ADVANCEMENT OF AND A MARKET STUDY FOR WALLEYE AQUACULTURE

Chairperson: Terrence B. Kayes, University of Nebraska-Lincoln

Extension Liaison: Ronald E. Kinnunen, Michigan State University (lead) & Jeffrey L. Gunderson, University of Minnesota-Duluth

Funding Request: $175,000

Duration: 2 Years (September 1, 1995 - August 31, 1997)

Objectives:

1. Evaluate growth, feed efficiency, and stress responses as functions of density, loading, temperature, and feeding regimes (feeding rate and frequency) under tank and open-pond rearing conditions for raising juvenile walleye to food size.

2. Characterize the economics and institutional aspects of the domestic market for walleye as food fish, fingerlings, and other intermediate products.

3. Offer several workshops in the North Central Region, using extension materials (fact sheets, videos, etc.) and other information that has or will be developed necessary to demonstrate the technology of culturing walleye and its hybrids.

4. Complete performance evaluations of walleye × sauger hybrids to finalize research initiated during the 2-year project period of the June 1993 proposal - including studies on fillet yield, proximate analysis, and organoleptic properties.

Proposed Budgets:

Institution	Principal Investigator(s)	Objective(s)	Year 1	Year 2	Total
Illinois Nat. History Survey	David H. Wahl	1	$5,862	$5,863	$11,725
Illinois State University	Patrick D. O'Rourke	2	$13,239	$0	$13,239
Purdue University	Marshall A. Martin Jean R. Riepe	2	$25,355	$0	$25,355
Iowa State University	Robert C. Summerfelt	1 & 3	$25,200	$9,486	$34,686
Kansas State University	Kenneth E. Neils	2	$500	$0	$500
Michigan State University	Ronald E. Kinnunen	3	$2,198	$2,199	$4,397
University of Minnesota	Jeffrey L. Gunderson	3	$488	$489	$977
Univ. of Nebraska-Lincoln	Terrence B. Kayes	1-4	$26,410	$17,162	$43,572
N. Dakota State University	Jay A. Leitch	2	$2,350	$7,421	$9,771
Univ. of Wisc.-Madison	Jeffrey A. Malison	1 & 4	$16,295	$14,483	$30,778
		TOTALS	**$117,897**	**$57,103**	**$175,000**

Non-funded Collaborators:

Facility	Collaborator(s)
Alexandria Technical College, Alexandria, Minnesota	Larry Belusz & Greg Raisanen
Pleasant Valley Fish Farm, McCook, Nebraska	William Hahle
Calamus State Fish Hatchery, Burwell, Nebraska	Nebraska Game & Parks Commission

TABLE OF CONTENTS

JUSTIFICATION

The walleye is a highly valued game and food fish in the North Central Region (NCR), certain parts of the northeastern United States, and central Canada. In the National Aquaculture Development Plan (Joint Subcommittee on Aquaculture 1983), the walleye was recognized as a species for which "strong interest exists for development of intensive culture of fingerlings to market size." The plan further indicated that this interest was driven by a strong market demand, coupled with a drop in landings by commercial fisheries - but also noted that fingerling production itself was a major constraint to walleye aquaculture. Since its inception in 1988, the North Central Regional Aquaculture Center (NCRAC), including both the NCRAC Industry Advisory Council (IAC) and the NCRAC Technical Committee, has identified the walleye as a high-priority species for commercial aquaculture development, based largely on its popularity as a food and game fish.

There is little question that the walleye is a popular sport fish, and is among the most heavily exploited fish species in North America (Kendall 1978). Except for the harvests of a few tribal fisheries in Minnesota and Wisconsin, commercial fishing for walleye in the U.S. has been prohibited to safeguard wild populations for exclusive exploitation by sport anglers and Native American tribes. To maintain these populations, various fisheries management agencies in North America collectively stock over one billion walleye fry and fingerlings each year (Conover 1986). Given this level of stocking, many such agencies in the U.S. and Canada have for years conducted applied research on various aspects of walleye culture (Coolwater Culture Workshop 1984 through 1994), as well as evaluations of stocking success (Ellison and Franzin 1992).

The fish culture activities traditionally associated with producing walleye for stocking include: (1) the collection and fertilization of eggs with milt from sexually mature wild adults captured during the normal spawning season; (2) incubating the eggs, hatching fry, and stocking them in ponds; and (3) pond-rearing the fry to fingerling size. Large numbers of fingerlings can be raised to a size of 25-50 mm total length (TL) by traditional pond-culture methods (Beyerle 1979; Fox 1989). However, the survival and production of fish by these methods can be highly variable, depending on circumstances. In most instances, walleye fingerlings of this size are harvested in late spring or early summer. Some agencies, as well as many commercial walleye producers in Minnesota, raise much larger fingerlings by stocking fry or small fingerlings in ponds at low rearing densities, and harvesting them in the late summer or autumn, when the fish reach 100-150 mm TL.

However, it is difficult to rear large numbers of walleye to sizes greater than 100 mm TL without providing forage fish, which is expensive. Accordingly, research on walleye culture by fisheries management agencies in recent years has focused largely on developing and improving procedures for training pond-reared early (25-50 mm TL) fingerlings to formulated feed in tanks (Cheshire and Steele 1972; Nagel 1974, 1976; Bayerle 1975; Nickum 1986). Factors that have been studied include stocking density, water temperature, light intensity and color, diet formulation, and feeding frequency (Nickum 1986; Summerfelt 1990), but nearly all such studies have been limited to walleye between 35 and 150 mm TL.

Considering the level of interest in the NCR in walleye aquaculture, remarkably little is known about the culture requirements of this species at sizes above 150 mm TL. A number of research laboratories and fish hatcheries in the region have reared walleye to food size for various reasons (e.g., for potential brood stock), but not in large numbers under production conditions. In 1990, a fairly large-scale attempt to rear food-size walleye was initiated by Aquaculture, Inc., Rolla, Missouri (NCRAC Journal 1990), but that company is no longer operating (L. Belusz, Alexandria Technical College, Alexandria, Minnesota, personal communication). More recently, other commercial enterprises have begun efforts to rear walleye to food size (T. Herz, Brandon Fisheries, Brandon, Minnesota, personal communication). However, these efforts are not based on a body of information published in the scientific literature.

Paralleling the activities of fisheries management agencies, commercial walleye aquaculture in the NCR has for decades been geared to the production and sale of fry and pond-reared fingerlings. Commercial walleye producers sell fry and fingerlings for stocking to lake associations, sportsmans clubs, municipalities, public and private electrical utilities, and individual lake and pond owners. For many years, excellent market prices for walleye fry and fingerlings bolstered such commercial production, as has the prospect of the eventual development of a food fish production industry. Newly hatched fry have sold for 1-1.5¢ each, and fish of 35-100 mm TL have been sold by producers for 25-75¢ each, and higher. The growth of private-sector pond production of walleye fingerlings has been particularly pronounced in Minnesota and Wisconsin, with some expansion as well in Illinois, Iowa, Michigan, and Nebraska. However, the market for fingerlings now appears to be saturated, and producers have an abundant supply of fish for rearing to food size.

Along with the popularity of walleye as a food and game fish, two factors that reinforce the rationale for the development of a walleye aquaculture industry in the U.S. are the high prices typically seen in retail markets for fillets, and the knowledge that nearly all food-size walleye marketed in the U.S. are imported from Canada, where they are harvested commercially from the wild. By all appearances, there is a limited and perhaps even declining supply of food-size walleye for commercial markets. For example, between 1973 and 1979, the commercial harvest of walleye in the Province of Manitoba was only 65% of the average annual harvest between 1945 and 1954 (Sifa and Ayles 1981). As a consequence of limited supply, retail prices for walleye fillets have ranged from $11.50-25.35/kg ($5.30-11.50/lb) since 1988. Such prices are encouraging to potential producers and advocates of walleye aquaculture. However, high retail prices do not provide insights into the complexities of fisheries products marketing, which in the long run is a major factor determining profitability.

Accurate market information is vital to any industry, including commercial aquaculture. Market information is particularly critical to industries during their initial stages of development, when such information can be especially difficult to obtain. Little has been published about the supply and demand relationships that shape the market for walleye, either historically or recently. Evidence suggests that interest in this species as a food fish is high in markets in close proximity to the Great Lakes and in the northern tier of states in the NCR, as well as central Canada. However, most of this evidence is anecdotal. National surveys by economists in the southern states have not shown interest in consuming walleye to be a national phenomenon (Engle et al. 1990).

On the supply side, exact sources and levels of availability of walleye, as well as prices paid for walleye products in market channels, are not well documented. From the available statistics summarized in Table 1, Canada is clearly the primary source of walleye consumed in the U.S. One critical factor not presently known is the extent to which Canadian wild harvests and imports could be increased to drive down prices, thereby stifling the development of a domestic walleye aquaculture industry. Concern over this possibility has been repeatedly expressed at NCRAC annual program planning meetings over the past several years.

Table 1. United States commercial catch and Canadian exports to the United States of walleye, 1981-1993.

Year	U.S. commercial catch[a] (metric tons)	Canadian exports to U.S.[b] (metric tons)	Year	U.S. commercial catch[a] (metric tons)	Canadian exports to U.S.[b] (metric tons)
1981	33	2,231	1988	9	1,861
1982	38	3,155	1989	13	1,492
1983	38	3,521	1990	9	2,662
1984	51	3,047	1991	10	2,371
1985	63	3,043	1992	N/A	2,195
1986	9	3,119	1993	N/A	2,908
1987	10	2,526			

[a]Various reports from the U.S. Fish and Wildlife Service, and the U.S. Department of Commerce.
[b]Various reports from the Canadian Department of Fisheries and Oceans.

The domestic markets for walleye products are influenced by: (1) the structure of the fisheries products industry; (2) state and federal fisheries and food industry regulations, and fisheries management priorities; (3) Native American commercial fisheries harvests; and (4) international markets. The North American Free Trade Agreement (NAFTA) may have a significant impact on the extent of walleye imports from Canada, ultimately affecting U.S. market prices. The viability of any newly developed walleye aquaculture industry will depend on consumer preferences, the magnitude of imports from Canada, and commercial catches by Native American tribes. An understanding of such institutional structures and related economic factors is essential to fully assess both existing and potential markets for walleye products.

Knowledge of various aspects of walleye marketing, such as desired product forms, prices paid, product size, sources of supply, etc., is necessary to determine whether the commercial production of walleye will be able to survive economically in the marketplace. Market information will also help guide researchers working on production technologies, who need to know market preferences for size, quantity, and seasonal fluctuations in demand. Potential walleye aquaculturists need concrete information on these factors, as well as on expected prices and market locations. Solid market information is vital to any good business plan, regardless of whether the plan is for the aquaculturist's own use, or will be submitted to bankers or venture capitalists to support investment decisions. Studies on walleye markets and the institutional structures controlling them are badly needed, because this type of information is difficult for individual entrepreneurs to obtain and properly evaluate on their own.

The production and marketing of walleye fingerlings is also strongly influenced by many of the same economic and institutional factors that affect food fish aquaculture. There is an interesting and changing mix of private and public involvement in the production of walleye fingerlings for public and private stocking. Present indications suggest increased privatization of many services traditionally provided by government, including fish production for stocking. If a larger proportion of walleye fingerlings for stocking is to come from commercial sources in the future, then information on historic and potential production capacity, as well as pricing, is badly needed, both for private-sector planning and for government policy making.

Since 1988, the various Research Work Groups and the Extension Work Group of NCRAC have operated largely as separate entities with distinctly different priorities. The main goal of most of the NCRAC Research Work Groups has been to pursue selected research objectives on key species or types of fishes identified as having significant potential for aquaculture development in the NCR. At the first NCRAC annual program planning meeting held in May 1988 in East Lansing, Michigan, the Research Subcommittee of the NCRAC Technical Committee ranked "brood stock development" and "early life stages production" as the number 1 and 2 research priorities for walleye. "Production systems," presumably of food-size fish, ranked third; "supply/demand characteristics" was listed, but not included in the top four priority research subject areas identified. The NCRAC Board of Directors essentially endorsed these priority rankings, and the first NCRAC Walleye Work Group was subsequently formed.

In light of the top priority ranking assigned to brood stock development, the first two NCRAC Walleye Work Groups, in three separate projects extending from May of 1989 to September of 1993, focused their efforts primarily on key aspects of genetic selection of various wild and captive walleye stocks for the eventual development of domesticated lines of brood stock, and secondarily on characterizing the annual reproductive cycle and developing procedures for manipulating walleye spawning. Certain specific problem areas associated with intensive walleye fry culture and pond fingerling production were also addressed. The specific objectives of these three projects, which have since been completed, were as follows:

> Project 1: (1) develop baseline information on mechanisms regulating the natural reproductive cycle of wild and pond-held walleye by characterizing seasonal changes in hormone titers and gonadal histology, (2) evaluate zooplankton seeding and clam shrimp control strategies for pond culture of walleye fingerlings, and (3) determine the etiology on non-inflation of the gas bladder in intensively cultured walleye fry.
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> Project 2: (1) develop baseline information on genetic composition of walleye populations for potential use as brood stock, and (2) conduct comparisons of phenotypic characterisics of progeny from selected walleye brood stock.
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> Project 3: (1) develop methods for manipulating the annual reproductive cycle of walleye to induce out-of-season spawning, and (2) measure genetic parameters required for efficient selection on fry and fingerling traits, using pedigreed families.

At the 1992 NCRAC Program Planning Meeting held February 14-16, in Columbus, Ohio, the NCRAC IAC expressed a strong desire for a shift in priorities, including an increased focus on applied research that produces results having greater potential for near-term benefit or use, and the production of more tangible techniques-centered educational tools that can help fish farmers culture those species indentified by NCRAC as having significant potential for commercial aquaculture. Concerns were also expressed regarding the lack of information on production costs for rearing these species. Responding to the needs and concerns expressed by the IAC, the NCRAC Board of Directors moved to bring closure to the heavy research emphasis on walleye brood stock development, and to implement a more "issues-centered," problem-solving approach to programming. Accomplishing such a goal necessarily calls for greater interaction among the various NCRAC work groups, individual investigators and extension professionals with different types of expertise, and the region's fish farmers.

To achieve this level of interaction and provide a necessary transition period, the NCRAC Walleye Work Group initiated a project in September 1993 to: (1) measure genetic parameters required for efficient combined selection on sub-adult and adult traits, using a pedigreed population of walleye; (2) compare performance (survival, growth, feed conversion) of walleye hybrids produced from different parental stocks reared under intensive and tandem extensive-intensive culture systems; and (3) conduct field trials that compare effectiveness and cost of different pond and tank culture strategies for producing advanced fingerlings. At the same time, the NCRAC Economics and Marketing Work Group began a project to "develop cost of production budgets and expected revenues for the raising of food-size walleye, yellow perch, and hybrid striped bass on farms in the NCR." As part of the walleye project, production data from the field trials (Objective 3) can be made available to the Economics and Marketing Work Group for appropriate economic analysis. These walleye and economic work group projects are both in progress, and will continue until September 1995.

The principal objectives of the NCRAC Extension Work Group have been to: (1) develop linkages with the various NCRAC Research Work Groups, (2) establish a NCRAC extension network for aquaculture information transfer, (3) provide inservice training to selected landowner assistance personnel, and (4) develop educational programs for the NCR. To date, the Extension Work Group's educational activities have focused primarily on the production of a number of fact sheets and bulletins and on holding workshops and a conference on an array of topics. As yet, no educational materials specifically centered on the research findings of the NCRAC Walleye Work Group have been produced. However, a NCRAC fact sheet on the conventional pond culture of walleye fingerlings has been published (Harding et al. 1992), and work is underway on the development of a walleye culture guide, as part of the ongoing NCRAC Extension Work Group project.

With projects underway to compare the effectiveness of pond and tank culture strategies for producing advanced walleye fingerlings, develop cost of production budgets and expected revenues for raising walleye, and produce an extension culture guide, the decision was made at the 1994 NCRAC Program Planning Meeting held February 4-6, in Lincoln, Nebraska, to initiate work on developing techniques for commercially culturing food-size walleye, to systematically investigate walleye markets and the factors influencing them, and to expand extension efforts on walleye aquaculture - all in a more integrated interdisciplinary fashion. Targeted objectives identified for the 1995-1997 Walleye Work Group project are to: (1) evaluate the growth, feed efficiency, and stress responses of walleye being reared to food size under various tank and open-pond production conditions; (2) characterize the economic and institutional aspects of the domestic markets for food-size and fingerling walleye; (3) conduct workshops and develop additional extension educational materials (e.g., videotapes) on various aspects of culturing the walleye and its hybrids; and (4) complete grow-out and performance evaluations of walleye × sauger hybrids. There was general agreement that ongoing research on the latter should be completed, because studies to date clearly suggest that hybrid walleye may be better suited to commercial aquaculture than purebred walleye.

The Walleye Work Group formed to address the four stated objectives of the proposed project is comprised of a mix of 11 research biologists, economists, and extension professionals, with a variety of different types of specific expertise, from nine states and 10 different institutions: the Illinois Natural History Survey (ILNHS), Illinois State University (ILSU), Purdue University (Purdue), Iowa State University (ISU), Kansas State University (KSU), Michigan State University (MSU), University of Minnesota (UMN), University of Nebraska-Lincoln (UNL), North Dakota State University (NDSU), and University of Wisconsin-Madison (UW-Madison).

RELATED CURRENT AND PREVIOUS WORK

Over the past 40 years, significant amounts of information have been published on fingerling walleye culture in the scientific literature and in government agency papers and reports (see references cited under **JUSTIFICATION**). Since 1988, various NCRAC Walleye Work Groups have made major advances in: (1) developing a technology for intensively culturing walleye fry to fingerlings on formulated feed in tanks; (2) greatly improving procedures for producing walleye fingerlings in ponds, and training these fish to formulated feed, both in tanks and directly in ponds; (3) characterizing the annual reproductive cycle of walleye, and developing techniques for inducing out-of-season spawning; (4) elaborating procedures to differentiate between different walleye genetic stocks, and identifying stocks with positive traits that suggest that they may be good candidates as starting points for the development of domesticated brood stocks; and (5) demonstrating that selected walleye × sauger hybrids may have greater potential for commercial aquaculture than purebred walleye.

More information on these advances made by the various Walleye Work Groups since 1988 is available in progress reports submitted to, and available from, the NCRAC Director's Office at MSU, or can be obtained from the chair, extension liaison, or other appropriate members of the present Walleye Work Group. This project proposal addresses the four targeted objectives that are outlined in the **JUSTIFICATION** section, and are described in greater detail below.

Evaulate Tank and Pond Rearing of Walleye to Food Size (Objective 1)

Although a few fish producers and researchers have reared walleye to food size, the only published report in this regard is by Siegwarth and Summerfelt (1993). The fish in their study grew much more slowly than walleye in many wild populations (Nickum 1978). Based on a growth curve for walleye that were reared from hatching to 783 d of age in small tanks at about 21°C, Siegwarth and Summerfelt (1993) estimated that it would take 965 d in a controlled environment for walleye to reach 0.68 kg, a typical size for the food fish market. Such slow growth rates for large walleye have also been observed by other researchers (e.g., J. Malison, UW-Madison and T. Kayes, UNL, unpublished observations), and are particularly surprising in light of the fact that near optimal temperatures and photoperiods can be maintained in a laboratory, whereas such conditions exist for only about half the year in the wild.

To our knowledge, no substantive studies have been conducted to determine why large walleye exhibit such poor growth and performance when reared under intensive culture conditions. In other fish species, however, a wide variety of factors are known to have major impacts on growth. Some of the most important of these include: feeds and feeding systems, temperature, loading, rearing density, spatial requirements, and the general culture method employed. Feeding systems (i.e., all feeding standards and practices; Cho 1992) directly affect growth, feed efficiency, and fish health. Feeding systems include the protein and energy contents of the feed, daily ration, and parameters such as pellet size, feeding frequency, and method of feeding. Almost nothing is known about feeding systems in walleye culture, including methods of calculating feeding rates.

The best temperature for rearing advanced fingerlings to food size has also not been established for walleye. Smith and Koenst (1975) reported 22°C as the temperature for optimum growth rate of fingerlings at a light intensity of 230 lx, but Hokanson and Koenst (1986) found that the optimum level for growth of fingerling walleye was 26°C when light intensity was 5 lx. The effect of light (photoperiod and light intensity) on fish growth is often not considered to be an independent controlling factor (Huh et al. 1976). However, Hokanson and Koenst (1986) stated that the higher temperature for optimum growth of walleye observed in their study, compared to that of Smith and Koenst (1975), was due to a difference in light intensity between the two experiments, which suggests that the optimal temperature for walleye growth may be inversely related to light intensity.

Cai and Summerfelt (1992) calculated 25.3°C as the maximum metabolic rate (oxygen consumption, mg/kg/h) of walleye from a light-temperature relationship. The temperature for maximum food intake and growth (i.e., 25°C), however, may be too high for commercial aquaculture. The food intake and specific growth rate of fish fall dramatically at temperatures slightly greater than those that result in optimum growth (Brett 1979; Jobling et al. 1993). Moreover, walleye seem to be highly sensitive to columnaris (*Flexibacter columnaris*) and bacterial gill disease (*Flavobacterium branchiophila*), both of which are more of a problem at 25°C than at 20°C. Based on what has already been published on walleye, we propose to evaluate temperatures of 20 and 24°C in a tank culture system using in-tank lighting.

Loading, rearing density, and spatial requirements are interrelated parameters that play major roles in determining production costs as well as affecting the growth and performance of walleye reared under intensive culture conditions. Loading is critical in intensive culture systems because of its effect on oxygen and toxic metabolite levels. Rearing density, because of its effects on aggressive behavior, feeding behavior, and the social interactions of fish, also greatly impacts fish growth. In one unpublished study, UW-Madison investigators observed reduced survival and increased rates of cannibalism when walleye fingerlings were raised at 5 fish/L, as compared to 3 fish/L. Little, however, is known about the effects of rearing density in larger walleye. Spatial constraints also greatly influence growth in many fish species. Siegwarth and Summerfelt (1992) reported that spatial constraints may have caused the poor growth rates that they observed in tank-cultured walleye. Confirming this report are the (unpublished) observations of UW-Madison researchers, who found that walleye reared in 750-L and 12,000-L tanks grew more than 60% faster than fish reared in 220-L tanks (similar-size walleye reared at the same densities, loadings and temperature).

From a broader perspective, culture methods themselves (e.g., tanks, ponds, or net pens) can have a significant effect on the growth and performance of cultured fish (Stickney 1986). Newton (1992) has reviewed the relative merits of pond and cage culture in catfish and rainbow trout, and concluded that the selection of a rearing method is highly species- and site-specific. Similarly, the development of food fish production techniques for striped bass in the mid-Atlantic states incorporated the evaluation of performance characteristics and cost-effectiveness in earthen ponds, circular cages, and cages placed in an estuary (Kerby 1986). To date, almost all studies on the culture of large walleye have been conducted in tanks or raceways. These methods for the commercial production of food-size walleye, however, may not be the most cost-effective. Several small-scale attempts at net-pen culture of food-size walleye (e.g., C. Stevens, Knoxville, Iowa, personal communication) have suggested that the growth of walleye reared in net-pens, just as in tanks, is quite slow.

Open pond culture of food-size walleye is an alternative to tank or net-pen culture that has not been investigated to date. Some advantages of open pond culture are that large numbers of fish can be produced at a comparatively low cost in labor and capital equipment, fish growth, performance and survival may be greatly improved, due to factors such as lower rearing densities and reduced stress levels. Although pond culture has not yet become a common grow-out method for food fish in the northern U.S., studies on the pond production of yellow perch to food size in southern Wisconsin have shown considerable promise (NCRAC 1993). In these studies, a high percentage of 1-year old (25 g) yellow perch fingerlings stocked in spring reached a market size of 100 g by fall. Similarly with walleye, stocking a 1-year old 150 g fingerling in April may yield a food-size fish (>450 g) by late fall.

Some factors that control or limit fish growth, such as feeds and temperature, exert their effects primarily by direct metabolic actions. Other factors, however, such as rearing density, spatial requirements, general culture methods, and fish husbandry procedures, impact growth largely by the degree to which they stress fish. It is well established that there are severe negative consequences of physiological stress on the growth, disease resistance, and performance of intensively cultured fish (Schreck 1981; Adams 1990; Barton and Iwama 1991; Pickering 1993). Most fish culturists and researchers who work with walleye have observed that this species is very excitable when reared under intensive culture conditions, and is extremely sensitive to nearby noise, shadows, and movements (Nagel 1976; Malison et al. 1990; Siegwarth and Summerfelt 1992). Fish managers have frequently identified stress as a probable cause of many incidents of disease and mortalities in walleye (Schneider 1979; Johnson et al. 1988). These and other observations strongly suggest that stress is a particularly important problem in walleye aquaculture. Despite this, almost nothing is known about the physiological stress responses of walleye, and the extent to which management and culture strategies can be refined in order to minimize stress.

The physiological stress response of fish begins with the perception of a stressor by the brain which triggers the release of corticotropin releasing factor and possibly other adrenocorticotropic hormone (ACTH) secretagogues (Donaldson 1981). In response to these agents, ACTH is released from the anterior pituitary, and subsequently acts on the interrenal to stimulate corticosteroid production and release (Donaldson 1981;

Sumpter and Donaldson 1986). Corticosteroids, primarily cortisol, then act on various target tissues to induce a broad spectrum of physiological responses. Wedemeyer and McLeay (1981) classified the stress response as follows: (1) primary alterations, consisting of the aforementioned neural and hormonal changes, and the release of catecholamines; (2) secondary alterations, characterized by changes in physiological parameters such as serum osmolality and concentrations of glucose and chloride; and (3) tertiary effects, referring to whole-animal measures such as growth, reproduction, and incidence of disease or death.

The adaptive significance of the physiological stress response in fish is the maintenance of homeostasis following exposure to a stressor (Wedemeyer and McLeay 1981). However, the stress response can also have profound maladaptive or negative consequences in fish. Two of the best documented effects in this regard are the stress-induced suppression of somatic growth and immune function (see Barton and Iwama 1991). Cultured fish are often exposed to many routine and unavoidable aquaculture procedures and conditions such as netting, handling, size-grading, crowding, hauling, tank cleaning and sub-optimal water quality. Such procedures often induce a physiological stress response (Donaldson 1981; other reviews in Pickering 1981). Schreck (1981) theorized that the intensity of a fish's stress response has a major "psychological" component and is governed by the extent to which stressors cause fright, discomfort or pain. Consequently, many aquaculture procedures, which are harmless in themselves, evoke a physiological stress response, which in turn can have detrimental effects on the growth and performance of cultured fish.

Almost nothing is known about the stress physiology of coolwater percids. As part of an ongoing project funded by the University of Wisconsin Sea Grant Institute, UW-Madison investigators are currently developing methods of assessing stress in both walleye and yellow perch. As an important part of these Sea Grant investigations, acute stressors applied as challenge tests will be used to assess the overall "stress load" on the fish, as initially proposed by Wedemeyer and McLeay (1981). For this NCRAC project, we propose to assess stress levels in walleye reared under different culture conditions using various husbandry procedures, and then use these stress measures to identify "least-stress" culture methods.

To develop walleye aquaculture in the Midwest, producers need information on such critical factors as feeding rates for different temperature regimes, optimum loading and rearing densities, and fish sizes obtainable in both tank and pond settings. Time and money are always limiting factors in research, and that is obviously true for the proposed project. Obtaining statistically valid results to answer the many facets of Objective 1, as stipulated by the NCRAC Board of Directors, would require complicated experimental designs that could only be achieved with very large and elaborate research facilities and many years of effort. Thus, the extent of experimental work required to evaluate all of the indicated variables exceeds the budget and 2-year time constraints for the project. Therefore, the procedures outlined for Objective 1 are able to target only on selected subsets of the variables listed for the objective. Hopefully, future projects will be able to address those variables not investigated in the proposed project.

As a partial way to address the need for many sets of complex and expensive multi-factorial experiments, a bioenergetics model will be developed that can simulate feeding rates for walleye of different sizes reared at different temperatures. Bioenergetics models are mathematical equations based on laboratory- derived data from experiments that incorporate information on body size and temperature to evaluate relationships between feeding rate and growth. These models have been developed for a wide range of fishes, but have not been adequately tested or applied to aquaculture questions. In our study, we will modify and update parameters of a bioenergetics model for walleye. The resulting model will then be tested in typical aquaculture settings, using information collected during the project, for tank (ISU, UNL, and UW-Madison) and pond (UNL and UW-Madison) culture of walleye. Once the model is tested and calibrated, it should be a useful tool for making recommendations regarding feeding and growth rates of walleye under different aquaculture conditions.

Growth in fish depends upon feeding rates, fish size, and water temperature. As a result, growth can be predicted using laboratory-derived estimates of food consumption and metabolism as functions of body weight and temperature. These parameters can be simply summarized and evaluated by a bioenergetics model. Such models are based on a mass balance equation: $G = C - (R + F + U)$ (Kitchell et al. 1977), where G is the specific growth rate or the difference between food consumption and energy losses. Consumption (C) or the specific feeding rate, and respiration or metabolism (R) are determined by water temperature and fish size. Egestion (E) and excretion (U) are functions of food consumption and water temperature. By developing equations for each of these parameters, growth can be estimated for a variety of conditions, including feeding rates, body size, and water temperature.

A preliminary model has been developed for walleye (Kitchell et al. 1977), but will need to be modified before it can be applied to juvenile through food-size fish. Parameters for the first walleye bioenergetics model were for age-3+ fish, and used food consumption, respiration, and waste parameters for yellow perch, with a modification for optimal and maximum temperatures. Post (1990) found that respiration and food consumption are allometric functions, and values for adult yellow perch should not be used for larval and juvenile fish. As a result, there is a need for a bioenergetics model that includes parameters for a range of walleye sizes.

Bioenergetics models have been applied to a variety of field situations, although there has been a general lack of testing of the accuracy of values from these models (Ney 1993; Wahl and Stein 1991). Many of the recent criticisms of bioenergetics models have revolved around a lack of good estimates of activity levels in natural populations (Boisclair and Leggett 1989), which should not be a critical factor in the confined areas used in aquaculture operations, except for differences in water current with exchange rates. In addition, previous models have been tested against results from fish fed live forage, rather than the formulated diets commonly used in aquaculture. Therefore, before results from bioenergetics models can be applied to aquaculture situations, they must be verified using tank and pond data. With such comparisons, bioenergetics models can be calibrated to make them applicable to aquaculture.

Characterize the Domestic Markets for Walleye (Objective 2)

Aquaculture is a fledgling industry in the NCR. Because of this, very little information is published about fish production or producers in the region, or about the marketability of freshwater species. In this section, we report on the past and current efforts of the Economics and Marketing Work Group related to the research proposed for Objective 2, and on the past activities of the NCRAC investigators addressing Objective 2.

<u>Efforts of Past Economics and Marketing Work Groups</u>

A total of 893 fish growers were identified and surveyed in the 12 states of the NCR in 1991 under a prior NCRAC economics and marketing project (Brown and Hushak 1991). There were 295 usable responses from the 451 respondents, who grew fish in the 12 states. The states with the most growers were Wisconsin, Minnesota, Ohio, Missouri, Michigan, and Illinois.

The most common species produced in the region were salmonids followed by catfish, bass, baitfish, sunfish, walleye, yellow perch, carp, crustaceans (including shrimp), temperate bass, pike, and tilapia. Table 2 shows the number of producers raising these species by state. The two most frequently grown species for food were trout and catfish. Of the 295 grower respondents, 104 or 35% raised trout, while 105 or 36% raised catfish. The total number of producers raising the surveyed species by state are also listed in Table 2.

One-fifth of the respondents stated that their aquaculture business represented 75 to 100% of their family income, while 64% raised fish as a supplement to their income or a "money-making" hobby. Fifty-seven percent reported their gross sales were less than $10,000, compared to 16% who declared gross sales exceeding $100,000.

Table 2. Number of producers raising species by state (Hushak 1993).

STATE	IL	IN	IA	KS	MI	MN	MO	NE	OH	SD	WI	TOTAL
SPECIES												
Baitfish[1]	6	3	4	6	5	26	10	7	16	1	9	93
Bass[2]	7	6	5	5	6	9	7	10	24		22	101
Carp[3]		5	2	5			11	2	8		1	34
Catfish	15	7	10	17	4	1	20	13	14	1	5	107
Crustaceans[4]	4	1		2			2	1	6			16
Perch					8	5		6	12	1	9	41
Pike	1		1		1	5			1	1	3	13
Temp. bass[5]	2	3	2	1			3		3			14
Tilapia	1		2	1			1		1		1	7
Salmonids[6]		1	4	2	19	13	5	16	9	2	39	110
Sunfish[7]	6	7	6	4	7	6	9	6	23		14	88
Walleye	**3**		**6**		**3**	**19**		**2**	**1**		**13**	**47**
Respondents	22	12	18	19	26	50	27	22	33	3	54	286

[1]Includes minnows (bluntnose, chub, fathead, red, and rosey red), shiners (golden and redfin), gambusia, horny head chub, buffalo fish, leeches, suckers, and tadpoles.
[2]Includes bass (black, largemouth, smallmouth, and rock) and crappie (black and white).
[3]Includes carp (bighead and grass), coppernose bream, goldfish, koi, and white amur.
[4]Includes shrimp.
[5]Includes bass (hybrid striped, striped, and white) and striped perch.
[6]Includes trout (brook, brown, Donaldson, golden, rainbow, steelhead, and tiger), salmon (Atlantic and coho), and Sunapee.
[7]Includes bluegill, hybrid bluegill, sunfish (green and hybrid), redear, and warmouth.

The most significant species by gross sales were salmonids (44% or $6,718,000), catfish (19% or $2,585,000), baitfish (14% or $1,888,000), walleye (8% or $1,108,000), and bass (5% or $653,000). The total gross sales by species and by state are listed in Table 3. Missouri reported the highest gross sales followed by Minnesota, Wisconsin, Ohio, Kansas, and Nebraska, with a regional total of $18,669,000.

Hushak (1993) and Hushak et al. (1993) investigated the fish and seafood (wild-caught and farm-raised) marketing channels in the NCR. These researchers found that fisheries products marketing firms in the region typically perform multiple functions (producer, processor, wholesaler, distributor, retailer, etc.). The majority of firms with farm-raised products reported sales of these products apparently passing through marketing channels in less traditional ways than wild-caught fish. The percentages of firms reporting that they sold walleye products differed greatly between the two Hushak publications, but a strong market potential for farm-raised walleye was indicated. Unfortunately, restaurants were not included in either survey.

In a study not funded by NCRAC, titled "Marketing Michigan Aquacultural Products," Chopak (1994) surveyed consumers as well as aquaculturists and fish marketing firms (brokers, wholesalers, retailers, and restaurants). Results showed that aquaculturists in Michigan have been able to sell their products to all types and sizes of firms in various marketing channels. While Michigan consumers rated yellow perch as their favorite fish, walleye ranked eighth in the top ten species.

Table 3. Gross sales by species and by state of five most prevalent species ($U.S. × 1000) (Hushak 1993).[1]

STATE	IL	IN	IA	KS	MI	MN	MO	NE	OH	SD	WI	TOTAL
SPECIES												
Baitfish	6	0	1	9	3	1,420	306	6	4	NR[2]	135	1,888
Bass	113	120	61	3	1	63	19	74	128	0	74	654
Catfish	169	130	116	98	24	NR	1,897	81	69	NR	1	2,585
Salmonids	0	NR	5	NR	573	1,134	1,714	585	786	NR	1,355	6,178
Walleye	**7**	**0**	**156**	**0**	**15**	**894**	**0**	**NR**	**NR**	**0**	**32**	**1,108**
TOTAL[3]	424	1,042	630	1,252	924	4,488	4,700	1,073	1,508	310	2,320	18,669

[1]Excluding sales from businesses that strictly capture baitfish, or those with fee-fishing operations using full-grown fish.
[2]NR = not reported due to confidentiality.
[3]Totals include species reported but not included in this table.

Efforts of Current Economics and Marketing Work Group

Pat O'Rourke and Jean Riepe are presently involved in developing cost-of-production budgets for walleye and yellow perch as part of the currently funded NCRAC economics and marketing project. In that work, they are assembling technical, economic, and some marketing information from three major sources: producers, vendors, and recognized experts (mostly research scientists).

The cost-of-production estimates developed in the present economics and marketing project, when considered together with the marketing and institutional information developed in this proposed project, are expected to be of great value to producers or potential investors/producers. While this newly developed information will not eliminate the significant uncertainties of aquaculture production, it will provide for better informed decision making.

Past Activities of the Proposed Work Group's Economics and Marketing Investigators

Pat O'Rourke of ILSU has been engaged in agribusiness management teaching and research for over 15 years. Since 1988, he has specifically been engaged in the economic analysis of commercial aquaculture in the Midwest. The focus of his research has been on ascertaining the economic viability of commercial food fish production in the Midwest, particularly in Illinois. That work has included the synthesis of cost-of-production budgets for commercial-scale food fish production and commercial-scale walleye fingerling production.

One serious limitation to these cost-of-production studies has been the lack of available data from commercial producers for several species with recognized aquaculture potential for the region (especially walleye, yellow perch, and hybrid striped bass). Although there are some basic cost-of-production data available for hybrid striped bass, verifiable cost-of-production data for the other two species are almost non-existent.

O'Rourke and other researchers at ILSU have conducted field trials on aquaculture production systems at the ILSU Laboratory Farm and ADM, Inc. headquarters in Decatur, Illinois. They have developed several simulation models for fish production in indoor intensive recirculating aquaculture systems. These systems, if economically viable, could be important to the future of commercial fish production in the Midwest for several reasons: (1) environmental control is enhanced with respect to water quality, temperature, and potential contaminants; (2) predator control is improved; and (3) year-round production and marketing are facilitated. These simulation models of indoor recirculating sytems can be adapted to generate pond or raceway production system simulations.

Ken Neils of KSU has worked extensively in commercial aquaculture production, marketing, extension, and research, both domestically and internationally since 1972. He has developed economic, financial, and marketing feasibility studies for many private aquaculture companies, including one he managed for six years. More recently, he has been a principal investigator on aquaculture feasibility projects jointly conducted by the KSU Food and Feed Grains Institute and the Oceanic Institute in Hawaii. The focus of the aquaculture project work at KSU involves marketing of various aquaculture products, and the feasibility of modifying feed formulations.

Jay Leitch of NDSU has been actively involved in projects to assess the economic development potential of alternative uses of various resources, including using waste-heat from coal-fired power plants as an input for aquaculture in cold climates. The Experiment Station at Carrington, North Dakota, has been involved with aquaculture research and is constructing an experimental production facility. Leitch has authored/co-authored nearly 300 research publications, much of his work having been interdisciplinary and international in nature. A recent five-year project involved extensive collaboration with researchers from the Canadian Freshwater Institute and the University of Manitoba.

Jean Riepe of Purdue, in a recent study not funded by NCRAC, surveyed a large sample of Indiana restaurants regarding their fish sales, purchasing behavior, and attitudes regarding farm-raised fish (Riepe et al. 1993). The results showed that walleye was the seventh most popular species. Of the restaurants that reported walleye as one of their three most popular species, over two-thirds: (1) were located in the northern third of the state; (2) were situated in suburban or urban locations; and/or (3) had a fish sales volume that placed them in the upper half of all responding restaurants.

All the fisheries products marketing surveys conducted to date in the NCR have been limited in ways that make them unsuitable as sources of the information necessary to achieve Objective 2. Hushak (1993) and Hushak et al. (1993) focused on firms in fisheries products marketing channels in order to determine market functions, relationships, and general preferences. Also, sample size by these researchers was small. The Michigan study done by Chopak (1994) also utilized a small sample size, was limited to one state, and focused primarily on farm-raised fish. The survey by Riepe et al. (1993), while having a large sample size, was limited to only one type of fish marketing outlet (i.e., restaurants). None of these surveys included all types of marketing firms in all the states of the NCR, particularly with respect to requests for extensive market information specific to walleye. This is not surprising, however, because market surveys are necessarily limited in scope, oftentimes extremely so.

Offer Workshops and Develop Extension Materials (Objective 3)

While significant amounts of information have been published on fingerling walleye culture in the scientific literature and in government agency papers and reports, extension efforts to disseminate information on walleye aquaculture have been small, fragmented, and limited almost entirely to the production of fact sheets and other printed materials on conventional methods of rearing fingerlings in ponds (e.g., Buttner 1989; Harding et al. 1992). With respect to NCRAC, certain members of the Walleye Work Group for years have routinely given talks and research updates at various local, state, and regional meetings and aquaculture conferences; but as yet, no educational materials or programmed activities specifically centered on recently developed culture techniques or the practical information generated by the research findings of the Walleye Work Group have been produced or put into action.

To address this deficiency, the NCRAC Extension Work Group in 1993 initiated an effort to produce a walleye culture guide, led by Robert Summerfelt of ISU, with the aid of a six-member committee comprised of NCRAC administrative, research, extension, and industry representatives. This guide should be completed and ready for release by the autumn of 1995. This proposed project by the Walleye Work Group will build on this development through Objective 3, by conducting workshops and producing techniques-centered videotapes on conventional and recently developed walleye culture methods. In addition, members of the work group will continue to give talks and research updates at meetings and conferences.

Complete Performance Evaluations of Walleye × Sauger Hybrids (Objective 4)

With certain fish species, interspecific crossbreeding has resulted in hybrids having behavioral and growth characteristics better suited for intensive culture than those of purebred fishes. For example, muskellunge (*Esox masquinongy*) × northern pike (*E. lucius*), striped bass (*Morone saxatilis*) × white bass (*M. chrysops*) and plaice (*Pleuronectes platessa*) × flounder (*Platichthys flesus*) hybrids accept formulated feeds more readily and are more easily habituated to intensive culture conditions than their respective parent species (Bishop 1968; Purdom 1976; Graff 1978; Kerby and Joseph 1979). Muskellunge × northern pike, lake trout (*Salvelinus namaycush*) × brook trout (*S. fontinalis*) and striped bass × white bass hybrids grow faster than either parental species, at least during the first few years of life (Hesser 1978; Fraser 1980; Kerby 1986). The improved performance resulting from hybridization is one of the factors responsible for the rapid growth of the hybrid striped bass aquaculture industry over the past several years. The NCRAC Walleye Work Group has consistently ranked the evaluation of walleye (*Stizostedion vitreum)* × sauger (*S. canadense*) hybrids as a high priority.

Natural hybridization between walleye and sauger has been documented (Colby et al. 1979), and both reciprocal hybrids have been artificially propagated in the laboratory (Nelson et al. 1965). Several fisheries management agencies, including the Ohio Department of Natural Resources, have reared fingerling walleye female × sauger male (W × S) hybrids in ponds for stocking into reservoirs (Smith and Carline 1982, 1983). Field studies of walleye and walleye hybrids have revealed improved survival and growth for the hybrids (Lynch et al. 1982; Humphreys et al. 1984; Leeds and Summers 1987; Leeds 1990; Johnson 1991). Because of the fast growth and high survival rates, hybrid walleye are fast becoming popular among natural resource agencies for stocking in reservoirs and small impoundments. In Ohio, since 1978, the "...numbers of stocked hybrids have risen to over 6.3 million fingerlings, while walleye stocking has declined from a high of about 2.25 million fingerlings in 1984 to 0.9 million in 1991" (Johnson 1991).

There is also evidence that hybrid walleye are more adaptable to aquaculture conditions. They have faster growth and lower food conversions than walleye when trained to formulated feed (Malison et al. 1990) and in rearing 100 mm-TL fingerlings to advanced sizes (Siegwarth and Summerfelt 1990, 1992). In addition, hybrids seem more docile and overall exhibit improved behavioral characteristics than purebred walleye when reared intensively (Malison et al. 1990). Together, these investigations indicate that the walleye × sauger hybrid may have significant potential for commercial culture. However, more studies need to be conducted before hybrid walleye can be generally recommended for that purpose.

The findings of Malison et al. (1990) and Siegwarth and Summerfelt (1990, 1992) were all based on crosses made from progeny of Rock Lake (Jefferson County, Wisconsin) walleye and Mississippi River saugers. Potential performance gains resulting from hybrid vigor will almost certainly be dependent upon the stocks of brood fish used to make hybrid crosses. Hybrids produced from stocks of walleye and sauger other than Rock Lake and Mississippi River, respectively, may have variable performance gains compared to purebred walleye. In one unreported study conducted at the UW-Madison, walleye × sauger hybrids produced using Mississippi River walleye and Mississippi River sauger as brood fish did not show the performance improvements observed in hybrids of Rock Lake walleye and Mississippi River sauger. In fact, the quantitative genetic analyses of performance traits of different walleye stocks in the region by Project 2 of the Walleye Work Group indicated that Iowa and North Dakota stocks of walleye outperformed other stocks tested, based on growth and incidence of cannibalism. Taken together, these findings suggest that the performance of hybrids will be affected by the specific walleye and sauger brood stocks crossed.

Although the studies by Malison et al. (1990) and Siegwarth and Summerfelt (1990, 1992) demonstrated that walleye hybrids grew faster than purebreds, their data were for fingerling fish; the largest average size the hybrids were reared to was 222.3 mm TL. Because research has not yet been conducted to evaluate the growth of hybrid walleye reared to food size (i.e., 681 g or 1.5 lb), it is not known whether the faster growth rate of the hybrids will continue until they reach market size.

Research on this topic is presently being done cooperatively by ISU and UW-Madison investigators, as part of the ongoing Walleye Work Group project. ISU has the responsibility of collecting semen and eggs to make the hybrids, fertilizing and incubating the eggs, and rearing the fish from fry to a size of about 75 mm TL in a tank culture system using formulated feeds. In April 1994, three hybrid crosses were prepared using male sauger from the Mississippi River, near Genoa, Wisconsin: Rock Lake (Wisconsin) walleye × Genoa sauger, Spirit Lake (Iowa) walleye × Genoa sauger, and Genoa walleye × Genoa sauger. In July 1994, fingerlings from each hybrid cross were transported to UW-Madison. The performance of these hybrids are being compared to purebred Rock Lake walleye. In the autumn of 1995, the fillet yields, proximate analyses, and organoleptic properties of these fishes will be compared. Three additional hybrid crosses will be prepared in April 1995 from a single source of female walleye and three stocks of male sauger (Mississippi River, Ohio River, and Upper Missouri River), and the performance and flesh quality characteristics of these hybrids will be evaluated.

ANTICIPATED BENEFITS

This project will address priority needs identified by the NCRAC Industry Advisory Council, as well as specific objectives adopted by the NCRAC Board of Directors, to advance the development of commercial walleye aquaculture in the NCR. Two major constraints that presently limit this development are the near total lack of substantive information on the feasibility of culturing walleye to food size under commercial conditions, and on the nature and true scope of domestic markets for walleye. In addition, a significant ongoing need exists to provide extension professionals and private fish producers with training on critical aspects of, and recent developments in, walleye aquaculture. Moreover, policy makers and the general public need to be kept informed of the advances being made in walleye aquaculture.

Perhaps the principal benefit of the NCRAC Walleye Work Group's research on Objective 1 is that it will directly address the question of whether this species <u>can</u> be grown to food size under practical conditions, at rearing densities and in a time frame conducive to commercialization. To facilitate the latter, feeding tables will be developed for rearing advanced fingerling walleye to food size, based on water temperature, fish size, and protein and energy relationships of the feed. This information will be useful to fish producers and feed manufacturers, and will provide data for estimating feed costs and for the development of a computerized bioenergetics model that could be used to predict growth and feeding level requirements under different culture conditions.

Research on Objective 1 to assess the effects of different culture methods and husbandry procedures on the growth, performance and stress responses in walleye will help identify "least-stress" culture strategies and elucidate techniques that both increase growth rate and reduce stress-associated culture problems. In a similar vein, Research on Objective 4 will make it possible to identify one or more combinations of walleye and sauger stocks that yield hybrids exhibiting superior growth and performance characteristics, compared to purebred walleye. Identification of such superior crosses could substantially reduce the time, and therefore the costs, required to produce food-size fish. Collectively, data generated by research on both Objectives 1 and 4 will provide baseline information to facilitate economic analyses of walleye production.

The characterization of walleye product markets described under Objective 2 should provide hard data that researchers and potential walleye culturists alike can use to good effect. Information on the historic and potential for increased import levels of walleye from Canada is especially important, given the negative price impact such imports could have on a fledgling U.S. walleye aquaculture industry. Harvests from the wild constitute perhaps the strongest potential market competition for any aquaculture industry. Therefore, reliable market information on wild-caught supplies is essential for walleye producers to be able to position themselves profitably. Market information can also serve as a guide for commercial growers to plan their production, financing and marketing strategies, and for researchers to help focus their production and economic studies.

A clearer understanding of marketing channels and institutional structures will provide aquaculturists with insights on the potential impact farm-raised walleye products will have on domestic markets for this species. Especially important is the assessment of the potential for increasing commercial harvests of wild walleye stocks, which could result in market prices below those compatible with profitable aquaculture production. The distribution of market research information through extension channels provides a structured dissemination system that is credible with producers, financial institutions, and others.

Under Objective 3, the Walleye Work Group will perform specifically targeted extension activities, including workshops and videotape productions. Four workshops in Iowa, held primarily at ISU, will provide training on various aspects of intensive walleye culture, from egg collection and fertilization, to the culture of fry on formulated feed in tanks, to the grow-out of fingerlings to food-size fish in tanks. A workshop held near Alexandria, Minnesota, will focus on various strategies for harvesting walleye fingerlings from ponds. All five workshops will provide opportunities for hands-on training, as well as relevant printed materials. The videotapes will be produced as teaching tools for regional distribution, and will provide techniques-centered information on recently developed or improved methods of culturing walleye fry to fingerlings in ponds or on formulated feed in tanks - and possibly on different procedures for harvesting walleye fingerlings from ponds.

One of the greatest potential benefits of the workshops conducted will be that regional fisheries and aquaculture extension professionals are expected to be among the major participants, which should result in a significant "multiplier effect" in disseminating the knowledge presented. In addition, Walleye Work Group investigators will continue to present research updates at various state and regional aquaculture conferences; and extension information will be published as regional or station fact sheets or bulletins, in collaboration with the NCRAC Extension Work Group. The research findings of the Walleye Work Group will be published in appropriate peer-reviewed journals, or regional or station bulletins, and will be summarized in a NCRAC project completion report.

OBJECTIVES

1. Evaluate growth, feed efficiency, and stress responses as functions of density, loading, temperature, and feeding regimes (feeding rate and frequency) under tank and open-pond rearing conditions for raising juvenile walleye to food size.

2. Characterize the economics and institutional aspects of the domestic market for walleye as food fish, fingerlings, and other intermediate products.

3. Offer several workshops in the NCR, using extension materials (fact sheets, videos, etc.) and other information that has or will be developed necessary to demonstrate the technology of culturing walleye and its hybrids.

4. Complete performance evaluations of walleye × sauger hybrids to finalize research initiated during the 2-year project period of the June 1993 proposal - including studies on fillet yield, proximate analysis, and organoleptic properties.

PROCEDURES

Evaluate Tank and Pond Rearing of Walleye to Food Size (Objective 1)

Research on Objective 1 will involve investigators from the ILNHS, ISU, UNL, and UW-Madison. Briefly, the responsibilities of those investigators at those institutions will be as follows: Data on fish growth, feed efficiency, and measures of digestible energy of walleye reared under laboratory conditions in tanks at two different temperatures and using two different feeding regimes will be collected by ISU workers. Studies by UNL researchers will focus on evaluating the effects of selected rearing densities on the production of walleye on formulated feed in tanks and ponds under practical conditions, and will include collaboration with UW-Madison investigators to assess the effects of different culture methods on walleye stress levels and response patterns. Researchers from the UW-Madison will compare growth rates and feed efficiencies of walleye reared in tanks of different sizes, and in ponds. They will also measure physiological indicators of stress in walleye reared using different culture techniques and husbandry methods, to identify "least stress" culture methods and procedures. Data from the ISU, UNL and UW-Madison studies will be used by ILNHS workers to develop a bioenergetics model. Findings (growth rate, time to reach market size, feed conversions, and feed costs) from these investigations will be useful in evaluating the economic feasibility of commercially culturing walleye to food size.

ILNHS

Researchers of the ILNHS will modify, update, and use a bioenergetics model to characterize growth and feeding efficiency of walleye for two temperatures and variable feeding rates. In the first year of the project, a bioenergetics model will be developed for walleye that can be used for juvenile (65 g) through food-size fish (0.68 kg). Existing models will be examined, and the parameters will be modified for late-juvenile and early-adult fish. For example, recent research has examined respiration and consumption parameters for these sizes of fish (Cai and Summerfelt 1992; Forsberg and Summerfelt 1992a, b; Madon and Culver 1993; Yager and Summerfelt 1993, 1994). Development of an updated model will also involve writing computer code, so that the model can be used by individuals interested in walleye aquaculture.

Results of the model will be tested in Year 1 and 2 of the project against tank and pond data generated by ISU, UNL and UW-Madison investigators. Input variables needed for the model, such as water temperature, body length, body weight, and food consumption, will be obtained from tank experiments conducted by ISU researchers and pond experiments conducted by UNL and UW-Madison investigators. Tank experiments will provide data on growth rates resulting from variable feeding regimes and two water temperatures. Pond experiments will provide data on temperature, growth rates, and feeding rates. In addition, we will determine caloric values of the walleye (at 1-2 month intervals) and of the pelleted feeds used in the tank and pond experiments by bomb calorimetry. With these data, we will be able to compare the predicted results of the model to results from actual culture conditions. Based on these comparisons, the model will be calibrated and further modified. After the model has been thoroughly tested, further simulations will be run to make recommendations regarding feeding rates for various aquaculture conditions (i.e., water temperature and fish size) that will maximize the growth of walleye to food size.

ISU

Investigators at ISU will rear walleye on formulated feed in tanks for 16 months (funds allocated for the project are insufficient to continue culture beyond 16 months). The goal will be to rear walleye from an initial size of about 150-mm TL (28 g) in September 1995 to 0.68 kg (1.5 lbs), a typical food size for walleye (Siegwarth and Summerfelt 1993). The experimental design will focus on an evaluation of methodologies for calculating feeding rates and growth rates at two temperatures. The information will be used to develop feeding tables for walleye based on fish size, water temperature, and protein-energy composition of the feed.

Given the interaction between light intensity and optimal temperature, and the advantages of in-tank compared with overhead lighting (see **CURRENT AND RELATED PREVIOUS WORK**) in the proposed study, walleyes will be reared at 20 and 24°C with in-tank (submerged) lighting. The 20 and 24°C temperatures span the range of temperatures most likely to be used in a controlled environmental culture system for rearing walleye to food size.

Feeding rates and feeding frequency are important factors affecting growth and feed efficiency, but there is a lack of information to guide fish culturists for raising walleye from fingerlings to food size. Feeding tables indicate the daily ration, that is the percent of the body weight (%BW) to feed fish per day when fish are of a certain size and reared at a given temperature (Piper et al. 1982). At a given temperature, the daily ration decreases with fish size, and for fish of a given size, the daily ration increases with water temperature. The daily ration, however, must be adjusted at frequent intervals (daily, every three days, or weekly) to feed the gain (i.e., the increased biomass of fish). Piper et al. (1982) suggests that under "normal" conditions, adjusting feeding levels four times during a month (i.e., about once per week) is adequate to prevent over- or under-feeding.

Two methods for calculating feeding rates will be evaluated, and the information from that evaluation will be used to develop size-temperature feeding guides. Although all methodologies used to determine %BW require prediction of growth, as feeding rates are designed to "feed-the-gain," contrasting methods for determining feeding rate have been described by Westers (1987) and Cho (1992). A basic difference in the methodology between the two procedures concerns differences for estimating growth.

Westers' method is a refinement of an earlier methodology developed by Haskell (1959) and Buterbaugh and Willoughby (1967), which is traditionally employed in trout hatcheries (Piper et al. 1982). Westers (1987) assumes that growth in length (L, total length in cm) of hatchery fish, reared at the same temperature and fed the same feed, is linear, at least during the production cycle, and that fish weight can be calculated from length-weight relationship ($\log_{10}w = a + b\log_{10}L$), or k factor [$k = w(g)/L(mm)^3$, therefore, $w = kL^3$]. The effects of variable temperature over a rearing interval can be accounted for by using a fish growth rate (cm/d) per temperature unit (GR/TU), which Westers terms unit growth rates (UGR), cm/d per degree-day (°C). Westers assumes that UGR and food conversion (FC) is a constant for a given stock and feed type (i.e., energy),and 300 × UGR × FC is also a constant, therefore,

$$\%BW = °C\ (300 \times UGR \times FC)/L \qquad (1)$$

in which L on successive days between intervals when lengths are measured can be predicted from an assumption of linear growth at a given temperature.

To account for variable condition factors (k) for fish of different body form, which changes as walleye increase in size, the formula (1) is written:

$$\%BW = °C\ (300 \times UGR \times FC)/100k \times L \qquad (2)$$

When initial stock number is known and mortality is recorded, the biomass (n × mean weight) on any day between one weighing interval (t_1) and the next (t_n) can be predicted, from which the biomass of the stock can be estimated.

Specific growth rate (SGR), based on the natural logarithm of body weight [($\log_e BW_2 - \log_e BW_1$)/d] has often been used in predicting growth. SGR may underestimate values between BW_1 and BW_2 and overestimate values beyond BW_2 (Cho 1992). Specific growth rate is not a constant over fish size, it declines with increasing fish size (Jobling et al. 1993). However, UGRs have been shown to vary with temperature, reaching a maximum at the optimum temperature (Westers 1987).

Therefore, in our study, we will evaluate UGRs for walleye at 20 and 24°C, from which feeding rates for intermediate temperatures can be extrapolated. Personal experience with the Westers' formula for calculating feeding rates for rainbow trout indicate that it is very effective for calculating %BW to obtain excellent food conversions when samples of individual fish lengths and weights, and total tank biomass were obtained at two-week intervals and feeding rates were adjusted every three days. For example, we obtained feed conversions of 1.04 to 1.09 for rainbow trout with good growth rates (Luzier et al. In press).

Cho (1992) recommended estimating the daily ration using what he termed "the nutritional energetics approach," which defines the minimum digestible energy requirement that should be fed to the fish based on the retained energy (RE) and energy lost as $HEf+HiE_{M,G}+ZE+UE$ (defined below). This recommendation is based on energy requirements of fish and an optimum protein:energy ratio (Cho and Kaushik 1990; Cho 1990). The process involves several steps beginning with calculation of a digestible energy thermal-unit growth coefficient (TGC):

$$TGC = (BW_2^{0.333} - BW_1^{0.333})/\Sigma(\text{temp.}(°C) \bullet d) \qquad (3)$$

and a model for predicting body weight (BW_2) that is based on the exponent of one-third power of body weight:

$$(BW_2) = [BW_1^{0.333} + \Sigma(\text{temp.}(°C) \bullet d)]^3 \qquad (4)$$

$$\text{Body weight gain} = (BW_2) - (BW_1) \qquad (5)$$

The %BW to be fed each day over an interval can be calculated directly from predicted body weight gain based on (3), (4) and (5). Cho's (1992) "nutritional energetics approach," however, contains five more steps which include an estimate of retained energy (RE) based on calorimetric analysis of the dried weight (DM) of the fish (kJ/gDM), allocating of the energy requirements for fasting (HEf), for feeding and growth ($HiE_{M,G}$), and non-fecal energy loss (ZE+UE), and calculating digestible energy (DE) in the diet.

We propose calculating DE by an indirect measurement (Lovell 1989):

$$DE = 100\ [(\text{Energy in food}/\text{Energy in feces}) \cdot (\text{Indicator in feces}/\text{Indicator in food}) \cdot 100] \qquad (6)$$

where the indicator is an inert, indigestible ingredient (0.5% chromic oxide) that is added to the food. Energy in the food and feces will be determined by calorimetry of dried samples.

Alternatively, if we can use the open formula WG9015 diet developed by Rick Barrows of the Fish Technology Center, Bozeman, Montana, digestibility of the food can be determined from the list of ingredients. Unfortunately, the only commercial source of the WG9015 (Sterling H. Nelson and Sons, Inc., Murray, Utah), only prepares the feed two or three times each year (late April, mid-June, and July). As the feed cannot be stored more than 90 days without potential loss of vitamins and oxidation of the fat, if WG9015 cannot be obtained year-around, we will use "BioDry" (BioProducts, Inc., Warrenton, Oregon) or Silver Cup (Sterling H. Nelson and Sons, Inc., Murray, Utah) because these feeds are available at any time of year in a complete variety of sizes.

Cho's (1992) "nutritional energetics approach" requires use of diets with minimum digestible energy content (DE_{min}) = RE and energy lost (HEf+HiE+ZE+UE). The daily ration for fish of different sizes can be calculated from the DE energy requirement using a spread sheet (Cho 1992). As stated by Cho (1992), "Since TGC values and the growth rate are dependent on species, stock, nutrition, husbandry, and other factors, it is first necessary to calculate specific TGC for a given aquaculture system using past growth records or records obtained from similar stocks and culture conditions."

The present research will include calculations of TGC values, direct measurements of DE, and preparation of a table containing estimates of minimum DE and daily ration for walleyes reared at 20 and 24°C.

UNL

Given the near total lack of substantive knowledge about the culture of walleye above fingerling size, the fundamental question that lies at the heart of Objective 1 is whether this species can be grown to food size under practical conditions, at rearing densities and in a time frame conducive to commercialization. Until this question is addressed, attempts to "enhance" the feasibility of culturing walleye to food size by trying to define optimum rearing conditions through detailed experimentation will remain an academic exercise. However, some such determinations are essential to ultimately achieving commercial feasibility. To resolve this dilemma on whether and how to proceed, one clear question that needs to be answered is whether any biological or environmental factors exist that effectively preclude the feasibility of commercially culturing walleye to food size.

The walleye for most of its life history is a solitary nocturnally active piscivore that is extremely sensitive to light, sound and low-frequency vibrations. Because these factors are intrinsic traits of the species, there is a high probability that limitations on rearing density, spacial requirements, and stress due to sensory overload are among the principal constraints to the commercial culture of walleye to food size. These constraints, in turn, are likely to determine the types of management practices (e.g., feeding regimes and harvesting methods) and culture systems (e.g., tanks, ponds, or net-pens) that are most likely to be conducive to the development of an aquaculture industry that can produce food-size walleye at a profit. Accordingly, UNL and UW-Madison researchers will: (1) initiate studies to evaluate the rearing density requirements (UNL) and spatial requirements (UW-Madison) of walleye cultured in tanks and ponds, (2) compare and contrast the production of walleye on formulated feed in tanks and ponds under various conditions, and (3) collaborate to assess the effects of stress on walleye cultured in tanks and ponds.

Research by UNL investigators to evaluate the feasibility of culturing walleye to food size on formulated feed in tanks and ponds will be done in cooperation with William Hahle, owner/operator of Pleasant Valley Fish Farm, near McCook, Nebraska, and with the Nebraska Game and Parks Commission at the Calamus State Fish Hatchery, near Burwell, Nebraska. The main focus of the UNL studies will be to assess the effects of selected rearing densities on the production of walleye in tanks and ponds - though some necessary preliminary tank loading trials and experiments to examine the effects of frequency and time of day of feeding will also be conducted. The walleye used in the UNL studies will be age-0 and age-1 fish originating from eggs fertilized with milt from wild brood stock collected from Merritt Reservoir in Cherry County, Nebraska, and raised on formulated feed to advanced fingerlings (100-150 mm TL), as part of the ongoing Walleye Work Group project.

In the first two months of the proposed project, preliminary (multifactorial-design) experiments of four to eight weeks duration will be conducted at the Calamus hatchery to evaluate the effects of feeding frequency and time of day of feeding. These experiments will be done in flow-through 1.2-m-diameter × 0.76-m-deep or 1.5-m-diameter × 0.76-m-deep cylindrical fiberglass rearing tanks supplied with filtered 18-22°C water from the Calamus Reservoir. All tanks will be stocked at a standard rearing density and operated at a set rate of water turnover determined to be acceptable on the basis of prior experience at the Calamus hatchery, as well as dissolved oxygen and un-ionized ammonia levels. The purpose of these experiments will be to gain an initial indication of the best feeding procedures to use to achieve maximum feed consumption and growth under near-optimum tank culture conditions. Present plans are to use these feeding procedures as a starting point to achieve near-satiation feeding in future grow-out experiments.

The feed used in all UNL studies will be either Silver Cup Salmon (Sterling H. Nelson and Sons, Inc., Murray, Utah) or "Biodry" (Bioproducts, Inc., Warrenton, Oregon). All studies will be done under ambient photoperiod conditions, and all experimental tanks employed in the project will be aerated by diffuser stones and equipped with in-tank lighting. Water supplied to tanks will first be aerated by passage through packed columns. Principal production data evaluated by UNL investigators will include survival, growth, condition factor, feeding times, feeding rate, feed conversion, and incidence of disease. Environment parameters routinely monitored will include water temperature, dissolved oxygen, pH, un-ionized ammonia, turbidity, day length, and light intensity.

Another important preliminary study that will be done by UNL researchers and their cooperators will be to compare the survival, weight change, and condition of feed-trained age-0 to age-1 walleye overwintered in tanks and ponds. In mid November 1995, replicate groups of fish at the Calamus hatchery will be stocked in the 1.2- or 1.5-m-diameter cylindrical tanks at density indices of about 0.5 and 1.0 (Piper et al. 1982; calculated as pounds of fish/cubic feet of rearing space per inch of fish length), and supplied either with well water at 13°C or with reservoir water, which during winter is normally about 4°C. At the same time, fish will be stocked in two 0.2-ha × 1.2-m-deep ponds at the Calamus hatchery at rates of 9,500 and 19,000 fish/ha. These ponds will be kept partially free of ice during the winter by supplying reservoir water.

In addition, fish will be stocked at the same rates at Pleasant Valley Fish Farm in two 0.06-ha × 1.2-m-deep ponds, which will be kept partially free of ice by supplying them with well water. The fish in all these tanks and ponds will be fed to satiation daily or at least three times weekly, depending on apparent levels of consumption. Data on overwinter survival, weight change and condition will be collected in late March 1996, and the study terminated. Walleye not used in this study, but held for use in future grow-out experiments, will be overwintered in a covered outdoor raceway supplied with well or reservoir water, and fed daily or three times weekly as needed.

The main UNL grow-out experiments to evaluate the effects of rearing density on the production of age-1 walleye on formulated feed in tanks and ponds will be initiated in late April and terminated in mid November 1996. The tank experiment will employ eight 1.8-m-diameter × 0.91-m-deep cylindrical fiberglass rearing tanks arranged in an outdoor raceway at the Calamus hatchery. The raceway will be equipped with a quonset-type cover that excludes light, but has doors to allow for feeding and maintenance. The tanks will be supplied with filtered reservoir water, the temperature of which typically varies between 19 and 22°C during the summer, and rarely exceeds 24°C. The feeding procedures initially used (which may be by hand or automatic feeders) will be those identified by the preliminary studies conducted the previous autumn. However, these procedures may be modified as the fish grow or circumstances demand. As with the winter study, rearing density indices (Piper et al. 1982) evaluated will be about 0.5 and 1.0, with four tanks of fish randomly assigned to each rearing density.

The main UNL grow-out experiments in ponds will employ the same size and number of ponds at the Calamus hatchery and Pleasant Valley Fish Farm and compare the same stocking densities (9,500 and 19,000 fish per ha) as the overwintering studies. The ponds at the Calamus hatchery and Pleasant Valley Fish Farm will be supplied with reservoir water and well water, respectively, to moderate pond water temperatures (to no more than 25°C during hot summer periods). Pond aeration is rarely needed in Nebraska, due to the climatically normal windy conditions. However, several different types of emergency aerators or aeration systems will be available and ready for operation at both facilities, should the need arise.

In the tank culture experiment, the water turnover rates through tanks will be adjusted as closely as possible to maintain equal loadings. To facilitate this, it will be possible to supply pure oxygen to the tanks to maintain near-equal dissolved oxygen levels. However, for practical reasons and to ensure good growing conditions, water temperature and critical water quality parameters, particularly dissolved oxygen and un-ionized ammonia levels, will be the principal criteria used to determine water inflows in both the tank and pond culture experiments.

Samples of fish from all treatment groups in all experiments will be collected at biweekly, monthly or bimonthly intervals, depending on predetermined data collection schedules. The number of fish in rearing tanks will be adjusted as needed to maintain the density indices being evaluated. If necessary, adjustments in the numbers of fish in ponds may also be made, to maintain water quality and good growing conditions. At appropriate intervals, blood and tissue samples will be taken from fish sampled from the different experimental groups, for the determination of baseline stress levels, and to assess the physiological response patterns of sampled fish to a stress challenge test (see UW-Madison procedures). The blood and tissue samples will be sent to collaborating project investigators at UW-Madison for detailed serological and other analyses of indicators of physiological stress (e.g., serum cortisol, glucose and chloride ion levels). Whenever possible, parametric statistical methods will be used to analyze numerical data. Non-parametric statistics will be employed when the application of parametric methods is found to be inappropriate or unfeasible.

<u>UW-Madison</u>

All walleye used in the studies conducted in Wisconsin will be the offspring of wild brood stock captured from Rock Lake (Jefferson County, Wisconsin) during the spring spawning season. Eggs will be collected as needed, fertilized according to the dry method, and incubated under a rising temperature regime (+0.5°C/d) for 8-14 d. Shortly before or after hatch, eyed-eggs or fry will be stocked into fertilized production ponds for larval and early juvenile rearing. After six to eight weeks, fingerlings will be harvested and brought into the laboratory. Fingerlings will be habituated to formulated feed and intensive culture conditions in flow-through fiberglass tanks provided with tempered water (21±0.5°C), airstone aeration, and constant illumination. Initially, the fish will be fed continuously with automatic feeders, and by hand several times daily, using appropriately-sized Ziegler Salmon Starter (Ziegler Bros. Inc., Gardners, Pennsylvania). We have found these conditions to result in habituation rates of 50-70%. The fish will then be reared until the following April, when two experiments will be conducted.

One experiment will be conducted to evaluate the spatial requirements of walleye in tank culture systems. Groups of fish (age-1 juvenile walleye, approximately 150 g each) will be weighed, measured, and stocked into replicate rearing tanks of 220-L, 750-L or 12,000-L volume. Water flow rates and stocking densities will be calculated to provide equal loadings and density indices (Piper et al. 1982) among treatments. Fish will be reared for a minimum of six months under near-optimum environmental and feeding conditions (e.g., 21±0.5°C and fed to satiation), during which time, growth, feed conversion rates, and stress levels will be determined.

A second experiment will be conducted to compare the growth and performance of walleye reared under various selected culture conditions, including ponds, tanks, and possibly net-pens (depending on cost and availability of sufficient numbers of fish). Because of limitations on pond availability and to provide information on seasonal variation, this experiment will be conducted using two replicates per treatment in each of the two years of the project. Age-1 juvenile walleye (approximately 150 g) will be assigned to one of two or three experimental treatments (i.e., rearing conditions): (1) flow-through tanks using internal tank lighting, (2) fish reared unconfined in ponds, and possibly (3) fish reared in net-pens in ponds.

Many critical culture conditions, including water temperature, dissolved oxygen level, and photoperiod, will be regularly monitored and kept as similar (and near-optimal) as possible between ponds, tanks, and net-pens (ponds are equipped for aeration and groundwater or lake-water addition to minimize temperature fluctuation, see **FACILITIES**). Fish rearing densities in tanks and net-pens will be identical, and rearing densities in all treatment groups will be within ranges practical for commercial aquaculture (e.g., beginning at 20 kg/m^3 and ending at 60-90 kg/m^3 for tanks and net-pens, and beginning at 2,000 kg/ha and ending at 6,000-9,000 kg/ha for ponds). As with the first experiment, growth, feed conversion rates, and stress levels will be determined during the six-month grow-out period of the study.

Walleye reared under the different culture conditions in Wisconsin, as well as walleye from the ISU and UNL studies, will be sampled to assess baseline stress measures and also evaluate their responses to a standardized acute stress challenge test (e.g., dip-netting fish and holding them out of the water for 60 seconds). At least six fish/experimental treatments will be sampled prior to the application of each stress challenge, and the challenged fish will then be sampled at selected intervals (e.g., 1, 3 and 6 h) over the next 24 hours. The specific protocols that will be used to assess stress levels in these studies are currently being developed and validated as part of a research project funded by the University of Wisconsin Sea Grant Institute.

The primary physiological stress response will be assessed by measuring plasma cortisol levels. Cortisol will be measured using a microplate ELISA, which is currently employed in our laboratory for measuring cortisol in rainbow trout and lake trout (*Salvelinus namaycush*; Barry et al. 1993). This assay uses an antibody that is highly specific for cortisol and a cortisol-3-CMO-horseradish peroxidase (HRP) enzyme conjugate. Advantages of the assay include its high sensitivity (0.04 nanogram/mL), and the small serum sample size (20 µL) and short length of time (3 h) required to complete the assay. Standards will be prepared by adding known amounts of cortisol to charcoal-stripped walleye serum. Secondary physiological stress responses measured will include serum glucose (using Sigma diagnostic kit 510-DA, Sigma Chemical Company, St. Louis, Missouri), chloride (using a Model 925 chloride analyzer, Ciba-Corning, Medfield, Massachusetts), and osmolality (using a Model 5500b vapor pressure osmometer, Wescor, Inc., Logan, Utah). Tertiary stress measures (e.g., incidence of disease, survival, interrenal histology, and lymphocyte counts) will also be determined for each treatment of each experiment.

Characterize the Domestic Markets for Walleye (Objective 2)

Research on Objective 2 will be conducted by investigators from ILSU, Purdue, KSU, and NDSU. Given the nature of economics and marketing research, a high degree of collaboration and interaction is anticipated between the investigators from the different institutions who will be involved in this effort. To identify and clarify the tasks to be addressed, Objective 2 has been divided into four subobjectives, as follows: (1) Describe the structure of the walleye products industry, and summarize historical data on the origins and destinations of walleye supplies; (2) Gather and evaluate the historical price series on walleye; (3) Ascertain the present status and potential of walleye purchases and sales by firms in the fisheries products marketing channels in the NCR; and (4) Elicit and evaluate historical data on fingerling (and other intermediate products) production and sales in the region.

Describe the Products Industry Structure (Subobjective 1)

Data will be gathered by investigators from all four participating institutions, from existing data bases maintained by state, provincial and national governments, and from interviews with persons responsible for monitoring or managing fisheries and/or food-products resources (e.g., government agency fisheries managers, Canadian fish marketing cooperative representatives). The National Marine Fisheries Service and National Oceanic and Atmospheric Administration of the U.S. Department of Commerce, and the provincial governments of Manitoba and Ontario, for example, are expected to be major sources of information. The data collected will be used to develop a descriptive profile of the industry, showing the relative market importance of various suppliers of walleye products.

Gather and Evaluate Historical Price Series (Subobjective 2)

This subobjective will be led by investigators from ILSU. The primary focus will be on fish wholesale firms in the NCR. However, some information may be gathered directly from Canadian public and private firms involved in exporting walleye to the U.S. A mail survey instrument will be developed and employed to identify those firms that have a history of prices paid and/or charged for the various product forms of walleye. A combination of mail, telephone and interview instruments and techniques will then be used to elicit and gather those price histories. The data compiled will provide a basis for an objective descriptive profile of historical walleye product pricing in the NCR.

Ascertain the Status and Potential of Purchases and Sales (Subobjective 3)

Purdue investigators will lead this subobjective by: (1) developing survey instrument(s), (2) obtaining and compiling mailing lists, (3) mailing a survey, and (4) compiling and analyzing the survey data. Some assistance will be provided by ILSU, particularly in the conceptualization and development of the survey instrument(s), and analyzing the survey responses. Present plans are to survey all types of firms in the fisheries products marketing channels between the producers (or wild fisheries) and consumers. This will include processors, distributors, wholesalers, retail grocers, other retailers, and restaurants. Such firms all constitute markets for walleye, whether wild-caught or farm-raised.

The exact target firms for this study have not yet been identified, as a comprehensive, readily available mailing list does not presently exist. The survey sample likely to be obtained will probably not be statistically representative of all the fisheries products marketing firms in the NCR, because the lack of a centralized list of their addresses makes obtaining such a sample both time and cost prohibitive. However, because there appear to be comparatively fewer marketing channel firms that are not restaurants, a representative survey of all or most of those types of firms discovered is expected. On the other hand, restaurants are plentiful and (perhaps) more readily discoverable. Therefore, a survey of a larger number but smaller proportion of existing restaurants is planned.

Present plans are to target fisheries products market channel firms in major cities or markets (with 100,000 or more population) in all states in which they can be found in the NCR. Such an approach excludes less densely populated areas, but given the methodologies and/or results from previous studies (Hushak et al. 1993; Riepe et al. 1993; Chopak 1994), and a limited budget, this seems a reasonable compromise.

Conceptualization and development of survey instrument(s) is the centerpiece of survey work. There is no such thing as a standardized survey instrument, because only a limited amount of information can be elicited in any survey, and the precise information needed typically differs dramatically between projects. The principal information desired from the proposed survey will be quantity, price, product form, and frequency information, all of which are related to specific walleye product forms. In addition, one goal is to elicit information from fisheries products marketing firms about what they would like to be able to purchase, as well as what they have purchased historically. Also, information on the characteristics of such marketing firms, such as their size and location, will also be sought.

Elicit and Examine Data on Fingerling Production and Sales (Subobjective 4)

This subobjective will be led by investigators from ILSU. The primary focus will be on fingerling producers/sellers/wholesalers - both public and private in the NCR. A mail survey instrument will be developed and employed to identify fingerling producers/sellers/wholesalers in the region who are able and willing to provide historical quantity and price information on fingerling supplies and sales in the region. Those firms identified will be queried further using a combination of mail, telephone and interview instruments and techniques to gather historical data. These data will provide a basis for an objective descriptive profile of the history of walleye fingerling production and sales in the NCR.

Offer Workshops and Develop Extension Materials (Objective 3)

Several researchers and all the extension professionals of the Walleye Work Group will cooperate and coordinate their activities to conduct workshops and produce extension materials on both conventional and recently developed techniques for culturing walleye. Robert Summerfelt of ISU, a researcher and past chair of the work group, will coordinate and lead four workshops in Iowa on various aspects of intensive walleye culture, from egg collection to the production of food-size fish in tanks. Terry Kayes of UNL, a researcher and extension specialist, will coordinate the development of educational videotapes on selected walleye culture topics that will particularly benefit from audiovisual demonstrations of practical procedures or specialized techniques, and will help put on a workshop in Minnesota on methods of harvesting walleye fingerlings from ponds. Ron Kinnunen of MSU and Jeff Gunderson of UMN, as extension members of the work group, will participate in and help with the workshops and videotaping, as appropriate and needed, and will disseminate information on the workshops and walleye aquaculture throughout the NCR.

ISU

Researchers at ISU will offer two 2-d workshops in 1996 and 1997 for extension personnel and fish farmers in the region, using extension materials (fact sheets, videotapes, etc.) and other information that has been or will be developed to demonstrate essential aspects of intensive walleye culture. Participants in the workshops will receive a copy of the walleye culture guide, which is presently being developed, other pertinent extension publications, and additional printed materials relevant to the workshop topics. The first workshop will be held in April 1996, during the walleye spawning season. Procedures demonstrated will include collection of wild brood stock, egg and milt collection, egg fertilization and handling, and egg incubation. Participants will have an opportunity to obtain hands-on experience with egg stripping and fertilization, treatments to prevent egg adhesion and clumping, egg incubation and disinfection, egg enumeration, and preparation of fertilized eggs and newly hatched fry for shipping.

The second workshop in 1996 will be held in May, after walleye hatching, to demonstrate techniques for intensively culturing fry on formulated feed in tanks. Topics covered will include tank design, lighting, stocking density, feeding rates, use of automatic timers and feeders, and assessment of water quality. In 1997, two 2-d workshops, one in mid June and the second in late July, will be held to demonstrate procedures for intensively culturing advanced walleye fingerlings in tanks to food size. Topics covered will include techniques for transporting fingerlings, training pond-reared fingerlings to formulated feed, feeds and feeding methods, feeders, disease prevention, stock assessment, management of loading and rearing density, and water quality assessment. The ISU researchers conducting the four workshops will also assist UNL with setups for videotaping, when appropriate and necessary.

UNL

Terry Kayes of UNL, with the help of other researchers and extension professionals of the Walleye Work Group, will coordinate the development of at least one, and probably two, educational videotapes on critical aspects of walleye culture that will particularly benefit from audiovisual demonstrations of techniques. This uncertainty regarding the number of videotapes to be produced is based on two facts: (1) recent experience has demonstrated that the time investment and funding levels required to produce the type of videotapes desired are difficult to predict with certainty, and (2) the cost of producing videotapes generally is highly variable and in a constant state of flux. Each videotape will have a duration of 15-30 minutes; be produced primarily for use in a workshop or classroom setting, or for library loan; and will be designed to complement related printed materials (e.g., the walleye culture guide presently being developed). Depending on time and available funds, selected parts of the Iowa and Minnesota workshops on walleye aquaculture will be videotaped, both for stand-alone use of the raw footage and for the incorporation of segments into the one or two finished videotape productions.

The finished videotape(s) will be scripted by Terry Kayes, working in collaboration with Robert Summerfelt of ISU, Jeff Malison of UW-Madison, and other members of the Walleye Work Group as appropriate, as well as with a designated videotape producer of the UNL Institute of Agriculture and Natural Resources Communications and Computing Services (or an associated agency or service). Present plans are to do most of the videotaping, video graphics, and editing in Year 1 of the project - though some overlap into Year 2 is anticipated to complete production and provide time and resources for final copying and distribution of the videotape(s). Top priority will be given to the production of a videotape that contrasts conventional methods of producing walleye fingerlings in ponds with: (1) recently developed improved procedures for pond-rearing fingerlings and training them to formulated feed in tanks, and (2) recently developed techniques for intensively rearing walleye from sac-fry to fingerlings on formulated feed entirely in tanks.

The second videotape will contrast conventional (highly stressful) methods of harvesting walleye fingerlings from ponds by seining and/or pond drawdown to a catch basin, with (less stressful) techniques presently being developed by UNL researchers for mass harvesting walleye fingerlings from ponds employing specially designed passive capture gear in combination with electronic systems that attract or alternatively drive fish using light or low-frequency sound. (A number of existing experimental light-harvesting systems can routinely capture 10,000-30,000 fingerlings of 18-30 mm TL in operating sets of 15-30 minute durations.) Much of the information and most of the new techniques presented in the two videotapes will come from ongoing or recently completed studies done by researchers of the Walleye Work Group. Compiling the footage necessary to produce both videotapes will require the cooperation of the researchers involved in the development of these techniques, as well as extensive travel to selected videotaping sites in Iowa, Minnesota, Nebraska and Wisconsin.

In Year 2 of the project, Terry Kayes of UNL will collaborate with Larry Belusz and Greg Raisanen of Alexandria Technical College to put on a one-day workshop near Alexandria, Minnesota, on walleye pond harvesting techniques. The exact scheduling and focus of that workshop will depend in part on the outcome of studies by UNL researchers on new procedures for harvesting fingerlings, as part of the ongoing Walleye Work Group project. However, topics covered will include the advantages and disadvantages of harvesting fingerlings at various sizes, pond cropping procedures, and conventional and nonconventional methods of harvesting young fish from both drainable and nondrainable ponds.

MSU and UMN

Ron Kinnunen of MSU, as the secretary and lead extension liaison for the Walleye Work Group, will record and distribute the minutes of the work group's meetings, assist the chair (Terry Kayes) with coordinating and reporting on the work group's research and extension activities, provide input from the NCRAC Extension Work Group, disseminate information on the Walleye Work Group's activities and on the five proposed walleye workshops, and extend information from the workshops and on walleye culture in general to clientele in the field - by conducting programs, performing site visits, and writing news articles on walleye culture for Native American fisheries programs, government agencies, private fish growers, and the general public - focusing on the latest information available. Kinnunen will also help Robert Summerfelt of ISU implement the two walleye workshops in Iowa in 1996, as well as the two in 1997, and will assist Terry Kayes with selected videotaping (including on-site staging) and with conducting the walleye workshop in Minnesota in 1997.

Minnesota has the NCR's largest number of commercial walleye fingerling producers. As the primary NCRAC extension contact for Minnesota, Jeff Gunderson of UMN will also participate in and help with the walleye workshops in Iowa in 1996 and 1997, assist Terry Kayes of UNL with selected videotaping in Minnesota, and help put on the workshop in Minnesota in 1997, coordinated by Larry Belusz and Greg Raisanen of Alexandria Technical College, and Terry Kayes.

Complete Performance Evaluations of Walleye × Sauger Hybrids (Objective 4)

UW-Madison

To achieve this objective, UW-Madison researchers will complete the evaluations of walleye × sauger hybrids as described in the June 1993 NCRAC Walleye Work Group proposal. Briefly, in the autumn of 1995, grow-out studies will be completed on the three hybrid crosses made from Rock Lake, Spirit Lake, and Mississippi River walleye × Mississippi River sauger. From September 1995 to September 1996, grow-out studies will be completed comparing hybrids produced from a single source of female walleye (Rock Lake) and three stocks of male sauger (Mississippi River, Ohio River, and Upper Missouri River). Rock Lake walleye will be included in both of these studies as a purebred control.

After each of these growth studies is completed, comparisons between the different fish test groups will be made of fillet yield, proximate analysis, and organoleptic properties. Fillet yield determinations will be made using at least 20 fish from each test group, and proximate analyses will be made using 8-10 eviscerated fish per group. Moisture content will be determined by drying at 80°C for 24 hours. Total organic nitrogen will be determined using a Kjeldahl digestion procedure (Association of Analytical Chemists 1984). Total lipid content will be measured using the method of Bligh and Dyer (1959), and total ash will be measured following the method of the Association of Analytical Chemists (1984). Organoleptic evaluations will be conducted through the Sensory Analysis Laboratory of the UW-Madison Department of Food Science.

FACILITIES

Evaluate Tank and Pond Rearing of Walleye to Food Size (Objective 1)

ISU

The ISU aquaculture facilities are located on campus in Science Hall II. Presently, the facilities consist of 12 150-L and six 250-L cylindrical tanks, and 16 100-L cuboidal-shape tanks; there are also hatching jars for incubating eggs. These facilities will be used to hatch and rear walleye to fingerling size from April to August 31, 1995, for use in the proposed study. The fish will be hatched, stocked at two days of age into rearing tanks at 20 fish/L, and fed a formulated feed (Fry Feed Kyowa, Biokyowa Inc., Chesterfield, Missouri). The walleye should be over 150 mm TL by September 1, 1995. They will be grown to 150 mm TL in 250-L cylindrical tanks with a water depth of 0.64 m. Thereafter, they will be reared in 1.55-m-diameter tanks with a water depth of 0.75 m and a water volume of about 1,136 L. Each tank will be equipped with a center drain, flowmeter, and an auger feeder. Two timers will be used to control the on/off interval of the feeders, to regulate daily ration. Temperature can be controlled to ±0.5°C; and pH can be regulated to ±0.2 pH units with a pH monitoring system that actuates a peristaltic pump which adds an acidic solution to the water supply of the culture tanks.

An analytical laboratory located adjacent to the aquaculture facilities is dedicated to the analysis of water quality. It is equipped with an analytical balance, incubator, centrifuge, pH meter, two YSI oxygen meters, and a DR3000 spectrophotometer (HACH Company, Loveland, Colorado). Analyses are routinely performed for pH, dissolved oxygen, total ammonia-N, nitrite-N, nitrate-N, all forms of alkalinity, hardness, chlorides, ortho- and total phosphorus, and residual chlorine. Other water quality analyses, for special needs, are carried out in the Analytical Services Laboratory of the ISU Engineering Research Institute. Another room adjacent to the aquaculture facilities has research-grade compound and dissecting microscopes equipped for photomicrography. Facilities of the ISU College of Veterinary Medicine are available for the preparation of histological sections. Proximate analyses of fish will be carried out by the ISU Meat Laboratory. Proximate analyses of feed for crude protein, crude fiber, moisture, and fat will be determined by a commercial laboratory (Woodson-Tenent Laboratories, Des Moines, Iowa).

UNL

The Nebraska studies on the growth and performance of walleye in tanks and ponds will be done by UNL investigators, in cooperation with William Hahle (a Nebraska fish farmer with 23 years of experience at producing a wide variety of fish, including walleye) at Pleasant Valley Fish Farm, near McCook, and with the Nebraska Game and Parks Commission at the Calamus State Fish Hatchery, near Burwell. Physical resources available at Pleasant Valley Fish Farm include: 40 1.2- to 1.5-m-deep earthen ponds ranging in surface area from 100 m^2 to 0.3 ha; seven wells with pumping depths of 3-24 m and a combined capacity of 1,800-L/min of 14-15°C water; a 93-m^2 hatch house supplied with both pond and well water; a variety of indoor and outdoor rearing tanks; and ample electrical power to run pond and tank feeding and aeration systems. In addition, UNL has a number of cylindrical fiberglass rearing tanks ranging in size from 0.76-2.4 m in diameter and in volume from 220-4,900-L, which can be set up at Pleasant Valley Fish Farm, should the need arise.

The Calamus State Fish Hatchery is a 24-ha facility located immediately downstream of the 2,023-ha Calamus Reservoir in north central Nebraska. Physical resources available at the Calamus hatchery include: 11 0.20-ha and 40 0.40-ha fish production ponds; 8 1.8-m-wide × 20-m-long × 1.2-m-deep and 16 2.4-m-wide × 27-m-long × 1.2-m-deep outdoor raceways; an 886-m^2 indoor fish production and research facility (which is equipped for water-temperature and light control and includes an analytical and fish pathology laboratory); 10 0.61-m-wide × 6.1-m-long × 0.61-m-deep and 8 0.91-m-wide × 6.1-m-long × 0.61-m-deep indoor raceways; and numerous hatchery troughs, egg incubators, and 1.2-, 1.5- and 1.8-m-diameter cylindrical rearing tanks. Ten 0.20-ha and at least 11 0.40-ha ponds in close proximity to the main hatchery buildings can be equipped with automatic feeding systems by UNL, as needed.

Water resources at the Calamus hatchery include: reservoir water (with a seasonal temperature variation from about 4°C in winter to about 22°C in summer) supplied to all the indoor and outdoor facilities via a 91-cm-diameter main; and about 11-m^3/min and 1.1-m^3/min water flow from eight wells supplying 13° and 11°C water, respectively, from two separate aquifers, to all the raceways and indoor facilities. A very large pure-oxygen supply system is in place at the Calamus hatchery, and oxygen supplementation in individual tanks and raceways can be achieved through the use of sealed packed-columns. The UNL, Nebraska Game and Parks Commission, and Pleasant Valley Fish Farm together have all the live-haul trucks, facilities, and equipment needed to transport fish; artificially propagate and hatch eggs from brood stock captured in the field; stock, fertilize, manage, and harvest ponds; raise fingerlings and food-size fish; and monitor water quality and other critical environmental factors.

UW-Madison

Research will be conducted at the UW-Madison Aquaculture Program's laboratory facilities at the Lake Mills State Fish Hatchery, Lake Mills, Wisconsin, and at the Water Science and Engineering Laboratory (WSEL) on the UW-Madison campus. The design of the Lake Mills facility makes it ideally suited for research on the effects of fish culture strategies and rearing conditions as stressors on walleye. The Lake Mills facility has three sources of water (Rock Lake, dechlorinated municipal, and high-capacity well); a variety of 110- to 3,020-L fiberglass tanks; and eight environmental control suites, each having independent water-temperature, light-intensity and photoperiod control. This facility also has 29 fish production ponds ranging in size from 0.05-0.5 ha, many of which have aeration and water circulation systems, and available cool (15°C) water for tempering as needed. The UW-Madison tank studies on this project will be conducted in 220- to 12,000-L flow-through tanks at the WSEL.

The UW-Madison Aquaculture Program's analytical laboratories are equipped with a high speed centrifuge, micro-ELISA plate reader, chloride analyzer, microbalance, several compound and dissecting microscopes, histology facilities, and all the equipment needed for proximate analyses. The Aquaculture Program also has access to a computer-controlled high pressure liquid chromatography (HPLC) system, liquid scintillation counter, gamma counter, and other equipment of the Endocrinology-Reproductive Physiology Program and the WSEL at the UW-Madison campus. For this project, a 0.1-ha pond will be made available for walleye fingerling production each year and two 0.05-ha ponds will be used for grow-out. All ponds can be supplied with either lake or groundwater for summer temperature control.

Characterize the Domestic Markets for Walleye (Objective 2)

The four institutions working on Objective 2, specifically ILSU, Purdue, KSU and NDSU, all have sufficient computer equipment and support staff to perform the research and analyses proposed. In addition, Purdue has the staff and facilities necessary for handling a large-scale mail survey.

Offer Workshops and Develop Extension Materials (Objective 3)

ISU

The first workshop on walleye culture will be scheduled in April 1996 in Iowa, to observe spring spawning techniques and egg incubation at the Rathbun or Spirit Lake state fish hatcheries. Workshops in 1996 and 1997 to demonstrate the technology of intensive mass culture of walleye fry on formulated feed in tanks, and on the intensive tank culture of walleye from fingerlings to food size, will be conducted at the ISU aquaculture facilities described under Objective 1.

UNL

Production of the videotapes on the "best" methods of culturing walleye in ponds and tanks will be coordinated by Terry Kayes and key support staff of the UNL Department of Forestry, Fisheries and Wildlife (FFW), and done in cooperation with researchers, extension professionals and others from ISU, MSU, UW-Madison, and possibly UMN and Alexandria Technical College. This collective effort will be done in collaboration with the professional video and media staff of the UNL Institute of Agriculture and Natural Resources (IANR) Communications and Computing Services. The UNL FFW has the necessary "in-house" audio-video equipment and expertise to perform much of the routine field and laboratory videotaping. Any specialized videotaping required, essential video graphics, and final tape editing will be done by the appropriate professionals of the UNL IANR Communications and Computing Services, or associated agencies or services which have the equipment and expertise necessary to perform these functions. The workshop on methods of harvesting walleye fingerlings from ponds will be held in 1997 in Minnesota at Alexandria Technical College and selected field sites nearby.

Complete Evaluations of Walleye × Sauger Hybrids (Objective 4)

<u>UW-Madison</u>

As described under Objective 1, the UW-Madison Aquaculture Program's facility at the Lake Mills State Fish Hatchery has all the equipment and supplies necessary to capture and transport brood fish and fingerlings, collect and incubate eggs, and rear several groups of hybrid walleye fingerlings. This equipment includes a live-haul truck, two boats, 11 trap-nets, over 30 McDonald hatching jars, and over 100 fiberglass rearing tanks. For the proposed growth studies, 110-L cylindrical tanks will be used initially; but as the fish grow, they will be moved to larger tanks as appropriate. Studies on sensory evaluations and organoleptic properties of walleye hybrids will be done in collaboration with the UW-Madison Food Science Department, and proximate analyses will be performed by UW-Madison Aquaculture Program personnel.

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PROJECT LEADERS

State	Name/Institution	Area of Specialization
Illinois	David H.Wahl Illinois Natural History Survey	Aquatic Ecology/Fisheries Management/ Aquaculture
	Patrick D. O'Rourke Illinois State University	Aquaculture Marketing/Production Economics
Indiana	Marshall A. Martin Purdue University	Technology Assessment/Aquaculture Marketing/Production Economics
	Jean R. Riepe Purdue University	Technology Assessment/Aquaculture Marketing/Production Economics
Iowa	Robert C. Summerfelt Iowa State University	Finfish Aquaculture/Larviculture/Fish Health and Nutrition
Kansas	Kenneth E. Neils Kansas State University	Aquaculture Marketing/Production Economics
Michigan	Ronald E. Kinnunen Michigan State University	Aquatic Resources/Fisheries and Aquaculture Extension
Minnesota	Jeffrey L. Gunderson University of Minnesota	Aquatic Resources/Fisheries and Aquaculture Extension
Nebraska	Terrence B. Kayes University of Nebraska-Lincoln	Fish Culture/Fish Physiology/Feeding and Nutrition/Aquaculture Extension
North Dakota	Jay A. Leitch North Dakota State University	Aquaculture Marketing/Production Economics
Wisconsin	Jeffrey A. Malison University of Wisconsin-Madison	Finfish Aquaculture/Fish Physiology and Endocrinology

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PROPOSED WALLEYE BUDGET FOR
ILLINOIS NATURAL HISTORY SURVEY

(Wahl)

Objective 1

					Year 1	Year 2
	Year 1		Year 2			
A. Salaries and Wages	No.	FTEs	No.	FTEs		
1. No. of Senior Personnel & FTEs[1]						
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	1	0.25	1	0.25	$4,792	$4,792
d. Prebaccalaureate Students						
e. Secretarial-Clerical						
f. Technical, Shop, and Other						
Total Salaries and Wages					$4,792	$4,792
B. Fringe Benefits (1.46% of 2c)					$70	$70
C. **Total Salaries, Wages and Fringe Benefits**					$4,862	$4,862
D. Nonexpendable Equipment					$0	$0
E. Materials and Supplies					$250	$251
F. Travel - Domestic (*Including Canada*)					$500	$500
G. Other Direct Costs					$250	$250
TOTAL PROJECT COSTS PER YEAR (*C through G*)					$5,862	$5,863
				TOTAL PROJECT COSTS	$11,725	

[1]FTEs = Full Time Equivalents based on 12 months.

BUDGET JUSTIFICATION FOR ILLINOIS NATURAL HISTORY SURVEY

(Wahl)

Objective 1

A. **Salaries and Wages.** Part of a research assistantship is needed to provide a stipend for a graduate student to help develop and test the model. The stipend for both years ($4,792/year) for 0.25 FTE is prorated based on the standard $10,200 (0.50 FTE) stipend of the ILNHS for the present academic year.

B. **Fringe Benefits.** The ILNHS fringe benefit rate for graduate research assistants is presently 1.46% of their salaries, for workman's compensation and Medicare.

E. **Materials and Supplies.** For paper, computer disks, and other miscellaneous supplies.

F. **Travel.** Travel for the principal investigator and graduate student to attend work group meetings or scientific meetings to present research results.

G. **Other Direct Costs.** Photocopying, postage, and other miscellaneous costs.

PROPOSED WALLEYE BUDGET FOR
ILLINOIS STATE UNIVERSITY

(O'Rourke)

Objective 2

	Year 1 No.	Year 1 FTEs	Year 2 No.	Year 2 FTEs	Year 1	Year 2
A. Salaries and Wages						
1. No. of Senior Personnel & FTEs[1]						
a. (Co)-PI(s)	1	0.08	1	0.08	$4,800	$0
b. Senior Associates						
2. No. of Other Personnel (Non-Faculty) & FTEs						
a. Research Assoc./Postdoc						
b. Other Professionals						
c. Graduate Students	1	0.50			$5,400	$0
d. Prebaccalaureate Students						
e. Secretarial-Clerical						
f. Technical, Shop, and Other						
Total Salaries and Wages					$10,200	$0
B. Fringe Benefits (22.5% of 1a)					$1,080	$0
C. **Total Salaries, Wages and Fringe Benefits**					$11,280	$0
D. Nonexpendable Equipment					$0	$0
E. Materials and Supplies					$500	$0
F. Travel - Domestic (*Including Canada*)					$759	$0
G. Other Direct Costs					$700	$0
TOTAL PROJECT COSTS PER YEAR (*C through G*)					$13,239	$0
TOTAL PROJECT COSTS					$13,239	

[1]FTEs = Full Time Equivalents based on 12 months.

BUDGET JUSTIFICATION FOR ILLINOIS STATE UNIVERSITY

(O'Rourke)

Objective 2

A. **Salaries and Wages.** The principal investigator is an Associate Professor on an annual 9-month contract to teach courses and conduct departmentally assigned research. Most externally funded research contracts are allocated to summer salaries, with the exception of graduate students. The 1-month summer faculty salary indicated in the budget is necessary to cover the principal investigator's commitment to the project.

A graduate student research assistant is also needed in Year 1 of the project.

B. **Fringe Benefits.** The ILSU fringe benefit rate is 22.5% of faculty salaries.

E. **Materials and Supplies.** Covers part of estimated expenses for office and computer supplies.

F. **Travel.** Covers part of estimated travel costs for visits to aquaculture producers, university professionals, and others in the fish processing and marketing industry, for consultation and data collection. May be used to defray travel costs to work group meetings and for professional meetings related to the conduct and presentation of results of the project.

G. **Other Direct Costs.** Covers part of estimated costs for postage, telephone, photocopying, printing, computer services, etc.

PROPOSED WALLEYE BUDGET FOR
PURDUE UNIVERSITY

(Martin and Riepe)

Objective 2

	Year 1 No.	Year 1 FTEs	Year 2 No.	Year 2 FTEs	Year 1	Year 2
A. Salaries and Wages						
1. No. of Senior Personnel & FTEs[1]						
a. (Co)-PI(s)	2	0.47			$13,404	$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						
e. Secretarial-Clerical						
f. Technical, Shop, and Other	1	0.04			$670	$0
Total Salaries and Wages					$14,074	$0
B. Fringe Benefits (27.1% of 1a and 29.0% of 2f)					$4,328	$0
C. **Total Salaries, Wages and Fringe Benefits**					$18,402	$0
D. Nonexpendable Equipment					$0	$0
E. Materials and Supplies					$0	$0
F. Travel - Domestic (*Including Canada*)					$400	$0
G. Other Direct Costs					$6,553	$0
TOTAL PROJECT COSTS PER YEAR (*C through G*)					$25,355	$0
TOTAL PROJECT COSTS					$25,355	

[1]FTEs = Full Time Equivalents based on 12 months.

BUDGET JUSTIFICATION FOR PURDUE UNIVERSITY

(Martin and Riepe)

Objective 2

A. **Salaries and Wages.** Jean Riepe, who is named as a co-principal investigator, is a nonfaculty research associate whose salary and benefits are totally supported through grant funding. Allocation of project funds for Ms. Riepe's salary and benefits is therefore a prerequisite for her participation in the project. Jean Riepe's demonstrated interest and experience in aquaculture economics and marketing research in the NCR make her an essential contributor to the pursuit of Objective 2 of the project. Because of her past work and initiative in this area, it is appropriate that she be included in the project as a "Co-PI," and not merely as funded personnel. The named lead principal investigator from Purdue University must be Marshall Martin, because he is a faculty member and is officially responsible for Jean Riepe's activities.

Salary moneys requested under 2.f. are for computer support personnel to code survey data.

B. **Fringe Benefits.** Purdue's fringe benefit rate is 27.1% of research associate salaries, and 29.0% of service staff salaries.

F. **Travel.** Funds will be used to attend work group meetings and to travel to work in person with other project investigators and personally interview selected fish/seafood marketing channel firms.

G. **Other Direct Costs.** Most of the funds will be used to produce and mail the food fish market survey, including: paper, printing, envelopes, survey folding, envelope stuffing, and mailing. Other expenses covered will include telephone, postage, fax, and photocopying costs, etc.

PROPOSED WALLEYE BUDGET FOR
IOWA STATE UNIVERSITY

(Summerfelt)

Objectives 1 and 3

					Year 1	Year 2
	Year 1		Year 2			
A. Salaries and Wages	No.	FTEs	No.	FTEs		
1. No. of Senior Personnel & FTEs[1]						
a. (Co)-PI(s)	1	0.10	1	0.10	$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	0.24	1	0.09	$3,020	$1,182
e. Secretarial-Clerical						
f. Technical, Shop, and Other . . .	1	0.75	1	0.25	$12,480	$4,368
Total Salaries and Wages					$15,500	$5,550
B. Fringe Benefits (9% of 2d and 15% of 2f)					$2,125	$805
C. **Total Salaries, Wages and Fringe Benefits**					$17,625	$6,355
D. Nonexpendable Equipment					$0	$0
E. Materials and Supplies					$4,975	$1,459
F. Travel - Domestic (*Including Canada*)					$1,500	$1,200
G. Other Direct Costs					$1,100	$472
TOTAL PROJECT COSTS PER YEAR (*C through G*)					$25,200	$9,486
TOTAL PROJECT COSTS					$34,686	

[1]FTEs = Full Time Equivalents based on 12 months.

BUDGET JUSTIFICATION FOR IOWA STATE UNIVERSITY

(Summerfelt)

Objectives 1 and 3

A. **Salaries and Wages.** For Objective 1, a technician, working under the supervision of the principal investigator, is required to provide continuous daily care of the fish and culture system for the 16 months it will take to rear the fish from advanced fingerlings to food size. Duties of the technician will include renovation, repair, and daily operation of the culture facilities, day-to-day fish husbandry, water quality monitoring, data entry (fish and water quality), and supervision of prebaccalaureate student hourly helpers.

Prebaccalaureate student hourly helpers will be needed for Objective 1 to relieve the technician on weekends and holidays, and to assist the technician with routine tasks and on days when fish are weighed and measured ($2,520 in Year 1 and $682 in Year 2).

Regarding Objective 3, to prepare for and conduct the two 2-d sequential workshops in the spring of 1996 and the two workshops in the summer of 1997, student clerical assistance (about 75 h) is required for errands, copy work, library searches for reference materials, help with correspondence with workshop participants, etc. ($500 in each year).

B. **Fringe Benefits.** The ISU fringe benefit rate for technicians is presently 15% of their hourly wages. Undergraduate student employees are not eligible for fringe benefits except during vacation breaks and summer term, when the rate is 9% of hourly wages.

E. **Materials and Supplies.** The culture tanks, timers, and feeders needed for the Objective 1 rearing study are already available. The two largest components of the materials and supplies budget are for the purchase of fish feed ($1,400) and activated carbon media for dechlorination of the water supply ($1,800). Other items needed include plumbing supplies (valves, PVC pipe, pumps) to change the culture system in the ISU facility from the present fry culture tanks to larger tanks for rearing fish to food size. In addition, sodium sulfite is needed to ensure that all residual chlorine and chloramines are removed from the water supply; hydrochloric acid is needed to adjust pH; reagents and glassware are needed to monitor water quality; and paper is needed for the strip chart recorders to monitor pH, temperature, current flow, and dissolved oxygen.

Instructional materials are needed for the Objective 3 workshops ($875 in Year 1 and $200 in Year 2), including fact sheets, videos, and other information that has been or will be developed to demonstrate the technology for intensive culture of walleye and its hybrids. Other supplies needed include posterboard, pens, photographic film, and chemical supplies for water quality analysis.

F. **Travel.** Travel funds for Objective 1 are required to carry out research functions and to attend work group meetings, the annual Coolwater Fish Culture Workshop, regional aquaculture meetings, and meetings of professional societies ($900 in Year 1 and $600 in Year 2). For Objective 3, funds are needed to pay for ISU vans to transport workshop participants from campus to field sites (Rathbun and Spirit Lake fish hatcheries), and for travel by the principal investigator to the field sites before the workshops ($600 in each year).

G. **Other Direct Costs.** Funds are needed for Objective 1 for telecommunications, postage, shipping, photocopying, and other miscellaneous expenses ($300 in Year 1 and $200 in Year 2). For Objective 3, funds are needed for telecommunications, postage, express mail, photocopying of handouts, graphic art services, and photographic processing services ($800 in Year 1 and $272 in Year 2).

PROPOSED WALLEYE BUDGET FOR KANSAS STATE UNIVERSITY

(Neils)

Objective 2

	Year 1 No.	Year 1 FTEs	Year 2 No.	Year 2 FTEs	Year 1	Year 2
A. Salaries and Wages						
1. No. of Senior Personnel & FTEs[1]						
a. (Co)-PI(s)	1	0.08	1	0.08	$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 . . .						
e. Secretarial-Clerical						
f. Technical, Shop, and Other . . .						
Total Salaries and Wages					$0	$0
B. Fringe Benefits (25% of 2e and 2f)					$0	$0
C. **Total Salaries, Wages and Fringe Benefits**					$0	$0
D. Nonexpendable Equipment					$0	$0
E. Materials and Supplies					$0	$0
F. Travel - Domestic (*Including Canada*)					$500	$0
G. Other Direct Costs					$0	$0
TOTAL PROJECT COSTS PER YEAR (*C through G*)					$500	$0
TOTAL PROJECT COSTS					$500	

[1]FTEs = Full Time Equivalents based on 12 months.

BUDGET JUSTIFICATION FOR KANSAS STATE UNIVERSITY

(Neils)

Objective 2

F. **Travel.** Travel to obtain information from growers, suppliers, and marketers. May include travel to work group meeting(s).

PROPOSED WALLEYE BUDGET FOR
MICHIGAN STATE UNIVERSITY

(Kinnunen)

Objective 3

	Year 1 No.	Year 1 FTEs	Year 2 No.	Year 2 FTEs	Year 1	Year 2
A. Salaries and Wages						
1. No. of Senior Personnel & FTEs[1]						
a. (Co)-PI(s)	1	0.20	1	0.20	$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						
e. Secretarial-Clerical						
f. Technical, Shop, and Other						
Total Salaries and Wages					$0	$0
B. Fringe Benefits					$0	$0
C. **Total Salaries, Wages and Fringe Benefits**					$0	$0
D. Nonexpendable Equipment					$0	$0
E. Materials and Supplies					$100	$100
F. Travel - Domestic (*Including Canada*)					$1,998	$1,999
G. Other Direct Costs					$100	$100
TOTAL PROJECT COSTS PER YEAR (*C through G*)					$2,198	$2,199
TOTAL PROJECT COSTS					$4,397	

[1]FTEs = Full Time Equivalents based on 12 months.

BUDGET JUSTIFICATION FOR MICHIGAN STATE UNIVERSITY

(Kinnunen)

Objective 3

E. **Materials and Supplies.** About $100/year is needed for general office supplies to support the activities of the work group secretary and lead extension liaison, and to gather and disseminate information on the walleye workshops and work group activities.

F. **Travel.** Out-of-state travel funds are required to help Robert Summerfelt of ISU implement the walleye workshops in Iowa in Year 1 and 2, and to assist Terry Kayes of UNL with selected videotaping (including on-site staging) and with conducting the walleye workshop in Minnesota in Year 2 of the project. Travel funds are also needed to extend information gained from the workshops to clientele in the field.

G. **Other Direct Costs.** About $100/year is necessary for telecommunications, photocopying, and mailing costs related to walleye extension activities.

PROPOSED WALLEYE BUDGET FOR
UNIVERSITY OF MINNESOTA

(Gunderson)

Objective 3

	Year 1 No.	Year 1 FTEs	Year 2 No.	Year 2 FTEs	Year 1	Year 2
A. Salaries and Wages						
1. No. of Senior Personnel & FTEs[1]						
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						
e. Secretarial-Clerical						
f. Technical, Shop, and Other						
Total Salaries and Wages					$0	$0
B. Fringe Benefits					$0	$0
C. **Total Salaries, Wages and Fringe Benefits**					$0	$0
D. Nonexpendable Equipment					$0	$0
E. Materials and Supplies					$88	$89
F. Travel - Domestic (*Including Canada*)					$400	$400
G. Other Direct Costs					$0	$0
TOTAL PROJECT COSTS PER YEAR (*C through G*)					$488	$489
TOTAL PROJECT COSTS					$977	

[1]FTEs = Full Time Equivalents based on 12 months.

BUDGET JUSTIFICATION FOR UNIVERSITY OF MINNESOTA

(Gunderson)

Objective 3

E. **Materials and Supplies.** About $88/year is needed for general office supplies to support the activities of the primary NCRAC extension contact for Minnesota, which has the NCR's largest number of commercial walleye producers.

F. **Travel.** Travel funds are required to help with and participate in the walleye workshops in Iowa in Year 1 and 2, to assist Terry Kayes of UNL with selected videotaping in Minnesota, and to help put on the workshop in Minnesota in Year 2 on walleye pond-harvesting techniques, coordinated by Larry Belusz and Greg Raisanen of Alexandria Technical College, and Terry Kayes of UNL.

PROPOSED WALLEYE BUDGET FOR
UNIVERSITY OF NEBRASKA-LINCOLN

(Kayes)

Objectives 1 and 3

	Year 1		Year 2		Year 1	Year 2
A. Salaries and Wages	No.	FTEs	No.	FTEs		
1. No. of Senior Personnel & FTEs[1]						
a. (Co)-PI(s)	1	0.10	1	0.10	$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						
e. Secretarial-Clerical	1	0.083	1	0.083	$1,600	$1,599
f. Technical, Shop, and Other	1	0.58	1	0.33	$11,667	$6,667
Total Salaries and Wages					$13,267	$8,266
B. Fringe Benefits (25% of 2e and 2f)					$3,318	$2,067
C. **Total Salaries, Wages and Fringe Benefits**					$16,585	$10,333
D. Nonexpendable Equipment					$0	$0
E. Materials and Supplies					$2,525	$1,329
F. Travel - Domestic (*Including Canada*)					$5,100	$3,600
G. Other Direct Costs					$2,200	$1,900
TOTAL PROJECT COSTS PER YEAR (*C through G*)					$26,410	$17,162
TOTAL PROJECT COSTS					$43,572	

[1]FTEs = Full Time Equivalents based on 12 months.

BUDGET JUSTIFICATION FOR UNIVERSITY OF NEBRASKA-LINCOLN

(Kayes)

Objectives 1 and 3

A. Salaries and Wages. A secretary (0.083 FTE/year) is needed (relative to all four project objectives) to assist the work group chair with coordinating the work group and preparing communications and reports. For Objective 1, a technician (0.50 and 0.33 FTE) is required in Year 1 and 2, respectively, to assist with the conduct of the pond and tank walleye rearing studies. For Objective 3, a technician (0.08 FTE) is required in Year 1 to help with: (1) the preparation of video graphics; and (2) the coordination, staging, and shooting of videotape segments at selected videotaping sites in Iowa, Minnesota, Nebraska and Wisconsin.

B. Fringe Benefits. UNL has a standard fringe benefit rate of 25% of staff salaries.

E. Materials and Supplies. For Objective 1, about $900 in Year 1 and $200 in Year 2 will be required for hardware and other supplies to modify, repair, and/or replace vital components of existing pond and tank rearing systems, and to maintain them for the duration of the project. About $500 will be needed each year for miscellaneous supplies (e.g., hand nets, tools, chemicals, computer supplies). About $500 in Year 1 and $250 in Year 2 will be needed for cost-sharing on feed purchases with Pleasant Valley Fish Farm and the Nebraska Game and Parks Commission. For Objective 3, about $300 will be needed in Year 1 for the purchase of a "liquid-mount" video camera tripod, and $300-$400 will be needed in both Year 1 and 2 for videotape and photographic, art and computer-graphics supplies.

F. Travel. The UNL component of Objective 1 will require considerable in-state travel between the UNL campus and the two Nebraska project sites where the pond and tank walleye rearing studies will be conducted. Round-trip distances between the UNL campus and Pleasant Valley Fish Farm and the Calamus State Fish Hatchery are about 576 and 400 miles, respectively. Both short and long-term stays by UNL researchers at the two project sites will be necessary. Most of the cost of long-term stays will be covered by mechanisms separate from NCRAC. Total estimated in-state travel costs for short-term lodging, meals, and fleet vehicle rental for Year 1 and 2 are about $3,800 and $2,500, respectively. About 40% of these costs can be covered by pooling appropriate travel expenses on various UNL projects under the principal investigator's supervision, which brings the total funds requested for in-state travel for Year 1 and 2 down to $2,300 and $1,500, respectively. About $500 will be needed each year for travel to scientific and work group meetings.

For Objective 3, the production of effective techniques-centered videotapes on the "best" methods of culturing walleye in ponds and tanks will require extensive travel from UNL to different videotaping sites in Iowa, Minnesota, Nebraska and Wisconsin. Present plans are to do most of the videotaping in Year 1 of the project, though travel funds will also be needed in Year 2 to conduct selected videotaping at regional walleye workshops in Iowa and Minnesota, as well as other possible sites. Each year, about 40% of the estimated travel costs are for fleet vehicle rental (including mileage charges), and about 60% are for lodging and meals for the principal investigator and a UNL staff professional to assist with field coordination, set-up, and videotaping at the sites selected.

Part of the travel funds for Objective 3 in Year 2 will be spent coordinating and putting on the 1-d workshop in Minnesota on walleye pond harvesting techniques, in collaboration with Larry Belusz and Greg Raisanen of Alexandria Technical College.

BUDGET JUSTIFICATION FOR UNIVERSITY OF NEBRASKA-LINCOLN

(Kayes)

Objectives 1 and 3 (Continued)

G. Other Direct Costs. Funds will be needed for Objective 1 in both Year 1 and 2 for computer and graphic arts services, shop services, photographic processing, telecommunications, postage, shipping, and photocopying expenses related to the project. Regarding Objective 3, videotape production will be done in collaboration with professional staff of the UNL IANR Communications and Computing Services, and/or with the assistance of professional videographers and editors of associated agencies (e.g., public television and private-sector video production services) as needed. Projected budget needs for Year 1 are: staff time and use of production equipment (at $35.00-$50.00/h) $600; editing, video-graphics production, and dubbing (at $50.00-$80.00/h) $900. Projected costs for the same services for Year 2 are $520 and $780, respectively.

PROPOSED WALLEYE BUDGET FOR
NORTH DAKOTA STATE UNIVERSITY

(Leitch)

Objective 2

	Year 1 No.	Year 1 FTEs	Year 2 No.	Year 2 FTEs	Year 1	Year 2
A. Salaries and Wages						
1. No. of Senior Personnel & FTEs[1]						
a. (Co)-PI(s)	1	0.07	1	0.03	$0	$0
b. Senior Associates						
2. No. of Other Personnel (Non-Faculty) & FTEs						
a. Research Assoc./Postdoc						
b. Other Professionals						
c. Graduate Students	1	0.15	1	0.50	$2,000	$6,500
d. Prebaccalaureate Students						
e. Secretarial-Clerical						
f. Technical, Shop, and Other						
Total Salaries and Wages					$2,000	$6,500
B. Fringe Benefits (5.0% of 2c)					$100	$325
C. **Total Salaries, Wages and Fringe Benefits**					$2,100	$6,825
D. Nonexpendable Equipment					$0	$0
E. Materials and Supplies					$0	$100
F. Travel - Domestic (*Including Canada*)					$150	$396
G. Other Direct Costs					$100	$100
TOTAL PROJECT COSTS PER YEAR (*C through G*)					$2,350	$7,421
TOTAL PROJECT COSTS					$9,771	

[1]FTEs = Full Time Equivalents based on 12 months.

BUDGET JUSTIFICATION FOR NORTH DAKOTA STATE UNIVERSITY

(Leitch)

Objective 2

A. Salaries and Wages. A graduate research assistantship for one Master's student.

B. Fringe Benefits. The NDSU fringe benefit rate for graduate research assistants is about 5%.

E. Materials and Supplies. General office and computer supplies.

F. Travel. Funds are needed to travel to Winnipeg and other locations to collect data.

G. Other Direct Costs. Telephone, fax, and other communications.

PROPOSED WALLEYE BUDGET FOR
UNIVERSITY OF WISCONSIN-MADISON

(Malison)

Objectives 1 and 4

	Year 1 No.	Year 1 FTEs	Year 2 No.	Year 2 FTEs	Year 1	Year 2
A. Salaries and Wages						
1. No. of Senior Personnel & FTEs[1]						
a. (Co)-PI(s)	1	0.06	1	0.06	$0	$0
b. Senior Associates						
2. No. of Other Personnel (Non-Faculty) & FTEs						
a. Research Assoc./Postdoc						
b. Other Professionals	1	0.40	1	0.33	$9,500	$8,300
c. Graduate Students						
d. Prebaccalaureate Students						
e. Secretarial-Clerical						
f. Technical, Shop, and Other						
Total Salaries and Wages					$9,500	$8,300
B. Fringe Benefits (31% of 2b)					$2,945	$2,573
C. **Total Salaries, Wages and Fringe Benefits**					$12,445	$10,873
D. Nonexpendable Equipment					$0	$0
E. Materials and Supplies					$3,050	$2,810
F. Travel - Domestic (*Including Canada*)					$700	$700
G. Other Direct Costs					$100	$100
TOTAL PROJECT COSTS PER YEAR (*C through G*)					$16,295	$14,483
TOTAL PROJECT COSTS					$30,778	

[1]FTEs = Full Time Equivalents based on 12 months.

BUDGET JUSTIFICATION FOR UNIVERSITY OF WISCONSIN-MADISON

(Malison)

Objectives 1 and 4

A. **Salaries and Wages.** The salary of a research specialist is needed for Objective 1 (0.25 FTE/year) to assist the principal investigator with fish propagation and the conduct of experiments, including: (1) fish husbandry, (2) collection of biological samples, (3) conduct of stress and performance tests, (4) analysis of physiological stress indicators, and (5) analysis and publication of results. For Objective 4, the salary of a research specialist is needed (0.15 FTE in Year 1 and 0.08 FTE in Year 2) to assist the principal investigator with fish propagation and the conduct of experiments, including: (1) fish husbandry, (2) collection of biological samples, (3) performance of proximate analyses, and (4) conduct of sensory evaluations.

B. **Fringe Benefits.** The UW-Madison fringe benefit rate for staff research specialists is 31% of their salaries.

E. **Materials and Supplies.** For Objective 1, biochemicals, reagents, and laboratory supplies are needed to conduct analyses of plasma cortisol, glucose and chloride; fish feed and wet laboratory supplies are required for fish husbandry and to conduct fish culture experiments. For Objective 4, various chemicals, reagents, and laboratory supplies are needed to conduct proximate analyses; fish feed and wet laboratory supplies are required for fish husbandry and to conduct fish culture experiments.

F. **Travel.** For each objective, about 50% of the travel budget requested is for the presentation of project findings at a scientific conference; the remainder of the travel funds will be used to attend work group meetings.

G. **Other Direct Costs.** About $50/year is needed for telephone, fax, postage, and photocopying for each objective.

ADVANCEMENT OF AND A MARKET STUDY FOR WALLEYE AQUACULTURE

Budget Summary for Each Participating Institution at $117.9K for the First Year

	ILNHS	ILSU	PURDUE	ISU	KSU	MSU	UMN	UNL	NDSU	UWMA	TOTALS
Salaries and Wages	$4,792	$10,200	$14,074	$15,500	$0	$0	$0	$13,267	$2,000	$9,500	$69,333
Fringe Benefits	$70	$1,080	$4,328	$2,125	$0	$0	$0	$3,318	$100	$2,945	$13,966
Total Salaries, Wages and Benefits	$4,862	$11,280	$18,402	$17,625	$0	$0	$0	$16,585	$2,100	$12,445	$83,299
Nonexpendable Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Materials and Supplies	$250	$500	$0	$4,975	$0	$100	$88	$2,525	$0	$3,050	$11,488
Travel	$500	$759	$400	$1,500	$500	$1,998	$400	$5,100	$150	$700	$12,007
Other Direct Costs	$250	$700	$6,553	$1,100	$0	$100	$0	$2,200	$100	$100	$11,103
TOTAL PROJECT COSTS	$5,862	$13,239	$25,355	$25,200	$500	$2,198	$488	$26,410	$2,350	$16,295	$117,897

Budget Summary for Each Participating Institution at $57.1K for the Second Year

	ILNHS	ILSU	PURDUE	ISU	KSU	MSU	UMN	UNL	NDSU	UWMA	TOTALS
Salaries and Wages	$4,793	$0	$0	$5,550	$0	$0	$0	$8,266	$6,500	$8,300	$33,409
Fringe Benefits	$70	$0	$0	$805	$0	$0	$0	$2,067	$325	$2,573	$5,840
Total Salaries, Wages and Benefits	$4,863	$0	$0	$6,355	$0	$0	$0	$10,333	$6,825	$10,873	$39,249
Nonexpendable Equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Materials and Supplies	$250	$0	$0	$1,459	$0	$100	$89	$1,329	$100	$2,810	$6,137
Travel	$500	$0	$0	$1,200	$0	$1,999	$400	$3,600	$396	$700	$8,795
Other Direct Costs	$250	$0	$0	$472	$0	$100	$0	$1,900	$100	$100	$2,922
TOTAL PROJECT COSTS	$5,863	$0	$0	$9,486	$0	$2,199	$489	$17,162	$7,421	$14,483	$57,103

RESOURCE COMMITMENT FROM INSTITUTIONS[1]

Institution/Item		Year 1	Year 2
Illinois Natural History Survey			
Salaries and Benefits: SY @ 0.05 FTE		$3,731	$3,731
Supplies, Expenses, Equipment, and Waiver of Overhead		$4,253	$4,253
	Total	$7,984	$7,984
Illinois State University			
Salaries and Benefits: SY @ 0.08 FTE		$4,800	$4,800
Waiver of Overhead		$5,406	$0
	Total	$10,206	$4,800
Purdue University			
Salaries and Benefits: SY @ 0.14 FTE		$11,183	$0
Waiver of Overhead		$18,634	$0
	Total	$29,817	$0
Iowa State University			
Salaries and Benefits: SY @ 0.10 FTE		$10,400	$10,900
	Total	$10,400	$10,900
Kansas State University			
Salaries and Benefits: SY @ 0.08 FTE		$4,500	$4,500
Waiver of Overhead		$200	$0
	Total	$4,700	$4,500
Michigan State University			
Salaries and Benefits: SY @ 0.20 FTE		$10,000	$10,000
	Total	$10,000	$10,000
University of Minnesota			
Salaries and Benefits: SY @ 0.05 FTE		$2,281	$2,281
Waiver of Overhead		$1,246	$1,247
	Total	$3,527	$3,528
University of Nebraska-Lincoln			
Salaries and Benefits: SY @ 0.10 FTE		$6,731	$6,933
Supplies, Expenses, Equipment, and Waiver of Overhead		$14,056	$5,042
Nebraska Game and Parks Commission			
Labor, Supplies, Expenses, and Equipment		$15,200	$10,400
Pleasant Valley Fish Farm			
Labor, Supplies, Expenses, and Equipment		$7,600	$5,200
	Total	$43,587	$27,575

RESOURCE COMMITMENT FROM INSTITUTIONS[1]

Institution/Item		Year 1	Year 2
North Dakota State University			
Salaries and Benefits: SY @ 0.07 and 0.03 FTEs (Year 1 and 2)		$5,000	$2,100
Waiver of Overhead		$3,034	$3,956
	Total	$8,034	$6,056
University of Wisconsin-Madison			
Salaries and Benefits: SY @ 0.06 FTE		$3,930	$4,126
Supplies, Expenses, Equipment, and Waiver of Overhead		$11,170	$10,372
	Total	$15,100	$14,498
	Total per Year	$143,355	$89,841
	GRAND TOTAL	$233,196	

[1]Because cost sharing is not a legal requirement, some universities may choose not to provide resource commitment from institutions, and are not required to provide or maintain documentation of such a commitment.

SCHEDULE FOR COMPLETION OF OBJECTIVES

Objective 1: Initiated in Year 1 and completed in Year 2.

Objective 2: Initiated in Year 1 and completed in Year 2.

Objective 3: Initiated in Year 1 and completed in Year 2.

Objective 4: Continued in Year 1 and completed in Year 2.

LIST OF PRINCIPAL INVESTIGATORS

Jeffrey L. Gunderson, University of Minnesota

Terrence B. Kayes, University of Nebraska-Lincoln

Ronald E. Kinnunen, Michigan State University

Jay A. Leitch, North Dakota State University

Jeffrey A. Malison, University of Wisconsin-Madison

Marshall A. Martin, Purdue University

Kenneth E. Neils, Kansas State University

Patrick D. O'Rourke, Illinois State University

Jean Rosscup Riepe, Purdue University

Robert C. Summerfelt, Iowa State University

David H. Wahl, Illinois Natural History Survey

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EDUCATION

B.S. University of Wisconsin-Stevens Point, 1975
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POSITIONS

Assistant Specialist-Fisheries, Extension Education and Associate Professor (1979-present), University of Minnesota-Minnesota Extension Service and Sea Grant Extension
Fishery Specialist/Fishery Biologist (1978-1979), Missouri Conservation Department

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Fisheries Society: Minnesota Chapter (President 1991-1992)
International Association of Astacology
International Association for Great Lakes Research
Minnesota Association of Extension Agents (President of the MACENRDP Section 1989-1990)
Sea Grant Advisory Service Association - Great Lakes Network

SELECTED PUBLICATIONS

McDonald, M., C. Richards, and J. Gunderson. 1993. Crayfish in Minnesota wild rice paddies. Minnesota wild rice research 1992. Miscellaneous Publication 78-1993, Agricultural Experiment Station, University of Minnesota, St. Paul.

Gunderson, J.L. 1993. Northern crayfish: an update. Minnesota Sea Grant Extension Publication, Minnesota Sea Grant College Program, St. Paul.

McDonald, M., P. DeVore, C. Richards, J. Skuria, and J. Gunderson. 1992. Economic and technologic developments for the crayfish industry in Minnesota. Technical Report, Natural Resources Research Institute, Duluth.

Gunderson, J.L., and A. Kapuscinski. 1992. Crayfish aquaculture demonstration in Minnesota wild rice paddies. Report, Legislative Commission on Minnesota Resources, St. Paul.

Gunderson, J.L., and G. Kreeg. 1991. Estimated economic impact of recreational fishing on Minnesota waters of Lake Superior. Minnesota Sea Grant Extension Publication, Minnesota Sea Grant College Program, St. Paul.

Gunderson, J.L. 1988. 1987-88 Charter fishing study: Minnesota waters of Lake Superior. Minnesota Sea Grant Research Report Number 27, Minnesota Sea Grant College Program, St. Paul.

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EDUCATION

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POSITIONS

Associate Professor (1990-present), Dept. of Forestry, Fisheries and Wildlife, University of Nebraska-Lincoln
Assistant Director and Associate Scientist (1979-1990), University of Wisconsin Aquaculture Program, University of Wisconsin-Madison
Project Biologist (1974-1979), Aquaculture Research Laboratory, University of Wisconsin-Madison
EPA Trainee (1970-1972), Laboratory of Limnology, University of Wisconsin-Madison
Instructor (1968-1970), Department of Biological Sciences, Chico State College

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Fisheries Society: Fish Culture, Bioengineering, Fish Health, Water Quality, and Early Life History
American Society of Zoologists: Comparative Endocrinology, Comparative Physiology and Biochemistry, Ecology, and Comparative Immunology
World Aquaculture Society

SELECTED PUBLICATIONS

Kohler, C.C., R.J. Sheehan, C. Habicht, J.A. Malison, and T.B. Kayes. In press. Habituation to captivity and controlled spawning of white bass. Transactions of the American Fisheries Society.

Malison, J.A., L.S. Procarione, T.P. Barry, A.R. Kapuscinski, and T.B. Kayes. 1994. Endocrine and gonadal changes during the annual reproductive cycle of the freshwater teleost, *Stizostedion vitreum* ("walleye"). Fish Physiology and Biochemistry 13:473-484.

Malison, J.A., T.B. Kayes, J.A. Held, T.P. Barry, and C.H. Amundson. 1993. Manipulation of ploidy in yellow perch (*Perca flavescens*) by heat shock, hydrostatic pressure shock, and spermatozoa inactivation. Aquaculture 110:229-242.

Heidinger, R.C., and T.B. Kayes. 1993. Yellow perch. Pages 215-229 *in* R.R. Stickney, editor. Culture of nonsalmonid freshwater fishes. CRC Press, Boca Raton, Florida.

Kebus, M.J., M.T. Collins, M.S. Brownfield, C.H. Amundson, T.B. Kayes, and J.A. Malison. 1992. Effects of rearing density on the stress response and growth of rainbow trout. Journal of Aquatic Animal Health 4:1-6.

Malison, J.A., T.B. Kayes, J.A. Held, and C.H. Amundson. 1990. Comparative survival, growth and reproductive development of juvenile walleye (*Stizostedion vitreum*), sauger (*S. canadense*) and their hybrids reared under intensive culture conditions. The Progressive Fish-Culturist 52:73-82.

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EDUCATION

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POSITIONS

Michigan Sea Grant Extension Agent (1981-present), Upper Peninsula, Michigan State University
Acting Alger County Extension Director (1988-1989), Michigan State University Cooperative Extension Service
Fisheries Pathologist (1981), Rangen Research Laboratory, Hagerman, Idaho
Fisheries Biologist (1979-1980), U.S. Fish and Wildlife Service, Leetown, West Virginia

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Fisheries Society: Fish Health
Michigan Association of Extension Agents
National Association of Extension Agents
Sea Grant Advisory Service Association

SELECTED PUBLICATIONS

Kinnunen, R.E. 1992. North Central Region 1990: salmonid egg and fingerling purchase, production, and sales. Technical Bulletin Series #103, North Central Regional Aquaculture Center, Michigan State University, East Lansing.

Kinnunen, R.E., and E.M. Mahoney. 1989. 1987 Upper Michigan charter fishing study. Michigan Sea Grant Extension Publication MICHU-SG-89-501, Michigan Sea Grant College Program, Ann Arbor.

Kinnunen, R., J. Lempke, and T. Sundstrom. 1987. Behavior patterns of divers visiting the Alger Underwater Preserve. Michigan Sea Grant Extension Publication MICHU-SG-87-505, Michigan Sea Grant College Program, Ann Arbor.

Peterson, J., T. Sundstrom, and R. Kinnunen. 1987. 1986 Recreational diving activity in Michigan bottomland preserves. Michigan Sea Grant Extension Publication MICHU-SG-87-506, Michigan Sea Grant College Program, Ann Arbor.

Kinnunen, R., and H. Johnson. 1986. Pathology of sea lamprey inflicted wounds on rainbow trout. Technical Report Number 48, Great Lakes Fishery Commission, Ann Arbor.

Kinnunen, R., J. Peterson, S. Stewart, and C. Swinehart. 1986. Sea grant research and community development make Michigan's bottomland preserves a reality. Marine parks and conservation: challenge and promise, volume 2. International Experiences, National and Provincial Parks Association of Canada.

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EDUCATION

B.A. Moorhead State University, 1974
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POSITIONS

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Director (1986-1993), Tri-College University Center for Environmental Studies, Fargo, North Dakota

Associate Director (1986-1992), North Dakota Water Resources Research Institute, North Dakota State University

Visiting Professor, University of Minnesota-St.Paul (1991), University of Alaska-Fairbanks (1990)

Scientific Advisor/Visiting Scholar (1985-1986), Office of the Assistant Secretary of the Army (Civil Works), Washington, D.C.

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

Western Agricultural Economics Association
American Agricultural Economics Association
American Water Resources Association
Canadian Water Resources Association
Society of Wetland Scientists

SELECTED PUBLICATIONS

Krenz, G., and J.A. Leitch. 1993. A river runs north: managing an international river. Red River Water Resources Council, Bismarck, North Dakota.

Anderson, R.S., C.J. Schwinden, and J.A. Leitch. 1986. Regional economic impact of the Devils Lake fishery. Fisheries 11(5):14-17.

Leitch, J.A. 1984. Feasibility of utilizing waste-heat for fish production in North Dakota. North Dakota Farm Research 43(4):27-29.

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EDUCATION

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POSITIONS

Director (1995-present), Assistant Director (1990-1995), Associate Researcher (1987-1990), and Project Associate (1985-1987), University of Wisconsin-Madison Aquaculture Program, University of Wisconsin-Madison

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Association for the Advancement of Sciences
American Fisheries Society
American Society of Zoologists
World Aquaculture Society

SELECTED PUBLICATIONS

Malison, J.A., L.S. Procarione, T.B. Barry, A.R. Kapuscinski, and T.B. Kayes. 1994. Endocrine and gonadal changes during the annual reproductive cycle of the freshwater teleost, *Stizostedion vitreum* ("walleye"). Fish Physiology and Biochemistry 13:473-484.

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Malison, J.A., L.S. Procarione, J.A. Held, T.B. Kayes, and C.H. Amundson. 1993. The influence of triploidy and heat and hydrostatic pressure shocks on the growth and reproductive development of yellow perch (*Perca flavescens*). Aquaculture 116:121-133.

Malison, J.A., T.B. Kayes, J.A. Held, T.P. Barry, and C.H. Amundson. 1993. Manipulation of ploidy in yellow perch (*Perca flavescens*) by heat shock, hydrostatic pressure shock, and spermatozoa inactivation. Aquaculture 110:229-242.

Malison, J.A., and J.A. Held. 1992. Effects of fish size at harvest, initial stocking density and tank lighting conditions on the habituation of pond-reared yellow perch (*Perca flavescens*) to intensive culture conditions. Aquaculture 104:67-88.

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EDUCATION

B.S. Iowa State University, 1966
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POSITIONS

Professor (1990-present), Associate Professor (1981-1990), and Assistant Professor (1976-1981), Department of Agricultural Economics, Purdue University

Director (1988-present), Center for Agricultural Policy and Technology Assessment, Purdue University

Graduate Instructor in Research (1974-1975), Department of Applied Social Sciences, University of Sao Paulo, Piracicaba, Sao Paulo, Brazil

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Agricultural Economics Association
American Economics Association
American Association for the Advancement of Science

SELECTED PUBLICATIONS

Riepe, J.R., M.A. Martin, and L.F. Schrader. 1993. Indiana restaurants as a market for farm-raised fish: results from a 1991 survey. Station Bulletin Number 665, Department of Agricultural Economics, Office of Agricultural Research Programs, Purdue University, West Lafayette, Indiana.

Edwards, C.R., T.N. Jordan, M.A. Martin, A.C. Mason, J.R. Riepe, and F. Whitford. 1993. Toward a complete and consistent data set: an assessment of pesticide use surveys for ten commercial crops, 1975-1991. Research Bulletin RB-990, Agricultural Experiment Station, Purdue University, West Lafayette, Indiana.

Riepe, J.R., and M.A. Martin. 1992. Indiana restaurants: a promising market for Indiana aquaculture. Purdue Agricultural Economics Report (August), Purdue University, West Lafayette, Indiana.

Foltz, J.C., and M.A. Martin. 1991. Inclusion of alfalfa (*Medicago Sativa L.*) in crop rotations in the Eastern Corn Belt: some environmental and economic implications. Journal of Sustainable Agriculture 2:117-133.

Baumgardt, B.R., and M.A. Martin, editors. 1991. Agricultural biotechnology: issues and choices. Agricultural Experiment Station, Purdue University, West Lafayette, Indiana.

Martin, M.A., M.M. Schreiber, J.R. Riepe, and J.R. Bahr. 1991. The economics of alternative tillage systems, crop rotations, and herbicide use on three representative East-Central Corn Belt farms. Weed Science 39:299-307.

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EDUCATION

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Ph.D. Texas A&M University, 1989

POSITIONS

Associate Agricultural Economist (1994-present) and Assistant Agricultural Economist (1988-1994), FFGI, Kansas State University
Agricultural Commodity Marketing Specialist (1984-1988), Department of Agricultural Economics, Texas A&M University
Fish Production/Marketing Manager (1977-1982), Three-Springs Fisheries, Inc., Maryland
Consultant/Aquacultural Specialist for various agencies: Belize (1990), El Salvador (1988), Honduras (1988), Pakistan (1983/84), Philippines (1979), Nepal (1974/75)
Assistant Hatchery Manager (1976), U.S. Fish and Wildlife Service, Senecaville, Ohio
Aquacultural Extension Agent (1972-1974), U.S. Peace Corps, Nepal

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Agricultural Economics Association

SELECTED PUBLICATIONS

Neils, K. 1993. Comparative economic analysis of the substitutability of an extruded fish-based product for the commercial PROPAK product in a broiler diet. Consultant's report to the Oceanic Institute, Waimanalo, Hawaii.

Neils, K., P. Vergne, and E. Guier. 1988. USAID action plan for shrimp mariculture in El Salvador. Tropical Research and Development, Inc., Gainesville, Florida.

Vergne, P., J. Dickinson, C. Villeda, G. Sharp, K. Dorsay, F. Pannier, K. Neils, C. Peckham, and W. Griffin. 1988. Study of the Honduran shrimp industry. Tropical Research and Development, Inc., Gainesville, Florida.

Neils, K. 1984. Aquacultural extension manual. Pakistan Aquacultural Development Project, Pakistan.

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EDUCATION

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Ph.D. Purdue University, 1979

POSITIONS

Associate Professor (1987-present) and Assistant Professor (1983-1987), Department of Agriculture, Illinois State University
Assistant Professor (1979-1983), Department of Agricultural Economics, Purdue University

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Agricultural Economics Association
Southern Agricultural Economics Association
International Agribusiness Management Association

SELECTED PUBLICATIONS

Kneller, P.B., W.N. Lockwood, Jr., P.D. O'Rourke, and S.W. Waite. 1993. Aquaculture and mobile fish processing. Journal of Environmental Health 56(1) July/August.

Rosati, R.R., P.D. O'Rourke, K.T. Tudor, and R.D. Henry. 1993. Performance of a raceway and vertical screen filter while growing *Tilapia nilotica* under commercial conditions. Presented at Aquaculture Engineering: An International Conference of Engineering Techniques for Modern Aquaculture, Spokane, Washington, June 20-23, 1993.

O'Rourke, P.D. 1991. Preproduction analysis of economic profitability for recirculating aquaculture systems. Workshop on design of high density recirculating aquaculture systems. Louisiana State University, Baton Rouge.

O'Rourke, P.D. 1991. Current status on profits in recirculating systems. Proceedings of the second annual workshop: commercial aquaculture using water recirculating systems. Illinois State University, Normal.

Rosati, R.R., P.D. O'Rourke, and R.D. Henry. 1990. Preliminary results of high density fish culture in a water recirculating system. Presented at the National Symposium for Freshwater Crayfish Aquaculture, Fremantle College, Fremantle, Australia.

Rosati, R.R., P.D. O'Rourke, and R.D. Henry. 1989. Commercial tilapia production in a water reuse system. Presented at the 1989 International Winter Meeting of the American Society of Agricultural Engineers, New Orleans, Louisiana.

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Graduate Research Assistant (1987-1988), Department of Agricultural Economics, Purdue University
Graduate Research Assistant (1984-1987), Department of Agricultural Economics, North Dakota State University
Economist (Co-op) (1985-1986), USDA, Foreign Agricultural Service

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

Sigma Xi (Associate Member)
Indiana Aquaculture Association

SELECTED PUBLICATIONS

Swann, D.L., J.R. Riepe, J.D. Stanley, M.E. Griffin, and P.B. Brown. 1994. Cage culture of hybrid striped bass in Indiana and evaluation of diets containing three levels of dietary protein. Journal of the World Aquaculture Society 25.

Riepe, J.R., M.A. Martin, and L.F. Schrader. 1993. Indiana restaurants as a market for farm-raised fish: results from a 1991 survey. Station Bulletin Number 665, Department of Agricultural Economics, Office of Agricultural Research Programs, Purdue University, West Lafayette, Indiana.

Riepe, J.R., and M.A. Martin. 1992. Indiana restaurants: a promising market for Indiana aquaculture. Purdue Agricultural Economics Report (August), Purdue University, West Lafayette, Indiana.

Riepe, J.R., L. Swann, and P.B. Brown. 1992. Analyzing the profitability of hybrid striped bass cage culture. Fact Sheet AS-487, Sea Grant Publication IL-IN-SG-FS-92-18, Aquaculture Extension, Illinois-Indiana Sea Grant Program, Purdue University, West Lafayette, Indiana.

Swann, L., and J.R. Riepe. 1991. Making wise choices when direct marketing your aquaculture products. Fact Sheet AS-464, Sea Grant Publication IL-IN-SG-FS-91-2, Aquaculture Extension, Illinois-Indiana Sea Grant Program, Purdue University, West Lafayette, Indiana.

Schrader, L.F., and J.R. Riepe. 1990. Marketing aquaculture products. Pages 44-48 *in* D.L. Swann, editor. Proceedings of the regional workshop on commercial fish culture using water reuse systems. Illinois State University, Normal.

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EDUCATION

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POSITIONS

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Associate Director of the North Central Regional Aquaculture Center (1988-1990)
Chairman (1976-1985), Department of Animal Ecology, Iowa State University
Leader (Fishery Research Biologist, U.S. Fish and Wildlife Service, GS-13) (1966-1976), Oklahoma Cooperative Fishery Research Unit, Oklahoma State University
Assistant Professor (1964-1966), Department of Zoology, Kansas State University
Lecturer (1962-1964), Department of Zoology, Southern Illinois University, Carbondale
Visiting Professor: Utah State University (1983), Oregon Institute of Marine Biology (1975), and Southern Illinois University (1965)

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Fisheries Society: Fish Culture, Fish Health, Education, Bioengineering, Computer Users, and Fisheries Management Sections; Iowa Chapter
American Institute of Fishery Research Biologists (Fellow)
Aquacultural Engineering Society
Fisheries Society of the British Isles
World Aquaculture Society
Honorary: Sigma Xi, Phi Kappa Phi, Gamma Sigma Delta

SELECTED PUBLICATIONS

Yager, T.K., and R.C. Summerfelt. 1994. Effects of feeding frequency on metabolism of juvenile walleye. Aquacultural Engineering 13:257-282.

Moore, A., M.A. Prange, B.T. Bristow, and R.C. Summerfelt. 1994a. Influence of stocking densities on walleye fry viability in experimental and production tanks. Progressive Fish-Culturist 56:194-201.

Moore, A., M.A. Prange, R.C. Summerfelt, and R.P. Bushman. 1994b. Evaluation of tank shape and a surface spray for rearing larval walleye on formulated feed. Progressive Fish-Culturist 56:100-110.

Harding, L.M., and R.C. Summerfelt. 1993. Effects of fertilization and of fry stocking density on pond production of fingerling walleye. Journal of Applied Aquaculture 2:59-79.

Hussain, M., M.A. Gabal, T. Wilson, and R.C. Summerfelt. 1993. Effect of aflatoxin-contaminated feed on morbidity and residues in walleye fish. Veterinary and Human Toxicology 35:396-399.

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Research Assistant (1983-1988), Ohio State University
Fishery Biologist (1982-1983), U.S. Fish and Wildlife Service
Research Assistant (1979-1982), Virginia Polytechnic Institute and State University

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Fisheries Society
Ecological Society of America
North American Benthological Society

SELECTED PUBLICATIONS

Brecka, B.J., M.L. Hooe, and D.H. Wahl. In press. Comparison of growth, survival, and body composition of muskellunge and tiger muskellunge fed four commercial diets. Progressive Fish-Culturist.

Szendrey, T.A., and D.H. Wahl. In press. Effect of feeding experience on vulnerability to predation, growth, and survival of esocids. North American Journal of Fisheries Management.

Hooe, M.L., D.H. Buck, and D.H. Wahl. 1994. Growth, survival, and recruitment of hybrid crappies stocked in small impoundments. North American Journal of Fisheries Management 14:137-142.

Santucci, V.J., Jr., and D.H. Wahl. 1993. Survival and growth of walleye stocked in a centrarchid-dominated impoundment. Canadian Journal of Fisheries and Aquatic Sciences 50:1548-1558.

Wahl, D.H., and R.A. Stein. 1991. Food consumption and growth among three esocids: field tests of a bioenergetics model. Transactions of the American Fisheries Society 120:230-246.

Wahl, D.H., and R.A. Stein. 1988. Selective predation by three esocids: the role of prey behavior and morphology. Transactions of the American Fisheries Society 117:142-151.