

## LIST OF PRINCIPAL INVESTIGATORS

**Donald W. Floyd**, Ohio State University

**Jeffrey E. Hanson**, Michigan State University

**David J. Landkamer**, University of Minnesota

**Judith A. Maxwell**, Ohio State University

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### EDUCATION

B.S. Humboldt State University 1974  
M.S. University of Wisconsin 1976  
Ph.D. University of Arizona 1986

### POSITIONS

Assistant Professor, School of Natural Resources, Ohio State University (1988-present)  
Extension Specialist (Natural Resources), University of Arizona (1985-1988)  
Assistant Professor (Extension), Oregon State University (1980-1983)  
Extension Agent, Colorado State University (1978-1980)

### SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

The Wildlife Society  
Society of American Foresters  
Society for Range Management

### SELECTED PUBLICATIONS

- Floyd, D.W. 1988. Reducing multiple use conflicts through experimental stewardship. *Environmental Management* 12(4):457-462.
- Floyd, D.W. 1988. Managing Arizona's riparian habitats. *Arizona land and people*. College of Agriculture, University of Arizona, Tucson.
- Floyd, D.W., P.R. Ogden, B.A. Roundy, G.B. Ruyle, and D. Stewart. 1988. Improving riparian habitats. *Rangelands* 10(3):132-134.
- Floyd, D.W. 1987. The role of user fees in reestablishing a public rangelands coalition. *Renewable Resources Journal* 5(1):15-18.
- Floyd, D.W., and W.R. Frost. 1987. Measuring management objectives with condition classes: time for a change. *Rangelands* 9(4):161-162.



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### EDUCATION

B.S. Whitworth College 1976  
M.S. Washington State University 1982  
M.A. Washington State University 1984  
Ph.D. Washington State University 1987

### POSITIONS

Assistant Professor, Department of Fisheries and Wildlife, Michigan State University (1987-present)  
Economist, U.S. Department of Commerce, National Marine Fisheries Service, Northwest and Alaska fisheries Center, Seattle (1984-1987)  
Graduate Research Assistant, Department of Agricultural Economics, Washington State University (1981-1984)

### SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Agricultural Economics Association  
American Fisheries Society  
Michigan Academy of Science, Arts and Letters  
Ruffed Grouse Society

### SELECTED PUBLICATIONS

- Matulich, S.C., J.E. Hanson, and R.C. Mittelhammer. 1988. A recursive age-structured model of Alaskan red king crab. Alaska Department of Fish and Game, Division of Commercial Fisheries, Fishery Research Bulletin 88-06, Juneau.
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- Hanson, J.E., and R.A. Rustem. 1987. Preliminary economic assessment of angler attitudes toward no-kill regulation of the Au Sable River in Michigan. Research report to the Michigan Department of Natural Resources, Fisheries Division, Lansing.
- Matulich, S.C., and J.E. Hanson. 1986. Modeling supply response in bioeconomic research: an example from wildlife enhancement. Land Economics 62:292-305.

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### EDUCATION

B.S. Utah State University 1977  
M.Ag. Oregon State University 1986

### POSITIONS

Assistant Aquaculture Extension Specialist, Department of Fisheries and Wildlife, University of Minnesota (1987-present)  
Interpretive Ranger, Tuzigoot National Monument, U.S. Department of Interior, National Park Service (1987)  
Instructor/Naturalist, Everglades Center Outdoors, Homestead, Florida (1986-1987)  
Master Gardener/Master Food Preserver, Oregon Extension Service (1986)  
Graduate Assistant, Department of Agriculture and Resource Economics, Oregon State University (1985)  
Research Assistant, Swanson Aquaculture Laboratory, Oregon State University (1984-1985)

### SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Fisheries Society  
World Aquaculture Society  
Canadian Aquaculture Association  
Minnesota Fish Farmers Association

### SELECTED PUBLICATIONS

Landkamer, D.J. 1988. Fish farming. Minnesota Extension Service.  
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### POSITIONS

Assistant Professor, School of Natural Resources, Ohio State University (1985-present)  
Section Head, Australian Department of Primary Industry, Bureau of Agricultural Economics,  
Forestry Economics, Research Section, Canberra (1983-1985)  
Extension Economist, U.S. Department of Agriculture, University of Minnesota (1981-1983)  
Research Assistant, U.S. Department of Agriculture, University of Minnesota (1977-1981)  
Graduate Research Assistant, Department of Forestry and Range Management, Washington State  
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### SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

Association of Environmental and Resource Economics  
American Agricultural Economics Association  
Society of American Foresters  
International Society of Ecological Modelling

### SELECTED PUBLICATIONS

- Costanza, R., S.C. Farber, and J. Maxwell. (In press). The valuation of wetland benefits: Implications for the management of wetland ecosystems. *Ecological Economics*.
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