AQUACULTURE WASTES AND EFFLUENTS

Chairperson: Fred P. Binkowski, University of Wisconsin-Milwaukee

Industry Advisory Council Liaison: Harry Westers, Rives Junction, Michigan

Extension Liaison: LaDon Swann, Purdue University

Funding Request: $100,000

Duration: 2 Years (September 1, 1996 - August 31, 1998)

Objectives:

1. Study and evaluate solid waste management by:
   a. describing the relevant physical characteristics of fecal material from fish fed commonly used commercial feeds,
   b. developing diets to maximize integrity of fecal pellets without loss of fish performance and compare the physical characteristics of these pellets to those in subobjective a, and
   c. developing operational and engineering solutions to minimize destruction of larger particles and to remove all particulates.
2. Develop a report that:
   a. Describes the potential benefits of aquacultural by-products (effluents and solids) in the context of Integrated Resource Management and Sustainable Development,
   b. Characterizes the differences between the aquacultural discharges and other agricultural and industrial discharges, and
   c. Identify case studies of previous controversies highlighting real versus perceived impacts of aquaculture.

Proposed Budgets:

Institution	Principal Investigator(s)	Objective(s)	Year 1	Year 2	Total
Univ. of Wisconsin-Milwaukee	Fred P. Binkowski	1a, 1b & 2a-c	$22,884	$23,116	$46,000
Southern Illinois University-Carbondale	Christopher C. Kohler	1a & 1b	$15,000	$15,500	$30,500
University of Minnesota	Ira R. Adelman	1a & 1c	$3,820	$19,680	$23,500
		TOTALS	**$41,704**	**$58,296**	**$100,000**

Non-funded Collaborators:

Facility	Collaborator(s)
UW-Madison Aquaculture	Jeff Malison
Glacial Hills Inc., Starbuck, Minnesota	
Alpine Farms	John Hyink and John Wolf
Milwaukee County House of Correction Fish Hatchery	Antony Grabowski

TABLE OF CONTENTS

JUSTIFICATION

Effective Solid Waste Management in Aquaculture Systems (Objective 1)

Effective solid waste management is a key factor both for maintaining water quality in intensive aquaculture systems and for minimizing potential adverse environmental impacts of aquaculture development. The European Inland Fisheries Advisory Commission (EIFAC) work group on fish farm effluents recommended in 1987 that waste solids should be removed from fish rearing units as rapidly as possible, ideally without unnecessary disturbance to the structure of the solids.

Several possible deleterious effects of high levels of suspended solids within intensive aquaculture systems include: 1) gill tissue damage resulting in reduced disease resistance (Wickins 1981), 2) growth reduction (Wickins 1981), 3) clogging of biofilters (Muir 1982), 4) reduced nitrification rates (Kruner and Rosenthal 1987), 5) increased ammonia load through mineralization (Liao and Mayo 1974), and 6) increased biochemical oxygen demand (BOD) (Muir 1982). These potential problems are most acute in recirculating systems where retained solids are progressively reduced to smaller sizes. Levels of 40 mg/L and above of total suspended solids (TSS) have been reported for recirculating aquaculture systems (Libey 1993; Westerman et al. 1993) although these levels were probably of a transitory nature. Westerman et al. (1993) found that suspended solids in their recirculating systems were typically between 10 and 30 mg/L. Levels of 15 mg/L are often reached and exceeded by even moderately loaded recirculating systems (Chen et al. 1994).

Current guidelines for suspended solids are based on limited information or on situations that are not necessarily applicable to aquaculture systems. Recommended suspended solids limits vary by author. Wickins (1981) recommended a limit of 15 mg/L. Muir (1982) listed environmental requirements for recirculating aquaculture systems with a recommended suspended solids limit of 20 to 40 mg/L while acknowledging that few of the limits were obtained experimentally. In a table of recommended environmental conditions for salmonid aquaculture, Wedemeyer (1981) listed a total suspended, settleable solids concentration of 80 mg/L or less, citing the 1976 EPA Quality Criteria for Water.

In addressing potential environmental impacts of solids from aquaculture discharges, the nature of the solid material is significant. Impacts of high levels of inorganic solids, such as the reported 60% reduction in macroinvertebrate density where discharge from a rock quarry had increased the suspended solids concentration to 80 mg/L downstream (USEPA 1976), aren't necessarily applicable to aquaculture systems. Suspended solids guidelines for aquaculture effluents must protect against the potential organic enrichment of the environment as well as any possible deleterious physical effect of the solids themselves. In this context the suspended solids concentration in an effluent is most important as an index of the portion of the waste that is not yet dissolved and is more readily removable than dissolved material. Rapid and effective solids removal can circumvent further leaching of nutrients through waste decomposition. According to Westers (1991), the removal of intact fecal pellets is the key to effective solids and associated waste nutrient management. He stated that undivided excreta particles have a rapid settling velocity, but when fragmented, various fractions may become suspended, thus significantly reducing settling velocities. In addition, leaching of nutrients and decomposition will be accelerated on smaller suspended particles. Changes that occur in solid wastes during the first 24 h suggest that the removal time window to achieve desired results may be limited. Butz and Vens-Cappell (1982) found that the BOD in fish feces can decline by as much as 50% in 12 h. Sumari (1984) reported that 24-h old sludge, from a variety of diets, underwent reductions in BOD ranging from 35 to 46% in 15 d. Westers (1991) has reported extensive reductions of the phosphorus concentrations in the effluents from the Platte River fish hatchery in Michigan due to a reduction in feed wastage, removal of fines from the feed fed, lowering of the phosphorus levels in the fish diets, and use of dietary phosphorus sources that are more available to the fish's digestive system. Feed composition and feeding practices influence the amount and character of the particles entering the system and the design and operational characteristics of the system determine their fate. Before improved removal methods can be developed, the characteristics of the solid wastes must be determined. Because different aquaculture systems may have different effects on the particles present, a variety of configurations should be evaluated using standard protocols and measurement methods.

Describe Relevant Physical Characteristics of Fecal Material (Objective 1a)

The size of waste particles and their specific gravity are principal factors influencing their rate of settling out of the water column. The size of the fish generally dictates the upper limit for the particle sizes of both the foods used and of the waste particles in aquaculture systems. The turbulence of the water in the production system at high density can work to keep wastes in suspension. The mechanical action of pumps, filters and aerators in aquaculture systems can grind wastes to small size. The efficient isolation and removal of waste is best accomplished before particles are broken up. The durability of the fecal material influences the time window in which it is most effectively removed. Questions remain about the level of disturbance that can be tolerated as a function of diet ingredients, age of the fecal material, etc. Additional quantification of fecal properties can provide better direction for culture system design and determining allowable solids residence time in raceways before solids must be removed. This will minimize phosphorus solubilization and release as effluent waste. Much of the information concerning fecal characteristics in hatchery systems has been based on salmonid culture. Little is known concerning the physical characteristics and settling properties of fecal material for important alternative aquaculture species in our region. Specifically, information on fecal settling properties and decomposition characteristics for yellow perch, hybrid striped bass, or walleye in intensive culture situations and water reuse systems would be beneficial. Commonly used commercial diet formulations for these coolwater species may influence the properties of the wastes produced, as much as species or lifestage differences can influence the size and physical integrity of the wastes.

Develop Diets to Maximize Integrity of Fecal Pellets Without Loss of Performance (Objective 1b)

Feed composition may alter the physical properties of fecal wastes that, in turn, affects their removal from fish culture systems. Stechey and Trudell (1990), from a study of methods of separating waste solids from three types of fish culture systems, concluded that: 1) feed related factors such as feed brand, feed type, and feeding method appear to be subordinate to facility design and culture practices with respect to pollution impact; and 2) the required level of effluent treatment (in Ontario) will be governed by total dissolved phosphorus concentration because solids can be removed to desired levels even at relatively high flow rates.

Several dietary approaches to waste management in aquaculture have potential. Reducing the phosphorus content and improving the efficiency of utilization of feed nutrients by fish is currently an active field of investigation. Another approach is to alter the durability of food pellets and resultant fecal material through changes in diet composition. Binding agents are used to stabilize fish feeds (Hardy 1989), and can have significant effects on pellet stability (Heinen 1981; Reinitz 1983), the stability of fecal materials, and on trout physiology (Storebakken 1985; Storebakken and Austreng 1987). High levels of polycellulose binders have been associated with hepato-renal syndrome in cultured turbot (Anderson et al. 1976; Roberts and Bullock 1989). In evaluating such diets, the benefits of pellet stability will have to be weighed against any potential risks to fish health and growth performance. Fiber is generally considered to have no functional value in fish feeds except possibly to control rate of movement through the digestive tract (Lovell 1989). Fiber is a generic term that refers to all indigestible plant matter such as cellulose, lignins, and other complex carbohydrates. Fish diets are usually formulated so as to avoid excessive levels of fiber because high fiber serves to inhibit feed intake, increase fecal waste production, and, consequently, pollute the culture water (National Research Council 1983). However, the use of high fiber content (>5%) in fish diets as a means to increase fecal stability in water to facilitate mechanical removal in intensive rearing systems has apparently not been examined.

A common strategy in the pet food industry is to formulate diets high in certain fiber sources to produce firm stools (Dr. Denny Hughes, Feed Division, Farmland Industries, Inc., Kansas City, Missouri, personal communication). These diets are formulated with high quality protein sources with the added fiber being offset by reduction in carbohydrates. Fat is added as needed to retain sufficient caloric content. Beet pulp is a fiber source commonly used in dog diets that has an effective complement of viscous and nonviscous structural carbohydrates (Fahey et al. 1990). Dried beet pulp is the dried residue from sugar beets which have been cleaned and freed from crowns, leaves, and sand, and then extracted to manufacture sugar. To our knowledge, it has not been used in fish diets. Beet pulp is currently in stable supply and available at a reasonably low price ($85-$150/ton). It would likely provide some limited nutritional benefits by virtue of being about 8% protein and 0.5% fat. Some non-structural carbohydrates are likely present, but most would be expected to be lost from the sugar extraction process. Beet pulp is considered to essentially be fiber for formulation purposes. Its relatively low cost and potential for some boost in nutrient levels offers clear advantages to more inert sources of fiber such as cellulose, agar, carrageenan, guar gum, etc. There is clearly a need to examine the utility of beet pulp in fish diets to determine if fecal water stability can be improved without significant loss in fish growth.

Develop Operational and Engineering Solutions for Solid Waste Management (Objective 1c)

Optimum culture system design and operation is influenced by a broad array of physical and biological variables. From the perspective of waste removal some relevant factors are culture system geometry and hydraulic flow patterns, water flow and exchange rates, rearing density and loading, and feeding procedures and waste properties.

Knowledge of fecal water stability, specific gravity and settling properties provide useful guides for the design of waste removal in a variety of intensive culture situations. For single pass and flow through situations solids removal needs to be done before discharge as effluent to avoid eventual impact. In recirculation systems design, the opportunity for mechanical breakdown is increased due to the need for pumping to control circulation through the system, and settling and durability of waste particles is more critical because the residence time of small particles will be longer if initial removal is unsuccessful. Clogging of system components will influence their performance. Chen et al. (1993a,b) characterized the suspended solids in several recirculating aquaculture systems and found that 95% of the suspended material had a diameter of less than 20 µm. Particles of that size have such low settling rates that they are impractical to remove by gravitational methods. Typical mechanical screens and filters are designed to remove particles >80 µm, and particles of this size generally pass through biological filters. Greater economy and efficiency of waste removal is achieved when a larger proportion of waste is removed before it is broken down to small-sized particles.

When selecting treatment options for nitrification, aeration, disinfection, or the removal of larger solids (greater than 50 µm), the producer is able to choose from a wide variety of system components. These range from simple settling basins for the largest particles to microscreen filtration as the size decreases. A considerable amount of research effort has been expended on the development of these components and their effect on related water quality. In contrast, relatively little effort has been put forth on the effects and characterization of solids in recirculating aquaculture systems and the removal of smaller suspended solid particles (<20 µm).

As the particle size decreases, the capital and operating costs of removal generally increase significantly. Microscreens have low operating costs (Libey 1993) but have high initial costs and are not practical for removal of particles below 40 µm. Granular media filters can remove smaller particles but have high operating costs and are susceptible to biofouling. Diatomaceous earth and cartridge filters are able to remove fine particles (less than 30 µm) but have high operating costs and are generally suitable only for low loadings of high value fish such as ornamentals (Chen et al. 1994). Foam fractionation has lower operating and capital costs, but has the disadvantage of being dependent upon surface active substances in the culture water and thus particle removal is less reliable (Chen et al. 1994).

As part of the operational and engineering data needed to develop solutions to the problem of solid waste management, the effect of suspended solids on the growth of fish held in recirculating aquaculture systems should be evaluated. This information is lacking in the literature, but it is needed if an engineer is to apply cost /benefit analyses to removal technologies. In addition, it has been suggested that the more difficult to remove smaller particles (<20 µm) are potentially more hazardous to fish (Chen et al. 1993a,b).

Develop a Report About Aquaculture Wastes and Effluents (Objective 2)

As a frequently large water user, aquaculture is perceived by the public and the regulatory community as an industry that has the potential to degrade the nation's waters. To further magnify this concern, aquaculture is more and more recognized as a form of agriculture, and agriculture is recognized as the leading source of water pollution in the U.S. This includes both point source and nonpoint source impacts (Weinberg 1992). It is, therefore, important for the aquaculture community to be ahead of the public, the environmental groups, and the regulators in order to avoid unrealistic regulations based on emotions and bad information or poor science. In 1974, the EPA published tentative effluent limitation values for aquaculture systems (USEPA 1974), but these were never promulgated and Harris (1981) pointed out the federal regulations of fish hatchery discharges have been inconsistent because of the lack of a properly prepared guidance document. Additionally, a broad range of state laws and regulations apply to aquaculture and these often constrain the development of aquaculture in the respective states (Ziemann et al. 1990). Indeed the National Research Council in 1978 reported that the orderly development of aquaculture is constrained due to political and administrative rather than scientific and technological problems.

Aquaculture needs clean, quality water and as such, the industry must practice good resource stewardship. Aquaculture producers should support the goals of the Clean Water Act (CWA) of 1977 that protect the nation's water against further degradation. The aquaculture industry is wholly dependent upon sources of high quality water for current and future production.

To prevent misperception of the impacts of aquaculture, accurate characterizations of aquaculture effluents are required. A previous North Central Regional Aquaculture Center (NCRAC) funded project measured the changes in water quality associated with typical aquaculture production systems in the North Central Region (NCR). The results of that study provide a foundation for further assessment and comparison to alternative municipal, industrial and agricultural effluents. That study suggests that for flow-through and pond production systems detectable moderate changes in water quality in terms of solids and nutrients occur. These moderate changes can support an argument that aquaculture is relatively benign compared to other regional agricultural practices and land use activities. There is a need for this information to be organized into an easily understood format so that normal aquaculture operating conditions can be viewed against the existing general background of water quality fluctuation and environmental impact. Educating the public through such comparison may help to alleviate the perception that aquacultural effluents are synonymous with general industrial and agricultural effluents.

The more dramatic changes in water quality from aquaculture operations are associated with clean out events for removal of settled aquaculture waste materials, but such periodic events can be controlled. Recycle systems, also, produce expectedly more concentrated waste, but they also permit more opportunities for innovative reuse or disposal. Wise resource management calls for finding beneficial use for these concentrated aquaculture by-products. Nutrients that are detrimental in one context can be beneficial in another, as has been recently pointed out with regard to fisheries productivity and phosphorus (Fetterolf 1993). There is currently great interest in finding and promoting beneficial uses for nutrients recovered from aquaculture wastes, as evidenced by the presentations in the special session on "Sustainability of Aquaculture: Status and New Strategies in the U.S." and other water quality sessions at the "Aquaculture ‘95" conference. Options examined included constructed wetland, irrigation uses, hydroponics and even biogas production strategies. Hopkins (1995) in his opening presentation at this session pointed out how the development of aquaculture may generate environmental pitfalls analogous to those experienced due to the "Green Revolution" in land agriculture. He also pointed out the necessity of considering the variations and diversity of aquacultural practices. In considering strategies for aquaculture sustainability for the NCR, there is a need to interpret these new options and strategies that are generally from other regions of the U.S. or world, within the context of our own regional land use practices, climate, and ecological communities.

RELATED CURRENT AND PREVIOUS WORK

Describe Relevant Physical Characteristics of Fecal Material (Objective 1a)

Previous NCRAC aquacultural effluent investigations have characterized water quality changes associated with regional production systems. This work has measured the levels of solids produced by representative regional facilities as settleable solids, TSS, and dried solids. The University of Wisconsin-Milwaukee (UW-Milwaukee) examined effluents from yellow perch culture at Alpine Farms as part of these efforts. Previous NCRAC Yellow Perch Work Group investigations concerned with intensive tank rearing of yellow perch from egg using cultured live foods will enable us to handle and maintain yellow perch stocks in sufficient sizes and numbers to investigate wastes associated with this early life history phase and expand knowledge of waste characteristics over the entire yellow perch life cycle.

Develop Diets to Maximize Integrity of Fecal Pellets Without Loss of Performance (Objective 1b)

Solid wastes are most easily removed from culture systems by conventional water treatment processes, while nutrients, once they become dissolved, require treatment technologies that are cost prohibitive. Phosphorus is especially of concern in this regard. For this reason attention has focused on reducing the phosphorus content of commercial feeds to the minimal content required by the fish, and on using phosphorus containing ingredients that increase the assimilation of phosphorus by fish, leaving less in unassimilated form in the feces. In NCRAC Salmonid Work Group investigations, Purdue University (Purdue) investigators are examining the availability and absorption of phosphorus from plant protein feedstuffs rather than fish meals. The addition of phytase to the diet significantly increased the absorption of phosphorous by fish from plant feed stuffs.

Another strategy to improve commercial fish foods from the perspective of waste management is to influence the stability of food pellets and or the fecal material resulting from a particular diet. Binding agents are used to stabilize fish feeds (Hardy 1989), and can have significant effects on pellet stability (Heinen 1981; Reinitz 1983), the stability of fecal materials, and on trout physiology (Storebakken 1985; Storebakken and Austreng 1987). High levels of polycellulose binders have been associated with hepato-renal syndrome in cultured turbot (Anderson et al. 1976; Roberts and Bullock 1989). In NCRAC funded experiments in the Salmonid Work Group, Michigan State University investigators are evaluating the effects of different feed binders (Cain 1993) in all-plant protein-source diets on rainbow trout performance and the stability of trout feces. The diets developed for the proposed investigations will build on this background and incorporate promising aspects of these previous investigations, and expand the fecal pellet stability investigations to appropriate regional non-salmonid species.

Another approach is the addition of fiber to the diet to influence fecal durability in water and permit easier removal. Fiber has received relatively little attention in fish nutrition studies. It is generally believed to be of little benefit to fish and may at high levels depress growth and lead to fouling of water. Buhler and Halver (1961) observed depressed growth rates in chinook salmon, *Oncorhyncus tschawytscha*, reared on diets with increasing levels of α-cellulose. Conversely, Dupree and Sneed (1966) found that channel catfish, *Ictalurus punctatus,* exhibited improved growth rates when fed purified diets with 21% cellulose. The fiber may have slowed the rate of the purified ingredients passing through the digestive tract, thus allowing for improved digestion and growth. However, Leary and Lovell (1975) observed growth depression in channel catfish fed practical diets with 8% or more of cellulose. Likewise, Hilton et al. (1983) showed that rainbow trout, *Oncorhynchus mykiss*, had decreased growth when 10 and 20% α-cellulose was incorporated in a practical diet. Similar results were found for Nile tilapia, *Oreochromis niloticus*, as α-cellulose was increased from 0 to 40% in semi-purified diets (Anderson et al. 1984). Shiau and Kwok (1989) followed-up on this study by examining various fiber sources (cellulose, agar, carrageenan, guar gum, carboxymethyl cellulose) in diets of hybrid tilapia (*O. niloticus* × *O. mossambicus*). Their results were consistent with those of Anderson et al. (1984), but the degree of decrease in weight gain percentage and feed conversion ratio were not the same among the different fiber sources. Moreover, the diets were not isocaloric. Shiau and Kwok (1989) used glucose as a control, while Anderson et al. (1984) used various non-structural carbohydrate sources (glucose, sucrose, and starch). Alternatively, Hilton et al. (1983) and Leary and Lovell (1975) utilized basal diets which were then diluted with cellulose. The quantity of nutrients was held constant by assigning proportionally higher feed allowances in relation to fiber content.

Develop Operational and Engineering Solutions for Solid Waste Management (Objective 1c)

Chen et al. (1994) summarized the research findings of three groups of researchers who had characterized the particle size distributions in recirculating aquaculture systems. The studies were not directly comparable due to different species and methods used but showed that fine particles (6 to 20 μm) were the dominant size represented. A study on reducing aquaculture waste generation and discharge is currently being conducted by Cornell University, Illinois State University, Louisiana State University, and the University of Maryland. Although some of the objectives are similar to the objectives of this proposed study, the systems involved are smaller (between 265- and 4542-L) and the methods of particle size analysis differ between institution (John Hochheimer, Ohio State University, personal communication).

Information on the effects of suspended solids on fish in recirculating aquaculture systems is lacking. Reductions in growth and disease resistance due to suspended solids have been observed in studies with wastes of industrial origin (Alabaster and Lloyd 1980). Chapman et al. (1987) found aluminum processing wastes to be physically toxic with the lethal effects associated with particles 5-10 µm in size. These studies give cause for concern, but it is possible that the types and levels of suspended solid particles found in recirculating aquaculture systems may not elicit the same effects.

Develop a Report About Aquaculture Wastes and Effluents (Objective 2)

The previous NCRAC Effluent Work Group investigation of aquaculture effluents has created a database of information and extensive bibliography of effluent information for representative regional production systems. This will provide a foundation for comparison to the effluent characteristics and potential environmental impacts of other contemporary land use practices. This regionally cooperative effort has generated water quality information on pond, flow through, cage culture and recirculating aquaculture production systems. The bibliography from this study will serve as a foundation that will be expanded and updated to include as much regionally relevant material as possible.

Over the last two decades, there have been several significant national and international workshops dealing with aquaculture effluents (Alabaster 1982; Pursiainen 1988), water quality (Brune and Tomasso 1991), and waste management (Blake et al. 1992). Effluent production and characterization and the integration of aquaculture with agriculture (Wang 1993) were also the topics of a recent national Aquaculture Engineering conference. Pillay (1992) has reviewed the relationship of aquaculture and the environment from a world wide perspective and more recently special sessions on the "Sustainability of Aquaculture: Status and New Strategies in the U.S." and "Permitting Procedures for Aquaculture Effluents" were convened at the "Aquaculture ‘95" conference. There are also many additional and relevant papers in diverse technical journals over this same period.

Often the situations and examples presented in this literature deal with species, climate, etc., which may or may not be applicable to the environmental and regulatory situations in our region. There is still a need to review and present this information in relation to its relevance and application to aquaculture in the NCR.

ANTICIPATED BENEFITS

Improved solid waste management will both improve the water quality in regional aquaculture production systems and assist regional producers in improving effluent water quality and meeting effluent regulatory standards. Characterization of the possible differences in fecal waste properties of important regional alternative species will assist in the engineering design and operation of rearing systems for waste removal. Much of the previous information of this sort is based on salmonid culture. Our results will provide a broader base of information with regard to alternative species for rearing system design. Possible differences in specific gravity and settling properties of waste will have a bearing on design of settling basins, and clarifiers for rearing systems. This is especially pertinent to the development of recirculating aquaculture systems for these species.

This project will provide needed information for engineers and producers attempting to make cost/benefit analyses before employing removal technologies. In addition, data obtained under objectives 1a and 1c will be reviewed with engineering collaborators to suggest possible engineering solutions to waste management.

Better understanding of the influence of commercial diet formulations on the integrity of fecal solids and the consequent impact on nutrient release, holds promise of reducing the release of phosphorus into aquaculture effluents. This is one of the aspects of greatest regulatory concern due to its potential role in the eutrophication of receiving waters.

The use of a petfood nutrition strategy whereby diets are designed to produce firmer stools offers promise for waste management in aquaculture. Removal of feces from the water rather than actual fecal volume is the primary waste management problem in intensive rearing systems. The use of beet pulp in fish diets may significantly and economically improve fecal pellet stability allowing for more efficient mechanical removal.

Stickney (1994) cautions that when fish are fed a diet high in fiber, even when fed on an *ad libitum* basis, they may not obtain sufficient food in a day to meet their protein or energy requirements. Apparently no studies have been conducted with fish whereby fiber replaced carbohydrates and fat was increased to retain an isocaloric diet (on a per gram basis).

Efficient solids removal and management provides an avenue for the utilization of waste by-products as potentially beneficial resources in the context of integrated resource management plans. These types of practices can promote aquaculture as a beneficial or at least a benign influence on water resources when good stewardship is practiced. In this regard, comparison of real-life aquaculture production situations to other common land and water use practices will be helpful in arguing for realistic and just regulatory and permit situations. This information will allow industry advocates to put aquaculture related alterations in water quality, that are detectable with sensitive analytical techniques, into the context of inherent natural variations in water quality and the general prevailing context of land use in our region. Otherwise, public perception of any detectable difference can easily be blown out of proportion without a realistic appraisal. Comparing aquaculture waste production within the context of other contemporary land use practices with regard to impact on regional water quality should be useful for demonstrating that current and prospective regional aquaculture is relatively benign environmentally.

OBJECTIVES

1. Study and evaluate solid waste management by:
    a. describing the relevant physical characteristics of fecal material from fish fed commonly used commercial feeds,
    b. developing diets to maximize integrity of fecal pellets without loss of fish performance and compare the physical characteristics of these pellets to those in subobjective a, and
    c. developing operational and engineering solutions to minimize destruction of larger particles and to remove all particulates.
2. Develop a report that:
    a. Describes the potential benefits of aquacultural by-products (effluents and solids) in the context of Integrated Resource Management and Sustainable Development,
    b. Characterizes the differences between the aquacultural discharges and other agricultural and industrial discharges, and
    c. Identify case studies of previous controversies highlighting real versus perceived impacts of aquaculture.

PROCEDURES

Describe Relevant Physical Characteristics of Fecal Material (Objective 1a)

Using commercially available feeds, Effluent Work Group cooperators will characterize relevant physical characteristics of fecal material for a variety of regionally important aquaculture species in a variety of production situations.

Southern Illinois University-Carbondale (SIUC) Work Group participants will characterize fecal characteristics resulting from two 36% crude protein (CP) feeds designed for channel catfish (low fish meal diets) and two 40% CP feeds formulated for rainbow trout (high fish meal diets). These diets will be fed to fingerling Nile tilapia, hybrid striped bass, yellow perch, and rainbow trout. Each fish feed/species experiment will be conducted independently in triplicate. Three 110-L glass aquaria will be used, each with a water flow rate of 1.2-L/min in a recirculating water system with charcoal-filtered municipal water. Water quality variables, particularly temperature, dissolved oxygen (DO), pH, and NH_3 will be closely monitored and maintained at appropriate and comparable levels for each experiment and during holding periods. Each aquarium will be stocked with 10 juvenile fish (about 25 g mean weight), and will contain a plexiglass feces collector of sloping walls (see Ayala et al. 1993). With the feces collector in place, aquaria will be divided into two chambers: a feeding compartment (about one-third of the aquarium volume) and a fecal collector compartment. A removable screen will separate the two chambers.

For each fish feed/species experiment, fish will be fed the test diet for one week before fecal collections begin. Fish will be fed 3% of their wet body weights once each morning. Prior to feeding, the screen separating the two chambers will be removed and fish will manually be coaxed to swim to the feeding chamber, whereupon the screen will be reset. Feed residue will be siphoned out after each feeding session. Subsequently, the screen will be removed, the fish will be forced to return to the chamber containing the feces collector, after which the screen will be reset. Feces will be collected once each afternoon from a removable plexiglass box at the bottom of the collector.

The following procedures will be tested for measuring fecal durability, and with appropriate modifications will be used by all Work Group investigators as a standard technique for comparing fecal durability resulting from various diet and species combination for Objectives 1a and 1b. Feces from each replicate will be placed into a labeled petri dish and left uncovered in a refrigerator at 1-3°C for a 24-h drying period. Cold, semi-dry feces from each replicate will be weighed to the nearest 0.01 g. A 1.0 ± 0.05 g subsample from each replicate will be placed into a labeled, 250 mL Erlenmeyer flask with 100 mL of distilled water. As a second alternative, a 1.0 ± 0.05 g subsample from each replicate will be placed into a labeled, round bottomed tube and centrifuged at 2,500 RPM at room temperature for 5 min. The resulting pellet will then be placed in a 250 mL Erlenmeyer flask with 100 mL of distilled water. The flasks will be continuously agitated on a Lab-Line type orbital shaker set to 500 RPM, and individually timed in seconds until the pellets disintegrate into individual particles. Time-to-disintegration will serve as the measure of relative fecal stability among treatment groups (four fish species and four feeds).

University of Wisconsin-Milwaukee (UW-Milwaukee) will investigate the size and settling properties of feces and unused food wastes of yellow perch with regard to changes that occur during growth from larval through marketable size. Using the availability of these various life history stages at the Aquaculture Institute/UW System Great Lakes Research Facility (UWGLRF), they will define the size distribution and physical properties of freshly egested yellow perch feces. These tests would be conducted at the normal rearing temperatures (18-23°C) for yellow perch and under rearing conditions representative of commercial tank rearing conditions. Yellow perch in specific size ranges would be used to characterize the relationship between waste and fecal particle sizes and the size of the perch. Groups of experimental perch would be temporarily confined over night in aquaria and feces collected to characterize the particle size distribution and other physical properties in relation to fish size following the time windows presented in Table 1. This information along with some information based on collection of larger amounts of waste collected from normal lab rearing tanks with specific sizes and ages of fish (but less finely sorted) would be used to characterize solids from actual rearing conditions. Once perch are habituated from live food to formulated diet at approximately 25 mm size, they will be reared with Biodiet® (Bioproducts Inc., Warrenton, Oregon) and Ziegler Brothers (Gardener, Pennsylvania) diets. Because these commercially available feeds are those routinely fed to these perch stocks, no additional period of acclimation to these will be required. Pertinent production condition details such as ration level, fish density and size distribution will be recorded. In addition to tank-reared perch at the Aquaculture Institute/UWGLRF, we have potential access to perch reared at the Milwaukee County House of Corrections fish hatchery and at Alpine Farms hatchery, a private operator conducting yellow perch rearing in a recirculating aquaculture system.

Table 1. Time windows for characterization of fecal solids from various sizes of yellow perch and commercial diets.

Time window	Characterization of solids from:
September-December 1996	75-100 mm yellow perch (Ziegler Food)
December 1996 - February 1997	100-150 mm yellow perch (Ziegler Food)
February-March 1997	150-250 mm yellow perch (Ziegler Food)
April-June 1997	5-25 mm yellow perch (live foods to Biodiet®)
June-August 1997	25-75 mm yellow perch (Biodiet® to Ziegler Food)

Particle size characterization of fresh fecal material would be characterized utilizing a variety of techniques appropriate to the various particle sizes. For freshly egested feces anticipated sizes will range from >1 cm down to tenths of millimeters. For these sizes, an ocular micrometer of a dissecting microscope will be used to make the measurements. For waste particles from culture system samples, particle size distributions will also be achieved by gently settling materials of a measured volume (in the range of 0.2- to 2-L of collected waste) through a graded series of sieve sizes (1.00 mm, 500 µm, 300 µm, 150 µm) washing the material on the sieve (or an appropriately measured fraction of it) into an evaporating dish, oven drying it at 105°C, cooling it in a desiccator and determining the weight with an analytical balance. We will further characterize particle size distribution under 150 µm in the washings from the above samples using a filtration method similar to the technique used by Hinrichs (1994), that fractionates the solids collected on 105 µm, 75 µm and 43 µm filters. The solids in the final filtrate with particles less than 43 µm will be determined with the standard glass microfiber filter used in the determination of TSS, i.e., particles >2 µm. We will also determine TSS on subsamples of the washings from the 150 µm screening as a cross check on the small particle size fractionation. As an alternative for small (<150 µm) particle size characterization, electronic particle size analyzers, as used by Chen et al. (1993a;b) and Cripps (1993), are available for use at the UWGLRF.

Determinations of specific gravity of wastes will be made based on modification of the methods of APHA et al. (1992) and Chen et al. (1993a;b), utilizing gravimetric comparison of equal volumes of water and of centrifuged waste material.

For determination of settling properties, subsamples of collected waste from fish rearing units will be placed in Imhoff Cones or a Warrer-Hansen (1982) type settling column and the volume of settled material over time will be recorded after 5, 10, 15, 30 min and one hour. Alternatively, settleable solids will be determined gravimetrically using the change in TSS, as described in Standard Methods (APHA et al. 1992).

In order to determine the response of settled waste to movement by tank currents, we will examine the accumulation of wastes in the bottoms of 2.44-m diameter rearing tanks. Using a current meter, velocities in both areas swept clear of settled waste and in areas of deposition will be measured. We will record pertinent rearing tank conditions including fish size, fish density, biomass loading, food type and ration level, tank inflow and discharge arrangement. By manipulating inflow rates and the direction of the inflow into circular tanks we will be able to create enough variation in tank current and fish activity to determine current speeds near the bottom that permit solids settling and compare them to those that keep wastes suspended. The tank current velocities from these trials will be compared to the 0.24-0.3 m/s level that Burrows and Chenoweth (1955) found to be the minimum required to prevent settling of salmon waste, and that have been applied to improve hatchery raceway design (Boerson and Westers 1986).

To determine the resistance of perch aquaculture wastes to mechanical breakdown over time, the Work Group's standardized procedures using an orbital shaking device will be employed.

The University of Minnesota (UM) Work Group participants will sample wastes from operating recirculating aquaculture systems located at the University of Minnesota Fisheries and Aquaculture Laboratory and at the Glacial Hills production facility in Starbuck, Minnesota. Analysis will provide baseline data on solids production related to feed input for tilapia and rainbow trout held under production conditions using standard management practices in the industry. Total solids (TS), total volatile solids (TVS), TSS, BOD, and particle size distribution will be determined weekly. Ammonia-nitrogen, nitrite-nitrogen, DO, pH, and temperature will be monitored daily. All on-site water quality tests will be performed according to standard methods (APHA et al. 1992). Particle size distribution will be determined with a Lasentec particle size analyzer (Labtec 1000) located in the Limnological Research Center's Core Lab facility operated by the Department of Geology and Geophysics, UM.

Develop Diets to Maximize Integrity of Fecal Pellets Without Loss of Performance (Objective 1b)

SIUC Work Group cooperators will develop a high fiber diet designed to improve fecal stability and run production trials to compare the resulting fecal physical properties to those resulting from the commercial feeds used in Objective 1a. Isonitrogenous and isocaloric test diets containing 0, 8, and 18% beet pulp or α-cellulose (Table 2) will be prepared using a Univex model M-12B mixer and a General model SD-50 grinder. No nutritional contribution from beet pulp is assumed in the formulations. Semi-purified ingredients will be obtained from United States Biochemical Co. (Cleveland, Ohio), while menhaden meal and beet pulp will be obtained from Farmland Industries, Inc. (Kansas City, Missouri). A vitamin premix for salmonids and a generic (for fish) mineral premix (see Tables 2.6 and 6.4 in Lovell 1989) will be custom ordered from Purina Test Diets, Richman, Indiana. The digestible energy (DE) levels for carbohydrate, lipid, and protein (2.25, 8.25, and 4.2 Kcal/g, respectively) are based upon the average digestibilities for Pacific salmon and channel catfish (Piper et al. 1982). Carboxymethyl cellulose (CMC) will be provided at 2% as a binder for all diets. The pressed strands (0.32 cm; 1/8-in die) will be cut into edible-size pellets, air dried, and stored in plastic bags at -3°C.

Table 2. Experimental diets (%) to examine utility of beet pulp in fish feeds.

	Experimental Diets					
Ingredient	Conditioner	Control	8% Beet Pulp	18% Beet Pulp	8% α-Cellulose	18% α-Cellulose
Menhaden meal	10	10	10	10	10	10
Gelatin	8	8	8	8	8	8
Casein	28	28	28	28	28	28
α-Cellulose	10	--	--	--	8	18
Beet pulp[1]	--	--	8	18	--	--
Dextrin	25	39	28	14	28	14
Fat/oil[2]	11	7	10	14	10	14
Vitamin Premix	1	1	1	1	1	1
Ascorbic acid	1	1	1	1	1	1
Mineral Premix	4	4	4	4	4	4
CMC[3]	2	2	2	2	2	2
Dry Matter (est.)	94.9	94.9	94.9	94.9	94.9	94.9
Protein	36.6	36.6	36.6	36.6	36.6	36.6
Lipid	12.1	8.1	11.1	15.1	11.1	15.1
Fiber	12.1	2.1	10.1	20.1	10.1	20.1
Ash	2.5	2.5	2.5	2.5	2.5	2.5
NFE[4]	26.5	40.5	29.5	15.5	29.5	15.5
DE (Kcal/100g)	313.5	312.0	312.0	313.5	312.0	313.5

[1]Considered as 100% fiber for formulations
[2]50:50 fish oil:corn oil
[3]carboxymethyl cellulose
[4]nitrogen free extract

The experimental diets will be fed to advanced fingerling Nile tilapia and sunshine bass,. Fecal analyses will be performed as previously described. Results will be compared to the commercial feed studies (Objective 1a).

Production trials will be conducted for Nile tilapia (herbivore/omnivore model) and sunshine bass (piscivore model). Trials for each species will be run sequentially. For each study, five fish weighing approximately 25 g each will be stocked in each of 20 75-L aquaria, all connected to a common biofilter. Water flow will be regulated to achieve approximately 12 turnovers per day. Water temperature will be maintained at 28 and 24°C for tilapia and sunshine bass studies, respectively. Photoperiod (14-h light/10-h dark) will be held constant. Fish will be stocked two weeks prior to trials and fed daily the conditioning diet (Table 2) at a rate of 3% wet body weight, equally split into two meals (early morning/late afternoon). Excess feed and feces will be removed daily by siphon. Four aquaria will randomly be assigned to each of five treatments (Table 2). The same rationing and feeding schedule as the conditioning diet will be maintained. All fish will be marked using fin clips or passive integrator transponder (PIT) tags. Fish will individually be weighed every two weeks and feed rations adjusted accordingly using treatment means. Major water quality parameters (temperature, DO, pH, total ammonia nitrogen, CO_2, alkalinity, and hardness) will regularly be monitored using standard aquaculture procedures (Hach kits, DO meter, etc.). Specific growth rate (SGR), feed conversion ratio (FCR), protein efficiency ratio (PER), and condition (K) will be determined bi-weekly as follows:

SGR = 100 [ln final liveweight (g) - ln initial liveweight (g)]/time (d)

FCR = feed offered (g)/liveweight gain (g)

PER = liveweight gain (g)/protein offered (g)

K = liveweight (g)/length $(cm)^3$

At termination of each study (10 weeks), fish from each treatment will randomly be selected, taken off feed for a 24-h period, and then frozen pending whole body proximate analysis. Percent moisture, fat and ash will be determined using standard methods (AOAC 1984). CP will be determined using Hach's modification of the AOAC (1984) standards (Watkins et al. 1987). Proximate analysis will also be conducted for each test diet. Fiber analyses (crude fiber, total dietary fiber, neutral detergent fiber, acid detergent fiber, and acid detergent lignin) will be conducted at the laboratory of Dr. George Fahey (Animal Sciences Department, University of Illinois at Urbana-Champaign).

Isonitrogenous and isocaloric practical diets will be formulated to include two levels of beet pulp and three controls (0% beet pulp, and two levels of α-cellulose equivalent to the beet pulp diets). The levels of fiber will be determined based on the results of the semi-purified diet studies. Sources of fiber from natural ingredients (corn, soybean, etc.) will be factored in the determinations. These diets will be extruded by Farmland Industries, Inc. (Kansas City, Missouri). Studies identical to those described for the semi-purified diet trials will be conducted.

In cooperation with nutritionists at the United States Fish and Wildlife Service Bozeman Laboratory, UW-Milwaukee will develop an experimental diet for perch, incorporating binders anticipated to improve fecal stability. Groups of laboratory perch will be habituated to the experimental diets over an approximate two week period. Once the fish have adjusted to the new diet we would characterize solid waste using the same methods employed in the previous trials using the time windows presented in Table 3.

Table 3. Time windows for characterization of fecal solids from various sizes of yellow perch and an experimental diet.

Time window	Characterization of solids from:
September-December 1997	75-100 mm yellow perch (with experimental diet)
December 1997 - February 1998	100-150 mm yellow perch (with experimental diet)
February-March 1998	150-250 mm yellow perch (with experimental diet)

Fecal properties of wastes produced by perch fed this experimental diet will be compared to those based on the commercially available feeds used in Objective 1a. (Alternatively, if diet development is unsuccessful UW-Milwaukee will expand its activities for Objective 1a to include crappie or walleye.)

Develop Operational and Engineering Solutions for Solid Waste Management (Objective 1c)

UM Work Group cooperators will examine the impact of small size solids generated in recirculating production systems on tilapia and rainbow trout Using data from the literature and gathered in Objective 1a, concentrations of suspended solids spanning the range experienced in rainbow trout and tilapia production recirculating systems will be determined. Growth trials will be conducted with fish held in 190-L tanks adjacent to production tanks at the University and Glacial Hills. Each tank will be stocked with 15 to 30 fish, depending on the fish size. Water with different concentrations of suspended solids will be obtained by diluting untreated water from the production system with production system water which has been passed through a 60 µm microscreen drum filter and a granular media polishing filter. Granular media will be exchanged as needed to maintain homogeneous levels of ammonia-nitrogen and nitrite-nitrogen among treatments. Each treatment will have three replicates. Water quality will be monitored as in Objective 1a. Tilapia will be used at the University site and rainbow trout at Glacial Hills. Growth trials will last six weeks.

Particles less than 10 µm in diameter have been reported as potentially hazardous in recirculating aquaculture systems (Chen et al. 1993a;b). If a TSS level is found to cause a reduction in growth in the previous growth trial, we will duplicate the growth trial with one set of treatments receiving water with the same particle size distribution as found in the production tank. The other set of treatments will receive water with the same range of TSS concentrations, but with a particle size distribution consisting predominately of particles less than 10 µm. Each treatment will have three replicates. Particle size will be controlled by selection of filtration method. The concentration of TSS will be controlled by dilution as in the previous growth trial. All other aspects will be the same as the previous growth trial. Growth trials will last six weeks.

Data will be analyzed using analysis of variance (ANOVA).

Develop a Report About Aquaculture Wastes and Effluents (Objective 2)

Using the previous NCRAC Effluent Work Group study of effluents from regional aquaculture production systems and its bibliography as a foundation, UW-Milwaukee will prepare a report that contrasts the potential impact of regional aquaculture development with other contemporary agricultural, municipal, industrial, and natural resource land uses. This report will review and evaluate current research on alternative beneficial uses of aquaculture by-products, emphasizing integrated resource management and aimed at developing sustainable aquacultural practices. This review will point out possible beneficial uses of aquaculture by-products that have application specifically within the NCR.

The reuse or diversion to beneficial plant production of settled solid waste and nutrients will be a major theme. In reviewing these potential reuse strategies, we will identify factors that may currently restrict or limit their beneficial application and show where improvements are needed and how such barriers may be overcome. Applications of aquaculture by-products that will be reviewed will include but not be limited to constructed wetlands, application of wastes as fertilizer for field crops, and hydroponics uses.

Even with information characterizing the changes in water quality associated with effluents, it is difficult to determine the environmental impact (Pillay 1992) of a single factor such as aquaculture, because impacts generally result from the cumulative effect of several factors. One useful approach is to compare alternative uses and the potential nutrient loads they contribute. Pillay (1992) gives examples of such comparisons for marine fish farms in northern Europe based on nutrient loading estimates of Hånkanson et al. (1988). We would make similar comparisons of regional aquaculture situations to non point impacts of wastes from typical regional agricultural operations, to urban area drainage, to managed forests and natural areas drainage. Comparison to each of these alternative impacts will be in separate sections of the report. For each of these sections an annotated guide to the existing literature and regional case studies will be included, as they are identified, so that producers will have access to information that closely corresponds to their own situations.

Where possible, actual applications and case study examples of such techniques in our region will be highlighted. Potential cases for inclusion are long established private, or agency hatcheries that have been operating without apparent impact as a contrast to more controversial situations such as that of Michigan's Platte River Hatchery. In comparison of controversial versus non-controversial cases, differences in site-specific situations or operations will be highlighted to point out how controversy might potentially be avoided. The engineered wetland and hydroponics applications currently being developed at Illinois State University will also be followed as a model for application in the region. If possible, NCR cases where nutrient content in local ground water supplies to hatcheries may be lowered by passage through hatchery ponds in a manner analogous to the situation that has been identified for trout hatcheries with water reconditioning facilities on the Snake River, Idaho (Brannon 1992) will also be included.

FACILITIES

UW-Milwaukee

UW-Milwaukee will conduct experiments at the Aquaculture Institute - UWGLRF. A portion of the Aquaculture Institute rearing facilities (>1900-L/min water supply; >930 m^2 area) would be used for conducting these trials. The water supply for the rearing facilities is dechlorinated Milwaukee tapwater derived from Lake Michigan as its original source. The facility has water heaters capable of supporting intensive flow through rearing in large capacity tanks.

A wide assortment of other tanks and aquaria are also available ranging in size from 2.4 m diameter (4000-L) fiberglass tanks down to less than 20-L. These tanks are fitted with the required screened mesh and water supply hardware for specialized larval rearing. In addition, there are a wide variety of supporting facilities and analytical laboratories at the UWGLRF that can provide refrigerated storage, instrument shop capabilities, etc. which will enhance the conduct of the proposed activities. The orbital shaking devices, and particle analysis devices necessary for the characterization of fecal durability and small particle size distributions are available at the UWGLRF.

UM

UM has recently completed a new 998.7 m^2 (10,750 ft^2) Fisheries and Aquaculture Laboratory. The lab houses tanks ranging in size from 0.75 m to 3 m in diameter served by either well water or recycled water from a central water treatment area. The central recycling system features microscreen particulate removal, biofiltration, and ozone and UV disinfection. Several individual recycling systems are also available.

The tilapia portion of the project will be carried out in six commercial scale 11.3 m^3 (3,000 gal) recirculating aquaculture systems located in the Fisheries and Aquaculture Laboratory. The systems utilize three types of biofilters: fluidized bed sand filter, submerged thin film filter, and high rate trickling tower. Each system is replicated twice.

Glacial Hills, Inc. is a supplier of recirculating aquaculture systems based in Starbuck, Minnesota. Glacial Hills has a rainbow trout production facility which utilizes central biofilters and microscreen filtration to service banks of 18.9 m^3 (5,000 gal) culture tanks.

SIUC

Over 150 glass aquaria with volumes ranging from 38- to 209-L are maintained by the Fisheries Research Laboratory. Most of these are located in the University Vivarium, a National Institute of Health-approved animal housing facility under the direction of a veterinarian. Most aquaria are arranged in batteries with attachments to biofilters. The systems are highly flexible in terms of numbers that can be attached to a given biofilter. Several large indoor water recycle systems are also available at the University Wetlab. These systems will be used for housing fish prior to initiation of trials. All necessary equipment for measuring and maintaining water quality, measuring and weighing fish, preparation of feed, and conducting proximate analyses are available. A Lab-Line orbital shaker and all necessary glassware for conducting fecal studies are available.

REFERENCES

Alabaster, J.S., and R. Lloyd. 1980. Water quality criteria for freshwater fish. Butterworth and Co., Ltd. London, England.

Alabaster, J.S. 1982. Report of the EIFAC workshop on fish farm effluents. Silkeborg, Denmark, May 26-28, 1981. EIFAC Technical Paper 41.

Anderson, C.D., R.J. Roberts, K. MacKenzie, and A.H. McVicar. 1976. The hepato-renal syndrome in cultured turbot (*Scophthalmus maximus* L.). Journal of Fish Biology 8:331-341.

Anderson, J., A.J. Jackson, A.J. Matty, and B.S. Capper. 1984. Effects of dietary carbohydrate and fibre on the tilapia *Oreochromis niloticus* (Linn). Aquaculture 37:303-314.

AOAC (Association of Official Analytical Chemists). 1984. Official Methods of Analysis, 14th edition. Association of Official Analytical Chemists, Bethesda, Maryland.

APHA (American Public Health Association), American Water Works Association, and Water Pollution Control Federation. 1992. Standard methods for examination of water and wastewater, 18th edition. American Public Health Association, Washington, D.C.

Ayala, C.E., C.C. Kohler, and R.R. Stickney. 1993. Protein digestibility and amino acid availability of fish meal fed to largemouth bass infected with intestinal acanthocephalans. Progressive Fish-Culturist 55:275-279.

Blake, J., J. Donald, and W. Magette, editors. 1992. National livestock, poultry, and aquaculture waste management: proceedings of the national workshop. ASAE Publication 03-92. American Society of Agricultural Engineers, St. Joseph, Michigan.

Boerson G., and H. Westers. 1986. Waste solids control in hatchery raceways. Progressive Fish Culturist 48:151-154.

Brannon, E.L. 1992. Fish farm effluent quality. Pages 171-176 *in* J. Blake, J. Donald, and W. Magette, editors. National livestock, poultry, and aquaculture waste management: proceedings of the national workshop. ASAE Publication 03-92. American Society of Agricultural Engineers, St. Joseph, Michigan.

Brune, D.E., and J.R. Tomasso, editors. 1991. Aquaculture and water quality. Advances in world aquaculture, volume 3. World Aquaculture Society, Baton Rouge, Louisiana.

Buhler, D.R., and J.E. Halver. 1961. Nutrition of salmonid fishes, IX. Carbohydrate requirements of chinook salmon. Journal of Nutrition 74:307-318.

Burrows , R.E., and H.H. Chenoweth. 1955. Evaluation of three types of rearing ponds. U.S. Fish and Wildlife Service Research Report 39. U.S. Fish and Wildlife Service, Washington, D.C.

Butz, I., and B. Vens-Cappell. 1982. Organic load from the metabolic products of rainbow trout fed with dry food. Pages 1-166 *in* J.S. Alabaster, editor. Report of the EIFAC workshop on fish farm effluent. EIFAC Technical Paper 41, Silkeborg, Denmark.

Cain, K.D. 1993. Pretreatment of salmonid diets with phytase to reduce phosphorus concentrations in hatchery effluents. Master's thesis. Michigan State University, East Lansing.

Chapman, P.E., J.D. Popham, J. Griffin, and J. Michaelson. 1987. Differentiation of physical from chemical toxicity in solid waste fish bioassays. Water, Air, and Soil Pollution 33:295-308.

Chen, S., D. Stechey, and R.F. Malone. 1994. Suspended solids control in recirculating aquaculture systems. Pages 61-100 *in* M.B. Timmons and T.M. Losordo, editors. Aquaculture water reuse systems: engineering design and management. Elsevier, Amsterdam.

Chen, S., M.B. Timmons, J.J. Bisogni, Jr., and D.J. Aneshansley. 1993a. Suspended solids removal by foam fractionation. Progressive Fish-Culturist 55(2):69-75.

Chen, S., M.B. Timmons, D.J. Aneshansley, and J.J. Bisogni. 1993b. Suspended solids characteristics from recirculating aquacultural systems and design implications. Aquaculture 112:143-155.

Cripps, S.J. 1993. The application of suspended particle size characterization techniques to aquaculture systems. *In* J-K. Wang, editor. Techniques in modern aquaculture: proceedings of an aquacultural engineering conference. ASAE Publication 02-93. American Society of Agricultural Engineers, St. Joseph, Michigan.

Dupree, H.K., and K.E. Sneed. 1966. Response of channel catfish to different levels of major nutrients in purified diets. U.S. Department of the Interior, Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife Technical Paper Number 9. U.S. Fish and Wildlife Service, Washington, D.C.

EIFAC. 1987. European Inland Fisheries Advisory Commission Working Party on fish farm effluents. J.F. de L.G. Solbe, editor. WRC Environmental, Medmenham.

Fahey, Jr., G.C., N.R. Merchen, J.E. Corbin, A.K. Hamilton, K.A. Serbe, S.M. Lewis, and D.A. Hirakawa. 1990. Dietary fiber for dogs: I. Effects of graded levels of dietary beet pulp on nutrient intake, digestibility, metabolizable energy and digesta mean retention time. Journal of Animal Science 68:4221-4228.

Fetterolf, C.M., Jr. 1993. How clean is clean? Who's making those decisions. Presidents Corner. Fisheries 18(6):29-30.

Hånkanson, L., A. Ervik, T. Makinen, and B. Moller. 1988. Basic concepts concerning assessments of environmental effects of marine fish farms. Nordic Council of Ministers, Copenhagen.

Hardy, R.W. 1989. Diet preparation. Pages 475-547 *in* J.E. Halver, editor. Fish nutrition. Academic Press, New York.

Harris, G. 1981. Federal regulation of fish hatchery effluent quality. *In* L.J. Allen, and E.C. Kinney, editors. Proceedings of the bio-engineering symposium for fish culture. Freshwater biological monitoring. Premagon Press, Oxford, England.

Heinen, J.M. 1981. Evaluation of some binding agents for crustacean diets. Progressive Fish-Culturist 43:142-143.

Hilton, J.W., J.L. Atkinson, and S.J. Slinger. 1983. Effect of increased dietary fiber on the growth of rainbow trout *Salmo gairdneri.* Canadian Journal of Fisheries and Aquatic Sciences 40:81-85.

Hinrichs, D.E. 1994. Effluent characterization from the production of *Oreochromis niloticus* in two distinct recirculating aquaculture systems. Master’s thesis. Illinois State University, Normal.

Hopkins, S.J. 1995. Aquaculture sustainability: avoiding the pitfalls of the Green Revolution. Abstracts Aquaculture '95. February 1-4, 1995, San Deigo, California.

Kruner, G., and H. Rosenthal. 1987. Circadian periodicity of biological oxidation under three different operational conditions. Aquacultural Engineering 6:79-96.

Leary, D.F., and R.T. Lovell. 1975. Value of fiber in production-type diets for channel catfish. Transactions of the American Fisheries Society 104:328-332.

Liao, P.B., and R.D. Mayo. 1974. Intensified fish culture combining water reconditioning with pollution abatement. Aquaculture 3:61-85.

Libey, G. S. 1993. Evaluation of a drum filter for removal of solids from a recirculating aquaculture system. Pages 519-532 *in* J-K. Wang, editor. Techniques for modern aquaculture. ASAE Publication 02-93. American Society of Agricultural Engineers, St. Joseph, Michigan.

Lovell, R.T. 1989. Nutrition and feeding of fish. Van Nostrand Reinhold, New York.

Muir, J.F. 1982. Recirculated water systems in aquaculture. Pages 358-456 *in* J.F. Muir, F. and R.J. Roberts, editors. Recent advances in aquaculture, volume 1. Croom Helm and Westview Press, London.

National Research Council. 1983. Nutrient requirements of warm water fishes and shellfishes. National Academy of Sciences, Washington, D.C.

Pillay, T.V.R. 1992. Aquaculture and the environment. Fishing News Books, Blackwell Scientific Publications Ltd., Cambridge, Masachusetts.

Piper, R.G., I.B. McElwain, L.E. Orme, J.P. McCarren, L.G. Fowler, and J.R. Leonard. 1982. Fish hatchery management. U.S. Fish and Wildlife Service, Washington, D.C.

Pusaininen, M. 1988. National contributions on suspended solids from land based fish farms. Papers presented at the first session of the EIFAC Working Party On Fish Farm Effluents. The Hague, Netherlands, May 29-30 and June 1, 1987. Riista--Ja Kalatalouden Tutkimuslaitos, Kalantutkimusosasto Monistettuja Julkaisuja. No. 74.

Reinitz, G. 1983. Evaluation of sodium bentonite in practical diets for rainbow trout. Progressive Fish-Culturist 45:100-102.

Roberts, R.J., and A.M. Bullock. 1989. Nutritional pathology. Pages 423-473 *in* J.E. Halver, editor. Fish nutrition. Academic Press, New York.

Shiau, S.Y., and C.C. Kwok. 1989. Effects of cellulose, agar, carrageenan, guar gum, and carboxymethylcellulose on tilapia growth. World Aquaculture 20:60.

Stechy, D., and Y. Trudell. 1990. Aquaculture wastewater treatment: wastewater characterization and development of appropriate treatment technologies for the Ontario Trout Production Industry. Final Report. Canadian Aquaculture Systems, Windsor, Ontario, Canada.

Stickney, R.R. 1994. Principles of aquaculture. John Wiley & Sons, Inc., New York.

Storebakken, T. 1985. Binders in feeds. I. Effect of alginate and guar gum on growth, digestibility, feed intake and passage through the gastrointestinal tract of rainbow trout. Aquaculture 47:11-26.

Storebakken, T., and E. Austreng. 1987. Binders in feeds. II. Effect of different alginates on the digestibility of macronutrients in rainbow trout. Aquaculture 60:121-131.

Sumari, O. 1984. Feed and waste water. The international conference Aquacoltura '84.

USEPA (United States Environmental Protection Agency). 1974. Development document for proposed effluent limitations guidelines and new source performance standards for fish hatcheries and farms. National Field Investigations Center, Denver, Colorado.

USEPA (United States Environmental Protection Agency). 1976. Quality criteria for water. U.S. Environmental Protection Agency, Washington, D.C.

Warrer-Hansen I. 1982. Methods for the treatment of wastewater from trout farming. Pages 113-121 *in* J.S. Alabaster, editor. Report of the EIFAC Workshop on Fish Farm Effluents, Denmark, May 1981. EIFAC Technical Paper 41.

Wang, J.-K., editor. 1993. Techniques for modern aquaculture: proceedings of an aquacultural engineering conference. ASAE Publication 02-93. American Society of Agricultural Engineers, St. Joseph, Michigan.

Watkins, K.L., T.L. Veum, and G.F. Krause. 1987. Total nitrogen determinations of various sample types: a comparison of the Hach, Kjeltec and Kjeldahl methods. Journal of the Association of Official Analytical Chemists 70:410-412.

Weinberg, A. C. 1992. EPA programs addressing animal waste management workshop. Pages 128-133 *in* J. Blake, J. Donald, and W. Magette, editors. National livestock, poultry, and aquaculture waste management: proceedings of the national workshop. ASAE Publication 03-92. American Society of Agricultural Engineers, St. Joseph, Michigan.

Westers, H. 1991. Operational waste management in aquaculture effluents. Pages 231-238 *in* C.B. Cowey and C. Y. Cho, editors. Nutritional strategies in managing aquaculture wastes. Fish Nutrition Research Laboratory, Department of Nutrition Science, University of Guelph, Guelph, Ontario.

Wedemeyer, G.A. 1981. The physiological response of fishes to the stress of intensive aquaculture in recirculation systems. Pages 3-18 *in* K. Tiews, editor. Proceedings of the world symposium on aquaculture in heated effluents and recirculation systems, volume 2. EIFAC, Stavanger, Norway, May 28-30, 1980.

Westerman, P. W., T. M. Losordo, and M. L. Wildhaber. 1993. Evaluation of various biofilters in an intensive recirculating fish production facility. Pages 326-334 *in* J.-K. Wang, editor. Techniques in modern aquaculture: proceedings of an aquacultural engineering conference. ASAE Publication 02-93. American Society of Agricultural Engineers, St. Joseph, Michigan.

Wickins, J. F. 1981. Water quality requirements for intensive aquaculture: a review. Pages 17-37 *in* K. Tiews, editor. Proceedings of the world symposium on aquaculture in heated effluents and recirculation systems, volume 1. EIFAC, Stavanger, Norway, May 28-30, 1980.

Ziemann, D. A., Pruder, G. D., and Wang, J. K. 1990. Aquaculture effluent discharge program. Year 1 Final Report. Center for Tropical and Subtropical Aquaculture, Waimanalo, Hawaii.

PROJECT LEADERS

State	Name/Institution	Area of Specialization
Illinois	Christopher C. Kohler Southern Illinois University-Carbondale	Aquaculture
Minnesota	Ira R. Adelman University of Minnesota	Fish Physiology/Aquaculture
Wisconsin	Fred P. Binkowski University of Wisconsin-Milwaukee	Larval Fish Culture/ Fish Ecology

PARTICIPATING INSTITUTIONS AND PRINCIPAL INVESTIGATORS

University of Wisconsin-Milwaukee (UW-Milwaukee)
Fred P. Binkowski

Southern Illinois University-Carbondale (SIUC)
Christopher C. Kohler

University of Minnesota (UM)
Ira R. Adelman

UNITED STATES DEPARTMENT OF AGRICULTURE
COOPERATIVE STATE RESEARCH, EDUCATION, AND EXTENSION SERVICE

OMB Approved 0524-0022
Expires 5/31/98

BUDGET

ORGANIZATION AND ADDRESS
University of Wisconsin-Milwaukee - Center for Great Lakes Studies
600 E. Greenfield Avenue
Milwaukee, WI 53204

USDA AWARD NO. Year 1 - Objectives 1a-b & 2

PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S)
Fred P. Binkowski

	CSREES FUNDED WORK MONTHS: Calendar	Academic	Summer	Duration Proposed Months: 12 — FUNDS REQUESTED by PROPOSER	Duration Awarded Months: ____ — FUNDS APPROVED BY CSREES (If Different)
A. Salaries and Wages					$
1. No. of Senior Personnel					
a. ___ (Co)-PI(s)/PD(s)					
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty)					
a. ___ Research Associates-Postdoctorates					
b. 2 Other Professional	3.4			$13,968	
c. ___ Graduate Students					
d. ___ Prebaccalaureate Students				$990	
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages →				$14,958	
B. Fringe Benefits (If charged as Direct Costs)				$4,404	
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →				$19,362	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$2,097	
F. Travel 1. Domestic (Including Canada)				$925	
2. Foreign (List destination and amount for each trip.)					
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of Subcontracts, including work statements and budget, should be explained in full in proposal.) Telephone ($250), FAX ($150), Photocopying ($100)				$500	
J. Total Direct Costs (C through I) →				$22,884	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) →				$22,884	
M. Other →					
N. Total Amount of This Request →				$22,884	$
O. Cost Sharing (If Required Provide Details)	$ 13,125				

NOTE: Signatures required only for Revised Budget — This is Revision No. →

NAME AND TITLE (Type or print)	**SIGNATURE**	**DATE**
Principal Investigator/Project Director		
Authorized Organizational Representative		

Form CSREES-55 (6/95)

UNITED STATES DEPARTMENT OF AGRICULTURE
COOPERATIVE STATE RESEARCH, EDUCATION, AND EXTENSION SERVICE

OMB Approved 0524-0022
Expires 5/31/98

BUDGET

ORGANIZATION AND ADDRESS University of Wisconsin-Milwaukee - Center for Great Lakes Studies 600 E. Greenfield Avenue Milwaukee, WI 53204				**USDA AWARD NO.** Year 2 - Objectives 1a-b & 2	
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Fred P. Binkowski				Duration Proposed Months: 12 **FUNDS REQUESTED by PROPOSER**	Duration Awarded Months: ________ **FUNDS APPROVED BY CSREES** (If Different)
A. Salaries and Wages 1. No. of Senior Personnel	**CSREES FUNDED WORK MONTHS** Calendar	Academic	Summer		$
a. ___ (Co)-PI(s)/PD(s)					
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty) a. ___ Research Associates-Postdoctorates					
b. 2 Other Professional	3.2			$13,907	
c. ___ Graduate Students					
d. ___ Prebaccalaureate Students				$1,030	
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages →				$14,937	
B. Fringe Benefits (If charged as Direct Costs)				$4,386	
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →				$19,323	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$2,368	
F. Travel 1. Domestic (Including Canada)				$925	
2. Foreign (List destination and amount for each trip.)					
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of Subcontracts, including work statements and budget, should be explained in full in proposal.) Telephone ($250), FAX ($150), Photocopying ($100)				$500	
J. Total Direct Costs (C through I) →				$23,116	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) →				$23,116	
M. Other →					
N. Total Amount of This Request →				$23,116	$
O. Cost Sharing (If Required Provide Details)	$ 13,125				

NOTE: Signatures required only for Revised Budget — This is Revision No. →

NAME AND TITLE (Type or print)	**SIGNATURE**	**DATE**
Principal Investigator/Project Director		
Authorized Organizational Representative		

Form CSREES-55 (6/95)

BUDGET JUSTIFICATION FOR UNIVERSITY OF WISCONSIN-MILWAUKEE

(Binkowski)

Objectives 1a, 1b, 2a, 2b, and 2c

A. Wages and Salaries. One Researcher (0.18 FTE, Year 1) to conduct the fecal waste characterization for the five size categories of yellow perch on commercial feeds, analyze data, prepare a report and presentation for Objective 1a. One Researcher (0.17 FTE, Year 2) to conduct the fecal waste characterization for the three size categories on experimental diets, analyze data, prepare a report and presentation for Objective 1b. Salary for one Researcher (0.10 FTE/year) to compile literature and data, and to prepare the report for Objective 2.

Student helper (0.09 FTE/year) to assist in animal husbandry over weekends and holiday breaks.

E. Materials and Supplies. Fish foods (includes approximately $500 cost of experimental yellow perch diet in Year 2), aquaruim supplies, laboratory supplies (glassware, settling chamber device, solids filtration supplies, etc.). Computer supplies (word processing software upgrade) and other general office supplies for Objective 2.

F. Travel. Travel to interact with Alpine Farms and Milwaukee County House of Corrections yellow perch rearing operations and travel to NCRAC meeting or aquaculture meeting to present research findings.

I. Other Direct Costs. Telephone ($250), FAX ($150), and photocopying costs ($100).

UNITED STATES DEPARTMENT OF AGRICULTURE
COOPERATIVE STATE RESEARCH, EDUCATION, AND EXTENSION SERVICE

OMB Approved 0524-0022
Expires 5/31/98

BUDGET

ORGANIZATION AND ADDRESS Southern Illinois University-Carbondale Fisheries Research Laboratory Carbondale, IL 62901-6511				**USDA AWARD NO.** Year 1 - Objectives 1a & 1b	
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Christopher C. Kohler				Duration Proposed Months: 12 **FUNDS REQUESTED by PROPOSER**	Duration Awarded Months: ________ **FUNDS APPROVED BY CSREES** (If Different)
A. Salaries and Wages	**CSREES FUNDED WORK MONTHS**				$
1. No. of Senior Personnel	Calendar	Academic	Summer		
a. ___ (Co)-PI(s)/PD(s)					
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty) a. ___ Research Associates-Postdoctorates					
b. ___ Other Professional					
c. 1 Graduate Students				$11,500	
d. ___ Prebaccalaureate Students					
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages →				$11,500	
B. Fringe Benefits (If charged as Direct Costs)					
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →				$11,500	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$2,000	
F. Travel 1. Domestic (Including Canada)				$500	
2. Foreign (List destination and amount for each trip.)					
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of Subcontracts, including work statements and budget, should be explained in full in proposal.) Postage ($100), Report preparation ($200), Graphics ($250), Telecommunications ($100), Equipment repairs ($100), Fiber analysis ($300)				$1,000	
J. Total Direct Costs (C through I) →				$15,000	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) →				$15,000	
M. Other →					
N. Total Amount of This Request →				$15,000	$
O. Cost Sharing (If Required Provide Details)	$ 12,227				

NOTE: Signatures required only for Revised Budget — This is Revision No. →

NAME AND TITLE (Type or print)	**SIGNATURE**	**DATE**
Principal Investigator/Project Director		
Authorized Organizational Representative		

Form CSREES-55 (6/95)

UNITED STATES DEPARTMENT OF AGRICULTURE
COOPERATIVE STATE RESEARCH, EDUCATION, AND EXTENSION SERVICE

OMB Approved 0524-0022
Expires 5/31/98

BUDGET

ORGANIZATION AND ADDRESS Southern Illinois University-Carbondale Fisheries Research Laboratory Carbondale, IL 62901-6511				**USDA AWARD NO.** Year 2 - Objectives 1a & 1b	
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Christopher C. Kohler				Duration Proposed Months: 12 **FUNDS REQUESTED by PROPOSER**	Duration Awarded Months: ________ **FUNDS APPROVED BY CSREES** (If Different)
A. Salaries and Wages	**CSREES FUNDED WORK MONTHS**				$
1. No. of Senior Personnel	Calendar	Academic	Summer		
a. ___ (Co)-PI(s)/PD(s)					
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty) a. ___ Research Associates-Postdoctorates					
b. ___ Other Professional					
c. 1 Graduate Students				$12,000	
d. ___ Prebaccalaureate Students					
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages →				$12,000	
B. Fringe Benefits (If charged as Direct Costs)					
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →				$12,000	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$2,000	
F. Travel 1. Domestic (Including Canada)				$500	
2. Foreign (List destination and amount for each trip.)					
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of Subcontracts, including work statements and budget, should be explained in full in proposal.) Postage ($100), Report preparation ($200), Graphics ($250), Telecommunications ($100), Equipment repairs ($100), Fiber analysis ($300)				$1,000	
J. Total Direct Costs (C through I) →				$15,500	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) →				$15,500	
M. Other →					
N. Total Amount of This Request →				$15,500	$
O. Cost Sharing (If Required Provide Details)	$ 12,711				

NOTE: Signatures required only for Revised Budget — This is Revision No. →

NAME AND TITLE (Type or print)	**SIGNATURE**	**DATE**
Principal Investigator/Project Director		
Authorized Organizational Representative		

Form CSREES-55 (6/95)

BUDGET JUSTIFICATION FOR SOUTHERN ILLINOIS UNIVERSITY-CARBONDALE

(Kohler)

Objectives 1a and 1b

A. **Wages and Salaries.** One graduate assistant (0.50 FTE) in years 1 and 2 to assist in nutrition studies.

E. **Materials and Supplies.** Expendable supplies such as fish nets, glassware, fish feed, plumbing supplies, chemicals, etc. ($500 is budgeted to obtain feed-trained yellow perch fingerlings from the University of Wisconsin-Madison.)

F. **Travel.** NCRAC meetings and professional meetings for paper presentations will require travel support.

I. **Other Direct Costs.** Postage ($100), report preparation ($200), graphics ($200), telecommunications ($100), equipment repair ($100), fiber analysis ($300).

UNITED STATES DEPARTMENT OF AGRICULTURE
COOPERATIVE STATE RESEARCH, EDUCATION, AND EXTENSION SERVICE

OMB Approved 0524-0022
Expires 5/31/98

BUDGET

ORGANIZATION AND ADDRESS University of Minnesota Department of Fisheries and Wildlife, 1980 Folwell Avenue St. Paul, MN 55108	**USDA AWARD NO.** Year 1 - Objectives 1a & 1c	
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Ira R. Adelman	Duration Proposed Months: 12 **FUNDS REQUESTED by PROPOSER**	Duration Awarded Months: ________ **FUNDS APPROVED BY CSREES** (If Different)

	CSREES FUNDED WORK MONTHS				
	Calendar	Academic	Summer		
A. Salaries and Wages 1. No. of Senior Personnel					$
a. ___ (Co)-PI(s)/PD(s)					
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty) a. ___ Research Associates-Postdoctorates					
b. ___ Other Professional					
c. 1 Graduate Students				$2,200	
d. ___ Prebaccalaureate Students					
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages →				$2,200	
B. Fringe Benefits (If charged as Direct Costs)				$640	
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →				$2,840	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$500	
F. Travel 1. Domestic (Including Canada)				$480	
2. Foreign (List destination and amount for each trip.)					
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of Subcontracts, including work statements and budget, should be explained in full in proposal.)					
J. Total Direct Costs (C through I) →				$3,820	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) →				$3,820	
M. Other →					
N. Total Amount of This Request →				$3,820	$
O. Cost Sharing (If Required Provide Details)	$ 28,780				

NOTE: Signatures required only for Revised Budget — This is Revision No. →

NAME AND TITLE (Type or print)	**SIGNATURE**	**DATE**
Principal Investigator/Project Director		
Authorized Organizational Representative		

Form CSREES-55 (6/95)

UNITED STATES DEPARTMENT OF AGRICULTURE
COOPERATIVE STATE RESEARCH, EDUCATION, AND EXTENSION SERVICE

OMB Approved 0524-0022
Expires 5/31/98

BUDGET

ORGANIZATION AND ADDRESS
University of Minnesota
Department of Fisheries and Wildlife, 1980 Folwell Avenue
St. Paul, MN 55108

USDA AWARD NO. Year 2 - Objectives 1a & 1c

Duration Proposed Months: 12

Duration Awarded Months: ________

PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S)
Ira R. Adelman

Item	CSREES FUNDED WORK MONTHS: Calendar	Academic	Summer	FUNDS REQUESTED by PROPOSER	FUNDS APPROVED BY CSREES (If Different)
A. Salaries and Wages 1. No. of Senior Personnel					$
a. ___ (Co)-PI(s)/PD(s)					
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty) a. ___ Research Associates-Postdoctorates					
b. ___ Other Professional					
c. 1 Graduate Students				$13,200	
d. ___ Prebaccalaureate Students					
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages →				$13,200	
B. Fringe Benefits (If charged as Direct Costs)				$3,830	
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →				$17,030	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$1,250	
F. Travel 1. Domestic (Including Canada)				$400	
2. Foreign (List destination and amount for each trip.)					
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of Subcontracts, including work statements and budget, should be explained in full in proposal.) Consultant ($1,000)				$1,000	
J. Total Direct Costs (C through I) →				$19,680	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) →				$19,680	
M. Other →					
N. Total Amount of This Request →				$19,680	$
O. Cost Sharing (If Required Provide Details)	$				

NOTE: Signatures required only for Revised Budget — This is Revision No. →

NAME AND TITLE (Type or print)	**SIGNATURE**	**DATE**
Principal Investigator/Project Director		
Authorized Organizational Representative		

Form CSREES-55 (6/95)

BUDGET JUSTIFICATION FOR UNIVERSITY OF MINNESOTA

(Adelman)

Objective 1a

A. Salaries and Wages. One staff person is needed for this portion of the project. This individual's salary will be covered by a grant from Minnesota Technology, Inc. (MTI) through June of 1997.

E. Materials and supplies. This budget is for analysis costs (particle size analysis) and lab supplies. MTI grant will also contribute to materials and supplies.

F. Travel. The amount budgeted will be for travel (mileage charges) to commercial farm locations for sampling. MTI grant will also contribute to travel budget.

Objective 1c

A. Salaries and Wages. One staff person is needed for this portion of the project. In addition, $1000 is needed for partial payment to consulting engineer.

E. Materials and supplies. This budget partially covers fish rearing expenses and lab supplies.

F. Travel. The amount budgeted will be for travel (mileage charges) to commercial farm locations for set up and sampling during growth trials.

AQUACULTURE WASTES AND EFFLUENTS

Budget Summary for Each Participating Institution for the First Year

	UW-Milwaukee	SIUC	UM	TOTALS
Salaries and Wages	$14,958	$11,500	$2,200	$28,658
Fringe Benefits	$4,404	$0	$640	$5,044
Total Salaries, Wages and Benefits	$19,362	$11,500	$2,840	$33,702
Nonexpendable Equipment	$0	$0	$0	$0
Materials and Supplies	$2,097	$2,000	$500	$4,597
Travel	$925	$500	$480	$1,905
Other Direct Costs	$500	$1,000	$0	$1,500
TOTAL PROJECT COSTS	**$22,884**	**$15,000**	**$3,820**	**$41,704**

Budget Summary for Each Participating Institution for the Second Year

	UW-Milwaukee	SIUC	UM	TOTALS
Salaries and Wages	$14,937	$12,000	$13,200	$40,137
Fringe Benefits	$4,386	$0	$3,830	$8,216
Total Salaries, Wages and Benefits	$19,323	$12,000	$17,030	$48,353
Nonexpendable Equipment	$0	$0	$0	$0
Materials and Supplies	$2,368	$2,000	$1,250	$5,618
Travel	$925	$500	$400	$1,825
Other Direct Costs	$500	$1,000	$1,000	$2,500
TOTAL PROJECT COSTS	**$23,116**	**$15,500**	**$19,680**	**$58,296**

RESOURCE COMMITMENT FROM INSTITUTIONS[1]

State/Institution		Year 1	Year 2
University of Wisconsin-Milwaukee			
Salaries and Benefits: SY @ 0.05		$11,125	$11,125
Supplies, Expenses, Equipment, and Waiver of Overhead		$2,000	$2,000
	Total	$13,125	$13,125
Southern Illinois University-Carbondale			
Salaries and Benefits: SY @ 0.05 FTE		$4,174	$4,367
Supplies, Expenses, Equipment, and Waiver of Overhead		$8,053	$8,344
	Total	$12,227	$12,711
University of Minnesota			
Salaries and Benefits:		$20,530	
Supplies, Expenses, Equipment, and Waiver of Overhead		$8,250	
	Total	$28,780	
	Total per Year	$54,132	$25,836
	GRAND TOTAL	$79,968	

[1]Because cost sharing is not a legal requirement universities are not required to provide or maintain documentation of such a commitment.

SCHEDULE FOR COMPLETION OF OBJECTIVES

Objective 1a:
- SIUC - Initiated in Year 1 and completed in Year 2.
- UM - Initiated prior to start of this project through a grant from Minnesota Technology, Inc. (MTI) and completed in Year 1.
- UW-Milwaukee - Initiated in Year 1 and completed in Year 1.

Objective 1b:
- SIUC - Initiated in Year 1 and completed in Year 2.
- UW-Milwaukee - Initiated in Year 2 and completed in Year 2.

Objective 1c:
- SIUC - Initiated in Year 1 and completed in Year 2.
- UM - Initiated prior to start of this project through a grant from Minnesota Technology, Inc. (MTI) and completed in Year 2.

Objective 2:
- UW-Milwaukee - Initiated in Year 1 and completed in Year 2.

LIST OF PRINCIPAL INVESTIGATORS

Ira R. Adelman, University of Minnesota

Fred P. Binkowski, University of Wisconsin-Milwaukee

Christopher C. Kohler, Southern Illinois University-Carbondale

VITA

Ira R. Adelman
Department of Fisheries and Wildlife
University of Minnesota
1980 Folwell Avenue
St. Paul, MN 55108

Phone: (612) 624-4228
FAX: (612) 625-5299
E-mail: ira@finsandfur.fw.umn.edu

EDUCATION

B.S. University of Vermont, 1963
M.S. State University of New York at New Paltz, 1964
Ph.D. University of Minnesota, 1969

POSITIONS

Assistant, Associate, Full Professor (1974-present), University of Minnesota
Department Head (1982-present), University of Minnesota
Special Assistant to the Director (1990 sabbatical position), Division of Fish & Wildlife, Minnesota Department of Natural Resources

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Institute of Fisheries Research Biologists
American Association for the Advancement of Science
American Fisheries Society
National Association of University Fisheries and Wildlife Programs

SELECTED RECENT PUBLICATIONS

Palmer, E.E., P.W. Sorensen, and I.R. Adelman. In press. A histological study of seasonal ovarian development in freshwater drum, *Aplodinotus grunniens* Rafinesque, in the Red Lakes, Minnesota. Journal of Fish Biology.

Woiwode, J.G., and I.R. Adelman. 1992. Effects of starvation, oscillating temperatures, and photoperiod on the critical thermal maximum of hybrid striped by white bass. Journal of Thermal Biology 17:271-275.

Woiwode, J.G., and I.R. Adelman. 1991. Effects of temperature, photoperiod, and ration size on growth of hybrid striped × white bass. Transactions of the American Fisheries Society 120:217-229.

Cai, Y., and I.R. Adelman. 1990. Temperature acclimation in respiratory and cytochrome c oxidase activity in common carp (*Cyprinus carpio*). Comparative Biochemistry and Physiology 95A:139-144.

Busacker, G.P., I.R. Adelman, and E.M. Goolish. 1990. Growth. Pages 363-387 *in* P. Moyle, and C. Schreck, editors. Methods in fish biology. American Fisheries Society, Bethesda, Maryland.

Woiwode, J.G., and I.R. Adelman. 1989. Influence of density and multipass water use on channel catfish performance in raceways. Progressive Fish-Culturist 54:183-188.

Goolish, E.M., and I.R. Adelman. 1987. Tissue-specific cytochrome oxidase activity in largemouth bass: The metabolic costs of feeding and growth. Physiological Zoology 60:454-464.

Goolish, E. M. and I.R. Adelman. 1988. Tissue-specific allometry of an aerobic respiratory enzyme in a large and small species of cyprinid (Teleostei). Canadian Journal of Zoology 66:2199-2208.

VITA

Fred P. Binkowski
Center for Great Lakes Studies
University of Wisconsin-Milwaukee
600 E. Greenfield Ave.
Milwaukee, WI 53204

Phone: (414) 382-1700
FAX: (414) 382-1705
E-mail: sturgeon@csd.uwm.edu

EDUCATION

B.S. University of Wisconsin-Milwaukee, 1971
M.S. University of Wisconsin-Milwaukee, 1974

POSITIONS

Director (1993-present), Aquaculture Institute, University of Wisconsin Great Lakes Research Facility
Senior Scientist (1991-present), Associate Scientist (1987-1990), Senior Fisheries Biologist (1984-1986), Associate Fisheries Biologist (1981-1983), and Assistant Fisheries Biologist (1978-1980), Center for Great Lakes Studies/ University of Wisconsin Great Lakes Research Facility
Research Specialist (Fisheries) (1975-1978), Department of Zoology, University of Wisconsin-Milwaukee

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Fisheries Society
World Aquaculture Society

SELECTED PUBLICATIONS

Binkowski, F.P., and L.G. Rudstam. 1994. The maximum daily ration of Great Lakes bloater. Transactions of the American Fisheries Society 123:335-343.

Rudstam, L.G., F.P. Binkowski, and M.A. Miller. 1994. A bioenergetics model for analysis of food consumption patterns by bloater in Lake Michigan. Transactions of the American Fisheries Society 123: 344-357.

Binkowski, F.P., J.J. Sedmack, and S.O. Jolly. 1993. An evaluation of *Pfaffia* yeast as a pigment source for salmonids. Aquaculture Magazine March/April:1-4.

Miller, T., L. Crowder, J. Rice, and F.P. Binkowski. 1992. Body size and the ontogeny of the functional response in fishes. Canadian Journal of Fisheries and Aquatic Sciences 49:805-812.

Miller, T., L. Crowder, and F.P. Binkowski. 1990. Effects of changes in the zooplankton assemblages on growth of Bloater and implications for recruitment success. Transactions of the American Fisheries Society 119:483-491.

Sommer, C.V., F.P. Binkowski, M.A. Schalk, and J.M. Bartos. 1986. Stress factors that can affect studies of drug metabolism in fish. Veterinary and Human Toxicology 28 (Supplement 1):45-54.

Binkowski, F.P., and S.I. Doroshov, editors. 1985. Proceedings of North American sturgeons: biology and aquaculture potential. Kluwer Academic Publishing, Dordrecht, Netherlands.

VITA

Christopher C. Kohler
Department of Zoology/Fisheries Research Laboratory
Southern Illinois University-Carbondale
Carbondale, IL 62901-6511

Phone: (618) 453-2890
FAX: (618) 536-7761
E-Mail: ckohler@siu.edu

EDUCATION

B.S. St. Mary's College of Maryland, 1973
M.S. University of Puerto Rico, 1975
Ph.D. Virginia Polytechnic Institute and State University, 1980

POSITIONS

Professor (1993-present), Associate Professor (1989-1993), Assistant Professor (1982-1988), and Research Associate, (1980-1981), Department of Zoology, Southern Illinois University-Carbondale
Associate Director (1991-present) and Assistant Director (1988-1991), Fisheries Research Laboratory, Southern Illinois University-Carbondale
Assistant Professor (1980), Department of Fisheries and Wildlife Science, Virginia Polytechnic Insitute and State University

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Fisheries Society: Culture, Management, Introduced, Education and International Sections
World Aquaculture Society (USA Chapter)
Sigma Xi, Phi Kappa Phi

SELECTED PUBLICATIONS

Woods, III, L.C., C.C. Kohler, R.J. Sheehan, and C.V. Sullivan. 1995. Volitional tank spawning of female striped bass with male white bass produces hybrid offspring. Transactions of the American Fisheries Society 124:628-632.

Kelly, A.M., and C.C. Kohler. 1994. Human chorionic gonadotropin injected in fish degrades metabolically and by cooking. World Aquaculture 25(4):55-57.

Kohler, C.C., R.J. Sheehan, C. Habicht, J.A. Malison, and T.B. Kayes. 1994. Habituation to captivity and controlled spawning of white bass. Transactions of the American Fisheries Society 123:964-974.

Ayala, C.E., C.C. Kohler, and R.R. Stickney. 1993. Protein digestibility and amino acid availability of fish meal in largemouth bass infected with Acanthocephala. Progressive Fish-Culturist 55:275-279.

Killian, H.S., and C.C. Kohler. 1991. Influence of 17-α-methyltestosterone on red tilapia under two thermal regimes. Journal of the World Aquaculture Society 22:83-94.

Phillips, P.C., and C.C. Kohler. 1991. Establishment of tilapia spawning families providing a continuous supply of eggs for *in vitro* fertilization. Journal of the World Aquaculture Society 22:217-223.

Roem, A.J., C.C. Kohler, and R.R. Stickney. 1990. Vitamin E requirements of the blue tilapia, *Oreochromis aureus* (Steindachner) in relation to dietary lipid level. Aquaculture 87:155-164.

Stickney, R.R., and C.C. Kohler. 1990. Maintaining fishes for research and teaching. Pages 633-663 *in* C. Schreck and P. Moyle, editors. Methods for fish biology. American Fisheries Society, Bethesda, Maryland.