YELLOW PERCH RECIRCULATING AQUACULTURE DEMONSTRATION AND RESEARCH PROJECT

Chairperson: Donald L. Garling, Michigan State University

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

Extension Liaison: Donald L. Garling, Michigan State University

Funding Request: $187,300

Duration: 2 Years (September 1, 1998 - August 31, 2000)

Objectives:

1. Evaluate recirculating aquaculture technology to optimize yellow perch growth, performance (survival, health, feed conversion), and water quality considering such factors as feed management, water replacement, flow rates, and density.

2. Conduct “break-even analysis” for raising yellow perch in a recirculating aquaculture system on a commercial scale with a minimum recirculating system size of 18,927 L (5,000 gal) per biofilter, capable of producing a minimum of 11,340 kg/yr (25,000 lb/yr).

Proposed Budgets:

Institution[1]	Principal Investigator(s)	Objec-tive(s)	Year 1	Year 2	Total
Bay Port Aquaculture Systems, Inc.	Christopher J. Starr	1 & 2	$32,040	$29,860	$61,900
Michigan State University	Donald L. Garling	1	$22,000	$24,000	$46,000
Paragon Aquaculture	Michael D. Libbin	1 & 2	$28,700	$28,700	$57,400
University of Wisconsin-Superior Sea Grant Institute	Harvey Hoven	2	$11,000	$11,000	$22,000
		TOTALS	**$93,740**	**$93,560**	**$187,300**

[1]This proposal is not to be used for advertising or promotional purposes. Citation of companies or trade names does not constitute an official endorsement or approval of commercial products or services.

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JUSTIFICATION

The yellow perch (*Perca flavescens)* is a highly valued food fish having many characteristics that make it an excellent candidate for commercial aquaculture in the North Central Region (Calbert 1975). Since its inception, the North Central Regional Aquaculture Center (NCRAC) has focused a significant percentage of its research and extension efforts on yellow perch. This proposal is a cooperative regional demonstration and research effort that involves participants with appropriate expertise from two universities and two commercial enterprises. The project targets the areas deemed highest priorities by the Industry Advisory Council (IAC) of the NCRAC. The partnership between researchers and commercial producers will enhance the demonstration, evaluation, development, and technology transfer of techniques and management options to optimize yellow perch production in commercial scale recirculating aquaculture systems (RAS).

First, two commercial producers will serve as demonstration and yield verification sites to evaluate RAS technology for yellow perch culture. A yield verification program can serve as a mechanism for data collection and technology transfer in commercial aquaculture (Heikes 1997). A yield verification program for the culture of yellow perch in RAS will provide valuable information to develop extension recommendations, help potential and current fish culturists estimate production parameters, costs and returns, and identify research needs. This project is designed to address these needs.

The commercial producers will evaluate growth, performance (survival, health, feed conversion), and water quality in systems with a minimum size of 18,927 L (5,000 gal) per biofilter and a minimum tank size of 3,785 L (1,000 gal). A commercial producer will use continuous loading-multiple size cohort management within individual culture tanks. Harvested yellow perch will be replaced with 10±3 g (0.35±0.11 oz) 5-7.5 cm (2-3 in) feed trained, fingerling perch every 8 to 12 weeks by Paragon Aquaculture. The theoretical benefits of continuous loading are continuous harvest and utilization of the RAS near threshold design limits. Bay Port Aquaculture Systems, Inc. will maintain single size cohorts within individual culture tanks. Concurrent with the demonstration site evaluations, Michigan State University (MSU) will conduct replicated yellow perch continuous loading-multiple size cohort management growth and performance comparisons. Treatments will be patterned after, but not limited to, the cohort management and feeding practices used at the commercial demonstration projects. MSU will also assist in field verification trials and coordinate marking and evaluation of the performance of three yellow perch cohorts stocked at each commercial demonstration site. A uniquely marked fish cohort from Bay Port Aquaculture Systems, Inc. will be stocked at both demonstration sites near the beginning of this project (September/October 1998) and subsequently at approximately 90 and 120 days. Each of the commercial aquaculture participants will collect mortality and harvest data by gender for the cohort during the two-year demonstration project. During and at the completion of the project, MSU will estimate gender and size distribution of members of the marked cohorts remaining in the system.

Second, the University of Wisconsin-Superior Sea Grant Institute will design a data collection system to obtain monthly operating financial information from active yellow perch producers. Data will initially be collected from the yellow perch commercial demonstration sites. The monthly data will be analyzed and reported on an annual basis. The analysis of operating data will be reported as follows: (1) break-even of revenues versus costs, (2) revenues and costs per L, (3) revenues and costs per kg (lb), and (4) food conversion ratios. Other producers will be solicited to supply additional financial data.

RELATED CURRENT AND PREVIOUS WORK

The market demand for yellow perch has always been high in the North Central Region (NCR), reflecting a strong consumer preference for seafood products derived from this fish (Lesser 1978; Lesser and Vilstrup 1979). The basis for this demand is tied to long-standing uses of perch, such as Friday-night fish fries. Advantages to the fish processing and restaurant industries include the perch's firm flesh and low fat and phospholipid content. Such characteristics are conducive to products having a long shelf life, resistance to freezer damage, and minimal problems with off-flavor and cooking. Its delicate flavor and relative lack of cooking odor make the yellow perch a favorite among restauranteurs and homemakers.

For many years, commercial harvests of yellow perch from the Great Lakes and Canada have failed to keep pace with market demands (Calbert 1975; Lesser and Vilstrup 1979). Increasingly, regulatory constraints designed primarily to protect recreational sport fishing are limiting commercial perch fishing in all Great Lakes waters, including Lake Michigan, Lake Erie, Green Bay, and Saginaw Bay (e.g., Belonger 1986). Another factor impacting the supply of perch is that recruitment of perch in Lake Michigan has been virtually non-existent since 1989 (M. Keniry, Wisconsin Department of Natural Resources, personal communication). The cause of this problem is unknown, but its threat to the Lake Michigan perch population has led to the indefinite closure of commercial perch fishing (except in Green Bay) and decreased recreational bag limits (down from 100 to 5-35 fish/day) by all states bordering the lake (D. Clapp, Michigan Department of Natural Resources, personal communication).

The imbalance between supply and demand of yellow perch fillets has resulted in prices that have remained high for over a decade and continue to climb. For example, in 1990-1991 fresh yellow perch fillets retailed for $17-25/kg ($7.71-11.34/lb) in most markets and by 1994 had increased to $22-32/kg ($9.98-14.52/lb). In 1996, restaurants in the NCR selling yellow perch paid $14.13/kg ($6.41/lb) for frozen and $17.00/kg ($7.71/lb) for fresh yellow perch fillets (Riepe 1997b). These restauranteurs indicated that they would nearly double their purchases of yellow perch if aquaculture could increase supplies and somewhat reduce prices. The reduction of domestic supplies of yellow perch together with high market prices and the concern over microcontaminant levels in Great Lakes fish (Downs 1985; Smith 1988), has resulted in a tremendous growth of interest in the feasibility of yellow perch aquaculture (Calbert 1975; Downs and Smith 1983). Much of the recent interest has focused on culture of yellow perch in RAS because of their ability to provide year-round optimum environmental conditions.

Studies on yellow perch conducted in the 1970s and 1980s demonstrated that this species has many biological characteristics that recommend it for commercial culture (see review by Heidinger and Kayes 1986). Among them are its: (1) ready acceptance of formulated feeds; (2) lack of aggressive behavior and cannibalism; and (3) relatively high tolerance of crowding, handling, and marginal water quality. Procedures for culturing perch under laboratory conditions have been known for some time (Huh 1975; Kocurek 1979), as are methods for raising perch to sexual maturity under natural photoperiod and temperature conditions so that they can be successfully spawned (see Malison et al. 1986).

Over the last several years, the commercial production of yellow perch fingerlings and food-size fish has become a reality, and many regional aquaculturists and scientists believe that commercial perch aquaculture is poised to undergo exponential growth in the coming years. Producers can now be found in many states and provinces including Indiana, Ohio, Nebraska, Wisconsin, Michigan, and Ontario. At the present time, almost all fingerlings are raised in ponds and food-size fish are being grown in ponds, flow-through systems, and RAS. The comparative costs of raising food-size perch using these different systems is not known.

Calbert and Huh (1976) were able to rear yellow perch fingerlings to market size using a small-scale RAS in 9 to 11 months. Estimates of the economic feasibility of raising yellow perch based on models of small scale RAS have indicated that they will not produce a profit for the operator (Kocurek 1979; Lipscomb 1995). Optimum management strategies and biological and economic data is needed for commercial-sized recirculating systems.

Evaluate Recirculating Aquaculture Technology (Objective 1)

Intuitively, candidate fishes for culture in commercial RAS should command a high price, be marketed at a relatively small size, and grow to market size in a short period of time to offset increased, up-front RAS costs. Yellow perch meet the first two criteria. However, compared to other fishes important to commercial aquaculture, perch grow relatively slowly when reared under intensive culture conditions, particularly as they approach market size.

Perch have several growth and maturational characteristics that may restrict their growth. First, the overall growth potential of this species is limited by its inherent small size. Second, although perch are generally considered to be indeterminate growers (i.e., growth continues throughout life), a considerable reduction in their growth rate occurs well before they attain a marketable size of 140 to 160 g (4.9 to 5.6 oz) (Huh 1975; Schott 1980; Malison et al. 1985). Third, male perch grow significantly slower and do not reach as large a size as females (Scott and Crossman 1973; Schott 1980; Malison et al. 1986). These three problems may be related. The second and third, at least, are associated with the onset of sexual maturation and gonadal development, which in perch can occur in the first year of life (Malison et al. 1986). Many authorities have hypothesized that growth and reproduction are antagonistic processes, each competing in the adult animal for available nutrients. Studies on perch as well as other species (Huh 1975; Purdom 1976; Utter et al. 1983; Malison et al. 1985) have shown a strong correlation between sexual maturation and reduced growth, food consumption, and food utilization efficiency.

Optimum RAS system management guidelines have not been developed for yellow perch culture. Researchers at Virginia Tech are beginning studies to compare the response of yellow perch reared in RAS employing three types of biofilters. Work conducted at the University of Wisconsin-Madison in the early 1970s (Calbert and Huh 1976; Huh 1975; Huh et al. 1976) indicated that juvenile yellow perch grew best at a temperature between 20 and 24°C (68.0-75.2°F) and at a photoperiod of 16-h light/9-h dark. Brown et al. (1994) evaluated juvenile yellow perch stocks collected from different geographical locales throughout the country. Fish were reared at 16, 22 or 28°C (60.8, 71.6 or 82.4°F). Although fish from the northern and southern stocks grew best at the lowest and highest temperatures, respectively, all fish grew best at 22°C (71.6°F). The effects of temperature on feed consumption and growth by yellow perch nearing market size has not been evaluated.

Glass (1991) evaluated the optimum loading (kg/L/min) and density (kg/m^3) for yellow perch reared in a single pass, flow-through system maintained at 20±1°C (68.0±1.8°F). Data developed in his study may be useful in planning and operating a RAS for yellow perch culture. Dissolved oxygen (DO) concentrations of 2-3 mg/L did not significantly reduce overall mean weight gain or increase feed conversion of yellow perch. DO levels of 3.5 to 4.0 mg/L were recommended as a safe minimum level for commercial production. During feeding periods, the mean oxygen consumption rate was 297 mg O_2/kg/h for 7-10 cm (2.8-3.9 in) yellow perch and 207 mg O_2/kg/h for 12-13 cm (4.7-5.1 in) perch. Oxygen consumption rates peaked 2-3 h following the first feeding and returned to prefeeding levels approximately 13-17 h after first feeding. Yellow perch consumed 251-277 g O_2/kg feed over a 16-24 h period. The mean ammonia production rate (as total ammonia nitrogen = TAN) during feeding periods for 12-13 cm (4.7-5.1 in) yellow perch was 22.72 mg TAN/kg/h. TAN peaked approximately 5-7 h after the first feeding and returned to prefeeding levels 14 -16 h later. Yellow perch produced 27.9-31.6 g TAN/kg feed consumed over a 16 to 24 h period. The maximum rearing density for yellow perch was not identified. Yellow perch (11-15 cm; 4.3-5.9 in) were reared at densities up to 108 kg/m^3 (1.2 lb/ft^3/in) without significant reductions in growth or performance.

The investigations to be conducted under the NCRAC-funded, yellow perch project initiated in 1997 will evaluate diets, feeding strategies, environmental manipulations, and mono-sex female versus mixed-sex populations as methods for promoting yellow perch growth. The results of the 1997 project may provide valuable tools to enhance growth of perch in recirculating systems. Controlled feeding strategies and environmental manipulations may be more suited for use in recirculating systems than pond or flow through systems. This project will build on evaluations conducted in the 1997 project by evaluating multiple cohort-continuous loading strategies used by most commercial RAS producers of yellow perch.

Multiple cohort-continuous loading strategies have not been evaluated for yellow perch. Commercial producers use variations of multiple cohort-continuous loading management for yellow perch within individual RAS culture tanks. Harvested fish are replaced with feed trained, fingerling perch at various time intervals. Normal variations in size, growth differences between the sexes, and feed wastage may be intensified by cohort management-continuous loading strategies. Because females have been shown to grow faster than males (Malison et al. 1985), females would be expected to predominate in initial harvests from the culture population. The harvested, faster growing females would be replaced by a nearly equal population of fingerling male and female perch. Over time, slower growing males may predominate in the culture tank population and reduce subsequent harvest levels.

A similar system, the multiple-batch system, is the most common method of culturing channel catfish (Busch 1985). Multiple size-cohorts of catfish are cultured within the same pond. When the largest cohort reaches market size and is harvested, fingerling fish are restocked. Although this management scheme enables the producer to extend harvest dates throughout the year, it also produces variation in fish size because of competition between large and small fish for food (Collier and Schwedler 1990) and higher feed conversion ratios (Busch 1985). Silva and Anderson (1995) reported that it is generally believed that more aggressive fish in a farmed population affect appetite and/or feeding of subordinates. Dominance and size hierarchies are most likely to occur when fish are at low densities and when feed is delivered at a single point source. Under these culture conditions, salmonids have been shown to establish defensive territories near food sources and inhibit subordinates from feeding (Ryer and Olla 1991; Thorpe et al. 1990). Studies of Atlantic salmon reared in cages where food is delivered at a single point source have shown that most pellets are consumed by 25% of the population (Olla et al. 1990).

Swindler et al. (1989; 1990) have reported that catfish raised in singe size-cohorts exhibit reduced size variation, competition, and feed conversion ratios. Disadvantages of single cohort systems include reduced product availability, because they are typically harvested only once per year, and cash flow problems (Terhune et al. 1997). Single cohort systems must also be designed to enable complete harvest of the fish. Schwedler et al. (1990) and Terhune et al. (1992; 1997) have designed production systems the can isolate individual size cohorts within a single pond. Catfish are stocked at different sizes in open water and cages within the same pond to gain the advantages of a multiple-batch system while isolating different sized fish. Terhune et al. (1997) has shown that stocking multiple, segregated size-classes in an annual production system can produce marketable size fish at different times throughout the year while maintaining high production rates. Similar strategies could be used by yellow perch culturists by employing multiple, smaller tanks per biofilter, each containing a single size cohort instead of using a single large tank per biofilter containing multiple size cohorts.

Grading fish into relatively uniform size classes is a common, long-standing practice on trout farms. The perceived advantages of grading include enhancing growth, reducing cannibalism, maintaining an accurate inventory, and facilitating calculation of the amount, frequency, and size of feed required if fish are of a nearly equal size (Leitritz 1959); however, few studies have been done to confirm these perceived advantages (Piper et al. 1982). Carmichael (1994) has speculated that conflicting reports of the effects of size grading may have been due to discrepancies in experimental design including differences in density between size-graded groups or in methods of reporting weight gain. For channel catfish, size-grading before stocking appeared to be a useful tool to reduce size variation at harvest from ponds (Huner et al. 1984) and from tanks (Carmichael 1994).

In addition to competition between size groups, feed management is more difficult in multiple cohort-continuous loading systems. As trout and other fishes grow, feed sizes have been increased to enhance feed utilization (Ramseyer and Garling 1997). Feeding a food particle that is too small will result in wasted feed and may increase nutrient leaching because of the increased particle surface area (Hardy 1989). Particles of extremely irregular shape, such as smaller-sized crumbled pellets have more surface area than round pellets (Pigott and Tucker 1989). Feeding a food particle that is too large will increase feed waste because the fish must wait until the particle breaks up before swallowing which increases leaching and wastes feed (Hardy 1989). Feeding smaller particle sizes is usually preferred to feeding larger sizes (Leitritz 1959). Optimum pellet size increases in proportion with fish size. Dabrowski and Bardega (1984) recommended that feed size should not exceed 20% of the mouth opening of cyprinids. Optimum pellet size has been determined for rainbow trout to be 0.5-1.5 mm granules for 1-10 g fish, 2-3 mm granules for 20- 40 g fish, 3-4 mm pellets for 50-100 g fish, and 5-7 mm pellets for fish over 200 g (Cho 1990). Tilapia have been shown to prefer smaller pellets than channel catfish and salmonids of comparable size (Kubaryk 1980). The most common pellet size for feeding tilapia to market size has been 3-5 mm in diameter (NRC 1993). C. Starr, Bay Port Aquaculture Systems, Inc. (personal communication) has observed that yellow perch fed well when feed pellets sized for similarly-sized rainbow trout were used.

Optimum feeding rate has also been shown to vary with fish size, species, feed composition, water temperature, and water quality. Deuel et al. (1937) established the first trout feeding tables that based the amount to feed fed in relation to fish size and weight. Since Deuel et al. (1937), many refinements have been made in methods used to determine the amount of feed fed which have been summarized by Smith (1989). Many feed companies provide feeding tables that relate feeding rate to temperature, species, and fish size. The reliability of these guides are variable; but, are generally more accurate for fishes such as salmonids where they are supported by years of research and culture experience (Silva and Anderson 1995).

The number of times fish should be fed daily has also been shown to vary with fish size, species, feed composition, water temperature, and water quality. Piper et al. (1982) recommended that feeding frequency be based on five basic parameters:

- For optimum growth and feed conversion, each feeding should ideally be 1% of the body weight.
- Survival is not significantly influenced by feeding frequency once the transition from an endogenous to an exogenous food supply has been completed.
- Higher feeding frequencies reduce starvation and stunting thereby resulting in uniformity in size.
- Dry feeds need to be distributed more frequently than moist feeds.
- At lest 90% of the feed should be consumed within the first 15 min of feeding.

Insufficient feed management data exists to make these types of feeding recommendations for yellow perch (Brown et al. 1996). Because of the importance of water quality management in RAS and the differential growth between male and female yellow perch, studies of the impacts of single and multiple cohort management strategies on production, feeds management, and water quality are imperative.

“Break-even Analysis” for Yellow Perch Aquaculture (Objective 2)

The continued strong retail consumer demand for yellow perch in the midwestern U.S., coupled with the decreased commercial and sport catch of yellow perch in the Great Lakes, has contributed to a dramatic increase in the production of yellow perch in RAS in the midwest. The production of yellow perch and many other similar species on a commercial scale using RAS technologies has been developed only recently and the financial results are not well known (O’Rourke and Edon 1995). The costs of production and the revenues produced from product sales vary considerably, based on location, type of technology employed, marketing efforts, and the final prices received for the products (Conrad 1990; O’Rourke and Edon 1995; Riepe 1997a,b; Riepe et al. 1992). In order to analyze and report the financial results of the yellow perch production process and the resulting profitability, it is necessary to study and analyze the financial operating data for several of the established producers (Conrad 1990;. Engle and Stone 1994).

There is no available public source of financial information specifically relating to the production of yellow perch in commercial-sized recirculating systems. Individual producers have maintained private records of expenses, revenues, and profits, but no coordinated effort to collect and analyze this data on a multi-producer scale has been attempted or accomplished.

Financial models for yellow perch production in recirculating systems were developed in 1996 from production and financial data collected in laboratory facilities, from a limited number of small start-up producers, and from information derived from extensive interviews with suppliers and vendors. The theoretical model which was developed can now be replicated and expanded with the inclusion of the expanded database provided by the two collaborating commercial producers during the next two years. The resulting financial information will be useful to existing growers and to potential aquaculture investors. The standardized reports can be easily used for profitability and break-even comparisons.

ANTICIPATED BENEFITS

This project will address priority needs identified by the NCRAC IAC for advancing yellow perch aquaculture in the NCR. The proposed demonstration component of Objective 1 will provide opportunities for individuals interested in yellow perch aquaculture to observe different RAS technologies and management strategies. The demonstration component of Objective 1 will develop yellow perch RAS yield verification through interaction between aquaculture extension specialists, economic researchers, and commercial cooperators. The yield verification will provide information to develop extension recommendations, estimate production parameters, identify research needs, update current recommendations, and develop protocol for future trials. The research activities in Objective 1 will complement the demonstration project by evaluating replicated multiple cohort-continuous loading management strategies compared to more traditional stocking and grow-out procedures. The cohort demonstration and research project will also address questions concerning the magnitude of differences in growth rates between males and females and if fingerlings with suppressed growth rates resume normal growth rates when conditions are no longer limiting. The information generated will help aquaculturists using RAS technology weigh the relative theoretical benefits of continuous loading (continuous harvest and utilization of the RAS near threshold design limits) against its potential drawbacks (reduced feed efficiency, increasing numbers/biomass of slow growing fish, and declining harvest rates over time).

In recent years, significant research has been done on the development of technologies and the basic knowledge necessary to culture yellow perch, but little information is available regarding the financial results of commercial producers. Data for Objective 2 will be derived, in part, from the demonstration projects. The project will provide valuable financial information to the current producers and to potential entrants into the industry. The break-even calculations will demonstrate to current and potential producers the relationship between production revenues and costs that will produce profit/loss results. Each producer can compare their levels of production output, market prices received, and total operating costs against the reported results of this study.

OBJECTIVES

1. Evaluate recirculating aquaculture technology to optimize yellow perch growth, performance (survival, health, feed conversion), and water quality considering such factors as feed management, water replacement, flow rates, and density.

2. Conduct "break-even analysis" for raising yellow perch in a recirculating aquaculture system on a commercial scale with a minimum recirculating system size of 18,927 L (5,000 gal) per biofilter, capable of producing a minimum of 11,340 kg/yr (25,000 lb/yr).

COMMON DEMONSTRATION SITE AND RESEARCH PROTOCOLS

Fish

All yellow perch will be provided at fair market price by Bay Port Aquaculture Systems, Inc. Initial stocking size will be 10±3 g (0.35±0.11 oz). Three fin clipped yellow perch cohorts will be stocked at both demonstration sites with the assistance of MSU in September/October 1998, December 1998/January 1999, and March/April 1999. Fish will be carefully monitored throughout the duration of the demonstration project.

Culture Conditions

Temperature	20±2°C (68.0±3.6°F)
Photoperiod	16-h light/8-h dark
Water Exchange Rate	1/h
Water Replacement Rate	10±2%/day
Solids Removal	daily
Mort Removal	daily

Feeds

Feed	Common Commercial Feed
Rate	Variable; dependent upon size - see **PROCEDURES**
Method	By hand

Water Quality Monitoring[2]

<table>
<tr><td>Temperature</td><td>daily</td><td rowspan="6">measurements taken from one culture tank in each reuse system</td></tr>
<tr><td>pH</td><td>daily</td></tr>
<tr><td>Ammonia</td><td>weekly</td></tr>
<tr><td>Nitrite</td><td>weekly</td></tr>
<tr><td>Nitrate</td><td>weekly</td></tr>
<tr><td>Carbon dioxide</td><td>weekly</td></tr>
<tr><td>DO</td><td>a minimum of weekly</td><td>each culture tank</td></tr>
</table>

Harvest Weight

115 g (4.1 oz)

Monitoring

MSU personnel will make visits to Bay Port Aquaculture Systems, Inc. and Paragon Aquaculture at the beginning of the project and every six months until completion. MSU will coordinate marking, stocking, and evaluating the fish at both commercial demonstration sites (see **PROCEDURES**).

The commercial cooperators agree to follow the protocols and maintain their systems for the duration of the project. Any proposed modifications in protocol or system design must be agreed to by all participants prior to implementation .

PROCEDURES

Demonstration and Evaluation of Recirculating Aquaculture Technology (Objective 1)

<u>Bay Port Aquaculture Systems, Inc.</u>

Demonstration activities at Bay Port Aquaculture Systems, Inc. will be conducted under the direction of Christopher Starr, General Operations Manager and Research Director. The demonstration activities will be conducted over a two year period. Bay Port Aquaculture Systems, Inc. will evaluate growth and performance of yellow perch reared using single sized cohort management practices (Objective 1). Bay Port Aquaculture Systems, Inc. will also collect and provide economic data related to the production of yellow perch using this management strategy (Objective 2).

[2] Tests will be performed using test kits and equipment which are commonly used by the fish farming industry.

Initial size of the fish to be used for the demonstration activities is 10±3 g (0.35±0.11 oz). Fish will be reared until they reach a market size of approximately 115 g (4.1 oz). Fish will be initially stocked into the 7,500-L (1,981-gal) rearing tanks, at a density not to exceed 20 kg/m^3 (1.2 lb/ft^3) of rearing volume. Maximum density in the rearing tanks will not exceed 70 kg/m^3 (4.4 lb/ft^3) of rearing volume. Fish will be reared in tanks or tank sections (in larger tanks, if necessary) with fish of similar size. Fish will be graded every two months, or as necessary, to maintain similar sized fish in the rearing unit. Target sizes of fish to be graded will be 25, 50, 80, and 115 g (0.9, 1.8, 2.8, and 4.1 oz). As fish grow and are moved to larger rearing tanks, additional fish (approximately 10 g; 0.35 oz), will be stocked into the system. All fish will be fed a maximum rate of 2% of total tank biomass daily.

Fish in each tank will be randomly sampled once per month to determine average weight per fish, total tank biomass, and feed conversion. All fish moved into or out of tanks will be weighed collectively to determine fish and biomass moved. Production records will be maintained monthly for individual rearing tanks and will include the following: (1) initial fish and biomass stocked, (2) fish and biomass added, (3) fish and biomass removed, (4) mortality numbers (and estimated biomass), (5) total biomass gain, (6) total feed used, and (7) feed conversion. Critical water quality parameters (temperature, pH, ammonia, nitrite, nitrate, carbon dioxide, and DO) will be measured as described in the protocol above.

Bay Port Aquaculture Systems, Inc. anticipates stocking fish into the system a minimum of three times throughout the brood year. All fish stocked into the system will be of similar initial size, regardless of the time of year they enter the system. A portion of each group of fish stocked into the system will be given a distinguishable mark (fin clip). Bay Port Aquaculture Systems, Inc. anticipates marking three groups of 9,000 fish per brood year. During the monthly sampling process, a sample of the marked fish in each tank will be weighed to determine average weight for individually marked groups of fish. As fish are graded and moved into other rearing units, a portion of these fish will be sampled to determine the percentage of marked fish moved. Market size fish (115 g; 4.1 oz) graded out of the system will be sorted by individual marks. Marked fish will be enumerated weighed, and sexed. All mortalities will be examined for marks, which will be noted on daily mortality records.

All yellow perch used for the demonstration and research components of the project will be produced by Bay Port Aquaculture Systems, Inc. Brood stock originates from Lake Huron (Saginaw Bay). A portion of the fish used will have had their growth suppressed prior to entering the system to provide similar sized fish (initial stocking size) throughout the year. All fish will be trained to accept pelleted feeds prior to entering the system. All fish will be fed a commercially available diet (to be determined) by hand .

<u>MSU</u>

Coordination of demonstration site cohort-management activities and research at MSU will be under the direction of Donald Garling. MSU will visit each commercial site at the beginning of the project and at six month intervals until the project has been completed. They will coordinate marking, stocking, and evaluating the performance of three yellow perch cohorts reared at each commercial demonstration site. Fish cohorts from Bay Port Aquaculture Systems, Inc. will be marked with a unique pelvic fin clip and will be stocked at each demonstration site near the beginning of the project (September/October 1998) and approximately 90 (December 1998/January 1999) and 180 (March/April 1999) days later. Each of the commercial aquaculture participants will collect growth, mortality, and harvest data at time of harvest for each cohort during the two year demonstration project. During each site visit, MSU researchers will randomly sample culture tanks to determine the relative abundance and size distribution of marked fish. A subsample of marked fish and a equal number of randomly selected unmarked fish will be euthanized in MS-222 and dissected to determine gender, gender related size distribution, and reproductive status.

MSU will conduct replicated comparisons of growth and performance of yellow perch grown under single cohort or continuous loading-multiple size cohort management. Treatments will include, but not be limited to, the cohort management and feeding practices used at commercial demonstration projects. Fingerling yellow perch will be obtained from Bay Port Aquaculture Systems, Inc. for each experiment. MSU will conduct their studies in 341-L (90-gal) or larger tanks with water supplied and quality maintained by a RAS. Critical water quality parameters (temperature, pH, ammonia, nitrite, nitrate, carbon dioxide, and DO) will be measured as described in the protocol and maintained within appropriate ranges for yellow perch.

In Year 1, triplicate groups of yellow perch fingerlings will be stocked as single size (8.9±1.3 cm, 3.5±0.5 in or 15.2±1.3 cm, 6.0±0.5 in) or as mixed-sized cohorts (obtained from Paragon Aquaculture as a subsample of their stocks). Different size groups of fish will be marked with a right, left, or double pelvic fin clip; for fish that are 8.9±1.3 cm (3.5±0.5 in) it will be a right fin clip and for those 15.2±1.3 cm (6.0±0.5 in) a double pelvic fin clip. Fish density will be similar between treatments and within the ranges used by the commercial cooperators. Fish will be fed a diet common to the commercial sites at rates and frequencies used by the commercial producers. The grow-out experiment will continue for nine months or until all fish from a 15.2±1.3 cm (6.0±0.5 in) size group (single or multiple cohort) reach harvest size of approximately 20 cm (8 in) and 115 g (4 oz).

Subsequent experiments will build on results from the first experiment and will involve different cohort management stocking strategies (frequent grading of marked, multiple cohorts into similar size classes reared in separate culture tanks) or different feeding strategies designed to enhance growth of multiple cohorts. The experimental design will be developed based on results of Year 1 demonstration and research projects in consultation with the commercial cooperators.

Growth (weight and length), gender frequencies, dress-out percentage (for harvest-sized fish), survival, feed consumption, feed conversion, and proximate analysis will be determined for each size class. All data will be statistically analyzed as a completely randomized design using the Statistical Analysis System (SAS).
MSU will coordinate compilation and analysis of data from the demonstration sites and disseminate the information through appropriate NCRAC reports, presentations, and appropriate extension/research publications.

Paragon Aquaculture

Demonstration activities at Paragon Aquaculture will be under the direction of Michael Libbin. Paragon will demonstrate yellow perch reared to market size using a continuous loading management system. At least two production units consisting of a 37,854-L (10,000-gal) rearing tank with individual RAS will be used for the project. Any disease, water quality or mechanical/hardware problems should be isolated to a single production unit. Water quality will be monitored as indicated under **COMMON DEMONSTRATION SITE AND RESEARCH PROTOCOLS**. Due to the cost of freight, fingerling stock obtained from an outside source will be added to rearing tanks at approximately 12 week intervals.

Operational procedures will be similar to those of Bay Port Aquaculture Systems, Inc. and will follow the protocols listed above. Fish in each tank will be sampled once per month to determine average weight per fish, total tank biomass, and feed conversion. All fish moved into or out of tanks will be weighed collectively to determine the amount of fish and biomass moved. Production records will be maintained monthly for individual rearing tanks and will include the following: (1) initial fish and biomass stocked, (2) fish and biomass added, (3) fish and biomass removed, (4) mortality numbers (and estimated biomass), (5) total biomass gain, (6) total feed used, and (7) feed conversion. Critical water quality parameters (temperature, pH, ammonia, nitrite, nitrate, carbon dioxide, and DO) will be measured as described in the protocol above.

Three cohorts of fish (10±3 g, 8.9±1.3 cm; 0.35±0.11 oz, 3.5±0.5 in) will be uniquely marked with the assistance of MSU and stocked into one of the production units already containing fish on three different dates: September/October 1998; December 1998/January 1999; and March/April 1999. Fish will be anesthetized using MS-222, clipped and stocked. Size of fish will be recorded at stocking time. Logs of general fish health, amount of feed per day, and a subjective view of feeding behavior will be maintained. As fish are harvested from the production unit, they will be identified by presence/absence of the fin clip, counted, weighed in-the-round, and weighed as fillets (with a percent yield calculated).

"Break-even Analysis" for Yellow Perch Aquaculture (Objective 2)

Break-even analysis for yellow perch aquaculture at the University of Wisconsin-Superior Sea Grant Institute (UW-Superior) will be under the direction of Harvey Hoven. The project will be conducted in three phases: (1) identify four collaborating yellow perch producers and establish the data collection arrangements, (2) design the monthly date collection instruments and the format of reports and the analysis to be produced, and

(3) collect and analyze the data, and the distribution and dissemination of the final information and NCRAC reports and extension/research publications.

Phase 1

Bay Port Aquaculture Systems, Inc. and Paragon Aquaculture will participate in this component of the project by providing monthly totals of all production revenues and expenses. The monthly operating reports will be mailed to Hoven and entered into a computer spreadsheet (MS Office/Excel). All data collected from the producers will be treated in a confidential manner. Semi-annual site visits will be made to each producer to review the data collection procedures and to answer any questions or make changes in the data collection procedures to insure accuracy and timeliness.

Phase 2

The monthly data collection instruments will be identical for the two producers so that the information is standardized. The monthly data sheets will report all revenues and expenses incurred during each reporting period. Adjustment for non-cash accounting charges, i.e., depreciation, will be reported on an annual basis. Annual operating profit reports will include all revenues and expenses and will be reported in a standardized format. A break-even calculation will be made for each producer at the end of each fiscal year.

The following financial information will be collected on a monthly basis and entered into the standardized computer data base:

1. Total monthly sales revenues
2. Total monthly operating expenses
   a. Cost of fingerlings purchased
   b. Feed
   c. Electrical
   d. Salaries and fringe benefits
   e. Other miscellaneous expenses
3. Calculation of net cash flow from operations

Phase 3

The annual reports of operating profits and the break-even calculation produced at the end of fiscal years one and two will be made available to be distributed to the aquaculture community in the 12-state NCR (i.e., growers, educators, bankers, vendors, etc.). The annual reports will be made available for posting on the Sea Grant Internet aquaculture web site (http://ag.ansc.purdue.edu/aquanic/). In addition, for those persons with computer capabilities, a user friendly interactive disk will be prepared using MS Office/Excel so that potential or other current producers can easily estimate their own break-even operating levels of revenues and expenses. Hoven will make presentations using these data at aquaculture technical workshops and conferences. Individual consultations could be conducted with current or prospective producers to review profitability and break-even levels.

FACILITIES

The Bay Port Aquaculture Systems, Inc. aquaculture research and production facility is located in West Olive, Michigan. The facility is located at the Consumers Energy Company, J.H. Campbell Electrical Generating Complex and has access to heated discharge water to maintain optimal growing temperatures (20-22°C; 68.0-71.6°F) nearly year-round with a computer assisted water temperature and flow control system. The facility has an analytical lab equipped for water quality monitoring. The flow-through system supplies both indoor tanks and outdoor raceways. The food fish production system is designed to annually produce 45,000 kg (99,206 lb) of yellow perch. Bay Port Aquaculture Systems, Inc. has a yellow perch brood stock, a hatchery with specially designed incubators supplied with aerated well water (12°C; 53.6°F), ponds at various sites managed for optimum zooplankton production, and a feed training facility to rear fingerlings for its facility and for sale.

The Bay Port Aquaculture Systems, Inc. commercial-scale research facility is under construction at Evart, Michigan. The facility will house three RAS, a water quality laboratory, and fingerling production ponds. Each RAS will consist of four 3,785-L (1,000-gal) rearing tanks and associated filtration tanks (18,927 L [5,000 gal] total volume per system) which will be available for these studies. The RAS to be used by Bay Port Aquaculture Systems, Inc. will consist of a minimum of six linear rearing tanks. Three tanks will have a rearing volume of 7,500 L (1,981 gal) and three tanks will have a rearing volume of 56,700 L (14,979 gal). Each rearing tank will have a solids settling area adjacent to the rearing tank. Additional solids removal (mechanical) may be designed into the system. Biofiltration will be conducted in aerated submerged beds. Biofiltration media surface area will be 100 m^2/kg (488 ft^2/lb)of feed to be fed daily. A common biofilter, used for three 7,500-L (1,981-gal) rearing tanks, will be sized to accommodate 28 kg (61.7 lb) of feed daily. Individual biofilters, for each of the 56,700-L (14,979-gal) rearing tanks, will be sized to accommodate 50 kg (110.2 lb) of feed daily. An oxygen injection system (to be designed) will be used to reoxygenate the rearing water. DO levels in rearing water outflow will be maintained at or above 5 mg/L. Packed columns will be used for carbon dioxide stripping if necessary. The system will be housed in a well insulated building to minimize energy costs necessary to maintain water temperatures at 20±2°C (68.0±3.6°F). A 16-h light/8-hour dark photoperiod will be maintained. Water flow rates will be maintained at the appropriate level so as to provide 1.0 to 1.5 water exchanges per hour, through the rearing tank. A total of 8-10% of the system water will be replaced with fresh well water on a daily basis.

MSU has an analytical lab equipped for water quality monitoring and a wet laboratory fully equipped to conduct the single versus multiple cohort-continuous loading grow-out studies. All studies will be conducted in an experimental RAS. The system will contains nine 340-L ([89.8-gal] or larger) culture tanks and a filtration system similar in design to the Bay Port Aquaculture Systems, Inc. RAS described above. Density (kg/m^3; lb/ft^3) of fish used in all studies will be similar to those used and verified during site visits at the commercial RAS demonstration sites.

Paragon Aquaculture has a 446 m^2 (4,800 ft^2) facility erected in 1995 specifically designed for raising fish. The facility contains three RAS with 113,562 L (30,000 gal) of rearing space and a total volume of 141,953 L (37,500 gal) including water treatment space. Each RAS consists of one sloped bottom 37,854-L (10,000 gal) rearing tank and an independent water filtration system. Water filtration is provided by gravity flow from the culture tank through two settling tanks, a bead filter, 16 foam fractionators, and biofilter. The two settling tanks are 1,893 L (500 gal) each and contain a “box” built around each water inlet pipe constructed from 1.27 cm (0.5 in) polyester furnace filters. The bead filters contain approximately 0.7 m^3 (25 ft^3) of polyethylene, positive buoyancy beads. The biofilters contain approximately 1.7 m^3 (60 ft^3) plastic interlocking bio-cubes resulting in a surface of approximately 1,812 m^2 (19,500 ft^2). Daily water replacement is approximately 10% of total volume. Discharge water is generated through the backwashing of bead filters. The rate of water exchange, or water turnover per system is 37,854 L/h (10,000 gal/h), or 632 L/min (167 gal/min).

UW-Superior has the computer hardware and software necessary to complete Objective 2. All operating records for Objective 2 will be completed and maintained by the collaborating producers. Monthly operating data will be sent to Hoven for analysis and storage in the computer database at UW-Superior.

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PROJECT LEADERS

State	Name/Institution	Area of Specialization
Michigan	Donald L. Garling Michigan State University	Fish Nutrition/Fish Culture/ Extension
Michigan	Christopher J. Starr Bay Port Aquaculture	Yellow Perch Aquaculture/ Recirculating Systems
Wisconsin	Harvey Hoven University of Wisconsin-Superior Sea Grant Institute	Business Planning
Wisconsin	Michael D. Libbin Paragon Aquaculture	Yellow Perch Aquaculture/ Recirculating Systems

PARTICIPATING INSTITUTIONS AND PRINCIPAL INVESTIGATORS

Bay Port Aquaculture Systems, Inc.
Christopher J. Starr

Michigan State University (MSU)
Donald L. Garling

Paragon Aquaculture
Michael D. Libbin

University of Wisconsin-Superior Sea Grant Institute (UW-Superior)
Harvey Hoven

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

OMB Approved 0524-0022
Expires 5/31/98

BUDGET

ORGANIZATION AND ADDRESS Bay Port Aquaculture Systems, Inc. 1008 First Street, Box 57 Bay Port, MI 48720-0057				**USDA AWARD NO.** Year 1: Objectives 1 and 2	
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Christopher J. Starr				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. ___ Other Professional					
c. ___ Graduate Students					
d. ___ Prebaccalaureate Students					
e. 1 Secretarial-Clerical				$1,200	
f. 1 Technical, Shop and Other				$9,000	
Total Salaries and Wages →				$10,200	
B. Fringe Benefits (If charged as Direct Costs)					
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →				$10,200	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$21,840	
F. Travel 1. Domestic (Including Canada)					
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) →				$32,040	
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) →				$32,040	
M. Other →					
N. Total Amount of This Request →				$32,040	$
O. Cost Sharing (If Required Provide Details)	$106,076				

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

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Expires 5/31/98

BUDGET

ORGANIZATION AND ADDRESS Bay Port Aquaculture Systems, Inc. 1008 First Street, Box 57 Bay Port, MI 48720-0057				**USDA AWARD NO.** Year 2: Objectives 1 and 2	
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Christopher J. Starr				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. ___ Other Professional					
c. ___ Graduate Students					
d. ___ Prebaccalaureate Students					
e. 1 Secretarial-Clerical				$1,200	
f. 1 Technical, Shop and Other				$9,900	
Total Salaries and Wages →				$11,100	
B. Fringe Benefits (If charged as Direct Costs)					
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →				$11,100	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$18,760	
F. Travel 1. Domestic (Including Canada)					
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) →				$29,860	
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) →				$29,860	
M. Other →					
N. Total Amount of This Request →				$29,860	$
O. Cost Sharing (If Required Provide Details)	$108,568				

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 BAY PORT AQUACULTURE SYSTEMS, INC.

(Starr)

Objectives 1 and 2

A. **Salaries and Wages.** A 0.5 time technician will assist the PI with general fish husbandry, water quality monitoring, fish sampling, and fish marking. Clerical assistance will be needed to record and report data collected for Objective 2.

E. **Materials and Supplies.** Bay Port Aquaculture Systems, Inc. anticipates rearing a minimum of 200,000 yellow perch fingerlings, per year, to market size for the planned demonstration activities. Bay Port Aquaculture Systems, Inc. typically sells the majority of its fish as fingerlings. Although 200,000 fingerlings will be needed per year, Bay Port Aquaculture Systems, Inc. is only requesting compensation for 27,000 fingerlings per year (the number of fish to be marked). The initial size of fish for this project is 10 g, which Bay Port Aquaculture Systems, Inc. typically sells for $0.31 each. Bay Port Aquaculture Systems, Inc. will expense the fingerlings as $0.26 each, or an annual total of $7,020 for fingerlings. Bay Port Aquaculture Systems, Inc. will expense $8,820 annually for fish feed, which is approximately 35% of the anticipated feed cost to rear 200,000 fingerlings to market size. Projected expenses for miscellaneous supplies (chemicals for water quality testing, sterilants, nets, etc.) are $6,000 for Year 1 and $2,920 for Year 2.

NOTE: Bay Port Aquaculture Systems, Inc., will only be asking for a portion of the total costs that will be incurred to conduct its portion of the project. Costs that are being requested are actual and do not include any mark-up or additional fees.

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

OMB Approved 0524-0022
Expires 5/31/98

BUDGET

ORGANIZATION AND ADDRESS Department of Fisheries and Wildlife Michigan State University East Lansing, MI 48824-1222				**USDA AWARD NO.** Year 1: Objective 1	
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Donald L. Garling				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				$12,675	
d. _2_ Prebaccalaureate Students				$1,000	
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages . . . . →				$13,675	
B. Fringe Benefits (If charged as Direct Costs)				$808	
C. Total Salaries, Wages, and Fringe Benefits (A plus B) . . . . →				$14,483	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$5,517	
F. Travel 1. Domestic (Including Canada)				$2,000	
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) . . . . →				$22,000	
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) . . . . →				$22,000	
M. Other . . . . →					
N. Total Amount of This Request . . . . →				$22,000	$
O. Cost Sharing (If Required Provide Details)	$23,207				

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 Department of Fisheries and Wildlife Michigan State University East Lansing, MI 48824-1222				**USDA AWARD NO.** Year 2: Objective 1	
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Donald L. Garling				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				$14,650	
d. 2 Prebaccalaureate Students				$1,000	
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages →				$15,650	
B. Fringe Benefits (If charged as Direct Costs)				$850	
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →				$16,500	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$6,000	
F. Travel 1. Domestic (Including Canada)				$1,500	
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.)					
J. Total Direct Costs (C through I) →				$24,000	
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) →				$24,000	
M. Other →					
N. Total Amount of This Request →				$24,000	$
O. Cost Sharing (If Required Provide Details)	$24,493				

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 MICHIGAN STATE UNIVERSITY

(Garling)

Objective 1

A. **Salaries and Wages**. Laboratory studies will be conducted with the assistance of a graduate student (0.50 FTE). Responsibilities of the graduate student will include: general fish culture, water quality testing, and marking fish cohorts for stocking at commercial demonstration sites. Prebaccalaureate students will assist in marking fish cohorts for stocking at commercial demonstration sites and general fish care.

B. **Fringe Benefits.** MSU requires medical coverage for graduate research assistants estimated to be $808 for Year 1 and $850 for Year 2 of the project.

E. **Materials and Supplies.** Year 1: Fish ($1,000), feeds ($1,500), water testing supplies and chemicals ($500), general wet lab supplies and equipment maintenance ($2,017), and general office supplies as extension liaison ($500). Year 2: Fish ($1,500), feeds ($1,500), water testing supplies and chemicals ($500), general wet lab supplies and equipment maintenance ($2,000), and general office supplies as extension liaison ($500).

F. **Travel.** Domestic travel will be required to obtain fish for experiments, mark fish for demonstration site cohort evaluations and for site visits each six months at the commercial demonstration sites ($2,000 in Year 1 and $1,500 in Year 2). Note: Trips to obtain fish for MSU experiments and to mark fish for cohort growth evaluations at commercial demonstration sites in Years 1 and 2 will coincide with six month site visits with commercial demonstration project leaders. Costs will include transportation, lodging, and meals.

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

OMB Approved 0524-0022
Expires 5/31/98

BUDGET

ORGANIZATION AND ADDRESS Paragon Aquaculture 5020 State Road 21 Oshkosh, WI 54904	USDA AWARD NO. Year 1: Objectives 1 and 2	
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Michael D. Libbin	Duration Proposed Months: 12 FUNDS REQUESTED by PROPOSER	Duration Awarded Months: ________ FUNDS APPROVED BY CSREES (If Different)

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. ___ Graduate Students					
d. ___ Prebaccalaureate Students					
e. 1 Secretarial-Clerical				$1,200	
f. 1 Technical, Shop and Other				$7,800	
Total Salaries and Wages →				$9,000	
B. Fringe Benefits (If charged as Direct Costs)					
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →				$9,000	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$19,335	
F. Travel 1. Domestic (Including Canada)				$250	
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 ($75), Fax ($25), Postage ($15)				$115	
J. Total Direct Costs (C through I) →				$28,700	
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) →				$28,700	
M. Other →					
N. Total Amount of This Request →				$28,700	$
O. Cost Sharing (If Required Provide Details)	$64,575				

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 Paragon Aquaculture 5020 State Road 21 Oshkosh, WI 54904				**USDA AWARD NO.** Year 2: Objectives 1 and 2	
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Michael D. Libbin				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. ___ Graduate Students					
d. ___ Prebaccalaureate Students					
e. 1 Secretarial-Clerical				$1,200	
f. 1 Technical, Shop and Other				$7,800	
Total Salaries and Wages →				$9,000	
B. Fringe Benefits (If charged as Direct Costs)					
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →				$9,000	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$19,335	
F. Travel 1. Domestic (Including Canada)				$250	
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 ($75), Fax ($25), Postage ($15)				$115	
J. Total Direct Costs (C through I) →				$28,700	
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) →				$28,700	
M. Other →					
N. Total Amount of This Request →				$28,700	$
O. Cost Sharing (If Required Provide Details)	$71,750				

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 PARAGON AQUACULTURE

(Libbin)

Objectives 1 & 2

A. Salaries and Wages. A 0.5 FTE technician will assist the PI with water quality monitoring, general fish husbandry, and identification of marked fish cohorts. Clerical assistance is required to collect, record, and report data for Objective 2.

E. Materials and Supplies. Annual costs: fingerlings ($9,335) and feed ($10,000).

F. Travel. Travel, lodging, meals, and miscellaneous expenses for one trip per year to meet with other Work Group members at Bay Port Aquaculture Systems, Inc.

I. Other Direct Costs. Annual costs: telephone ($75), fax ($25), and postage ($15) for reporting data.

NOTE: Paragon Aquaculture will only be asking for a portion of the total costs that will be incurred to conduct its portion of the project. Costs that are being requested are actual and do not include any mark-up or additional fees.

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

OMB Approved 0524-0022
Expires 5/31/98

BUDGET

ORGANIZATION AND ADDRESS	USDA AWARD NO. Year 1: Objective 2	
University of Wisconsin - Superior Sea Grant Institute Superior, WI 54880-9985	Duration Proposed Months: 12	Duration Awarded Months: ________
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Harvey Hoven	**FUNDS REQUESTED by PROPOSER**	**FUNDS APPROVED BY CSREES** (If Different)

	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. ___ Graduate Students					
d. 1 Prebaccalaureate Students				$6,240	
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages →				$6,240	
B. Fringe Benefits (If charged as Direct Costs)				$810	
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →				$7,050	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies					
F. Travel 1. Domestic (Including Canada)				$2,400	
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.) Telephone ($400), Fax ($300), Postage ($500), Photocopying ($350)				$1,550	
J. Total Direct Costs (C through I) →				$11,000	
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) →				$11,000	
M. Other →					
N. Total Amount of This Request →				$11,000	$
O. Cost Sharing (If Required Provide Details)	$12,800				

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 - Superior Sea Grant Institute Superior, WI 54880-9985				**USDA AWARD NO.** Year 2: Objective 2	
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Harvey Hoven				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. ___ Graduate Students					
d. 1 Prebaccalaureate Students				$6,240	
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages →				$6,240	
B. Fringe Benefits (If charged as Direct Costs)				$810	
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →				$7,050	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies					
F. Travel 1. Domestic (Including Canada)				$2,400	
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.) Telephone ($400), Fax ($300), Postage ($500), Photocopying ($350)				$1,550	
J. Total Direct Costs (C through I) →				$11,000	
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) →				$11,000	
M. Other →					
N. Total Amount of This Request →				$11,000	$
O. Cost Sharing (If Required Provide Details)	$14,690				

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-SUPERIOR SEA GRANT INSTITUTE

(Hoven)

Objective 2

A. Salaries and Wages. Monthly financial operating reports from the four participating producers will be collected and entered into the database by an undergraduate student (20 hours per week @ $12.00 per hour for 26 weeks per year).

B. Fringe benefits. Fringe benefits for prebaccalaureate students at UW Sea Grant Institute is 13%.

F. Travel. The PI will travel to each participating site twice annually. Travel funds will also be used to attend NCRAC work group meetings and the NCRAC conference to present annual results and a final project report. All travel costs include transportation, lodging, and meals.

I. All Other Direct Costs. Annual costs: telephone ($400), fax ($300), postage ($500), photocopying ($350).

BUDGET SUMMARY FOR EACH PARTICIPATING INSTITUTION

Year 1

	Bay Port	**MSU**	**Paragon**	**UW-Superior**	**TOTALS**
Salaries and Wages	$10,200	$13,675	$9,000	$6,240	$39,115
Fringe Benefits	$0	$808	$0	$810	$1,618
Total Salaries, Wages and Fringe Benefits	$10,200	$14,483	$9,000	$7,050	$40,733
Nonexpendable Equipment	$0	$0	$0	$0	$0
Materials and Supplies	$21,840	$5,517	$19,335	$0	$46,692
Travel	$0	$2,000	$250	$2,400	$4,650
All Other Direct Costs	$0	$0	$115	$1,550	$1,665
TOTAL PROJECT COSTS	$32,040	$22,000	$28,700	$11,000	$93,740

Year 2

	Bay Port	**MSU**	**Paragon**	**UW-Superior**	**TOTALS**
Salaries and Wages	$11,100	$15,650	$9,000	$6,240	$41,990
Fringe Benefits	$0	$850	$0	$810	$1,660
Total Salaries, Wages and Fringe Benefits	$11,100	$16,500	$9,000	$7,050	$43,650
Nonexpendable Equipment	$0	$0	$0	$0	$0
Materials and Supplies	$18,760	$6,000	$19,335	$0	$44,095
Travel	$0	$1,500	$250	$2,400	$4,150
All Other Direct Costs	$0	$0	$115	$1,550	$1,665
TOTAL PROJECT COSTS	$29,860	$24,000	$28,700	$11,000	$93,560

RESOURCE COMMITMENT FROM INSTITUTIONS[1]

Institution		Year 1	Year 2
Bay Port Aquaculture Systems, Inc.			
Salaries and Benefits SY 0.10		$17,456	$19,948
Supplies, Expenses, Equipment, and Wavier of Overhead		$88,620	$88,620
	Total	$106,076	$108,568
Michigan State University			
Salaries and Benefits SY 0.10 FTE		$9,177	$9,443
Supplies, Expenses, Equipment, and Wavier of Overhead		$14,030	$15,050
	Total	$23,207	$24,493
Paragon Aquaculture			
Salaries and Benefits SY 0.10 FTE		$14,350	$14,350
Supplies, Expenses, Equipment, and Wavier of Overhead		$50,225	$57,400
	Total	$64,575	$71,750
University of Wisconsin-Superior Sea Grant Institute			
Salaries and Benefits SY 0.10 FTE		$6,000	$7,350
Supplies, Expenses, Equipment, and Wavier of Overhead		$6,800	$7,340
	Total	$12,800	$14,690
	Total per Year	$206,658	$219,501
	GRAND TOTAL	$426,159	

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

SCHEDULE FOR COMPLETION OF OBJECTIVES

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

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

LIST OF PRINCIPAL INVESTIGATORS

Donald L. Garling, Michigan State University

Harvey Hoven, University of Wisconsin-Superior Sea Grant Institute

Michael D. Libbin, Paragon Aquaculture

Christopher J. Starr, Bay Port Aquaculture Systems, Inc. Systems, Inc.

VITA

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EDUCATION

B.S. University of Dayton, 1970
M.S. Eastern Kentucky University, 1972
Ph.D. Mississippi State University, 1975

POSITIONS

Professor (1990-present), Associate Professor (1985-1990), and Assistant Professor (1980-1985), Department of Fisheries and Wildlife, Michigan State University

Aquaculture and Fisheries Extension Specialist (1985-present), Department of Fisheries and Wildlife, Michigan State University.

Assistant Professor of Fisheries Science (1976-1980), Department of Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University

SCIENTIFIC and PROFESSIONAL ORGANIZATIONS

American Fisheries Society, Fish Culture and Fisheries Educators Section
World Aquaculture Society
Gamma Sigma Delta
Sigma Xi

SELECTED PUBLICATIONS

Ramseyer, L.J., and D.L. Garling. In press. Effects of dietary protein-to-metabolizable energy ratios and total protein concentrations on the performance of yellow perch, *Perca flavescens*. Journal of Aquaculture Nutrition.

Ramseyer, L.J., and D.L. Garling. 1997. Fish nutrition and aquaculture waste management. Pages 57-62 *in* L. Swan, editor. Proceedings of the North Central Regional Aquaculture Conference. Third North Central Regional Aquaculture Conference, Indianapolis, Indiana, February 6-7, 1997. Indianapolis, Indiana. Illinois-Indiana Sea Grant Program Publication CES-305.

Brown, P.B., K. Dabrowski, and D.L. Garling, Jr. 1996. Nutrition and feeding of yellow perch (*Perca flavescens*). Journal of Applied Ichthyology 12:171-174.

Cain, K.D., and D.L. Garling. 1995. Pretreatment of soy bean meal for salmonid diets with phytase to reduce phosphorus concentration in hatchery effluents. Progressive Fish-Culturist 57:114-119.

Ramseyer, L.J., and D.L. Garling. 1994. Amino acid composition of the ovaries, muscle, and whole body of yellow perch (*Perca flavescens*). Progressive Fish-Culturist 56:175-179.

Dean, J.C., L.A. Nielsen, L.A. Helfrich, and D.L. Garling, Jr. 1992. Replacing fish meal with seafood processing wastes in channel catfish diets. Progressive Fish-Culturist 54:7-13.

Garling, D.L. 1991. NCRAC research programs to enhance the potential of yellow perch aquaculture in the region. Pages 253-255 *in* Proceedings of the North Central Aquaculture Conference, Kalamazoo, March 18-21, 1991.

VITA

Harvey Hoven
University of Wisconsin-Superior
Sea Grant Institute
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Superior, WI 54880

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Fax: (715) 394-8454
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EDUCATION

B.B.A. University of Wisconsin, 1961
M.A. St. Thomas University, 1978
B.S. University of Wisconsin - Superior, 1990
M.B.A. University of Minnesota, In progress

POSITIONS

Advisory Services Business Specialist (1990-present), University of Wisconsin Sea Grant Institute, Madison
Laboratory Assistant (1988-1990), Lake Superior Research Institute, University of Wisconsin - Superior
Various banking and investment positions (1962-1987), Minneapolis, Minnesota

VITA

Michael D. Libbin
Paragon Aquaculture
5020 State Road 21
Oshkosh, WI 54904

Phone: (920) 232-8927
Fax: (920) 232-8928

EDUCATION

B.B.A. University of Wisconsin-Oshkosh, 1983

POSITIONS

Owner (1995-present), Paragon Aquaculture and Paragon Processing Inc., Oshkosh, Wisconsin
General Manager (1990-1994), ESE, Inc., Marghfield, Wisconsin
Director of Human Resources and Manufacturing (1987-1990), A&B Process Systems, Stratford, Wisconsin
Director of Human Resources (1993-1987), A&B Process Systems, Stratford, Wisconsin

SCIENTIFIC and PROFESSIONAL ORGANIZATIONS

Wisconsin Aquaculture Association

VITA

Christopher J. Starr
Bay Port Aquaculture Systems, Inc.
16990 Croswell
West Olive, MI 49460
Phone: (616) 399-3520
Fax: (616) 399-4434

EDUCATION

B.S. University of Idaho, 1983
M.S. Michigan State University, 1989

POSITIONS

Aquatic Biologist and Hatchery Manager (1989-present), Bay Port Aquaculture Systems, Inc., West Olive, Michigan
Graduate Research Assistant (1987-1989), Michigan State University
Fish Superintendent I (1985-1987), McCall Fish Hatchery, Idaho Department of Fish and Game
Fish Culturist (1984-1985), Niagara Springs Fish Hatchery, Idaho Department of Fish and Game

SELECTED PUBLICATIONS

Williams, F., and C. Starr. 1995. Evaluation of a filter press system to reduce moisture content of fish production wastes. Phase II Completion Report, Small Business Innovative Research Program, United States Department of Agriculture, Washington, D.C.

Williams, F., and C. Starr. 1993. The development of a commercially viable yellow perch (*Perca flavescens*) culture system. Phase II Completion Report, Small Business Innovative Research Program, National Science Foundation, Washington, D.C.

Williams, F., and C. Starr. 1992. Evaluation of a filter press system to reduce moisture content of fish production wastes. Final Report, State Research Fund, Michigan Department of Commerce, Lansing, Michigan.

Starr, C. 1989. The performance of stunted and nonstunted yellow perch (*Perca flavescens*) fed practical diets. Master's thesis. Michigan State University, East Lansing.

Starr, C. 1989. The development of a commercially viable yellow perch culture system. Final Report, State Research Fund, Michigan Department of Commerce, Lansing, Michigan.

Starr, C. 1987. Initial feeding of chinook salmon at the McCall fish hatchery. Proceedings of the 1986 Northwest Fish Culture Conference, Springfield, Oregon.