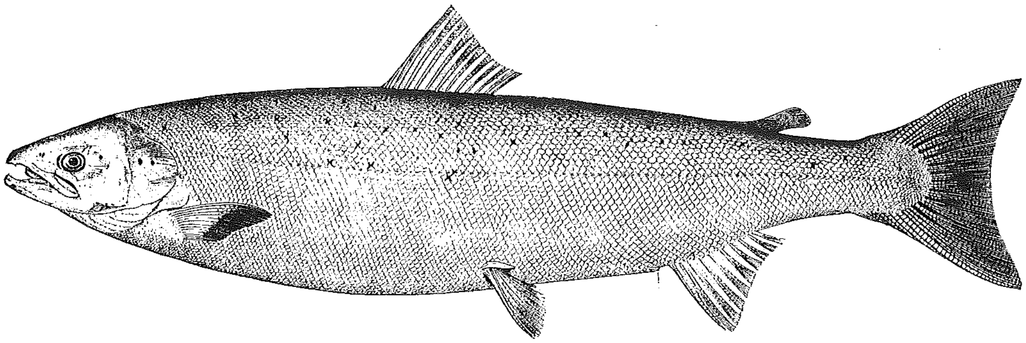
MINNESOTA AQUACULTURE ADVISORY COMMITTEE



AQUACULTURE COMMITTEE POSITION ON PHASE I AND II FEASIBILITY STUDY

MARCH, 1988

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Minnesota Department of Agriculture
Minnesota Department of Natural Resources
Iron Range Resources and Rehabilitation Board
Contract administered by:
Minnesota Department of Trade and Economic Development

Introduction

Minnesota's Aquaculture Advisory Committee was created in 1987. The Governor and State Legislators recognized that opportunities in aquaculture have not been fully pursued in Minnesota. That need was the impetus for the creation of this committee. The committee is seeking a thoughtful and informed approach to identifying the best current and long-term opportunities for aquaculture in this state.

The committee is made up of representatives of affected agencies and interest groups including: Private Aquaculture Developers; MN Fishfarmers Association; Departments of Agriculture, Natural Resources, Trade and Economic Development; Members of the State Legislative Environment and Natural Resources Committees; University of MN Fisheries and Wildlife Department; Minnesota Extension; Natural Resources Research Institute; Iron Range Resources and Rehabilitation Board; University of Minnesota School of Business and Economics; Farmers Home Administration; and The Soil Conservation Service. The State Planning Agency coordinates the committee.

Study Constraints

As one of its first projects, the Minnesota Aquaculture Advisory Committee identified the need for an assessment of systems and species with promising potential under environmental, technological and regulatory conditions presently existing in Minnesota.

Due to a limited budget, the committee limited the scope of the feasibility and market analysis. The consultants were asked to address the study under the following constraints:

1. Survey the current status of aquaculture in Minnesota.
2. Recommend up to four top species and production systems.
3. Select species that have the best <u>current</u> potential for <u>adult food-fish production</u>, and also bait fish (i.e., species with great market potential at the egg/fry/smolt/fingerling stages would not be analyzed in this study). We decided to review the potential for egg/fry/smolt/fingerling production in a later study, if possible.
4. Make recommendations based on current technology and current resource bases, current environmental conditions, current laws and existing regulatory conditions.
5. Phase I of the study will identify up to four species and four production systems.
6. Phase II will provide a production and economic feasibility analysis of the Phase I recommendations.

Committee Position on Consultants' Recommendations:

The <u>consultants</u> recommend the following:

1. Atlantic and Chinook salmon and trout: intensive culture in the abandoned iron pits.
2. Bait minnows: extensive culture in lakes and ponds.
3. White Sturgeon: extensive culture in large lakes.
4. Paddlefish: extensive culture in large lakes.

Committee Recommendations

1. The committee strongly supports the recommendations relating to salmon, trout and bait fish species with the following suggestions:

A. There is a need for a pilot study and analysis of the economic viability and returns of pond production of minnows. Although many people are in the minnow business today, there is little detailed economic information available on pond production of minnows.

B. Work with private developers in the iron pits to establish clear knowledge of the impacts and potential of further aquaculture development there (i.e., a public-private pilot study).

2. The committee rejects the notion completely of culture of white sturgeon and paddlefish in public waters because of the potential impacts on existing natural fisheries. However, we do support research on culturing these species on smaller winter-kill lakes and ponds.

A. Further research is needed on the ecological impacts, culture methodology, and economic potential of sturgeon and paddlefish culture in Minnesota.

3. The committee feels that the consultants may have misunderstood some of the regulations. Therefore, some of the recommendations with regard to regulations may be invalid.

4. The committee believes that several related side-issues have been brought to their attention by the consultants' report. We recommend the following:

A. Constraints on aeration in lakes which limit the potential of aquaculture in Minnesota should be examined.

B. There is a need for an aquaculture staff position at the Department of Natural Resources to facilitate permitting and technical advice for those in the aquaculture industry. This position could also serve as an agency liaison on issues relating to regulations affecting aquaculture.

C. There is a need for a staff position in the Department of Agriculture to work on promotion and market development of aquaculture in Minnesota.

D. There is an immediate need for a single industry organization to coordinate private sector/industry needs and interests with the agencies, the committee and State Legislature.

E. Technologies with the potential for success in the future should be identified, and research undertaken to delineate the details of a strategic plan, prepared by the Aquaculture Committee, for the future development of aquaculture in Minnesota.

F. There is a need for research in techniques and economic feasibility of culturing eggs/fry/smolt/fingerlings for production and stocking, using correct and wise management and good biology in ecosystems where it is known that stocking will enhance the yield.

To obtain additional copies of this report the following fees apply:

$15 for the complete report
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Make checks payable to:

Minnesota State Planning Agency

Submit your requests to:

Patty Burke, Coordinator
Minnesota Aquaculture Advisory Committee
State Planning Agency
300 Centennial Office Building
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St. Paul, MN 55155
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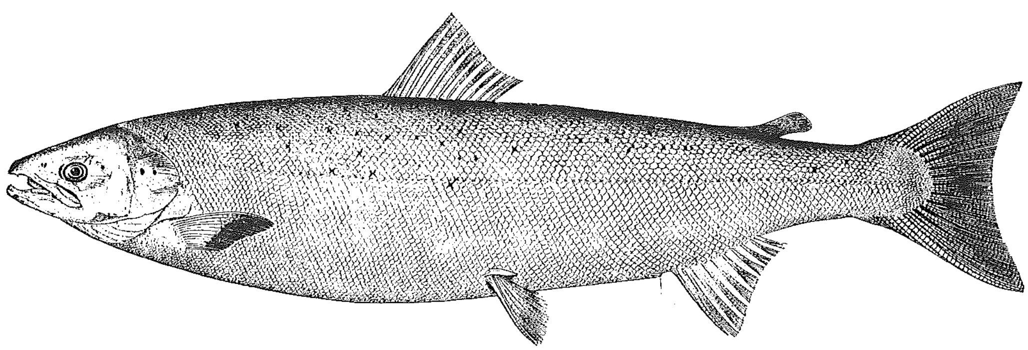
Aquaculture Advisory Committee
State of Minnesota

Phase I

AQUACULTURE FEASIBILITY STUDY AND MARKETING ANALYSIS



Fish Factory (International)
FFI No. 87/7-001

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October 13, 1987

Mr. Harry Rosefelt
Minnesota Department of Trade
and Economic Development
160 East Kellogg Boulevard
St. Paul, MN 55101

Subject: Aquaculture Feasibility Study
Phase I (FFI 87/7-001)

Dear Mr. Rosefelt:

Fish Factory (International) is pleased to present the attached Phase I Report for the Aquaculture Feasibility Study and Marketing Analysis. As per proposal, ten copies of this report are provided.

The detailed Phase I information documented in this report will be presented to the Aquaculture Advisory Group on October 15, 1987. With the submission of this report and the in-person presentation of our findings, Phase I of the study is completed.

The primary objective of this study is to identify aquaculture activities that will enhance rural economic development and diversification opportunities in Minnesota. Based on review of environmental conditions in Minnesota, present regulations, market demand for potential species, and available water and land resources, four groups of fish are recommended for an in-depth analysis in Phase II. The recommended species include (1) white sturgeon, (2) paddlefish, (3) bait minnows and (4) Atlantic and chinook salmon. Groups 1, 2, and 3 are best suited to extensive culture in lakes and ponds. Group 4 is best suited to intensive cage culture in the iron pits.

If aquaculture is to be considered a viable economic industry, some modification of existing regulations will be needed. Under favorable economic and regulatory conditions, aquaculture as an industry in Minnesota has the potential to generate up to an additional annual $50 million after 6 years.

Thank you for the opportunity to assist in this very interesting project. We stand ready to implement Phase II following notice to proceed. Please do not hesitate to call if you have any questions about this report.

Yours truly,

John E. Colt

John E. Colt, Ph.D.

Peter B. Scales

CONTENTS

I. EXECUTIVE SUMMARY

This report comprises the first phase of a project to evaluate the economic and environmental potential for aquaculture in the state of Minnesota.

The extent of aquaculture activity in Minnesota is presently at a relatively low level. The operations which are in production are primarily state run hatcheries supplying game fish for stocking in public waters, three major private salmonid hatcheries supplementing the state hatcheries' and supplying some food fish markets, thriving extensive operations for bait fish, and a number of hobby fish farms. This present level of production does not adequately reflect the potential for aquaculture production in the state's abundant water resources.

Based on environmental conditions in Minnesota, present regulations, market demand for potential species, and available water and land resources, four groups of fish were recommended for further in-depth analysis in Phase II. The recommended species include (1) white sturgeon, (2) paddlefish, (3) bait minnows and (4) Atlantic and chinook salmon trout. Groups 1, 2, and 3 are best suited for extensive culture in lakes and ponds, while group 4 is best suited to intensive cage culture in the iron pits. Recycle, waste heat, and integrated agriculture/aquaculture systems show little economic promise for Minnesota at this time.

If aquaculture is to achieve its full potential in Minnesota, some modification of existing regulations and interpretations may be needed. Regulations which currently limit sites available for aquaculture development include "public waters", "wetlands", and designated trout streams. Some of these regulations are beneficial to the long-term development of commercial aquaculture in Minnesota, because they protect the aquatic environment from undesirable environmental development and degradation. With appropriate regulatory control and monitoring, commercial aquaculture in Minnesota can develop in an environmentally responsible manner. There is a clear need for an in-depth, unbiased analysis of the impact of these regulations on aquaculture development. With a favorable economic and regulatory environment, aquaculture has the potential to generate up to an additional $50/year million after 6 years.

II. INTRODUCTION

Aquaculture is a rapidly expanding industry in the United States and in certain areas of the country supports a major employment and economic base. The industry often occurs in areas of high unemployment and can provide a number of entry level positions. In many areas, both agriculture and aquaculture have similar labor and equipment requirements. The potential increase in income due to their integration may be a definite plus in a state such as Minnesota with a heavy economic dependence on agriculture.

Minnesota's abundant water resources has great potential for increased aquacultural production. To date however, only limited aquaculture development has taken place. Reasons for this may be the low winter temperatures and competition for resources with a very strong sports fishing industry. The purpose of this study is to evaluate the actual potential for aquaculture in Minnesota.

The primary emphasis of the first phase of this study is to evaluate the water resources and their capability to sustain a viable aquaculture industry. This task was accomplished by evaluation of the pertinent environmental conditions and determination of which species possess the best chance for success. Based on existing culture systems in Minnesota or other areas with similar water resources and environmental conditions, the most promising culture systems were selected. The results of the species and systems evaluations were used to select those combinations with the most potential for Minnesota.

III. POTENTIAL FOR THE DEVELOPMENT OF AQUACULTURE

The potential for the development of aquaculture in Minnesota will depend on a number of interrelated environmental, regulatory, and geographic factors. Some of the most important factors are discussed in this section.

Climate

Compared to other major centers of commercial aquaculture in the United States, Minnesota has a relatively cold climate. Air temperatures for Long Prairie in Northern Minnesota are presented in Table 1 and may be considered typical for the state. The average minimum daily temperature for 1951 - 1980 ranged from -4.3 F in January to 57.7 F in July. Typically, the temperature is substantially below 32 F during November through March. Low air temperatures such as these make operation of aquaculture enterprises more expensive and risky.

Air temperature and the resulting water temperature has a critical effect on the metabolism and growth of fish. The water temperature of a representative river (Partridge River) is presented in Table 2. The minimum daily water temperature in this river is near 32 F for at least 6 months of the year, but reaches into the 70 F range during the summer months. Temperature of groundwater and springs in Minnesota is relatively uniform over the year and in the range of 45 to 51 F.

The growth of salmon and trout is minimal or negative below approximately 38 F, while water temperatures above 68 to 70 F may prove lethal. The growth of warmwater fish such as channel

TABLE 1 Air Temperature at Long Prairie, Minnesota (1951-1980) (NOAA, No Date)

Month	Daily Temperatures (F)			Days Below 32 F
	Max	Min	Lowest	
Jan	16.9	-4.3	-40	32
Feb	24.5	1.3	-42	28
Mar	35.6	14.4	-35	29
Apr	54.0	31.4	-7	17
May	68.4	43.1	19	4
Jun	77.1	53.1	30	0
Jul	82.5	57.7	35	0
Aug	80.0	55.4	33	0
Sep	70.0	45.8	19	3
Oct	58.9	35.6	3	12
Nov	38.8	21.0	-23	26
Dec	24.0	5.7	-35	31

TABLE 2 Water Temperatures for Partridge River During 1983-1984 (USGS, 1984)

Month	Temperature (F)		
	Max.	Min.	Mean
Jan	33	32	27.5
Feb	33	32	33
Mar	33	32	33
Apr	53	32	41
May	65	38	54
Jun	73	59	65
Jul	78	64	72
Aug	79	64	73
Sep	65	44	56
Oct	58	40	45
Nov	44	32	35
Dec	33	32	32.5

catfish is low below 50 F and is optimum between 82 to 86 F.

Water temperature is the most limiting environmental parameter in Minnesota. Winter water temperatures are too low to produce the growth required for either coldwater or warmwater commercial operations. Summer temperatures of surface waters may exceed lethal levels for trout or salmon species; conversely, the growth of warmwater fish such as channel catfish, largemouth bass, or striped bass may only occur during the warmer summer months. In the southern United States, 1 - 2 years are required to grow warmwater fish to market size, whereas, 3 - 4 years or more may be needed in Minnesota.

The major recreational fish in Minnesota are classified as "coolwater" fish. Their temperature preferences are lower than the warmwater fishes, but higher than the coldwater fishes. These fish may be ideally suited for stocking in Minnesota waters, but they are poorly suited as candidates for commercial aquaculture due to their slow growth rate and cannibalistic tendencies.

<u>Water</u>

Minnesota has four major drainage systems: Hudson Bay, Great Lakes, Mississippi River, and Missouri River (Phillips et al., 1982). Glacial action less than 10,000 years ago created many of the numerous lakes and ponds found in Minnesota. Listed here are the various fish habitats found in Minnesota:

Lake Superior (Northern Minnesota) - large, deep, and clear

Lake Trout Lakes (Northeastern Minnesota) - rocky and cold

Iron Pits (Northeastern Minnesota) - similar to the Lake Trout Lakes, but primarily stocked with rainbow trout

Walleye Lakes (Northern and Central Minnesota) - broad, shallow, and well-oxygenated

Bass-Sunfish Lakes (Central Minnesota) - smaller, less open to wind, but more fertile than walleye lakes

Game Fish - Rough Fish Lakes (South-Central and Southwestern Minnesota) - typically warm, shallow, and rich in nutrients.

Rivers - includes Mississippi, Minnesota, and Rainy Rivers

Trout Streams (North Shore and Southeastern part of Minnesota) - 481 designated trout streams. Some of these streams are spring-fed and therefore have good temperatures for trout and salmon year-round

Due to climate, hydrology, and morphology, many of the lakes and rivers in Minnesota present special problems for commercial aquaculture uses.

Rivers. Water temperature will limit both the culture of both warmwater and coldwater fishes in Minnesota. In most major streams, summer temperatures will be lethal for coldwater species such as salmon and trout. Low winter temperatures will greatly reduce the growth of warmwater fishes, and to a lesser degree coldwater fishes. In addition, cage culture in the larger rivers will be restricted by navigation considerations, potential spills of toxic chemicals, and ice damage in the spring.

Most of the North Shore streams are small to moderate in size, short, and steep (Waters, 1977). During periods of snow-melt or heavy rain flooding may result, while during the summer flows may be extremely low. The most desirable streams for trout and salmon are the springs in the Southeast part of state. These springs have relatively constant flows and temperatures.

Ponds and Lakes. Many of the small shallow lakes classified as bass-sunfish or game fish - rough fish lakes are quite fertile and productive (Eddy, 1963). Collapse of algal blooms in the summer, followed by rapid decomposition of the dead cells and subsequent oxygen depletion, can result in fish mortality called "summer kill" (Barica, 1975). Although the oxygen demand increases during this process, aeration is not practical or economic.

After ice forms on these lakes in the winter, bacterial and algal respiration may result in oxygen depletion and "winter kill". The potential for "winter kill" depends on the nutrient status of the lake, productivity, and depth, (Fulthorpe and Paloheimo, 1985; Babin and Prepas, 1985) as well as the duration of ice cover. "Winter kill" can be prevented by (a) maintaining an open area by mixing or aeration or (b) periodic snow removal to increase light penetration. "Winter kill" is common in lakes less than 12 - 15 feet deep. The costs of aeration will be increased by the necessity of supplying electrical power to each lake. Potential liability of open water area produced by aeration may require special insurance coverage. The stocking of fish in shallow lakes in the spring will be limited by lethal gas supersaturation levels (Mathias and Barica, 1985); therefore, stocking will have to be delayed until the ice has completely melted and the lake has re-equilibrated.

Although there is a lack of practical methods for control of "summer kill" and "winter kill", regression equations have been developed to estimate the potential affect by both types of problems. Control of "summer kill" and "winter kill" will be by management methods. Lakes that "summer kill" should not be stocked. The use of ponds that commonly "winter kill" for aquaculture will require harvest of fish in the fall or early winter prior to ice formation and stocking in larger water bodies. This technique is widely used in the rearing of walleye, northern pike, and muskellunge. One of the advantages of using "winter kill" lakes for aquaculture is the lack of competition from other fish, but the disadvantage is the requirement of annual stocking.

While larger lakes do not "winter kill", effective management of these water bodies limits the type of culture systems that can be used. Lake ranching or stocking of fish directly into the lake lowers total production costs, but has the lowest degree of control and management. Net pen or cage culture is another alternative that has been used in Europe (Beveridge, 1978), but to allow feeding or inspection of structural components some type of aeration or water mixing will be required to maintain an ice-free area around the culture area. Also, wind induced ice movement in Lake Superior may require (a) large floating log booms or (b) location of the facility in protected areas.

Regulations

While Minnesota has numerous ponds, lakes, and streams, the water bodies available for commercial development are limited due to state and federal regulations. The major limitation to commercial aquaculture at present is the interpretation of "public water" and regulations protecting "wetlands".

"Public waters" are regulated by the Department of Natural Resources and, at present, have limited potential for commercial aquaculture because of actual or perceived conflicts. Under Minnesota law, "public water" includes all of the following:

(1) All water basins assigned a shoreland management classification, except wetlands less than 80 acres and classified as natural environment lakes.

(2) Navigable waters

(3) All water basins previously designated for specific management purposes such as lake trout or game lakes

(4) All water basins previously designated as scientific and natural areas

(5) All water basins located within and totally surrounded by publicly owned land

(6) All water basins where there is a publicly owned and controlled access

(7) All watercourses with a total drainage area greater than two square miles and all designated trout streams regardless of the size of their drainage area.

Due to regulations protecting "wetlands", they also have limited potential for commercial aquaculture. Wetlands 10 acres or more in size in un-incorporated areas or 2 1/2 acres or more in incorporated areas are protected. It is important to note, that a wetland can be totally surrounded by private land with no public access, but it is still protected. Filling, dredging, or modification of protected wetlands requires a permit from either the Minnesota Department of Natural Resources or the U. S. Army

Corps of Engineers. Permits for extensive modification of wetlands are difficult or impossible to obtain. Shallow wetlands probably have the greatest potential for intensive aquaculture, but at this time are effectively protected from development by regulation.

In addition, Section 4a of the new regulation for the maintenance and operation of private fish hatcheries states:

> "No pond, lake, stream or other body of water shall be used for a minnow or game fish private fish hatchery or fish farm purpose where the water is so situated or connected that fish may be able to pass between the same and any public waters of the state during flood stages or at any other time either under natural conditions or by artificial means."

This regulation is vague and, depending on its interpretation, could be excessively restrictive to aquaculture development.

For aquaculture to be considered as a valuable and employment producing industry, government legislation must reflect this desire. The development of commercial aquaculture will require some flexibility and regulatory change in the determination of available water resources. The present problems represent a clear need for an in-depth and unbiased analysis of these regulations and their effect on aquaculture development. Many of the potential regulatory conflicts may be more of a perception than a reality and could be handled within existing laws.

Because of the Department of Natural Resources'role in Minnesota, it would be highly desirable to create a position for a "commercial aquaculture coordinator" within this agency. This person would represent commercial aquaculture interests within the agency and help individuals with permitting and monitoring problems.

Market Access

From a marketing point of view, the state of Minnesota is geographically well situated to take advantage of a huge potential market for seafood as well as bait fish products. Chicago, a nine hour drive from Minneapolis, exists as the major seafood market in North America. Within twenty four hours driving time from Minneapolis are the large markets of the eastern seaboard. This positioning provides Minnesota with a distinctive competitive edge in the realm of transportation costs, normally considered as the major constraint in other aquacultural areas of North America.

The demand for fresh seafood products is on the increase, a trend evidenced by the national per capita consumption topping 14 lb per year. It is likely that the prices paid for a number of high end cultured seafood species such as trout, salmon, sturgeon, and (in many cases) walleye will remain high for at least the next ten years. There is little question that the markets can absorb additional aquaculture production in this time period. The limiting factor in Minnesota will be the economics of production. The seafood marketing industry has become very sophisticated and as a consequence has developed a number of preferences. Over time these preferences will become even more entrenched. Almost without exception (listed in order of decreasing importance) they are: quality, consistency and reliability of supply, and price. Therefore, in order for Minnesota to successfully develop an aquaculture industry, the choice of species and culture system must effectively address these nationwide preferences.

<u>Available Resources for Commercial Aquaculture</u>

Climate, total water resources and characteristics, and governmental regulations control the resources available for commercial aquaculture. Table 3 presents the type of restrictions on the various types of water bodies in Minnesota and the available resources for commercial aquaculture development. The most promising areas for development are:

(1) Undeveloped iron pits

(2) Lakes less than 10 acres that do not "winter kill

(3) Large lakes on Indian Reservations

TABLE 3 Restrictions on Available Resources in Minnesota. [EN = restricted by climate, envirnoment, or morphology; FR = restricted by federal regulations; SR = restricted by state regulations; NR = no restrictions; NA = not applicable]

Type/size	Ranching	Cages	Flow-through
Lake Superior	FR,SR	EN,SR	NR
Iron Pits (developed and stocked)	SR	SR	SR
Iron Pits (undeveloped)	NR	NR	NR
Lakes < 10 acres (winter kill lakes)	EN	EN	EN
Lakes < 10 acres (non-winter kill lakes)	NR	NR	NR
Lakes > 10 acres (public)	SR	SR	SR
Lakes > 10 acres (Indian Reservation[a])	NR	NR	NR
Rivers and Streams	NA	EN	EN
Streams (North Shore)	NA	NA	EN,SR,FR
Streams (Southeastern area)	NA	NA	SR

[a] Depends on species at some Reservations

IV. POTENTIAL SYSTEMS

Because of climatic and aquatic conditions and environmental regulations, some typical culture systems used in other parts of the country may not be appropriate in Minnesota. The characteristics and operational advantages and disadvantages are presented for common types of culture systems.

Extensive Culture or Lake Ranching

Extensive culture in ponds or lakes is best described as growth under minimized control of the environment. This type of culture emphasizes utilization of a water source and its intrinsic potential to support growth. Supplemental feeding is minimized or nonexistent. Temperature and water levels are also not controlled. The principal requirements for labor in such systems are associated with stocking and harvest. Due to the lack of control over key variables, production from extensive systems may have significant temporal and spatial variability. To increase the reliability of production, fertilization with organic or inorganic chemicals, feeding, or aeration may be used.

Extensive pond and lake culture accounts for the successful bait industry in Minnesota, conservatively estimated to generate $25 million/year in sales (Peterson and Hennagir, 1980). Presently, extensive culture is being used to a small degree for food fish culture of trout in parts of Northern United States and Canada. For the most part, however, such operations are at best marginally profitable or simply used as hobby enterprises (Cauvin and Thompson, 1977). The primary problem with the extensive culture of food fish is the high cost of harvest. In general, state regulations will only allow this culture method to be used in lakes less than 10 acres; lakes that typically "winter kill". Therefore, extensive culture is only viable for fish that can be harvested in one growing season or for fish that require harvesting and restocking in larger lakes. Extensive culture will also be viable in lakes on Indian Reservations where state regulation do not apply.

Intensive Culture

Intensive culture incorporates highly managed aquaculture techniques compared to extensive culture. Food, stocking densities, water quality, oxygen levels, and if possible, temperature regimes are controlled to maximize production.

This type of system accounts for much of the production of salmonids by both state and commercial hatcheries in Minnesota. High feeding levels produce high growth rates and low mortality. The high density in intensive systems allows for ease of harvest on a regular basis. Some of the most common types of intensive systems are discussed below.

Ponds Intensive culture of warmwater fish in ponds is one of the most common culture methods. This involves construction of ponds 3 to 6 feet deep and 0.5 to 20 acres in size. The ponds are filled, then stocked with 2000 to 3000 fry or fingerlings per acre. Fish are fed 1 to 3 % of body weight per day. The use of this type of system will be limited in Minnesota due to state and federal regulations protecting wetlands, one of the most promising locations. Construction costs of intensive ponds in

Minnesota may be high due to potential excessive percolation through the glacial deposits common in the state. The short growing season and necessary winter aeration will incur higher production costs for warmwater fish in Minnesota than those in warmer climates. High summer time temperatures will prevent the use of intensive ponds for the production of trout and salmon. In short, the culture of fish in this type of ponds will be largely non-economic.

<u>Flow-Through</u> <u>Systems</u> Flow-through systems use large amounts of water to remove waste products and to supply dissolved oxygen to the fish. The water source may be from a spring, artesian well, river, or pumped well. This system is the method of choice for the culture of salmonids. Spring or well waters are more desirable as water sources because of relatively constant temperatures and reduced potential for disease transmission from wild fish. Pumped water supplies are more expensive than springwater sources.

In Minnesota, the use of flow-through systems is, at present, restricted. When a commercial operation requests use of a water source which supports an established sport fishery or "designed trout stream", there is little likelihood that the commercial operation will be granted a license to operate. It should be noted that in other areas of North America and, most notably, British Columbia, commercial aquaculture operations are located on designated sports fishery streams with little or no conflict. Without a clearly demonstrated significant negative environmental impact of salmon and trout production, the present regulations in

Minnesota have no rational basis and are unrealistically restrictive.

Waste Heat There has been a great deal of research in the use of waste heat from electrical generation plants to increase the growth rate of fish (Godfriaux et at., 1979; Tiews, 1981;Woiwode and Adelman, 1984). At the present time, there are no commercial waste heat operations in the United States and few in the world. A 1000 Mw plant may generate $500,000 to $1,000,000 of power per day; a sum many times greater than any possible annual revenue from fish production at a generation facility. This economic reality is why a generating plant can not lose even an hour of on-line time to accommodate the special needs of an aquaculture facility.

Problems with the use of waste heat from electrical generation plants include (1) toxicity of chlorine and other chemicals added to process water, (2) unreliability of heat due to scheduled or unscheduled outages (especially with nuclear plants) (3) marketing problems (especially nuclear plants), and (4) communication problems between electrical generation staff and fish culturalists. The use of waste heat in aquaculture is not a viable production system for Minnesota at the present time.

Water Recycle and Reuse Rather than discharge water after use, recycle systems treat the water and reuse it. The primary advantages of a recycle or reuse system includes reduced water requirements, optimization of temperature, and accelerated fish growth (Muir, 1982). Their disadvantages are high capital and operating costs, poor reliability, and potential disease problems. A number of federal and state recycle hatcheries were constructed in the U.S. for salmon, trout, and warmwater fish. Many of these facilities have not operated satisfactorily and are being operated as flow-through systems.

At the present time, there are <u>no</u> commercial private recycle hatcheries in the United States producing food fish. The breakeven point for recycle technology is in the range of $8 to $16/lb of live fish. Except for perhaps culture of fry or fingerlings, there are no fish in Minnesota that have market values in the required range. Even if these systems were economic for the culture of food fish, they are poorly suited for integration into existing agricultural facilities and enterprises; the modification of existing buildings designed for cattle or hogs will not allow for proper layout of tanks and filters or efficient operation of fish production system. Also, building costs for a new facility are probably less than 5 - 8 % of the total capital costs of a recycle system. In recycle systems, failure of critical components such as pumps and aeration systems can result in total mortality in less than 10 to 20 minutes. Operation of recycle systems requires highly trained personnel, extensive backup pumps and generators, and in most cases, continuous on-line computer monitoring of critical components and processes. Without extensive retraining, most farmers would be unable to operate a production-scale recycle system.

Numerous optimistic articles and press releases exist on the use of recycle systems, but many have been written by researchers working on a pilot-scale basis or by "consultants" trying to attract investment capital. Fish farms and extension personnel are much less enthusiastic about the economic potential of recycle systems and consider that this technology is still in the research phase (Dupree and Huner, 1984). An impressive number of production recycle systems failed (McCoy, 1986; Rosenthal and Murray, 1986). Approximately 10 years ago, the State of Wisconsin and the Federal Government funded pilot-scale systems for the recycle culture of yellow perch; this approach was not economic and no commercial facilities have resulted (Dr. Terry Kayes, personal communication).

Given the lack of commercial viability of these types of systems, water recycle and reuse systems can not be recommended at this time. Any work on these systems must be considered a demonstration or pilot project, not an economically oriented production system.

<u>Cage and Net Pen Culture</u> Where a relatively large surface area and deep body of water is available, intensive culture has been shown to be an effective methodology (Beveridge, 1987). Rather than allowing fish to forage widely for food as is the case in extensive operations, fish are enclosed within floating net or cage structures. In essence, the methodology provides all the benefits of a flow though system and more. In many areas, the water source does provide an opportunity for fish to feed on food

items found naturally in the water column, thereby providing the potential for reduced feed costs.

The area where this type of technology would be most applicable in Minnesota is the iron pits in the Iron Range. There, the deep pits left over from the mining industry present a large number (up to 80) of deep water areas which could support aquaculture. While there are many other "lakes" in Minnesota that could support cage culture, the mine pits are probably the only ones that can be developed, primarily due to regulatory considerations. Those pits that have not been stocked with fish by the Department of Natural Resources, do not yet fall under the classification of a "public water" or "wetland". Also, being relatively deep bodies of water lessens the problems associated with eutrophication caused by feed and feces deposition reported in the shallow waters of typical intensive fish culture systems. New technologies developed for the shallow water aquaculture areas of the Baltic Sea off Sweden and the southern areas of Norway should be very applicable here. In areas where excess feed and feces are not removed by tidal flushing, the pollutional impact of cages can be significantly reduced by trapping the solids in a flexible funnel below the cage which can then be removed by pumping.

From preliminary studies of the iron pits it is not yet determined what the growth potential in the various pits will be. It seems safe to assume, however, that these areas should be strongly considered for future development. In order to fully assess the potential of these pits, detailed limnological studies should be conducted. Key items of interest are water quality, temperature, and natural productivity.

Lake Superior is another area where net pen/cage culture might be considered. It is important to note, however, that the unsheltered north coast offers no protection from wind, currents, navigation, and ice flow. For these reasons, net pen/cage culture has less potential in this area than in the iron pits.

Cage culture in some of the large rivers probably does not offer much potential. This is due to high temperatures in the summer that will be lethal to trout and salmon and low temperatures in the winter that will significantly reduce the growth rate of both warmwater and coldwater fishes. In addition, conflicts with navigational uses, potential toxic spills, and problems with ice will make siting difficult and risky.

<u>Integrated Agriculture/Aquaculture</u> In tropical areas, wastes from traditional agriculture are commonly used as fish feed. This includes both processing wastes and animal manures. The fish species used in these systems feed low on the food chain, and typically include Chinese and Indian carps, and tilapia. These species have low market value in the United States and in most cases are prohibited or highly regulated due to potential environmental problems. Also the low winter temperatures will prohibit the growth rate of Chinese and Indian carps. Under natural conditions in Minnesota, tilapia will not successfully over-winter and 100 % mortality can be expected.

There seems little likelihood that other types of integrated methodologies can provide economic potential in Minnesota in the near future. This includes ecological-based recycle and hydroponic systems, as these systems are even less well understood than conventional recycle systems and must be considered experimental systems.

<u>Recommended Systems</u>

The following systems (unranked) have the most potential in Minnesota:

(1) cage or netpen culture

(2) extensive pond culture of food or bait animals

(3) intensive flow-through systems using surface or subsurface water.

V. SPECIES SELECTION

The species selection component of this project involves consideration of a number of biological, physical, and market parameters. The species currently cultured in Minnesota by private hatcheries and the Department of Natural Resources are presented in Table 4. It is not unreasonable to expect that some of the potential species for commercial aquaculture will be found in this table.

Species Grading System

For determination of the potential aquacultural success of a particular species in Minnesota, it was necessary to devise a system which evaluated culturing and marketing potential at three stages: egg sales, sale of fry or fingerlings, and sale as food fish. Such criteria as broodstock availability, ease of culture, growth rate, food costs, and marketability were analyzed for each of the three life stages investigated.

Each culture and marketing criteria was assigned a grade depending on its importance in the overall culture and marketing process:

Criteria	Grade
Availability	20
Ease of Culture	20 to 40 (depending on life stage)
Growth Rate	15
Food Costs	15
Marketability	30 to 40 (depending on life stage)

TABLE 4 Species Currently Cultured in Minnesota by Private Fish Hatcheries and Department of Natural Resources

Private	DNR
brook trout	brook trout
brown trout	brown trout
	lake trout
rainbow trout	rainbow/steelhead trout
	splake
	Atlantic salmon
	chinook salmon
walleye	walleye
	muskellunge
	lake sturgeon
white sucker	white sucker
tilapia	
fathead minnow	
golden shiners	
crappie	
bluegill	
largemouth bass	
channel catfish	

This table was derived from Private Fish Hatchery Reports (NA-01549-04) and the Minnesota Coldwater Hatchery Production Report for 1986. Other species may be purchased out of state by DNR and therefore are not listed in this table.

Table 5 SPECIES RATING COMPUTATIONS

Species: ______________________ Culture Type: ____________

SALE OF EGGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	_	__
Culture of Adults/Eggs	40	_	__
Marketability	40	_	__
		OVERALL RATING =	__

SALE OF FRY OR FINGERLINGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	_	__
Culture of Adults to Fingerlings	20	_	__
Growth Rate	15	_	__
Food Costs per lb of Fish	15	_	__
Marketability	30	_	__
		OVERALL RATING =	__

SALE OF FOOD FISH

Criteria	Grade	Score (0-3)	Rating
Availability	20	_	__
Culture of Adults to Juveniles	20	_	__
Growth Rate	15	_	__
Food Costs per lb of Fish	15	_	__
Marketability	30	_	__
		OVERALL RATING =	__

The next step involved rating each species for the three potential markets (Table 5). A score of 0 to 3 was assigned for each criteria listed above. This score was then multiplied by the grade to obtain the rating for the specific criteria.

Additional information on how the scores were estimated is provided below for each criteria:

<u>Availability.</u> For each potential marketable product, the availability of required stocking material (i.e., broodstock, eggs, fry, or fingerlings) from commercial sources was evaluated. For a given species, availability may vary for each saleable life stage. For example, broodstock is unavailable for white or lake sturgeon but, fry and fingerling white sturgeon can be purchased from out-of-state producers. The long-term availability and price of eggs from the Department of Natural Resources is difficult to assess at this time. The the specific score criteria for availability are presented below:

Egg Sale

Score	
0	Broodstock unavailable in state
1	Broodstock available some years
2	Broodstock available most years
3	Broodstock available all years

Fry or Fingerling Sale

Score	
0	Eggs or Fry unavailable in state
1	Eggs or Fry available some years
2	Eggs or Fry available most years
3	Eggs or Fry available all years

Food Fish Sale

Score	
0	Eggs, fry, or fingerlings unavailable in state
1	Eggs, fry, or fingerlings available some years
2	Eggs, fry, or fingerlings available most years
3	Eggs, fry, or fingerlings available all years

Culture (Ease of Culture). The ease of culture for each life-stage was scored on information obtained from published sources and agency and private producers interviewed during the in-state investigation. The specific score criteria for ease of culture are presented below:

Score	
0	Eggs, fry, or fingerlings unavailable
1	Culture is very difficult with a variable success rates even with highly trained personnel
2	Culture is difficult and requires well-trained personnel
3	Culture is simple with semi-trained personnel

Growth Rate. The growth rate score was based on the period of time required to produce a marketable fish. The specific score criteria for growth rate are presented below for fry and fingerlings and food fish:

Fry and Fingerlings Sale

Score	
0	Marketable at 12 - 24 months
1	Marketable at 6 - 12 months
2	Marketable at 4 - 6 months
3	Marketable at < 4 months

Food Fish Sale

Score	
0	Marketable at > 7 years
1	Marketable at 5 to 7 years
2	Marketable at 3 to 4 years
3	Marketable at 1 to 2 years

Food Costs per lb of Fish. The cost of feed per lb of fish has a significant impact on the economics of any fish farming operation. Both the food conversion ratio and the cost of feed effects this parameter. The specific score criteria for food costs per lb of fish are presented below for fry and fingerlings and food fish:

Fry and Fingerlings Sale

Score	
0	Requires live feed
1	Very difficult to train to feed on artificial feeds
2	Difficult to train to feed on artificial feeds
3	Readily accepts artificial feeds

Food Fish Sale

Score	
0	> $2.00 lb (intensive feeding with minnows)
1	$0.35 to $0.50/lb
2	$0.20 to $0.35/lb
3	Extensive culture (natural feed)

Marketability. The marketability of a fish product will depend on sale price and total sales volume that can be sold. For many fish (especially eggs and fry), present price is high because of the limited or nonexistent supply. The sale price of eggs marketed by Department of Natural Resources may not be set at this time and availability may vary from year to year. The scores used for this criteria, but will be refined in Phase II; the specific score criteria for marketability of fish are presented below for fry and fingerlings and food fish:

Eggs, Fry, and Fingerling Sale

Score	
0	No market for product
1	Limited market
2	Good market in state and region
3	Strong market in state, region, and nation

Food Fish Sale

Score	
0	< $1.00/lb
1	$1.00 - $1.50/lb
2	$1.50 - $2.00/lb
3	$2.00 - $3.00/lb

<u>Species Overall Rating.</u> The overall rating was determined by adding up the ratings for all the criteria. The total possible overall rating was 300. The final assessment of potential was determined from the overall rating of each life stage. The overall rating for each species are presented in Appendix A. Those species showing an overall rating greater than 200 are presented in Table 6.

TABLE 6 Potential Species With Overall Ratings Greater than 200

Group/Species	Overall Rating		
	Eggs	Fry	Food
Sturgeon Acipenseridae			
White Sturgeon (Acipenser transmontanus)	120	230	250
Paddlefish Polydontidae			
Paddlefish (Polyodon spathula)	120	205	225
Salmon and Trout Salmonidae			
Arctic Grayling (Thymallus articus)	120	190	210
Arctic Char (Salvelinus alpinus)	120	190	210
Coho Salmon (Oncorhynchus kisutch)	220	200	200
Chinook Salmon(Oncorhynchus tshawytscha)	260	245	245
Lake Trout (Salvenlinus namaycush)	220	200	200
Rainbow Trout (Salmo gairdneri)	240	190	220
Atlantic Salmon (Salmo salar)	240	265	250
Lake Whitefish (Coregonus clupeaformis)	140	180	210
Minnows Cyprinidae			
Golden Shiner (Notemigunus crysoleucas)	60	240	0
Fathead Minnow (Pimephales promelas)	60	240	0
Suckers Catostomidae			
White Sucker (Catostomus cummersoni)	220	255	190

Species Selected for Consideration in Phase II

Following the species selection process, it became evident that selection of three species as stated in the original request for proposal was inappropriate. As can be seen from Table 6, a large number of species qualified for selection. Considering the variable nature of Minnesota's environment, the wide variety of national seafood markets, and personal biases of culturist, it would be unwise to only select three species. Therefore, the study team has elected to recommend the use of four major groups (Table 7). Within each group, the one or two species which shared the best potential for production and the recommended production systems were selected.

It should be noted that other species with lesser ratings should not be totally discounted and additional discussion of potential of similar species are presented in Appendix B by group. Within any group, most of the species could be reared in the recommended culture system. While the most promising species were selected from each group, changes in availability of eggs, culture techniques, or market demand could rapidly change their ranking. At this time such species as Arctic grayling and Arctic charr have a higher market price than Atlantic salmon due to their commercial unavailability over much of the year. While the production of these two species will never approach that of the Atlantic Salmon, it may provide a highly profitable niche for several growers.

TABLE 7 Recommended Groups For Investigation in Phase II

Group/species	Culture System
Sturgeon	
white sturgeon	extensive/ponds and lakes
Paddlefish	
paddlefish	extensive/ponds and lakes
Salmonids	
chinook salmon	intensive/cage or netpen in mine pits
Atlantic salmon	intensive/cage or netpen in mine pits
Minnows and Suckers	
various species	extensive/ponds and lakes

VI. RECOMMENDED SPECIES AND OPERATING SYSTEMS

The following recommendations include (1) the species with the greatest aquacultural potential for Minnesota and (2) culture systems for each species or group.

<u>Extensive Food Fish Production in Ponds and Lakes</u>

Throughout the state there are thousands of ponds and lakes ranging from one to hundreds of acres. The greatest potential for these lakes and ponds is the extensive production of food fish. Development of this rich resource is, however, limited by the widely distributed nature of the resource, extreme ranges of temperature, "winter kill" problems, and laws regulating the aquatic environment.

While the total water area in a region could well support a significant aquaculture industry, a single land owner may not control enough area to support an economically viable business. This effectively limits the potential scale of any true aquaculture operation. As a consequence, the only aquaculture activity in much of the state has been the rearing and collection of bait minnows which is more of a fisheries than a true form of aquaculture.

Effective development of these lakes and ponds will be specific to each region. Possibly, the greatest potential for development is in the Southwestern and Central regions of the State, due to the large number of lakes and ponds. Development of this industry sector will require some form of collective or cooperative management structure to provide services and economies of scale. Critical services in this industry sector could include: (1) technical advise on stocking and management, (2) reliable supply of fry or fingerling, (3) monitoring of growth and population density, (4) coordination of harvesting and equipment, (5) hauling and processing, and (6) market development and maintenance. Minimum staffing for each region would require 3 full-time employees. The infrastructure would include (1) a general manager to oversee the operations and promote membership, (2) a biologist to coordinate stocking, management, and harvest efforts, and (3) a market and sales representative to develop and maintain markets. To ensure the success of this enterprise, at least 3 -5 years of state funding will be required. This could require 2 -3 years of total state funding, followed by decreasing state participation. This type of aquaculture development could be piloted in one region. Target species should include:

sturgeon
paddlefish

These species were selected because of their large size, harvestability, and high market value. Other species with lower ratings, may prove to be economic under local conditions. Under this development plan, aquaculture would depend on stocking of fry or fingerlings, but may not typically require feeding. If fry are stocked in "winter kill" lakes, relocation of fish will be required each year. Re-interpretation of the concept of "public water" or "wetlands" could have a critical and positive impact on this type of aquaculture by increasing the acreage available for development. The total gross revenue that could be generated from this type of culture is difficult to estimate at this time. Some characteristics of the suggested organization are that for an individual farmer there is a relatively low capital investment, moderate total return, and use of a presently under-utilized resource.

Some consideration should be given to allow commercial aquaculture of sturgeon and paddlefish in large public lakes, a form of aquaculture not presently allowed. These two species do not directly compete with game fish (at least in lakes with limited walleye reproduction), have limited potential for reproduction, and can be readily harvested with large-mesh nets. These two species are difficult to catch on hook and line and therefore have not been widely stocked in the state.

Rather than allow commercial fishing with unlimited entry, each lake or group of lakes could be harvested by a single operator. If a state agency was willing to assume responsibility for annual stocking of fingerlings, the commercial fishing rights for each lake or group of lakes could be awarded on a yearly basis by competitive bidding.

Under present laws, stocking of white sturgeon and paddlefish is limited in Minnesota to the Red Lake Indian Reservation. This reservation still retains complete control of the fisheries in the Reservation portion of Red Lake. A stocking/transportation permit may be needed from the Department of Natural Resources if eggs or fry are obtained from out-of-state sources. Since "sturgeon" and paddlefish are listed as game fish, the Department of Natural Resources controls the planting and harvest of these species on other Indian Reservations in Minnesota.

<u>Intensive Cage Culture in Mine Pits</u>

The mine pits in the North part of the state are a valuable water resource that may develop into a significant aquaculture industry sector. In contrast with the lakes and ponds discussed in the last section, this resource is concentrated in a relatively small band and is limited in number (80). Due to the potential for large scale development, a number of secondary industries may develop. These include: egg and fry production, feed distribution, equipment supply and manufacturing, primary processing, secondary processing, veterinary services, transportation, and marketing services.

Because of the size of the pits, the potential fish production from the area could be significant, leading to definite economies of scale and the possibility for vertical integration. Utilization of the pits will require the use of cages or netpens and intensive feeding. While cage culture systems are not well developed for this region, the technology is being used commercially in Northern Europe, Pacific and Atlantic Canada, and South America. Technology and management techniques more applicable to the iron pits in Minnesota are being used in the commercial netpen operations in Lake Huron and in limestone pits near Toronto.

Development of this particular industry sector will depend on the availability of large amounts of capital, cooperation with government agencies in the areas of economic incentives and regulations, and the general economic climate. The investment for a total vertically integrated operation (broodstock to market) will range from \$3 - \$10 million. Because of the inherently risky nature of pioneering a new industry, commercial credit will not likely be available during the initial development phase. As more secondary services are available, viable growout operations will cost less (from \$750,000 and up) and may then be capitalized from commercial credit or stock sales.

Potential species in these pits will include the high market value salmonids:

Atlantic salmon
chinook salmon
rainbow trout
lake whitefish
arctic grayling
arctic charr

Arctic charr have excellent market potential, although their commercial culture is still developing (Papst and Hopky, 1977). Assuming 20 active cage or netpen operations (in the next 6 years), each producing 150 tons/year, the primary and secondary revenues are estimated to be approximately \$44 million.

<u>Minnow Culture</u>

While the present minnow culture industry should be considered more of a fisheries than true aquaculture, it has significant economic potential. The current industry reportedly generates at least $25 million/year in sales (Peterson and Hennagir, 1980) and possibly higher due to under-reporting of harvest. Detailed information on this industry is difficult to obtain (Nielsen, 1982) and what information is available may be questionable.

Major limitations to the increased development of the minnow industry are conflicts with the Department of Natural Resources for lakes. Once walleye fry have been stocked in a lake, commercial harvest of minnows is not economic because of predation by the walleye. If a planted lake does not routinely "winter kill", this lake will be permanently lost from minnow production due to continuing predation by surviving walleye. Solutions to this resource conflict will require an elevated level of coordination and cooperation between the minnow harvesters and the Department of Natural Resources.

Several approaches could be used to increase minnow production. A more aggressive and prominent marketing effort in surrounding states could result in an increased market demand for Minnesota minnows. Increased extension activities in the areas of production, feeding, fertilization, and marketing could increase interest by both existing bait harvesters and land owners. Much of the techniques for increasing production have already been used in supporting states, so the cost of developing these programs will relatively low. The establishment of marketing cooperatives could also allow increased economies of scale and greater market penetration, especially in out-of-state markets. The end result could be increased long-term employment in the state with the potential to increase gross sales by $10 to $20 million in 5 years. Fathead minnows, golden shiners, and white suckers will continue to be the primary culture species.

Production of Eggs and Fry

The majority of salmon and trout eggs imported into the Great Lakes Region have been obtained from the West Coast. Minnesota has recently prohibited the importation of West Coast salmon and trout eggs due to potential disease problems. If the rest of the Great Lake states and provinces follow this lead (as recommended by some disease specialists), there will be a significant shortage of eggs within the region.

The development of an intensive aquaculture industry in Minnesota (i.e., the mine pits) will depend heavily on a reliable source of eggs or smolts. Without this support industry sector, an intensive salmon and trout industry in the state is doomed.

These facilities would have to be located in one of two regions: the north shore of Lake Superior or the Southeast area of Minnesota. These are the only areas with acceptable year-round water temperatures and reliable water supplies. The most desirable sites are located on designated trout streams, which are not currently available for commercial development. Re-examination and modification of current regulations and policy in this area could greatly help development of Minnesota's aquaculture industry. Commercial development in these areas must be done in an environmentally responsible manner. This may include more complete effluent treatment and environmental monitoring. Assuming 3 to 4 large-scale hatcheries produce 5 to 6 million eggs or smolts, a gross revenue of approximately $8 million/year could be generated after 8 years.

<u>Summary</u>

Four groups of fish show potential for increasing aquaculture production in Minnesota: (1) white sturgeon, (2) paddlefish, (3) bait minnows, and (4) Atlantic and chinook salmon. Phase II of this study will include an analysis of the cost of production, market value, job creation, and seasonality for these groups.

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APPENDIX A - DETAILED SPECIES GRADES

Table A-1 Summary of Weighted Ratings For Potential Species

Group/Species	Weighted Rating		
	Eggs	Fry	Food
Sturgeon Family Acipenseridae			
Lake Sturgeon (Acipenser fulvescens)	120	190	190
White Sturgeon (Acipenser transmontanus)	120	230	250
Paddlefish Family Polydontidae			
Paddlefish (Polyodon spathula)	120	205	225
Pike Family Esocidae			
Northern Pike (Esox lucius))	80	145	130
Muskellunge (Esox masquinongy)	80	145	130
Tiger Musky	80	150	100
Trout and Salmon Salmonidae			
Arctic Grayling (Thymallus articus)	120	190	210
Arctic Charr (Salvelinus alpinus)	120	190	210
Pink Salmon (Oncorhynchus gorbuscha)	180	180	180
Coho Salmon (Oncorhynchus kisutch)	220	200	200
Chinook Salmon (Oncorhynchus tshawytscha)	260	245	245
Lake Trout (Salvenlinus namaycush)	220	200	200
Rainbow Trout (Salmo gairdneri)	240	190	220
Brook Trout (Salvenlinus fontinalis)	180	180	180
Brown Trout (Salmo trutta)	180	150	150
Atlantic Salmon (Salmo salar)	240	265	250
Lake Whitefish (Coregonus clupeaformis)	140	180	210

Table A-1 (Continued)

Group/Species	Weighted Rating		
	Eggs	Fry	Food
Minnow and Carp Family _Cyprinidae_			
Carp (_Cyprinus carpio_)	160	185	185
Grass Carp (_Ctenopharyngodon idella_)	0	200	200
Golden Shiner (_Notemigonus crysoleucas_)	60	240	0
Fathead Minnow (_Pimephales promelas_)	60	240	0
Sucker Family _Catostomidae_			
White Sucker (_Catostomus cummersoni_)	220	255	190
Catfish Family _Ictaluridae_			
Channel Catfish (_Ictalurus punctatus_)	40	190	175
Flathead Catfish (_Pylodictis olivaris_)	40	170	155
Temperate Bass Family _Percichthyidae_			
White Bass (_Morone chrysops_)	40	115	115
Striped Bass (_Morone saxatilis_)	80	115	145
White x Striped (hybrids)	80	130	160
Sunfish Family _Centrachidae_			
Largemouth Bass (_Micropterus salmoides_)	80	130	130
Smallmouth Bass (_Micropterus dolomieui_)	80	145	145
Sunfish and Bluegill (_Lepomis_ spp.)	140	170	170
Crappie (_Pomoxis_ spp.)	140	170	170
Perch Family _Percidae_			
Yellow Perch (_Perca flavescens_)	120	175	160
Walleye (_Stizostedion vitreum_)	120	175	160

Table A-1 (Continued)

Group/Species	Weighted Rating		
	Eggs	Fry	Food
Tilapia Family _Tilapia_			
Mozambique Tilapia (_Tilapia mossambica_)	180	155	155

Appendix B - Species Rating Computation Sheets

General information on the biology, environmental requirements, and present culture of fish in Minnesota can be found in Becker (1983), Moyle (1976), Phillips et al. (1982), Scott and Crossman (1973), and Waters (1977).

Sturgeon Family

1. Species Considered

Lake Sturgeon

White Sturgeon

2. General Potential

These species have high market potential, grow to large size, and are not easily caught by fishing. Production of caviar may also be attractive. Techniques have been developed for the removal of eggs (caviar) without killing the females.

3. Ease of Culture

These species are difficult to spawn and rear. Intensive culture is possible, but extensive culture is more suited to Minnesota.

4. Problems

Broodstock or eggs are not available for either species in Minnesota. White sturgeon fry and fingerlings are commercially available in California and Oregon.

5. Recommendations

The white sturgeon have excellent potential for aquaculture in Minnesota. Lake sturgeon also have excellent potential if a source of broodstock or eggs can be obtained.

SPECIES RATING COMPUTATIONS

Species: Lake Sturgeon | Culture Type: Extensive

SALE OF EGGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	0	0
Culture of Adults/Eggs	40	0	0
Marketability	40	3	120
		OVERALL RATING =	**120**

SALE OF FRY OR FINGERLINGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Fingerlings	20	1	20
Growth Rate	15	1	15
Food Costs per lb of Fish	15	3	45
Marketability	30	3	90
		OVERALL RATING =	**190**

SALE OF FOOD FISH

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Juveniles	20	1	20
Growth Rate	15	1	15
Food Costs per lb of Fish	15	3	45
Marketability	30	3	90
		OVERALL RATING =	**190**

SPECIES RATING COMPUTATIONS

Species: White Sturgeon   Culture Type: Extensive

SALE OF EGGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	0	0
Culture of Adults/Eggs	40	0	0
Marketability	40	3	120
		OVERALL RATING =	**120**

SALE OF FRY OR FINGERLINGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	3	60
Culture of Adults to Fingerlings	20	1	20
Growth Rate	15	1	15
Food Costs per lb of Fish	15	3	45
Marketability	30	3	90
		OVERALL RATING =	**230**

SALE OF FOOD FISH

Criteria	Grade	Score (0-3)	Rating
Availability	20	3	60
Culture of Adults to Juveniles	20	2	40
Growth Rate	15	1	15
Food Costs per lb of Fish	15	3	45
Marketability	30	3	90
		OVERALL RATING =	**250**

Paddlefish Family

1. Species Considered

Paddlefish (only one species in the U.S.)

2. General Potential

This species has high market potential, grows to large size, and are not easily caught by fishing. Production of caviar may also be attractive. May be possible to remove eggs (caviar) without killing the females.

3. Ease of Culture

These species are difficult to spawn and rear. Intensive culture is not possible as this species is a filter-feeder.

4. Problems

Broodstock or eggs are not commercially available in Minnesota. Fry and fingerlings are commercially available from Missouri.

5. Recommendations

The paddlefish has excellent potential for aquaculture in Minnesota.

SPECIES RATING COMPUTATIONS

Species: Paddlefish   Culture Type: Extensive

SALE OF EGGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	0	0
Culture of Adults/Eggs	40	0	0
Marketability	40	3	120
		OVERALL RATING =	**120**

SALE OF FRY OR FINGERLINGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Fingerlings	20	1	20
Growth Rate	15	2	30
Food Costs per lb of Fish	15	3	45
Marketability	30	3	90
		OVERALL RATING =	**205**

SALE OF FOOD FISH

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Juveniles	20	2	40
Growth Rate	15	2	30
Food Costs per lb of Fish	15	3	45
Marketability	30	3	90
		OVERALL RATING =	**225**

Pike Family

1. Species Considered

Northern Pike

Muskellunge

Tiger Musky

2. General Potential

These species have some potential for stocking in lakes but have little or no potential as a food fish because of the difficulty of converting them to feed on an artificial diet. While the price of fingerlings may range from $3 to $10/lb, production of 1 lb of fish will require approximately $20 of minnows (10 to 1 conversion and $2.00/lb for minnows). Therefore, the culture of minnows is more economic.

3. Ease of Culture

The fry and fingerlings of these species are difficult to rear under intensive culture and are generally reared in extensive ponds.

4. Problems

Availability of broodstock and eggs is a critical problem with these species. A small number of eggs may be sold by DNR, but price and long-term availability is not well-defined at this time.

5. Recommendations

These species have little potential for commercial aquaculture in Minnesota.

SPECIES RATING COMPUTATIONS

Species: Northern Pike   Culture Type: Extensive

SALE OF EGGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	0	0
Culture of Adults/Eggs	40	0	0
Marketability	40	2	80
		OVERALL RATING =	**80**

SALE OF FRY OR FINGERLINGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Fingerlings	20	1	20
Growth Rate	15	2	30
Food Costs per lb of Fish	15	3	45
Marketability	30	1	30
		OVERALL RATING =	**145**

SALE OF FOOD FISH

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Juveniles	20	1	20
Growth Rate	15	1	15
Food Costs per lb of Fish	15	3	45
Marketability	30	1	30
		OVERALL RATING =	**130**

SPECIES RATING COMPUTATIONS

Species: Muskellunge   Culture Type: Extensive

SALE OF EGGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	0	0
Culture of Adults/Eggs	40	0	0
Marketability	40	2	80
		OVERALL RATING =	**80**

SALE OF FRY OR FINGERLINGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Fingerlings	20	1	20
Growth Rate	15	2	30
Food Costs per lb of Fish	15	3	45
Marketability	30	1	30
		OVERALL RATING =	**145**

SALE OF FOOD FISH

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Juveniles	20	1	20
Growth Rate	15	1	15
Food Costs per lb of Fish	15	3	45
Marketability	30	1	30
		OVERALL RATING =	**130**

SPECIES RATING COMPUTATIONS

Species: Tiger Musky   Culture Type: Intensive

SALE OF EGGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	0	0
Culture of Adults/Eggs	40	0	0
Marketability	40	2	80
		OVERALL RATING =	**80**

SALE OF FRY OR FINGERLINGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Fingerlings	20	2	40
Growth Rate	15	2	30
Food Costs per lb of Fish	15	2	30
Marketability	30	1	30
		OVERALL RATING =	**150**

SALE OF FOOD FISH

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Juveniles	20	1	20
Growth Rate	15	1	15
Food Costs per lb of Fish	15	1	15
Marketability	30	1	30
		OVERALL RATING =	**100**

Trout and Salmon Family

1. Species Considered

Arctic Grayling

Arctic Charr

Pink Salmon

Coho Salmon

Chinook Salmon

Lake Trout

Rainbow Trout

Brook Trout

Brown Trout

Atlantic Salmon

Lake White Fish

2. General Potential

These species have high market potential.

3. Ease of Culture

These species are moderately to difficult to spawn and hatch. Production techniques and systems are well-developed, although some modifications may be needed for Minnesota conditions.

4. Problems

Adequate numbers of eggs may not be available, especially if eggs can not be imported from the West Coast.

5. Recommendations

The following species have excellent potential for commercial aquaculture in Minnesota:

Arctic Grayling

Arctic Charr

Coho Salmon

Chinook Salmon

Lake Trout

Rainbow Trout

Atlantic Salmon

Lake White Fish

SPECIES RATING COMPUTATIONS

Species: Arctic Grayling   Culture Type: Intensive

SALE OF EGGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	0	0
Culture of Adults/Eggs	40	0	0
Marketability	40	3	120
		OVERALL RATING =	**120**

SALE OF FRY OR FINGERLINGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Fingerlings	20	1	20
Growth Rate	15	2	30
Food Costs per lb of Fish	15	2	30
Marketability	30	3	90
		OVERALL RATING =	**190**

SALE OF FOOD FISH

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Juveniles	20	2	40
Growth Rate	15	2	30
Food Costs per lb of Fish	15	2	30
Marketability	30	3	90
		OVERALL RATING =	**210**

SPECIES RATING COMPUTATIONS

Species: Arctic Charr Culture Type: Intensive

SALE OF EGGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	0	0
Culture of Adults/Eggs	40	0	0
Marketability	40	3	120
		OVERALL RATING =	**120**

SALE OF FRY OR FINGERLINGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Fingerlings	20	1	20
Growth Rate	15	2	30
Food Costs per lb of Fish	15	2	30
Marketability	30	3	90
		OVERALL RATING =	**190**

SALE OF FOOD FISH

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Juveniles	20	2	40
Growth Rate	15	2	30
Food Costs per lb of Fish	15	2	30
Marketability	30	3	90
		OVERALL RATING =	**210**

SPECIES RATING COMPUTATIONS

Species: Pink Salmon | Culture Type: Intensive

SALE OF EGGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults/Eggs	40	2	80
Marketability	40	2	80
		OVERALL RATING =	**180**

SALE OF FRY OR FINGERLINGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Fingerlings	20	2	40
Growth Rate	15	2	30
Food Costs per lb of Fish	15	2	30
Marketability	30	2	60
		OVERALL RATING =	**180**

SALE OF FOOD FISH

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Juveniles	20	2	40
Growth Rate	15	2	30
Food Costs per lb of Fish	15	2	30
Marketability	30	2	60
		OVERALL RATING =	**180**

SPECIES RATING COMPUTATIONS

Species: Coho Salmon   Culture Type: Intensive

SALE OF EGGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults/Eggs	40	2	80
Marketability	40	3	120
		OVERALL RATING =	**220**

SALE OF FRY OR FINGERLINGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Fingerlings	20	3	60
Growth Rate	15	2	30
Food Costs per lb of Fish	15	2	30
Marketability	30	2	60
		OVERALL RATING =	**200**

SALE OF FOOD FISH

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Juveniles	20	3	60
Growth Rate	15	2	30
Food Costs per lb of Fish	15	2	30
Marketability	30	2	60
		OVERALL RATING =	**200**

SPECIES RATING COMPUTATIONS

Species: Chinook Salmon Culture Type: Intensive

SALE OF EGGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults/Eggs	40	3	120
Marketability	40	3	120
		OVERALL RATING =	**260**

SALE OF FRY OR FINGERLINGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Fingerlings	20	3	60
Growth Rate	15	3	45
Food Costs per lb of Fish	15	2	30
Marketability	30	3	90
		OVERALL RATING =	**245**

SALE OF FOOD FISH

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Juveniles	20	3	60
Growth Rate	15	3	45
Food Costs per lb of Fish	15	2	30
Marketability	30	3	90
		OVERALL RATING =	**245**

SPECIES RATING COMPUTATIONS

Species: Lake Trout Culture Type: Intensive

SALE OF EGGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults/Eggs	40	2	80
Marketability	40	3	120
		OVERALL RATING =	**220**

SALE OF FRY OR FINGERLINGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	2	40
Culture of Adults to Fingerlings	20	2	40
Growth Rate	15	2	30
Food Costs per lb of Fish	15	2	30
Marketability	30	2	60
		OVERALL RATING =	**200**

SALE OF FOOD FISH

Criteria	Grade	Score (0-3)	Rating
Availability	20	2	40
Culture of Adults to Juveniles	20	2	40
Growth Rate	15	2	30
Food Costs per lb of Fish	15	2	30
Marketability	30	2	60
		OVERALL RATING =	**200**

SPECIES RATING COMPUTATIONS

Species: Rainbow Trout — Culture Type: Intensive

SALE OF EGGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	2	40
Culture of Adults/Eggs	40	3	120
Marketability	40	2	80
		OVERALL RATING =	**240**

SALE OF FRY OR FINGERLINGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	2	40
Culture of Adults to Fingerlings	20	3	60
Growth Rate	15	2	30
Food Costs per lb of Fish	15	2	30
Marketability	30	1	30
		OVERALL RATING =	**190**

SALE OF FOOD FISH

Criteria	Grade	Score (0-3)	Rating
Availability	20	2	40
Culture of Adults to Juveniles	20	3	60
Growth Rate	15	2	30
Food Costs per lb of Fish	15	2	30
Marketability	30	2	60
		OVERALL RATING =	**220**

SPECIES RATING COMPUTATIONS

Species: Brook Trout   Culture Type: Intensive

SALE OF EGGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults/Eggs	40	2	80
Marketability	40	2	80
		OVERALL RATING =	**180**

SALE OF FRY OR FINGERLINGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Fingerlings	20	2	40
Growth Rate	15	2	30
Food Costs per lb of Fish	15	2	30
Marketability	30	2	60
		OVERALL RATING =	**180**

SALE OF FOOD FISH

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Juveniles	20	2	40
Growth Rate	15	2	30
Food Costs per lb of Fish	15	2	30
Marketability	30	2	60
		OVERALL RATING =	**180**

SPECIES RATING COMPUTATIONS

Species: Brown Trout	Culture Type: Intensive

SALE OF EGGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults/Eggs	40	2	80
Marketability	40	2	80
		OVERALL RATING =	**180**

SALE OF FRY OR FINGERLINGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Fingerlings	20	2	40
Growth Rate	15	2	30
Food Costs per lb of Fish	15	2	30
Marketability	30	1	30
		OVERALL RATING =	**150**

SALE OF FOOD FISH

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Juveniles	20	2	40
Growth Rate	15	2	30
Food Costs per lb of Fish	15	2	30
Marketability	30	1	30
		OVERALL RATING =	**150**

SPECIES RATING COMPUTATIONS

Species: Atlantic Salmon   Culture Type: Intensive

SALE OF EGGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	0	0
Culture of Adults/Eggs	40	3	120
Marketability	40	3	120
		OVERALL RATING =	**240**

SALE OF FRY OR FINGERLINGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	2	40
Culture of Adults to Fingerlings	20	3	60
Growth Rate	15	3	45
Food Costs per lb of Fish	15	2	30
Marketability	30	3	90
		OVERALL RATING =	**265**

SALE OF FOOD FISH

Criteria	Grade	Score (0-3)	Rating
Availability	20	2	40
Culture of Adults to Juveniles	20	3	60
Growth Rate	15	2	30
Food Costs per lb of Fish	15	2	30
Marketability	30	2	90
		OVERALL RATING =	**250**

SPECIES RATING COMPUTATIONS

Species: Lake Whitefish Culture Type: Extensive

SALE OF EGGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults/Eggs	40	2	80
Marketability	40	1	40
		OVERALL RATING =	**140**

SALE OF FRY OR FINGERLINGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Fingerlings	20	2	40
Growth Rate	15	2	30
Food Costs per lb of Fish	15	2	30
Marketability	30	2	60
		OVERALL RATING =	**180**

SALE OF FOOD FISH

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Juveniles	20	2	40
Growth Rate	15	2	30
Food Costs per lb of Fish	15	2	30
Marketability	30	3	90
		OVERALL RATING =	**210**

Minnow and Carp Family

1. Species Considered

Carp

Grass Carp

Golden Shiner

Fathead Minnow

2. General Potential

Golden shiners and fathead minnows are excellent bait species and support a major industry in Minnesota. The culture of grass carp in Minnesota is restricted due to potential ecological impact on native and game species. Carp have low market potential, but may support limited fisheries in some lakes.

3. Ease of Culture

The minnows are relatively easy to culture.

4. Problems

Availability of rearing sites (lakes and ponds) is a problem, due to increased competition for the resources with DNR. Increased intensity of culture using feeding or fertilization may be required to expand their culture.

5. Recommendations

Both fathead minnows and golden shiners have excellent potential for commercial aquaculture in Minnesota.

SPECIES RATING COMPUTATIONS

Species: Carp | Culture Type: Extensive

SALE OF EGGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	2	40
Culture of Adults/Eggs	40	2	80
Marketability	40	1	40
		OVERALL RATING =	**160**

SALE OF FRY OR FINGERLINGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	2	40
Culture of Adults to Fingerlings	20	2	40
Growth Rate	15	2	30
Food Costs per lb of Fish	15	3	45
Marketability	30	1	30
		OVERALL RATING =	**185**

SALE OF FOOD FISH

Criteria	Grade	Score (0-3)	Rating
Availability	20	2	40
Culture of Adults to Juveniles	20	2	40
Growth Rate	15	2	30
Food Costs per lb of Fish	15	3	45
Marketability	30	1	30
		OVERALL RATING =	**185**

SPECIES RATING COMPUTATIONS

Species: Grass Carp

Culture Type: Extensive

SALE OF EGGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	0	0
Culture of Adults/Eggs	40	0	0
Marketability	40	0	0
		OVERALL RATING =	**0**

SALE OF FRY OR FINGERLINGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	2	40
Culture of Adults to Fingerlings	20	2	40
Growth Rate	15	3	45
Food Costs per lb of Fish	15	3	45
Marketability	30	1	30
		OVERALL RATING =	**200**

SALE OF FOOD FISH

Criteria	Grade	Score (0-3)	Rating
Availability	20	2	40
Culture of Adults to Juveniles	20	2	40
Growth Rate	15	3	45
Food Costs per lb of Fish	15	3	45
Marketability	30	1	30
		OVERALL RATING =	**200**

SPECIES RATING COMPUTATIONS

Species: Golden Shinner   Culture Type: Extensive

SALE OF EGGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	3	60
Culture of Adults/Eggs	40	0	0
Marketability	40	0	0
		OVERALL RATING =	**60**

SALE OF FRY OR FINGERLINGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	3	60
Culture of Adults to Fingerlings	20	3	60
Growth Rate	15	1	15
Food Costs per lb of Fish	15	3	45
Marketability	30	2	60
		OVERALL RATING =	**240**

SALE OF FOOD FISH

Criteria	Grade	Score (0-3)	Rating
Availability	20	0	0
Culture of Adults to Juveniles	20	0	0
Growth Rate	15	0	0
Food Costs per lb of Fish	15	0	0
Marketability	30	0	0
		OVERALL RATING =	**0**

SPECIES RATING COMPUTATIONS

Species: Fathead Minnow

Culture Type: Extensive

SALE OF EGGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	3	60
Culture of Adults/Eggs	40	0	0
Marketability	40	0	0
		OVERALL RATING =	**60**

SALE OF FRY OR FINGERLINGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	3	60
Culture of Adults to Fingerlings	20	3	60
Growth Rate	15	1	15
Food Costs per lb of Fish	15	3	45
Marketability	30	2	60
		OVERALL RATING =	**240**

SALE OF FOOD FISH

Criteria	Grade	Score (0-3)	Rating
Availability	20	0	0
Culture of Adults to Juveniles	20	0	0
Growth Rate	15	0	0
Food Costs per lb of Fish	15	0	0
Marketability	30	0	0
		OVERALL RATING =	**0**

Sucker Family

1. Species Considered

- White Sucker

2. General Potential

White suckers are widely used for bait and support a major industry in Minnesota.

3. Ease of Culture

White suckers are relatively easy to culture.

4. Problems

Availability of rearing sites (lakes and ponds) is a problem, due to increased competition for the resources with DNR. Increased intensity of culture using feeding or fertilization may be required to expand their culture.

5. Recommendations

The white sucker has excellent potential for commercial aquaculture in Minnesota.

SPECIES RATING COMPUTATIONS

Species: White Sucker	Culture Type: Extensive

SALE OF EGGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	3	60
Culture of Adults/Eggs	40	2	80
Marketability	40	2	80
		OVERALL RATING =	**220**

SALE OF FRY OR FINGERLINGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	3	60
Culture of Adults to Fingerlings	20	3	60
Growth Rate	15	2	30
Food Costs per lb of Fish	15	3	45
Marketability	30	2	60
		OVERALL RATING =	**255**

SALE OF FOOD FISH

Criteria	Grade	Score (0-3)	Rating
Availability	20	3	60
Culture of Adults to Juveniles	20	2	40
Growth Rate	15	1	15
Food Costs per lb of Fish	15	3	45
Marketability	30	1	30
		OVERALL RATING =	**190**

Catfish Family

1. Species Considered

Channel catfish

Flathead

2. General Potential

These species have limited potential due to the relatively long time required to produce a market sized fish compared to southern states.

3. Ease of Culture

These species are easy to spawn and rear.

4. Problems

Low water temperatures result in slow growth rates and poor production economics.

5. Recommendations

These species have little potential for commercial aquaculture in Minnesota.

SPECIES RATING COMPUTATIONS

Species: Channel Catfish   Culture Type: Intensive

SALE OF EGGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	0	0
Culture of Adults/Eggs	40	0	0
Marketability	40	1	40
		OVERALL RATING =	**40**

SALE OF FRY OR FINGERLINGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	2	40
Culture of Adults to Fingerlings	20	3	60
Growth Rate	15	2	30
Food Costs per lb of Fish	15	2	30
Marketability	30	1	30
		OVERALL RATING =	**190**

SALE OF FOOD FISH

Criteria	Grade	Score (0-3)	Rating
Availability	20	2	40
Culture of Adults to Juveniles	20	3	60
Growth Rate	15	1	15
Food Costs per lb of Fish	15	2	30
Marketability	30	1	30
		OVERALL RATING =	**175**

SPECIES RATING COMPUTATIONS

Species: Flathead Catfish Culture Type: Intensive

SALE OF EGGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	0	0
Culture of Adults/Eggs	40	0	0
Marketability	40	1	40
		OVERALL RATING =	**40**

SALE OF FRY OR FINGERLINGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	2	40
Culture of Adults to Fingerlings	20	2	40
Growth Rate	15	2	30
Food Costs per lb of Fish	15	2	30
Marketability	30	1	30
		OVERALL RATING =	**170**

SALE OF FOOD FISH

Criteria	Grade	Score (0-3)	Rating
Availability	20	2	40
Culture of Adults to Juveniles	20	2	40
Growth Rate	15	1	15
Food Costs per lb of Fish	15	2	30
Marketability	30	1	30
		OVERALL RATING =	**155**

Temperate Bass

1. Species Considered

White Bass

Striped Bass

White x Striped Bass Hybrids

2. General Potential

While these species have good market potential, water temperatures are not high enough to support rapid growth.

3. Ease of Culture

These species are very difficult to spawn and rear.

4. Problems

Low water temperatures result in slow growth rates.

5. Recommendations

These species have limited potential for commercial aquaculture in Minnesota.

SPECIES RATING COMPUTATIONS

Species: White Bass | Culture Type: Intensive

SALE OF EGGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	0	0
Culture of Adults/Eggs	40	0	0
Marketability	40	1	40
		OVERALL RATING =	**40**

SALE OF FRY OR FINGERLINGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Fingerlings	20	1	20
Growth Rate	15	1	15
Food Costs per lb of Fish	15	2	30
Marketability	30	1	30
		OVERALL RATING =	**115**

SALE OF FOOD FISH

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Juveniles	20	1	20
Growth Rate	15	1	15
Food Costs per lb of Fish	15	2	30
Marketability	30	1	30
		OVERALL RATING =	**115**

SPECIES RATING COMPUTATIONS

Species: Striped Bass Culture Type: Intensive

SALE OF EGGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	0	0
Culture of Adults/Eggs	40	0	0
Marketability	40	2	80
		OVERALL RATING =	**80**

SALE OF FRY OR FINGERLINGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Fingerlings	20	1	20
Growth Rate	15	1	15
Food Costs per lb of Fish	15	2	30
Marketability	30	1	30
		OVERALL RATING =	**115**

SALE OF FOOD FISH

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Juveniles	20	1	20
Growth Rate	15	1	15
Food Costs per lb of Fish	15	2	30
Marketability	30	2	30
		OVERALL RATING =	**145**

SPECIES RATING COMPUTATIONS

Species: White x Striped Bass Culture Type: Intensive

SALE OF EGGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	0	0
Culture of Adults/Eggs	40	0	0
Marketability	40	2	80
		OVERALL RATING =	**80**

SALE OF FRY OR FINGERLINGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Fingerlings	20	1	20
Growth Rate	15	2	30
Food Costs per lb of Fish	15	2	30
Marketability	30	1	30
		OVERALL RATING =	**130**

SALE OF FOOD FISH

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Juveniles	20	1	20
Growth Rate	15	2	30
Food Costs per lb of Fish	15	2	30
Marketability	30	2	60
		OVERALL RATING =	**160**

Sunfish Family

1. Species Considered

Largemouth Bass

Smallmouth Bass

Sunfish and Bluegill

Crappie

2. General Potential

These species have limited market potential for stocking in Minnesota.

3. Ease of Culture

Largemouth and smallmouth bass are relatively difficult to rear on artificial feeds. Sunfish, bluegill, and crappie are much easier to culture.

4. Problems

The primary problem with these species is limited market potential.

5. Recommendations

These species have limited potential for commercial aquaculture in Minnesota.

SPECIES RATING COMPUTATIONS

Species: Largemouth Bass Culture Type: Extensive

SALE OF EGGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	2	40
Culture of Adults/Eggs	40	1	40
Marketability	40	0	0
		OVERALL RATING =	**80**

SALE OF FRY OR FINGERLINGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Fingerlings	20	1	20
Growth Rate	15	1	15
Food Costs per lb of Fish	15	3	45
Marketability	30	1	30
		OVERALL RATING =	**130**

SALE OF FOOD FISH

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Juveniles	20	1	20
Growth Rate	15	1	15
Food Costs per lb of Fish	15	3	45
Marketability	30	1	30
		OVERALL RATING =	**130**

SPECIES RATING COMPUTATIONS

Species: Smallmouth Bass   Culture Type: Extensive

SALE OF EGGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	2	40
Culture of Adults/Eggs	40	1	40
Marketability	40	0	0
		OVERALL RATING =	**80**

SALE OF FRY OR FINGERLINGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Fingerlings	20	1	20
Growth Rate	15	2	30
Food Costs per lb of Fish	15	3	45
Marketability	30	1	30
		OVERALL RATING =	**145**

SALE OF FOOD FISH

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Juveniles	20	1	20
Growth Rate	15	2	30
Food Costs per lb of Fish	15	3	45
Marketability	30	1	30
		OVERALL RATING =	**145**

SPECIES RATING COMPUTATIONS

Species: Sunfish/Bluegill   Culture Type: Extensive

SALE OF EGGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	3	60
Culture of Adults/Eggs	40	2	80
Marketability	40	0	0
		OVERALL RATING =	**140**

SALE OF FRY OR FINGERLINGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	2	40
Culture of Adults to Fingerlings	20	2	40
Growth Rate	15	1	15
Food Costs per lb of Fish	15	3	45
Marketability	30	1	30
		OVERALL RATING =	**170**

SALE OF FOOD FISH

Criteria	Grade	Score (0-3)	Rating
Availability	20	2	40
Culture of Adults to Juveniles	20	2	40
Growth Rate	15	1	15
Food Costs per lb of Fish	15	3	45
Marketability	30	1	30
		OVERALL RATING =	**170**

SPECIES RATING COMPUTATIONS

Species: Crappie Culture Type: Extensive

SALE OF EGGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	3	60
Culture of Adults/Eggs	40	2	80
Marketability	40	0	0
		OVERALL RATING =	**140**

SALE OF FRY OR FINGERLINGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	2	40
Culture of Adults to Fingerlings	20	2	40
Growth Rate	15	1	15
Food Costs per lb of Fish	15	3	45
Marketability	30	1	30
		OVERALL RATING =	**170**

SALE OF FOOD FISH

Criteria	Grade	Score (0-3)	Rating
Availability	20	2	40
Culture of Adults to Juveniles	20	2	40
Growth Rate	15	1	15
Food Costs per lb of Fish	15	3	45
Marketability	30	1	30
		OVERALL RATING =	**170**

Perch Family

1. Species Considered

Yellow Perch

Walleye

2. General Potential

These species have some potential for stocking in lakes but have little or no potential as a food fish because of the difficulty of converting them to feed on an artificial diet. While the price of fingerlings may range from $3 to $10/lb, production of 1 lb of fish will require approximately $20 of minnows (10 to 1 conversion and $2.00/lb for minnows). Therefore, the culture of minnows is more economic.

3. Ease of Culture

The fry and fingerlings of these species are difficult to rear under intensive culture and are generally reared in extensive ponds.

4. Problems

Availability of broodstock and eggs is a critical problem with these species. A small number of eggs may be sold by DNR, but price and long-term availability is not well-defined at this time.

5. Recommendations

These species have little potential for commercial aquaculture in Minnesota.

SPECIES RATING COMPUTATIONS

Species: Yellow Perch   Culture Type: Extensive

SALE OF EGGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	0	0
Culture of Adults/Eggs	40	0	0
Marketability	40	3	120
		OVERALL RATING =	**120**

SALE OF FRY OR FINGERLINGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Fingerlings	20	1	20
Growth Rate	15	2	30
Food Costs per lb of Fish	15	3	45
Marketability	30	2	60
		OVERALL RATING =	**175**

SALE OF FOOD FISH

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Juveniles	20	1	20
Growth Rate	15	1	15
Food Costs per lb of Fish	15	3	45
Marketability	30	2	60
		OVERALL RATING =	**160**

SPECIES RATING COMPUTATIONS

Species: Walleye　　　　Culture Type: Extensive

SALE OF EGGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	0	0
Culture of Adults/Eggs	40	0	0
Marketability	40	3	120
		OVERALL RATING =	**120**

SALE OF FRY OR FINGERLINGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Fingerlings	20	1	20
Growth Rate	15	2	30
Food Costs per lb of Fish	15	3	45
Marketability	30	2	60
		OVERALL RATING =	**175**

SALE OF FOOD FISH

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Juveniles	20	1	20
Growth Rate	15	1	15
Food Costs per lb of Fish	15	3	45
Marketability	30	2	60
		OVERALL RATING =	**160**

Tilapia Family

1. Species Considered

Tilapia

2. General Potential

This species can only be cultured in waste heat or recycle systems due to its temperature tolerance.

3. Ease of Culture

This species is simple to spawn and rear. At 28 - 30 C it can be reared to harvest size in less than a year.

4. Problems

The possession and culture of this species is restricted by law due to possible impact on game and native species. There is a limited market for this species and prices are less than $1.00/lb in the round (live weight).

5. Recommendations

This species have limited potential for commercial aquaculture in Minnesota.

SPECIES RATING COMPUTATIONS

Species: Tilapia Culture Type: Intensive

SALE OF EGGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	3	60
Culture of Adults/Eggs	40	3	120
Marketability	40	0	0
		OVERALL RATING =	**180**

SALE OF FRY OR FINGERLINGS

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Fingerlings	20	3	60
Growth Rate	15	1	15
Food Costs per lb of Fish	15	2	30
Marketability	30	1	30
		OVERALL RATING =	**155**

SALE OF FOOD FISH

Criteria	Grade	Score (0-3)	Rating
Availability	20	1	20
Culture of Adults to Juveniles	20	3	60
Growth Rate	15	1	15
Food Costs per lb of Fish	15	2	30
Marketability	30	1	30
		OVERALL RATING =	**155**

Appendix C - People and Agencies Contact List

Table C-1 LIST OF PEOPLE AND AGENCIES CONTACTED

Ira Adelman, University of Minnesota

Bruce Cady, Peterson Trout Farm

Cord Cole, Berry Sound (Lake Huron netpen operator)

Mack Cook, Cook Fisheries and Consulting

John Daily, Minnesota Department of Natural Resources

John Durda, Aeration Industries

Mark Gross, University of Minnesota

Floyd Hennagir, Minnesota Department of Natural Resources

Martin Janousek, Minnesota Bait Dealers Association

Anne Kapucinski, University of Minnesota

Terry Kayes, University of Wisconsin

Lowell Kneudall, Northern States Power

David Milles, Minnesota Department of Natural Resources

Mike Papst, Freshwater Institute

Jessie Preiner, Trout Air

Ron Rademacher, Central Minnesota Fish Farmers Association

John Ringle, Leeach Lake Indian Reservation

Nigel Robins, Canadian Aquaculture Association

Harry Rosefelt, Minnesota Department of Trade and Economic Development

Ray Svatos, IRRRB

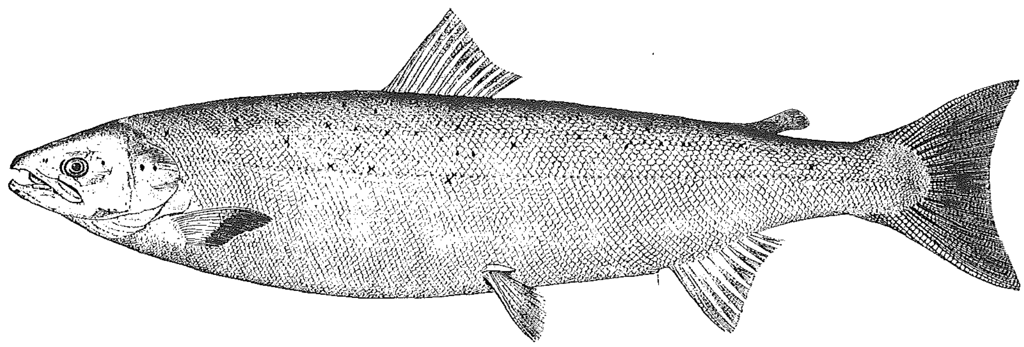
Jim Taylor, (fish farmer using limestone pits near Toronto)

Jack Wingate, Minnesota Department of Natural Resources

Aquaculture Advisory Committee
State of Minnesota

Phase II

AQUACULTURE FEASIBILITY STUDY AND MARKETING ANALYSIS



Fish Factory (International)
FFI No. 87/7-002

AQUACULTURE FEASIBILITY STUDY AND MARKETING ANALYSIS

PHASE II

Prepared for

Aquaculture Advisory Committee
State of Minnesota

Prepared by

John Colt
Peter Scales
Harry Westers

Fish Factory (International)
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Fish Factory Report No. 87/7-002F

December 1987

THE FISH FACTORY (International)

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PETER SCALES
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December 16, 1987

Mr. Harry Rosefelt
Minnesota Department of Trade
and Economic Development
160 East Kellogg Boulevard
St. Paul, MN 55101

Subject: Aquaculture Feasibility Study
Phase II (FFI 87/7-002)

Dear Mr. Rosefelt:

Fish Factory (International) is pleased to present the enclosed draft report for Phase II of the Aquaculture Feasibility Study and Marketing Analysis. Copies of the report have been mailed separately to the Aquaculture Advisory Committee.

The information documented in this report will be presented to the Aquaculture Advisory Committee on December 21, 1987. With the submission of this report and the in-person presentation of our findings, Phase II of the study is completed.

Detailed production cost and economic analysis were performed on the four groups of fish identified in Phase I as having the greatest potential for commercial aquaculture in Minnesota. We believe that aquaculture should be considered a viable economic industry in Minnesota. Based on our study, aquaculture in Minnesota has the potential to generate up to $34 million/year in direct revenue and 151 person years of employment after 7 years. While difficult to estimate, the long-term potential of aquaculture may be 3 - 4 times this number.

Thank you for the opportunity to assist in this very interesting project. Please do not hesitate to call if you have any questions about this report.

Yours truly,

John E. Colt

John E. Colt, Ph.D.

Peter B. Scales

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I. EXECUTIVE SUMMARY

This report comprises the second phase of a project to evaluate the economic and environmental potential for aquaculture in the state of Minnesota.

Working within the guidelines set by the Aquaculture Advisory Committee to provide analysis of aquaculture potential, Phase I evaluated existing regulations, market demand, availability of water and land resources, and the biological requirements of a number of species. As a consequence, four groups of fish were recommended for further study. These species included (1) white sturgeon, (2) paddlefish, (3) bait minnows, and (4) Atlantic and chinook salmon. A number of culture technologies were evaluated to grow these four fish groups and it was determined that recycle, waste heat, and integrated agriculture/aquaculture systems show little economic promise for Minnesota at this time.

The production and economic analysis conducted in Phase II suggests that aquaculture in Minnesota has the potential to generate up to $34 million/year in direct revenue and 151 person years of employment after 7 years. Under present regulatory constraints, the greatest development will occur near the Iron Range. This would likely include net pen culture of salmon and trout, processing, equipment manufacturing, and fish health and diagnostic services. The greatest potential to supplement rural income elsewhere in the state is intensive minnow culture. A third area which shows good potential is extensive culture of paddlefish and sturgeon. Attractive economic returns could be anticipated, but at the present time the culture of paddlefish and sturgeon will be limited to a very small number of lakes on Indian reservations.

To rapidly develop aquaculture in Minnesota, some form of state involvement will be necessary. This may come in the form of commercially oriented research, broodstock development, educational programs, market development, or financial assistance through direct loans or loan guarantees. Since many of the desirable sites for aquaculture development are unavailable due to laws and policy regulating the aquatic environment, changes in environmental regulation may need to be considered.

While difficult to assess, the long-term potential for aquaculture in Minnesota may be a factor of 3 - 4 times higher than estimated in this report. The full development of aquaculture will take both time and a strong and effective State commitment to this industry.

II. INTRODUCTION

This report is the second part of a two part study to analyze the potential for aquaculture in the state of Minnesota. Phase I defined the biological, environmental, and regulatory framework for the industry. The result of Phase I was a listing of species and systems showing the greatest potential for commercial aquaculture development in Minnesota.

Phase II was designed to analyze the economic potential of an aquaculture industry featuring extensive culture of:

Paddlefish

Sturgeon

Minnows

and intensive culture of:

Atlantic Salmon

Chinook Salmon

Steelhead Trout

Arctic Charr

In addition to the criteria specified in the original proposal, the Aquaculture Advisory Committee provided the following instructions at the completion of Phase I:

1. Market and production analysis was to be conducted within the context of current state and federal laws governing use of water resources in Minnesota.
2. The scope and size of all operations to be considered was to be stated with particular reference to break-even analysis of the size of operation and anticipated market price of product.

3. Both the in-state and out-of-state market for eggs and smolts was to be considered.

4. Consideration for the ecological impacts of reintroduction of sturgeon and paddlefish were to be made.

The economic and marketing data used in this phase was gathered primarily by telephone questionnaire and in-person interview methodologies. Two questionnaire forms were developed, one for production economics and the second for marketing and processing criteria. Recognizing that production and pricing information may often be considered proprietary by respondents in private industry, care was taken to design the questions to deal in generalities. As a consequence, production costs for a "generalized operation" were formulated.

III. AQUACULTURE AS AN INDUSTRY IN MINNESOTA

Market Access

Minnesota holds a number of attributes which favor marketing and distribution of seafood products. The most important feature is the state's centralized location in North America which facilitates transport and distribution of both import and export products. The potential areas of aquaculture development are within 5 hours by road from a major distribution center (Twin Cities and Duluth). Generally, the routes are considered "all-weather", with reliable transportation schedules.

While Minnesota is not yet considered a major market for fresh seafood products, it has easy and rapid access (by road or air) to the huge seafood markets of Chicago and the Eastern seaboard. As well as being a valuable market access for products destined directly for human consumption, it could become a major factor in establishing Minnesota as a supplier of certified, disease-free eggs and smolts.

Processing

Existing fish processing operations are presently underutilized and available to service a developing aquaculture industry. Representative fish processors/distributors in the state were contacted and represented a complete spectrum of operations in the state, from two of the largest and established firms to a small, recently incorporated firm. Of the four processors, all handled in excess of one million pounds within periods of approximately three months, the largest with an estimated capacity of four million pounds in the same period. When asked if they could handle the additional volumes anticipated for a developing aquaculture industry, the response was unanimous and favorable. In fact, all mentioned that they could handle at least twice their present volume with no requirement for major capital improvements. Adequate trained personnel for processing is available, especially in those months not traditionally used for processing of fisheries products. It should be noted however that processors would require proof of the viability of aquaculture before they would commit resources for expansion. Therefore, in the initial stages of aquaculture development, most processing would be done on the farms.

In general, Minnesota fish processors tend to specialize in frozen products. The primary processed species are whitefish, lake herring, Pacific salmon, and yellow perch. All respondents imported sizable quantities of Pacific salmon; however, only two of the major processor/distributors in the state presently handle fresh fish products on a regular basis. Therefore, assuming a viable aquaculture industry does develop in the state, processors will have to become familiar with new handling and processing techniques for each cultured species. Using the experience of many of the major processors in British Columbia as an example, the learning curve required to convert from primarily frozen natural stock salmon to fresh farmed salmon is about one year (Mr. Don Millard, Great Northern Packers).

Grading and Quality Control

Historically, temperate climate aquaculture produces relatively high value items. To obtain the full value of the product, grading and quality control standards are necessarily stringent. Simple skin cuts, abrasions, and blood spots, resulting from improperly bleeding and handling a salmon can greatly reduce the value of a fish. While there is little argument as to the need for strict quality control and grading standards in any of the established fish farming regions of the world, there is concern as to the added expense which may be incurred. As a consequence, a great deal of resistance to forced industry wide regulations is generated. A prime example is the resistance experienced by the British Colombia Salmon Farmers' Association effort to institute a set of grading and quality control standards which will try to ensure that no inferior fish leaves the province. To avoid a similar resistance in Minnesota, the state government should only develop and suggest standards to help establish the new industry.

Water Resources Available for Aquaculture

As mentioned in Phase I, many of the small lakes and ponds available for aquaculture in Minnesota "winter kill". In shallow ice covered lakes oxygen consumption by algae and bacteria can reduce the dissolved oxygen to lethal levels. Generally, "winter kill" will occur in 3 out of 5 years in lakes less than 12 to 15 feet in depth.

"Winter kill" lakes can of course be used for aquaculture, but the fish must be harvested and moved in the fall or early winter. Species which require more than one season to reach market size must be stocked in deeper waters that do not "winter kill". Most non "winter-kill" lakes (and ponds) are unavailable for aquaculture development due present regulations and policy. "Winter-kill" can be prevented by aeration or water mixing. While insurance and power costs are not excessive, the economics of intensive or extensive culture in small lakes less than 10 acres may not be favorable.

Therefore, the number of lakes biologically suitable and available for aquaculture development is a small fraction of the total number of lakes in Minnesota. Possible exceptions are the abandoned iron pits in the Iron Range and some of the lakes on Indian Reservations.

There are a number of springs and spring-fed streams in the Southern part of Minnesota which would make excellent sites for salmon and trout hatcheries due to relatively constant water temperatures and flows. Most of these sites may be unavailable for commercial aquaculture development because of state regulations governing designated trout streams and water use.

IV. MODEL DESIGN

The general costs of production for aquaculture operations were developed from information derived from the telephone questionnaires, in-person interviews, and with an extensive literature search. For each major operation type, generalized criteria were developed and used throughout the study. In those cases where biological requirements of a particular species differed from the norm, the specific criteria were separately listed.

Lotus 123 spreadsheets were used to develop generalized production costs for each operation. In most cases, a single template served as the primary analytic tool for each major facility type. As each new species was tested, only minor revisions in the criteria section were required to generate cost of production information.

The specific spreadsheets used in this study are in included in the inside of the back cover of this report:

CHINOOK.WK1	Pen culture of chinook salmon
ATLANTIC.WK1	Pen culture of Atlantic salmon
STEELHEA.WK1	Pen culture of steelhead trout
CHARR.WK1	Raceway culture of Arctic charr
SMOLT.WK1	Egg and smolt production
PROCESS.WK1	Processing
PADDLE.WK1	Extensive culture of paddlefish
STURGEON.WK1	Extensive culture of sturgeon
MINN1.WK1	Extensive culture of minnows

MINN2.WK1	Extensive culture of minnows with fertilization
MINN3.WK1	Intensive culture of minnows

Due to the variability in the design and operation of real facilities, the constructed model is by necessity a general model based on the whole industry. Price projections were derived from averaged annual quotations from the Urner-Barry Report, a weekly newsletter to fish wholesalers. Prices for eggs and smolt were based upon trends reported by the British Columbia Salmon Farmers' Association (Nelles, personal communication). The price projections used in the report reflected a historical trend where, in the initial stages of a salmonid aquaculture industry, eggs and smolt proved to be the major constraint to aquaculture development. Therefore, the projected prices for eggs and smolts reflect a state of elevated demand and reduced supply.

When designing hypothetical and generalized operations, the primary concern was to use systems and equipment which had a proven record of success. Also, where possible, non-permanent options for structures and equipment were used.

Costs and Economic Assumption

Generalized cost items were derived for models of representative operation types. The cost items, as a percent of total costs, were considered reasonable by respondents familiar with the specific operation types (hatchery, growout, processing).

The primary assumption used in development of cost projections was that fixed and variable costs should be as conservative as possible. Therefore, costs were increased by 5%/year, but revenue was assumed constant. The cost projections were calculated over a ten year period of operation. It is important to note that initial financing and operator investment were not listed as revenue, purposely, to show a true representation of the long-term performance of the operation. In all cases where equipment was used on the water, a five year straight-line depreciation was used. While most of this equipment is guaranteed for much longer, replacement represents a worst case and follows with the conservative nature of cost projections.

The four groups of fish recommended in Phase I were examined. These fish represent species which have been cultured effectively with a high market value or show strong potential. Arctic charr, while not yet proven under commercial conditions, has a very high market price. Recent studies conducted by Papst (1987) at the Fresh Water Institute (Department of Fisheries and Oceans, Winnipeg) has shown that Arctic charr's growth rates, loading densities, and feed conversion rates are similar to rainbow trout (steelhead). However, Arctic charr do not grow well in cages and seem to require a flow-through culture system.

<u>Fixed Costs</u>

The fixed costs for each category are listed yearly on each "spreadsheet" and include such items as land purchase, construction, and equipment.

<u>Total Capital Cost</u>

This represents the total of all the fixed costs for each year.

Variable Costs

The variable costs for each category are listed yearly on each "spreadsheet" and include such items as feed costs, eggs, fry, electrical power, etc.

Total Variable Costs

This represents the total of all the variable costs for each year.

Investment Required

The investment required is equal to the difference between the total revenue and the sum of the total capital costs and total variable costs.

Annual Finance

The annual finance charges were computed assuming that 50% of the investment required was borrowed at 9% for a 10 year period. It is assumed that the other 50% of the investment required was funded by investor equity. Financing requirements in subsequent years were calculated on a payback period of 10-x years where x is the time remaining until the end of the 10 year period).

Total Revenues

The revenues for growout facilities were calculated on the estimated annual production of the facilities. In the case of chinook growout, revenues were reported after the second year of operation; a consequence of rapid growth. Atlantics were not anticipated to reach market size until into the third year. Rainbow (Steelhead) and Arctic Charr were expected to reach marketable size after the first year while approximately one half could be sold in the first year. Revenues for the hatchery/smolt facilities were observed in the first year. Since the time to market size in all cases of salmonid culture in the iron pits is at present undefined, 12 month intervals were used for all production computations. Once growth rates can be better defined, use of shorter accounting intervals will likely result in more rapid profitability.

The revenues were assumed constant over the 10 year period. This assumption suggests that in real terms, the selling price of fish will be lower after 10 years and is consistent with the conservative nature of the financial projections presented in this report.

Net Revenues

The net revenue is equal to the total revenue minus the sum of the total fixed costs, total variable costs, and the annual finance charges.

Taxation

Property taxes were computed at 1.5% of capital costs (including residences). Capital items were deflated for five years then remained constant. Income Tax was based on a twenty percent (20%) charge on "Net Revenues" for those years where profits were realized. No tax averaging was used.

After Tax Revenues

The after tax revenue is equal to the net revenue minus the sum of the property and income taxes.

Return on Equity Investment (ROEI)

For this study, ROEI is defined as

$$\text{ROEI} = \left| \frac{\text{After Tax Revenue}}{(\text{Total Investment Required})/2} \right| 100$$

where depreciation is assumed to equal principal repayment. The calculation is performed for each year and averaged over the 10 years period.

Break Even Analysis For each operation a simple test of financial survivability was conducted. This test involved determining the price at which a particular sized operation was able to maintain a ROEI of 5.6%/year. If the return on equity invested is less than 5.6 %/year, one would be wise to keep their money in the bank.

Biological Criteria

Feed Conversion

This is the factor which determines what amount of feed is required to produce one pound of body weight. For this study an average value for the various life stages was used. Growout of chinook and Atlantics assumed a value of 1.6:1 while for rainbow trout (steelhead) and arctic charr, 1.3:1 was used.

Loading Density

This parameter of pounds of body weight/ft^3 is a critical factor in intensive fish culture planning. Generally, the higher stress levels and disease problems are experienced at higher loading densities. The loading densities used for this study represented a conservative and generally held assumption that loading densities used in salt water systems are not applicable for freshwater growout, especially under untried conditions such as the mine pits. Therefore, loading densities used are: chinook salmon (0.75 lb/ft^3), Atlantic salmon (0.65 lb/ft^3), steelhead trout and Arctic charr (1.65 lb/ft^3). For hatchery operations a loading density of 0.60 lb/ft^3 was utilized.

<u>Water Temperatures</u>

Since growth is closely related to temperature, all projections were based upon maintenance of water temperatures between 48 - 50 F (9 - 10 C). Generalized growth projection for Atlantic salmon, coho salmon, and steelheads are presented in Figure 1. At these temperatures, a growout period of 2+ years for chinook and 3+ years for Atlantics was anticipated. All species in the growout facilities were to be grown to an average weight of 6.5 lb, a weight which is considered the average between the size of West Coast coho and Norwegian Atlantic salmon.

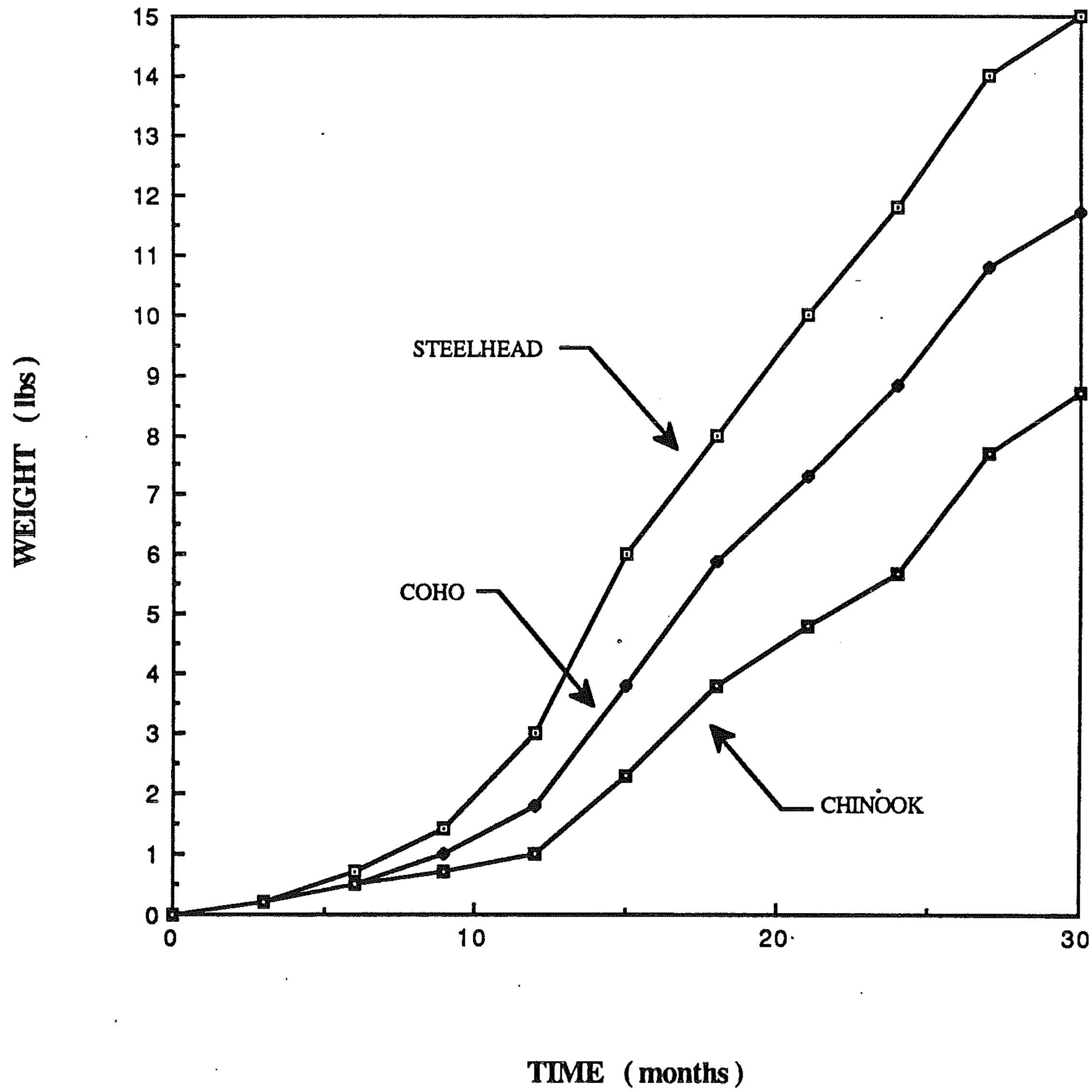

Figure 1 Growth of Chinook Salmon, Coho Salmon, and Steel Trout (Egan, 1986)

V. PRODUCTION COSTS AND ECONOMICS

In this section, detailed economic analysis will be presented for each species and facility type and includes a sample "spreadsheet" for a typically sized operation and information on breakeven costs, and ROEI. Additional profitability information for each facility type is presented in Appendix A.

Intensive Culture (Growout)

For designing and costing out a "net pen" or "cage culture" growout facility for salmonids, the British Columbia salmon farming industry has established "rule of thumb" cost estimates which appear highly applicable for the Minnesota situation. Calculated as a percentage of total annual costs, they are:

Fixed Costs	
Interest..............	4.0%
Capital...............	18.0%
Variable Costs	
Feed..................	45.0%
Smolts................	7.3%
Labor.................	8.9%
Fuel..................	3.5%
Insurance.............	6.6%
Miscellaneous.........	6.7%.

If cage culture is to be used in Minnesota, most if not all of the activity would probably take place in the Iron Pits. Essentially, these areas are currentless, deep water bodies which have highly variable surface temperature regimes. Therefore, if fish culture is to be successful, an extensive system of vertical water mixing must be developed. This factor will result in a major additional cost for electrical power not represented in the British Columbia model.

Chinook Salmon

Chinook salmon have proven to be a fish farmer's delight. They take well to intensive culture, have good growth rates, and they demand prices approaching those of top grade Atlantics (for at least the first 5 years). If chinooks are chosen as a primary production species, a good percentage of smolt and eggs must originate from the West Coast until such time as Great Lake stocks can sustain the demand. This may be considered a major problem, especially in light of the recent embargo on non disease-free certified stocks from the West Coast.

Growout operations conducting monoculture of chinook will likely produce most efficiently at the 350 to 500 ton range (Figure 2). Based on present prices of fish in the round, farmers can expect prices in the range of $2.35 to $2.60/lb. At such prices, operations of less than 150 tons will be unlikely to succeed. Financial requirements for the first three years of operation (until revenues can be realized) is anticipated to be approximately $2 million. The return on equity investment (ROEI) is approximately 26% for a 350 ton operation (Table 1). This estimate is generally lower than experienced elsewhere. As an example, Scantech Resources of British Columbia reports a farm of approximately 350 tons should expect a Return on Owner Equity Investment (ROEI) of around 32%.

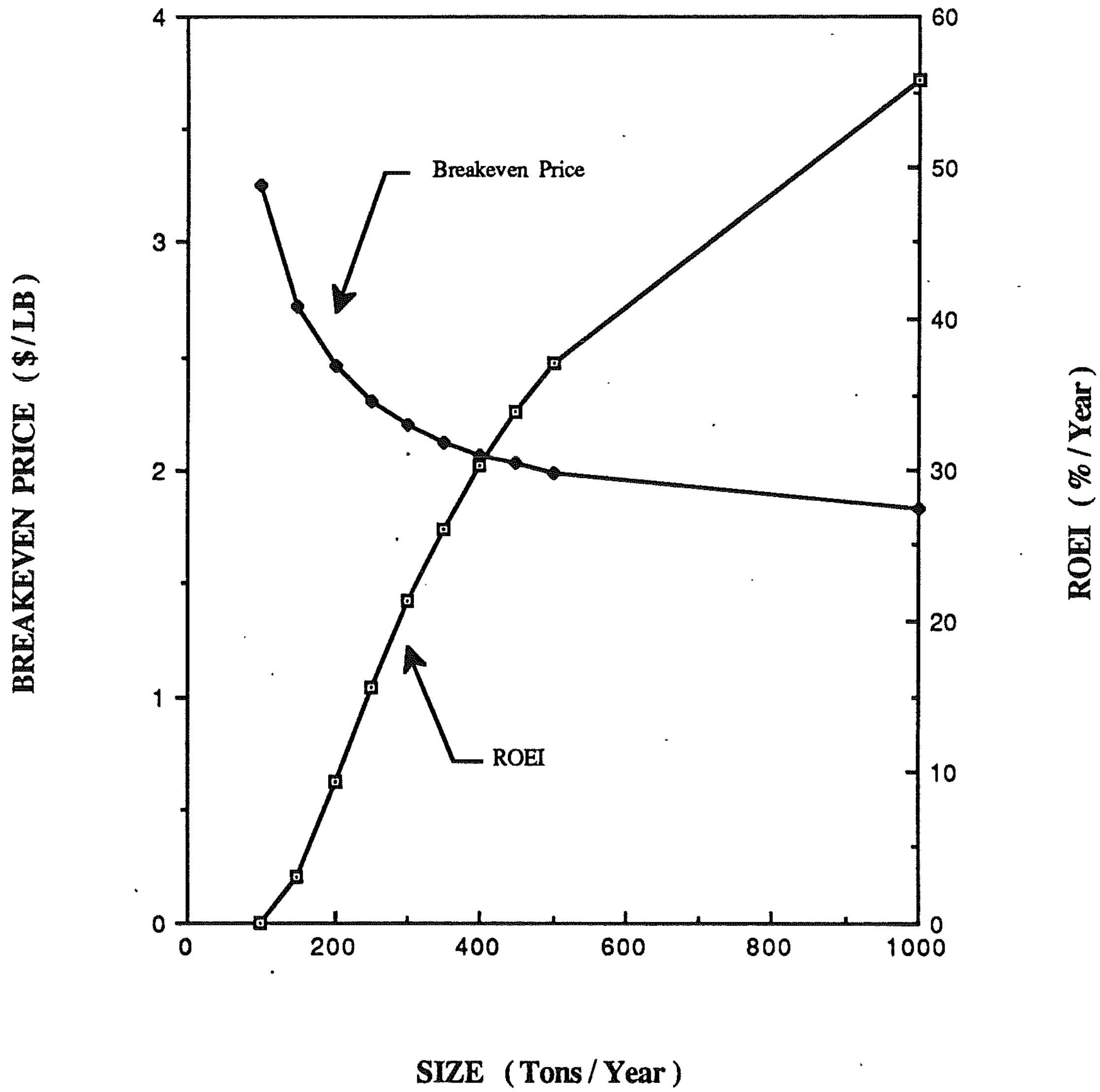

Figure 2 Breakeven Price and Return on Equity Investment (ROEI) for Chinook Salmon Reared in Cages (Selling Price =$2.60/lb)

Table 1 (Continued)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
VARIABLE COSTS										
Feed Costs	134400	470400	493920	518616	544547	571774	600363	630381	661900	694995
Smolts	66338	69655	73138	76795	80635	84667	88900	93345	98012	102913
Electrical	7665	8048	8451	8873	9317	9783	10272	10785	11325	11891
Utilities/Fuel	100000	105000	110250	115763	121551	127628	134010	140710	147746	155133
Fish Health	17500	18375	19294	20258	21271	22335	23452	24624	25855	27148
Labor	149000	156450	164273	172486	181110	190166	199674	209658	220141	231148
Insurance	72800	72800	72800	72800	72800	72800	72800	72800	72800	72800
Miscellaneous	85000	89250	93713	98398	103318	108484	113908	119604	125584	131863
Management	60000	63000	66150	69458	72930	76577	80406	84426	88647	93080
TOTAL VARIABLE	692703	1052979	1101988	1153447	1207479	1264213	1323784	1386333	1452010	1520970
Invest. Required	1314112	505112	0	0	0	0	0	0	0	0
Annual Finance	102383	144509	144509	144509	144509	144509	144509	144509	144509	144509
TOTAL COSTS	795086	1197487	1246496	1297956	1351988	1408722	1468292	1530842	1596518	1665479
TOTAL REVENUES	0	606667	1820000	1820000	1820000	1820000	1820000	1820000	1820000	1820000
NET REVENUE	-795086	-590821	573504	522044	468012	411278	351708	289158	223482	154521
TAXATION										
Property/capital	7923	6804	4847	2890	932	2227	3704	2603	932	2603
Income Tax	0	0	114701	104409	93602	82256	70342	57832	44696	30904
AFTER TAX REVENUE	-803009	-597625	453956	414746	373478	326795	277662	228724	177853	121014
ROEI (%)	26.1									

Table 1 Pen Culture of Chinook Salmon - 350 Tons/Year

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Feed conversion	1.60									
Feed Price	0.40	0.42	0.44	0.46	0.49	0.51	0.54	0.56	0.59	0.62
Market Price(fish)	2.60									
Smolt Price	0.55	0.58	0.61	0.64	0.67	0.70	0.74	0.77	0.81	0.85
Loading Density	0.75									
Mortality	0.12									
Production Size	350	700000								
Acres	100									
Land Price	150									
Const Costs										
Office/Process	40									
Res Perman	56									
Res Mobile	36									
Storage/Reas	30									
Cold Store	109									
Net Pens	2	4	6	2						
Annual prod volumes	210000	490000	700000							

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
FIXED COSTS										
Land Purchase	15000									
Land Prep.	40000									
Power Line	10000									
Building Const.										
office/process	80000									
residences	119600									
storage	36000									
cold store	31392									
Production										
net pens	35000	55125	57883	40516		112500	45500			
feeders	4667	3675	6417	2683		6563				
fork lift	15000						22500			
waste syst	7000					13125				
loading gear	15000						19500			
docks	15000									
General										
truck(s)	55000						71500			
boat(s)	34000					42500				
mixing units	8750									
miscellaneous	100000							81000		
TOTAL CAPITAL COST	621409	58800	64300	43199	0	174688	159000	81000	0	0

The difference in the two findings is likely a result of the conservative assumptions used in this analysis and, to a lesser extent, the additional electrical and lowered loading densities suggested for the Iron Pits. The yearly ROEI is approximately 49.9 % for the first year of production, and decreases linearly due to the increasing costs of production (Figure 3). The fixed costs for the cage systems are relatively large compared to the variable costs (Figure 4). For example, a 250 ton/year facility has a ROEI of 15.6% and required investment of $774,215 (Table A-1. Expansion to 500 tons/year only requires an additional investment of $338,493 and will increase the ROEI to 37.1%.

Atlantic Salmon

Atlantic Salmon hold the distinction of being an extremely popular product in world markets, a point shown very clearly by the success of the Norwegian salmon farming industry. As a farmed product, it garners prices to wholesalers (FOB New York) ranging from $4.65 to $6.20 per pound depending on size. Assuming a 42 percent increase in price from the farmer to the wholesaler, prices at the farm could range from $2.60 to $3.60/lb. Therefore, farms ranging from a size of approximately 200 tons up to 500 tons could be viable (Figure 5). Financial requirements for a farm in the 350 ton size is estimated to be $1.6 million with returns on equity investment estimated to be 34.6% (Table 2). The ROEI appears comparable to the industry standard in British Columbia.

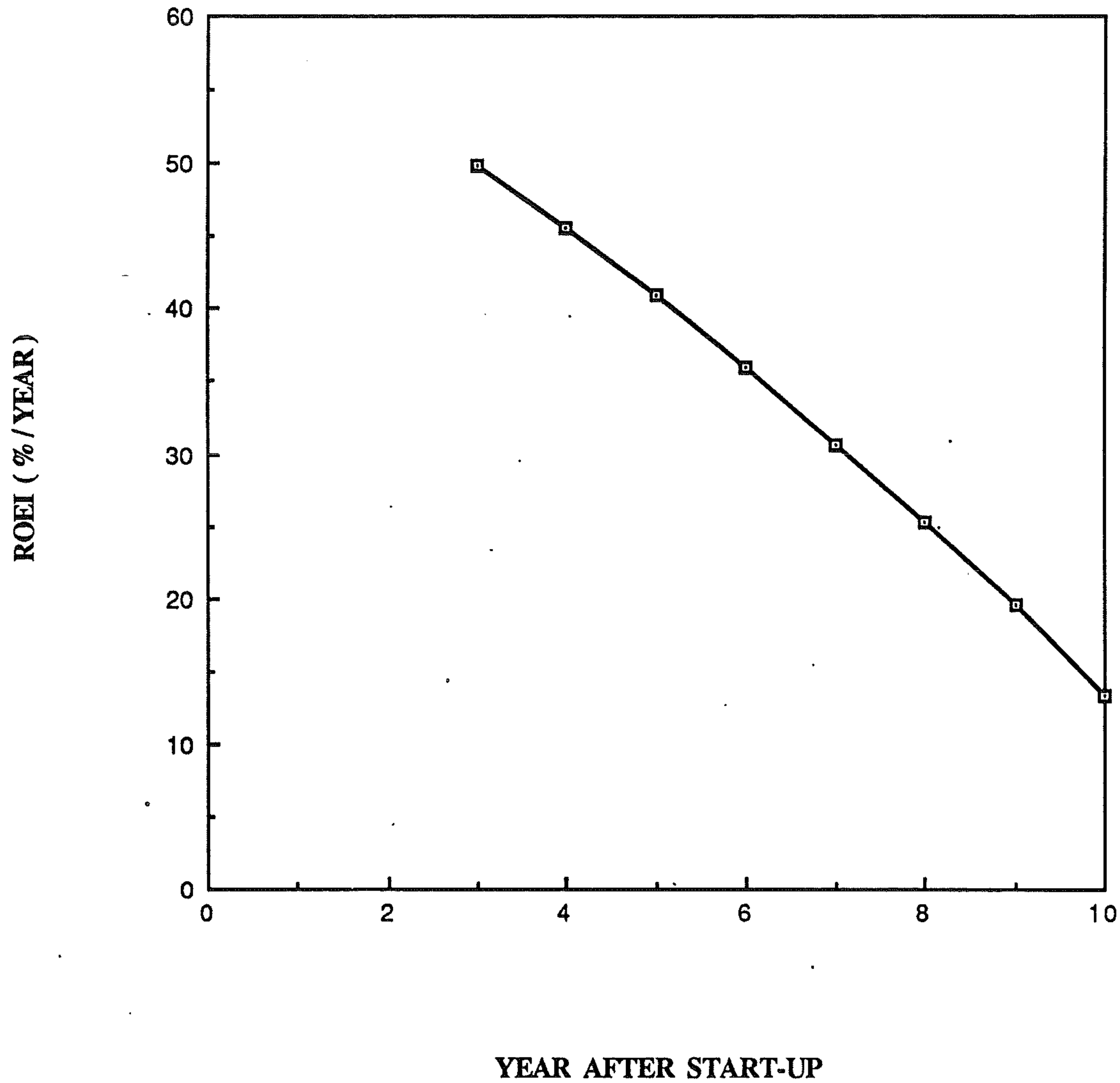

Figure 3 Yearly Return on Equity Investment (ROEI) for Chinook Salmon Reared in Cages (Selling Price =$2.60/lb)

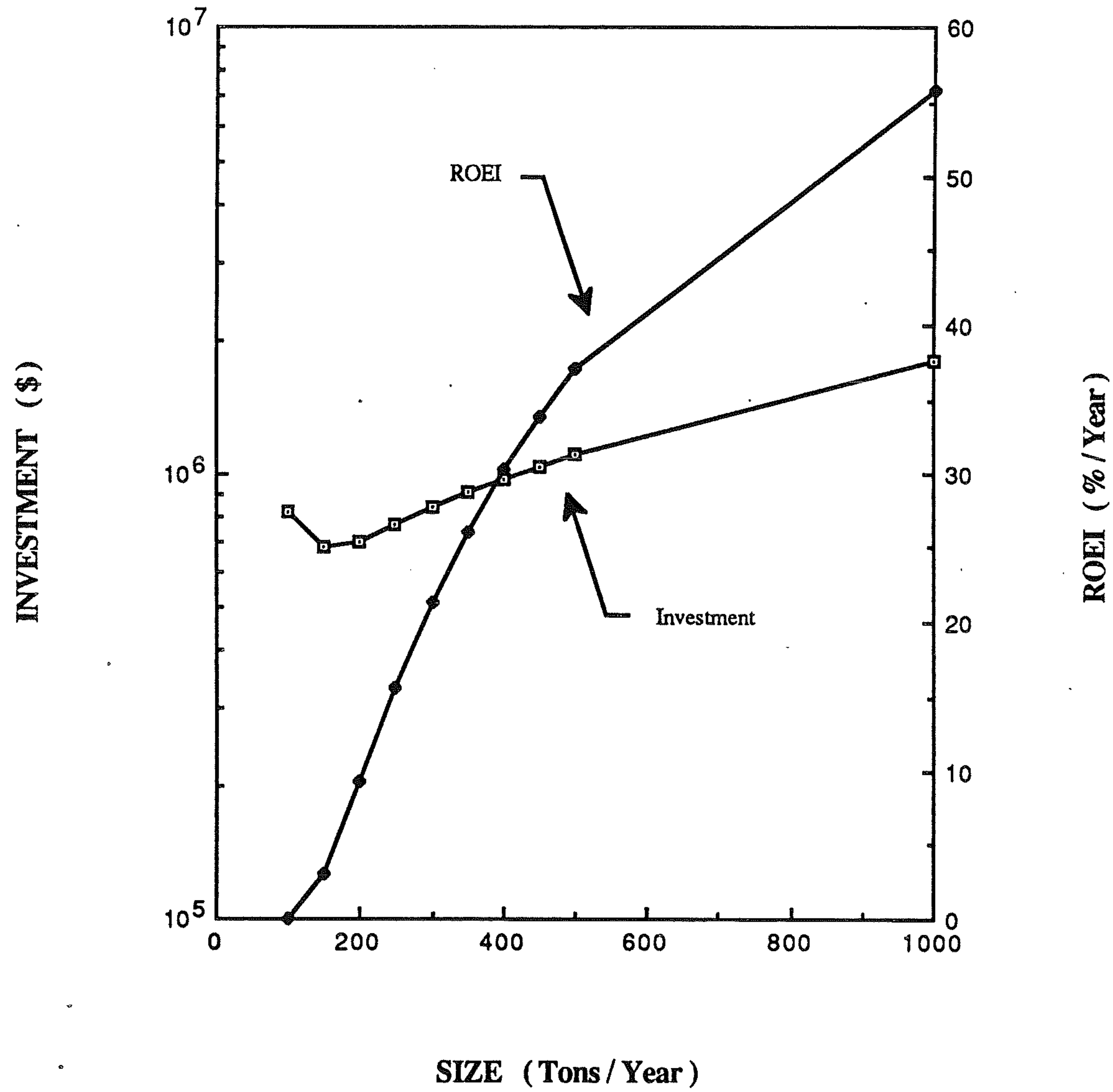

Figure 4 Return on Equity Investment (ROEI) and Investment Required for Chinook Salmon Reared in Cages (Selling Price = $2.60/lb)

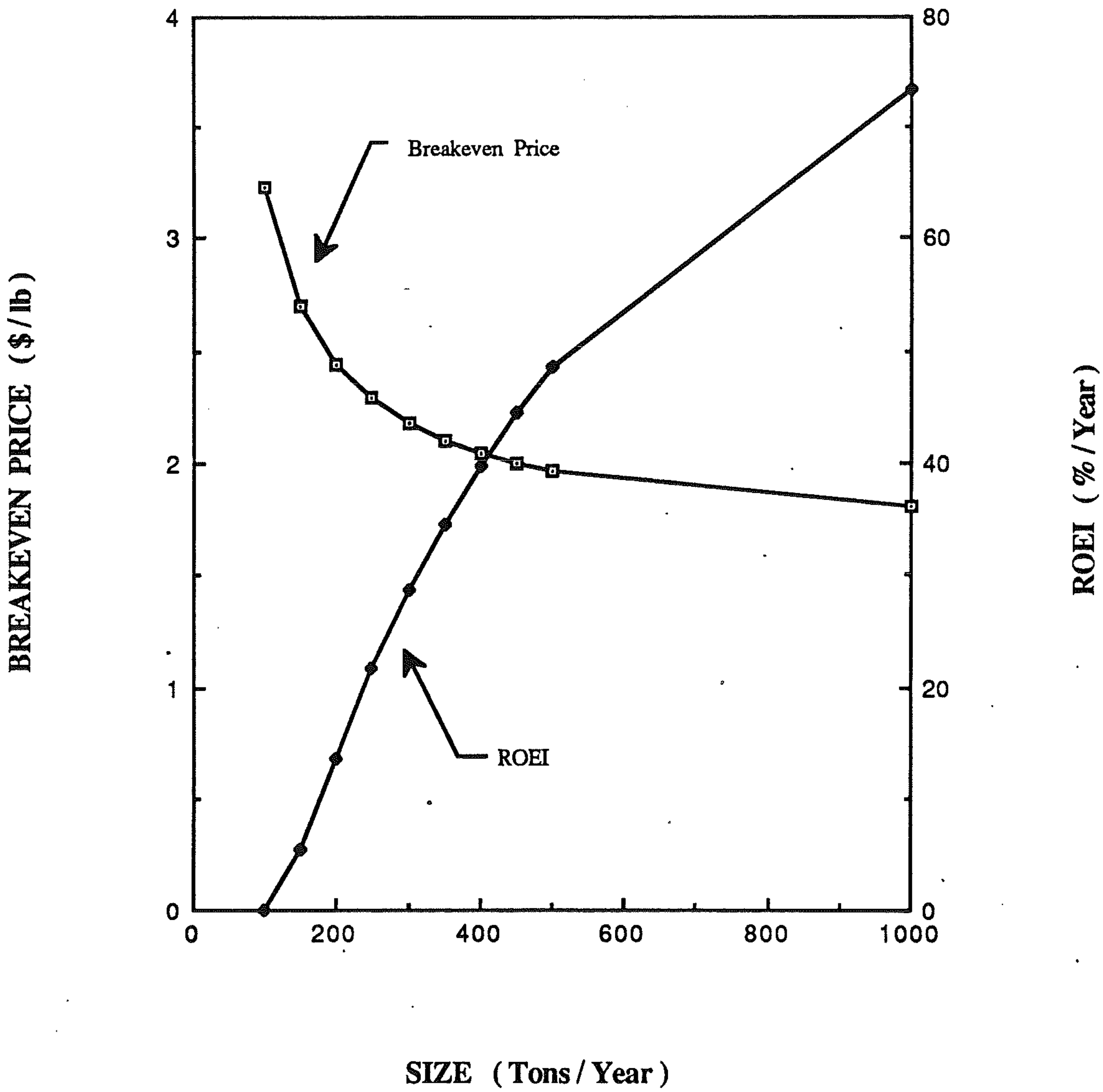

Figure 5 Breakeven Price and Return on Equity Investment (ROEI) for Atlantic Salmon Reared in Cages (Selling Price =$2.70/lb)

Table 2 Pen Culture of Atlantic Salmon - 350 Tons/Year

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Feed conversion	1.60									
Feed Price	0.40	0.42	0.44	0.46	0.49	0.51	0.54	0.56	0.59	0.62
Market Price(fish)	2.70									
Smolt Price	0.55	0.58	0.61	0.64	0.67	0.70	0.74	0.77	0.81	0.85
Loading Density	0.65									
Mortality	0.20									
Production Size	350	700000								
Acres	100									
Land Price	150									
Const Costs										
Office/Process	40									
Res Perman	56									
Res Mobile	36									
Storage/Reas	30									
Cold Store	109									
Net Pens	3	4	7	3						
Annual prod volumes	140000	350000	700000							

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
FIXED COSTS										
Land Purchase	15000									
Land Prep.	40000									
Power Line	10000									
Building Const.										
office/process	80000									
residences	119600									
storage	36000									
cold store	31392									
Production										
net pens	40385	63606	66788	46749		112500	52500			
feeders	5385	4240	7404	3096		7572				
fork lift	15000						22500			
waste syst	8077					15144				
loading gear	15000						19500			
docks	15000									
General										
truck(s)	55000						71500			
boat(s)	34000					42500				
mixing units	10096									
miscellaneous	100000							81000		
TOTAL CAPITAL COST	629934	67846	74192	49845	0	177716	166000	81000	0	0

Table 2 (Continued)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
VARIABLE COSTS										
Feed Costs	89600	329280	493920	518616	544547	571774	600363	630381	661900	694995
Smolts	71077	74631	78362	82280	86394	90714	95250	100012	105013	110264
Electrical	8844	9286	9751	10238	10750	11288	11852	12445	13067	13720
Utilities/Fuel	100000	105000	110250	115763	121551	127628	134010	140710	147746	155133
Fish Health	17500	18375	19294	20258	21271	22335	23452	24624	25855	27148
Labor	149000	156450	164273	172486	181110	190166	199674	209658	220141	231148
Insurance	75600	75600	75600	75600	75600	75600	75600	75600	75600	75600
Miscellaneous	85000	89250	93713	98398	103318	108484	113908	119604	125584	131863
Management	60000	63000	66150	69458	72930	76577	80406	84426	88647	93080
TOTAL VARIABLE	656621	920872	1111312	1163097	1217472	1274566	1334514	1397460	1463553	1532951
Invest. Required	1286555	358718	0	0	0	0	0	0	0	0
Annual Finance	100236	130152	130152	130152	130152	130152	130152	130152	130152	130152
TOTAL COSTS	756857	1051025	1241464	1293250	1347625	1404718	1464667	1527612	1593705	1663103
TOTAL REVENUES	0	630000	1890000	1890000	1890000	1890000	1890000	1890000	1890000	1890000
NET REVENUE	-756857	-421025	648536	596750	542375	485282	425333	362388	296295	226897
TAXATION										
Property/capital	8032	6898	4913	2929	945	2266	3823	2688	945	2688
Income Tax	0	0	129707	119350	108475	97056	85067	72478	59259	45379
AFTER TAX REVENUE	-764888	-427922	513915	474471	432955	385959	336444	287222	236091	178829
ROEI (%)	34.6									

Steelhead Trout

Steelhead trout, the sea ranging version of the common rainbow trout, takes well to cage culture and exhibits growth and feed conversion characteristics very similar to the rainbow trout. It has good market potential in that it can be sold as pan size or in the 5-6 lb range popular in restaurants.

The cage culture of steelhead trout will be viable for 350 to 500 ton facilities (Figure 6). Based on a production size of 350 tons, the breakeven price per pound is anticipated to be approximately $1.75/lb. Assuming current market prices maintains at approximately $2.10 to $2.40, a monoculture operation using this species would survive, but the margins are questionable considering the ability of Idaho trout growers to produce trout at a lower price than most other U.S. producers. The ROEI for a 350 ton/year operation is 21.8% (Table 3). Due to their rapid growth, Steelhead trout may provide early revenues in farms rearing chinook and Atlantic salmon, which may not have revenues until the second or third year of operation.

Arctic Charr

This species has received a great deal of interest in the past ten years. It has been the subject of two Canadian studies to determine its potential in intensive aquaculture. One of these studies conducted by the the Fresh Water Institute found that Charr do very well in flow through systems and achieve growth and feed conversion levels as good or better than Rainbow trout. These factors are extremely important when the current market price of $5.20/lb is considered. .

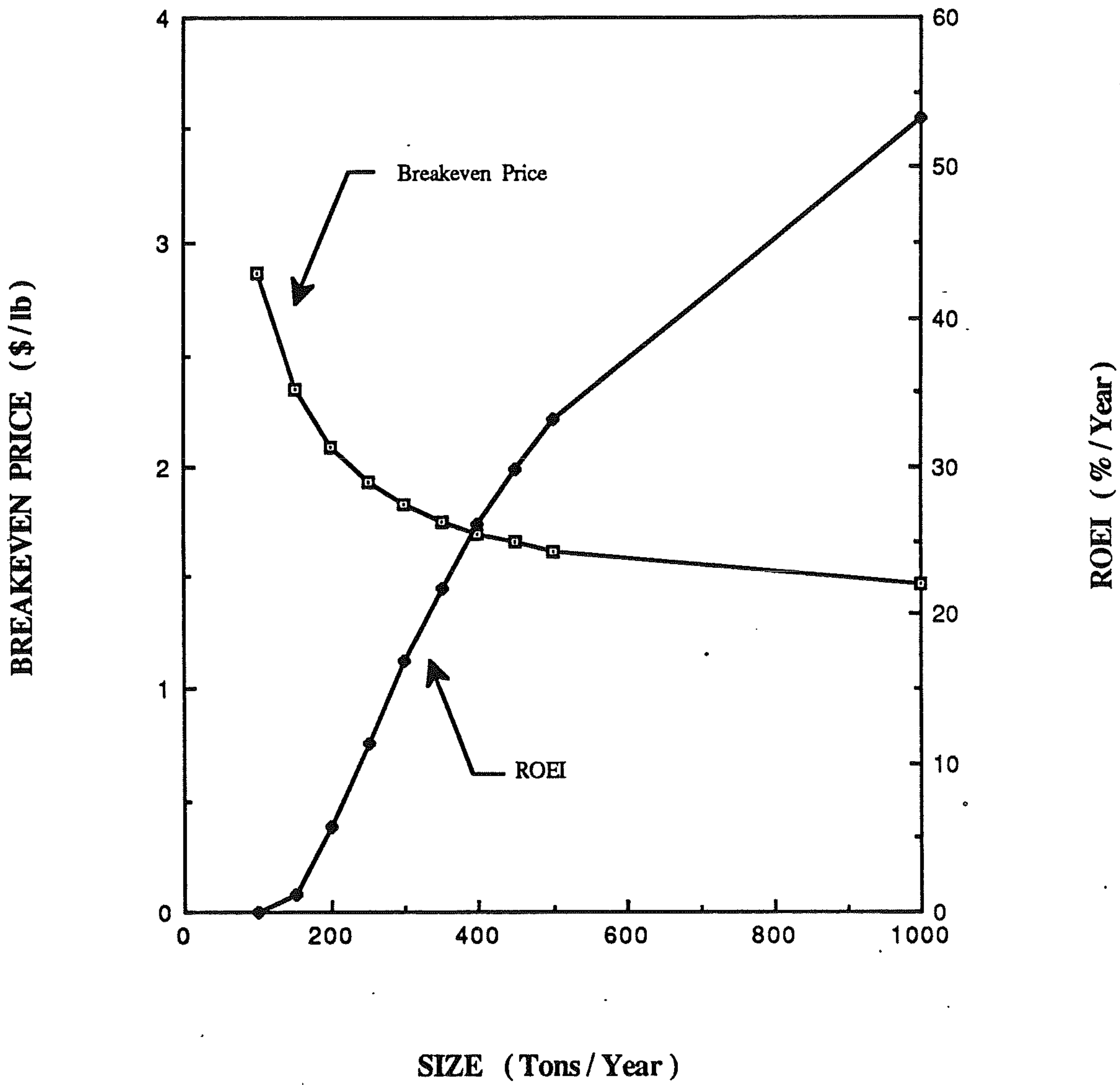

Figure 6 Breakeven Price and Return on Equity Investment (ROEI) for Steelhead Trout Reared in Cages (Selling Price =$2.10/lb)

Table 3 Pen Culture of Steelhead Trout - 350 Tons/Year

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Feed conversion	1.30									
Feed Price	0.35	0.37	0.39	0.41	0.43	0.45	0.47	0.49	0.52	0.54
Market Price(fish)	2.10									
Smolt Price	0.20	0.21	0.22	0.23	0.24	0.26	0.27	0.28	0.30	0.31
Loading Density	1.65									
Mortality	0.10									
Production Size	350	700000								
Acres	100									
Land Price	150									
Const Costs										
Office/Process	40									
Res Perman	56									
Res Mobile	36									
Storage/Reas	30									
Cold Store	109									
Net Pens	3	3	1							
Annual prod volumes	350000	700000								

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
FIXED COSTS										
Land Purchase	15000									
Land Prep.	40000									
Power Line	10000									
Building Const.										
office/process	80000									
residences	119600									
storage	36000									
cold store	31392									
Production										
net pens	39773	41761	43851			49716	51705			
feeders	5303	2784	1167			4972				
fork lift	15000						22500			
waste syst	5303					9943				
loading gear	15000						19500			
docks	15000									
General										
truck(s)	55000						71500			
boat(s)	34000					42500				
mixing units	1591									
miscellaneous	100000							81000		
TOTAL CAPITAL COST	617962	44545	45017	0	0	107131	165205	81000	0	0

Table 3 (Continued)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
VARIABLE COSTS										
Feed Costs	159250	318500	351146	368704	387139	406496	426820	448161	470570	494098
Smolts	23692	24877	26121	27427	28798	30238	31750	33337	35004	36755
Electrical	1394	1463	1536	1613	1694	1779	1868	1961	2059	2162
Utilities/Fuel	100000	105000	110250	115763	121551	127628	134010	140710	147746	155133
Fish Health	17500	18375	19294	20258	21271	22335	23452	24624	25855	27148
Labor	149000	156450	164273	172486	181110	190166	199674	209658	220141	231148
Insurance	58800	58800	58800	58800	58800	58800	58800	58800	58800	58800
Miscellaneous	85000	89250	93713	98398	103318	108484	113908	119604	125584	131863
Management	60000	63000	66150	69458	72930	76577	80406	84426	88647	93080
TOTAL VARIABLE	654636	835715	891282	932906	976612	1022502	1070687	1121282	1174406	1230186
Invest. Required	1272598	390261	0	0	0	0	0	0	0	0
Annual Finance	99148	131696	131696	131696	131696	131696	131696	131696	131696	131696
TOTAL COSTS	753784	967411	1022978	1064602	1108307	1154198	1202383	1252977	1306101	1361882
TOTAL REVENUES	0	490000	1470000	1470000	1470000	1470000	1470000	1470000	1470000	1470000
NET REVENUE	-753784	-477411	447022	405398	361693	315802	267617	217023	163899	108118
TAXATION										
Property/capital	7879	6767	4820	2874	927	1366	3135	2236	927	2236
Income Tax	0	0	89404	81080	72339	63160	53523	43405	32780	21624
AFTER TAX REVENUE	-761663	-484178	352798	321445	288427	251276	210959	171382	130192	84258
ROEI (%)	21.8									

Due to the high market prices, a charr operation will be profitable at a 100 tons/year (Figure 7). A 350 ton operation, requiring an owner investment of $1.45 million yields a ROEI of 112% (Table 4). The breakeven price for a 350 ton operation is $2.12.

Intensive Culture (Hatchery)

In this section a plan for a smolt production facility designed to accommodate Atlantics was developed. The basis of this decision was that, as a culture species, Atlantic salmon require specialized first feeding and rearing equipment which other salmonids do not necessarily require.

The basic economic considerations used in the design and the associated costing were based on the following cost percentages (calculated as a percentage of annual total costs):

Fixed Costs

- Interest..........................4.0%
- Capital and Financial maint.......6.0%

Variable Costs

- Eggs and Broodstock.............15.0%
- Feed...........................10.0%
- Labor..........................20.0%
- Fuel and Electricity...........19.5%
- Insurance...................... 5.5%
- Miscellaneous..................20.0%

The major financial assumption made was that the facility would produce one half of its egg requirements and purchase the rest

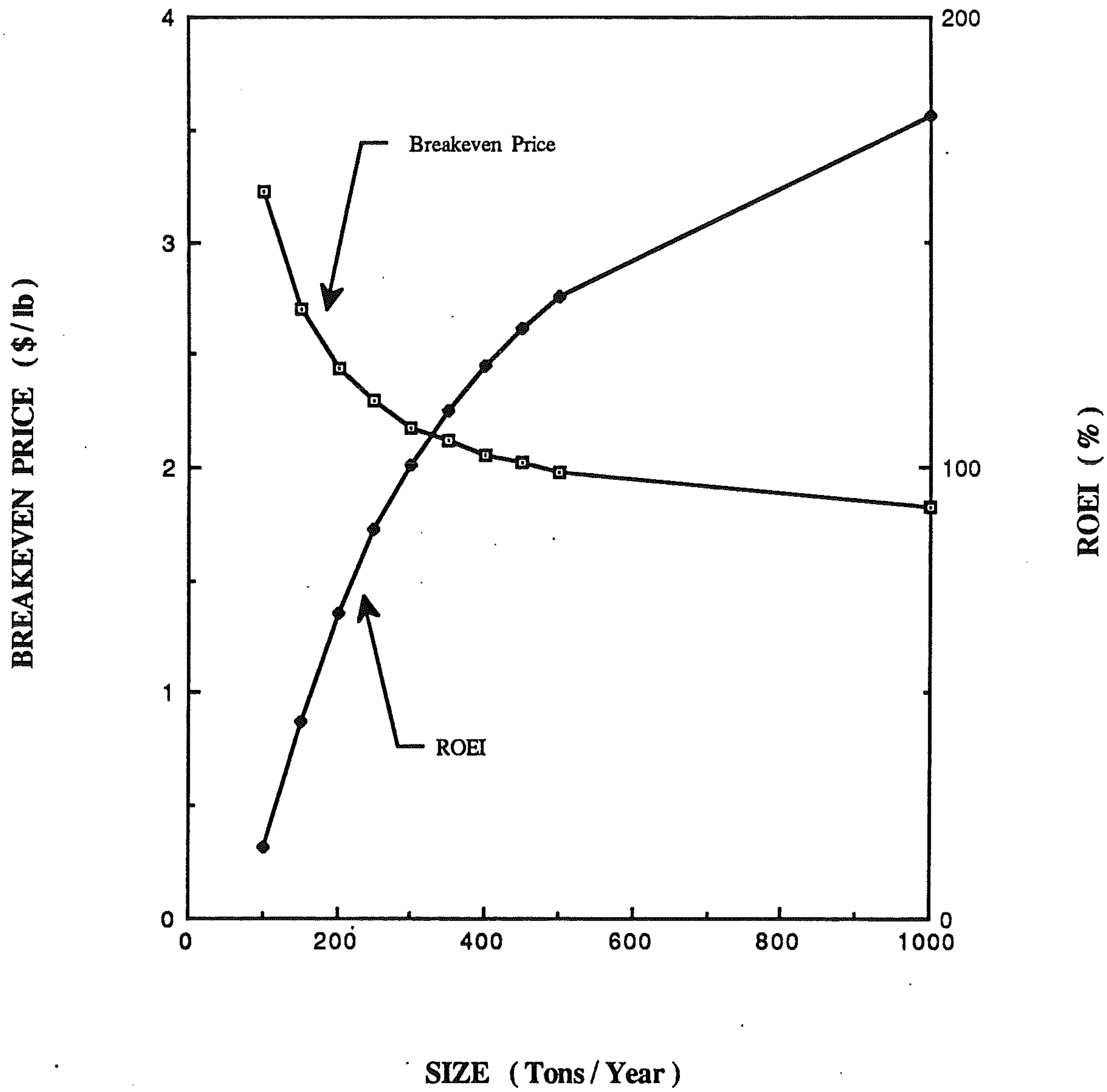

Figure 7 Breakeven Price and Return on Equity Investment (ROEI) for Arctic Charr Reared in Raceways (Selling Price =$3.50/lb)

Table 4 Raceway Culture of Charr - 350 Tons/Year

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Feed Conversion	1.30									
Feed Price	0.35	0.37	0.39	0.41	0.43	0.45	0.47	0.49	0.52	0.5
Market Price(fish)	3.50									
Smolt Price	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.5
Loading Density	1.00									
Mortality	0.15									
Production Size	350	700000								
Acres	5									
Land Price	$4,000.00									
Const Costs										
Office/Process	$40.00									
Res Perman	$56.00									
Res Mobile	$36.00									
Storage/Reas	$30.00									
Raceways	$4.00									
Cold Store	$109.00									
Annual Prod Volumes	350000	700000								

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
FIXED COSTS										
Land Purchase	20000									
Land Prep.	40000									
power Line	10000									
Building Const.										
office/process	80000									
residences	119600									
storage	36000									
cold store	31392									
Production										
raceways	1400000	1400000								
feeders	175000					227500				
fork lift	15000									
truck	30000						40500			
miscellaneous	50000							70000		
TOTAL CAPITAL COST	2006992	1400000	0	0	0	227500	40500	70000	0	

Table 4 (Continued)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
VARIABLE COSTS										
Feed Costs	159250	334425	351146	368704	387139	406496	426820	448161	470570	49409
Smolts	43346	45513	47789	50179	52688	55322	58088	60992	64042	6724
Electrical	44760	46998	49348	51815	54406	57126	59983	62982	66131	6943
Utilities/Fuel	100000	105000	110250	115763	121551	127628	134010	140710	147746	15513
Fish Health	17500	18375	19294	20258	21271	22335	23452	24624	25855	2714
Labor	149000	156450	164273	172486	181110	190166	199674	209658	220141	23114
Insurance	98000	102900	108045	113447	119120	125076	131329	137896	144791	15203
Miscellaneous	75000	78750	82688	86822	91163	95721	100507	105533	110809	11635
Management	60000	63000	66150	69458	72930	76577	80406	84426	88647	9308
TOTAL VARIABLE	746856	951411	998982	1048931	1101378	1156447	1214269	1274982	1338731	140566
Invest. Required	1528848	0	0	0	0	0	0	0	0	
Annual Finance	119113	119113	119113	119113	119113	119113	119113	119113	119113	11911
TOTAL COSTS	865969	1070524	1118095	1168044	1220490	1275559	1333382	1394095	1457844	152478
TOTAL REVENUES	1225000	2450000	2450000	2450000	2450000	2450000	2450000	2450000	2450000	245000
NET REVENUE	359031	1379476	1331905	1281956	1229510	1174441	1116618	1055905	992156	92521
TAXATION										
Property/capital	25589	21977	15655	9333	3010	2901	2700	1816	3010	181
Income Tax	71806	275895	266381	256391	245902	234888	223324	211181	198431	18504
AFTER TAX REVENUE	261636	1081604	1049870	1016232	980597	936652	890594	842908	790714	73835
ROEI (%)	112.4									

from other sources. While possible to locate anywhere there is available water, it was assumed that this specific example would be located in an iron pit. Therefore, the added pumping and water mixing costs associated with the pits were included. Significant cost savings could be achieved if both a hatchery and cage system were located on the same pit.

Using the market value per smolt of:

Atlantics............	$.60 to $.70
Chinook..............	$.42
Steelhead............	$.34

it is evident that facilities of 2 million smolts and up could be profitable (Figure 8). As an example, a 4 million smolt capacity operation requiring approximately $0.43 million in owner investment could provide a ROEI of approximately 19% at a smolt price of $0.40 (Table 5).

Processing

The successful development of an intensive salmonid based aquaculture industry requires a processing infrastructure which can handle a fresh product and get that product to market in excellent condition. As mentioned previously, there are a number of processing operations in the state which can easily handle added capacity. The question remains however as to their ability to convert some or all of their operation to fresh fish production. Therefore, it is likely that a small number of new processing businesses could develop around the Iron Range area to process the farmed salmon production.

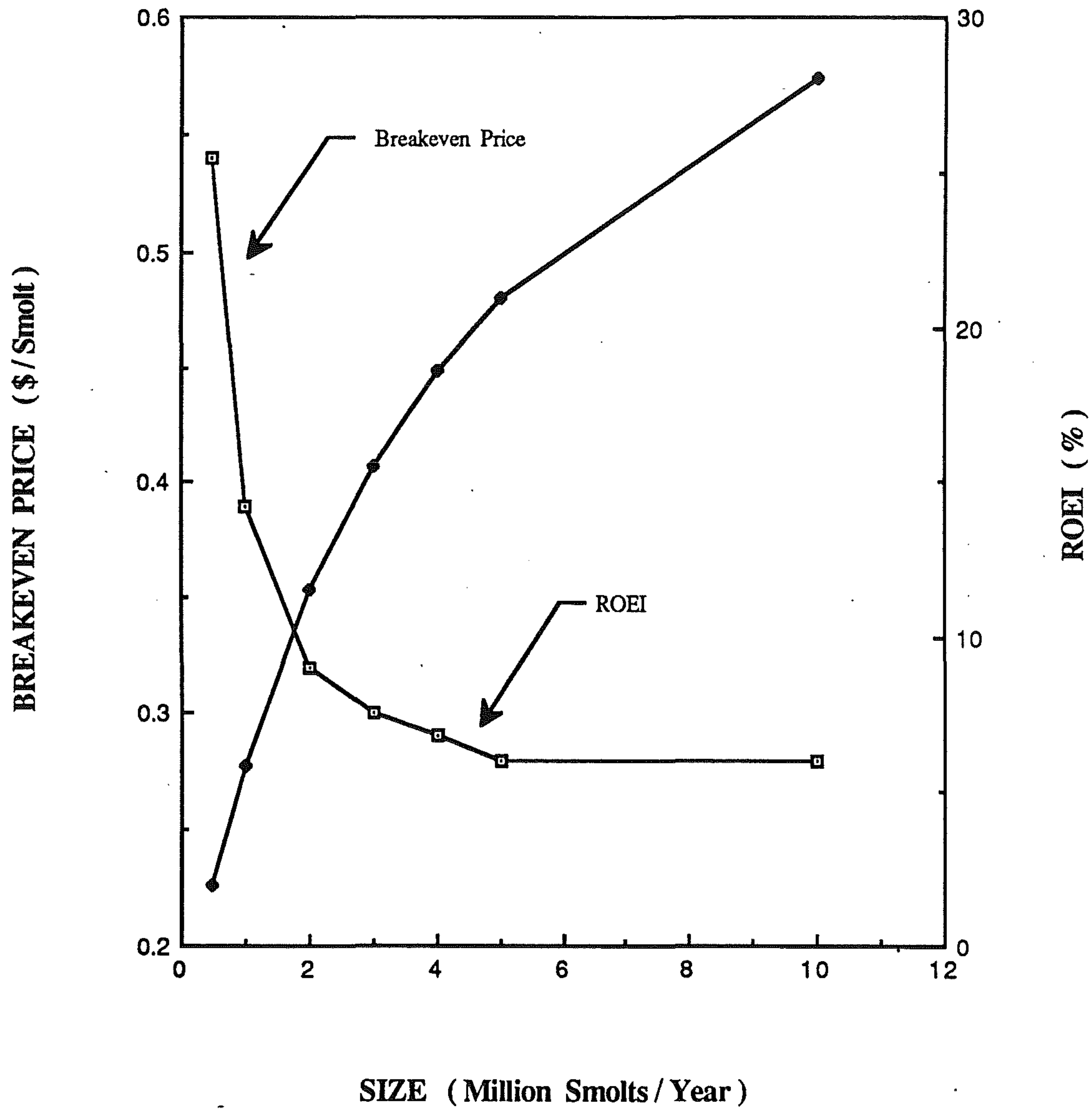

Figure 8 Breakeven Price and Return on Equity Investment (ROEI) for Smolt Production (Selling Price =$0.40/smolt)

Table 5 Smolt Production - 4 Million/Year

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Feed conversion	1.50									
Feed Price	0.40	0.42	0.44	0.46	0.49	0.51	0.54	0.56	0.59	0.6
Market Price(smolts)	0.40									
Egg Price	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.06	0.06	0.0
Loading Density	0.60	0.40	1.00							
Mortality	0.20									
Production Size	4.0 million									
Acres	2									
Land Price	5000									
Const Costs										
Office/Process	40									
Res Perman	56									
Res Mobile	36									
Storage/Reas	30									
Cold Store	109									
Hatchery Int	110									
FIXED VALUES										
Annual prod weights	100000	10000.0								
Incubation Units	102									
Large Grow out	33									
Net Pens	9	40								

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
FIXED COSTS										
Land Purchase	10000									
Land Prep.	20000									
Power Line	10000									
Road Prep.										
Building Const.										
office/process	80000									
residences	110400									
incubation/rear	144305									
plumbing	320000									
fencing/pred	9568									
storage	36000									
cold store	31392									
Production										
incubation units	60000									
tanks	650000									
net pens(rear)	62222				74667					
net pens(brood)		400000				480000				
feeders	21032						28393			
fork lift	10000						32500			
docks	7500									
General										
truck(s)	35000						71500			
boat	4500					5625				
mixers	13333					16667				
water pumps	20000									
water well	100000									
miscellaneous	60000							81000		
TOTAL CAPITAL COST	1815253	400000	0	0	74667	502292	132393	81000	0	

Table 5 (Continued)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
VARIABLE COSTS										
Feed Costs	60000	63000	66150	69458	72930	76577	80406	84426	88647	9308
Egg Purchase	192000	201600	211680	111132	116689	122523	128649	135082	141836	14892
Electrical	20000	21000	22050	23153	24310	25526	26802	28142	29549	3102
Utilities/Fuel	20000	21000	22050	23153	24310	25526	26802	28142	29549	3102
Fish Health	20000	21000	22050	23153	24310	25526	26802	28142	29549	3102
Labor	164000	172200	180810	189851	199343	209310	219776	230764	242303	25441
Insurance	80000	84000	88200	92610	97241	102103	107208	112568	118196	12410
Miscellaneous	65000	68250	71663	75246	79008	82958	87106	91462	96035	10083
Mangement	30000	31500	33075	34729	36465	38288	40203	42213	44324	4654
TOTAL VARIABLE	651000	683550	717728	642482	674606	708336	743753	780941	819988	86098
Invest. Required	866253	0	0	0	0	0	0	0	0	
Annual Finance	67490	67490	67490	67490	67490	67490	67490	67490	67490	5071
TOTAL COSTS	718490	751040	785217	709972	742096	775826	811243	848431	887478	91170
TOTAL REVENUES	1600000	1600000	1600000	1600000	1600000	1600000	1600000	1600000	1600000	160000
NET REVENUE	881510	848960	814783	890028	857904	824174	788757	751569	712522	68829
TAXATION										
Property/Capital	27229	27229	27229	27229	27229	27229	27229	27229	27229	2722
Income Tax	176302	169792	162957	178006	171581	164835	157751	150314	142504	13765
AFTER TAX REVENUE	881510	848960	814783	890028	857904	824174	788757	751569	712522	68829
ROEI (%)	18.6									

The basic assumptions made for the processing industry relate to generalized cost areas for a facility of about 4,000 ft^2 with a daily capacity of 20,000 lbs. These cost areas, again based on percent of Total Annual Costs, are as follows:

Fixed Costs	
Capital and Interest	1.0%
Variable Costs	
Packaging..............	10.0%
Labor..................	70.0%
Utilities..............	10.0%
Miscellaneous..........	9.0%

Assuming a normal processing charge of $.39/lb and a profit margin of 5 to 7 %, the cost analysis for a processing facility is shown in Table 6. The breakeven price is approximately $0.34/lb.

It was estimated that for an initial financial requirement of $143,000 a 4,000 ft^2 specialty facility, running for 200 days per year, could realize a ROEI of approximately 82%, a very healthy investment return (Figure 9). It is important to note however that such a facility would not be required until year 3 or 4 of the developing industry.

Extensive Culture

Paddlefish

If paddlefish were considered for stocking, they may support a reasonable cottage industry. Assuming a harvest density of 30

Table 6 Processing of Fresh Fish - 20,000 Lb/Day

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Daily Production	20000 lbs.									
Days of Operation	200									
Price of Boxes	$3.25	$3.41	$3.58	$3.76	$3.95	$4.15	$4.36	$4.57	$4.80	$5.04
Price Per Pound	$0.39									
CONSTANTS										
Const Costs	$125.00 sq ft									
Price of land	$10,000.00									
Size	4000 sq feet									
Annual Prod	4000000									
Acres	2									
Staff	20									
Management	3									

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
FIXED COSTS										
Land Purchase	20000									
Land Prep.	10000									
Power line	5000									
Road prep.	5000									
Building Const.										
Structure	500000									
General										
Truck(s)	55000						68750			
Ice machine	30000							39000		
Scales	5000									
Office equip	10000					12000				
Box wrapper	3500									
Miscellaneous	60000						78000			
TOTAL CAPITAL COSTS	703500	0	0	0	0	12000	146750	39000	0	0

Table 6 (Continued)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
VARIABLE COSTS										
Labor	640000	665600	692224	719913	748709	778658	809804	842196	875884	910920
Utilities	60000	63000	66150	69458	72930	76577	80406	84426	88647	93080
Insurance	7035	7387	7756	8144	8551	8979	9428	9899	10394	10914
Miscellaneous	95000	99750	104738	109974	115473	121247	127309	133675	140358	147376
Boxes	288889	303333	318500	334425	351146	368704	387139	406496	426820	448161
TOTAL VARIABLE	1090924	1139070	1189368	1241914	1296810	1354164	1414085	1476692	1542104	1610451
Invest. Required	234424	0	0	0	0	0	835	0	0	50451
Annual Finance	18264	18264	18264	18264	18264	18264	18264	18264	18264	18264
TOTAL COSTS	1812688	1157334	1207632	1260178	1315074	1384428	1579099	1533956	1560368	1628714
TOTAL REVENUES	1560000	1560000	1560000	1560000	1560000	1560000	1560000	1560000	1560000	1560000
NET REVENUE	-252688	402666	352368	299822	244926	175572	-19099	26044	-368	-68714
TAXATION										
Property/Capital	8970	7703	5487	5487	5487	5487	5487	5487	5487	5487
Income Tax	0	80533	70474	59964	48985	35114	0	5209	0	0
AFTER TAX REVENUE	-261657	314429	276407	234371	190453	134971	-24587	15348	-5855	-74202
ROEI (%)	81.6									

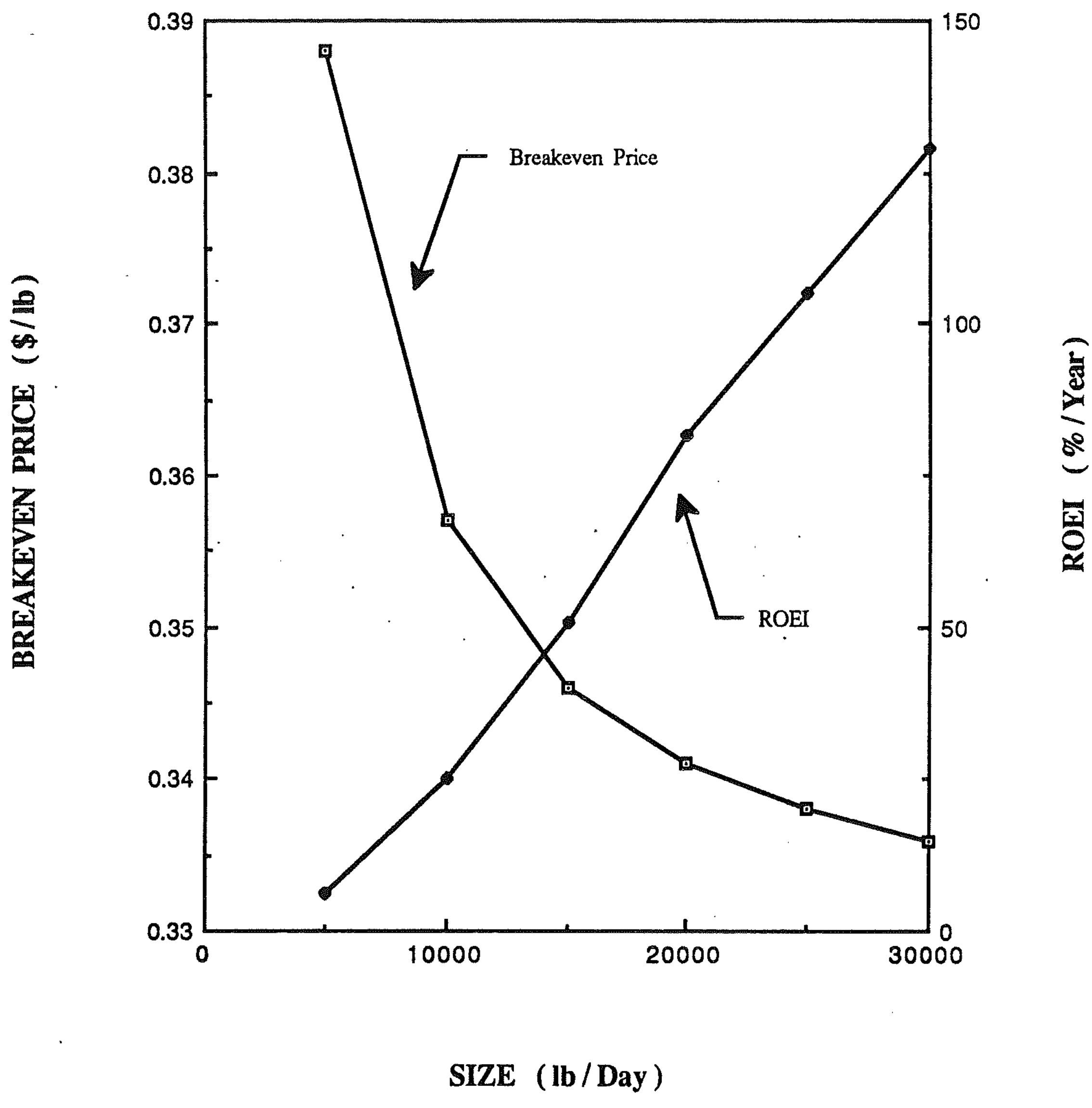

Figure 9 Breakeven Price and Return on Equity Investment (ROEI) for Processing (Processing Charges =$0.39/lb)

lb/acre/year and a sale price of $2.00/lb, this type of operation shows its best efficiencies at about 1,000 acres (Figure 10). Operations as small as 200 acres could generate a positive cash flow and still provide an opportunity for non-traditional labor. At 1,000 acres, the break even price would be approximately $.35/lb. At 20,000 acres, the ROEI is 563% with a required investment of $117,000 (Table 7).

Sturgeon

Extensive sturgeon culture could provide a good potential for development as a cottage industry, much like the case seen for paddlefish. The size of harvest area which shows the best efficiencies seems to be approximately 1,000 acres, though a harvest area of approximately 300 acres could generate a positive cash flow at fish prices over $1.77/lb (Figure 11). At the 1,000 acre level, the ROEI would be 98%, whereas, the ROEI at 20,000 acres would be approximately 160%. (Table 8).

Minnows

Extensive Minnow culture has become an established industry in the state although it is difficult to determine the costs of production. The production of minnows is considered at three levels of intensity. The first involves simply the stocking of winter kill ponds and lakes with subsequent seasonal harvesting (100 lb/acre/year). The second involves fertilizing water bodies in addition to stocking (300 lb/acre/year). The third method uses both stocking and supplemental feeding (500 lb/acre/year).

A non-fertilized baseline operation would require a minimum

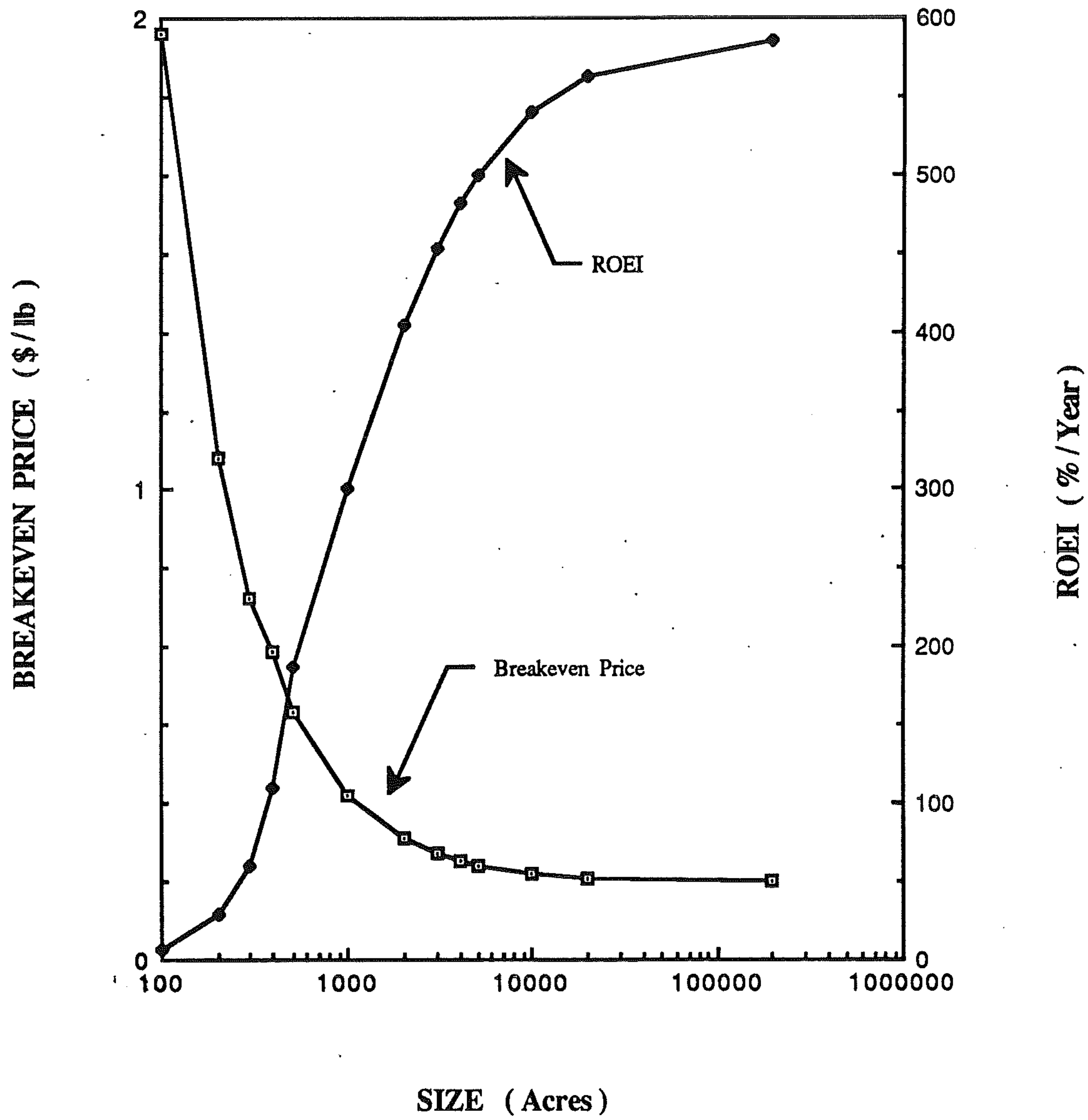

Figure 10 Breakeven Price and Return on Equity Investment (ROEI) for Extensive Paddlefish Culture (Selling Price = $2.00/lb)

Table 7 Extensive Paddlefish Culture - 20,000 Acres

Fry Price	$0.02
Sale Price	$2.00
Harvest Density	30.00 lbs./acre
Fry Survival	25 %
Adult Survival	60 %
Acres	20000

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
CAPITAL COSTS										
General										
truck(s)						20000				
boat						2500				
nets(fry)	1000				1250					
nets(adult)						200000				
miscellaneous	24500	20000	21000	22050	23153	24310	25526	26802	28142	29549
TOTAL CAPITAL COST	25500	20000	21000	22050	24403	246810	25526	26802	28142	29549
VARIABLE COSTS										
Fry Purchase	5333	5600	5880	6174	6483	6807	7147	7505	7880	8274
Utilities/Fuel	1000	1050	1103	1158	1216	3150	3308	3473	3647	3829
Labor	10000	10500	11025	11576	11000	11000	11550	12128	12734	13371
TOTAL VARIABLE	16333	17150	18008	18908	18698	20957	22005	23105	24260	25473
Invest. Required	41833	37150	39008	40958	0	0	0	0	0	0
Annual Finance	3259	6358	9881	13950	13950	13950	13950	13950	13950	13950
TOTAL COSTS	45093	43508	48889	54908	57051	281717	61481	63857	66352	68973
TOTAL REVENUES	0	0	0	0	1200000	1200000	1200000	1200000	1200000	1200000
NET REVENUE	-45093	-43508	-48889	-54908	1142949	918283	1138519	1136143	1133648	1131027
TAXATION										
Income Tax	0	0	0	0	228590	183657	227704	227229	226730	226205
AFTER TAX REVENUE	-45093	-43508	-48889	-54908	1142949	918283	1138519	1136143	1133648	1131027
ROEI (%)	563.4									

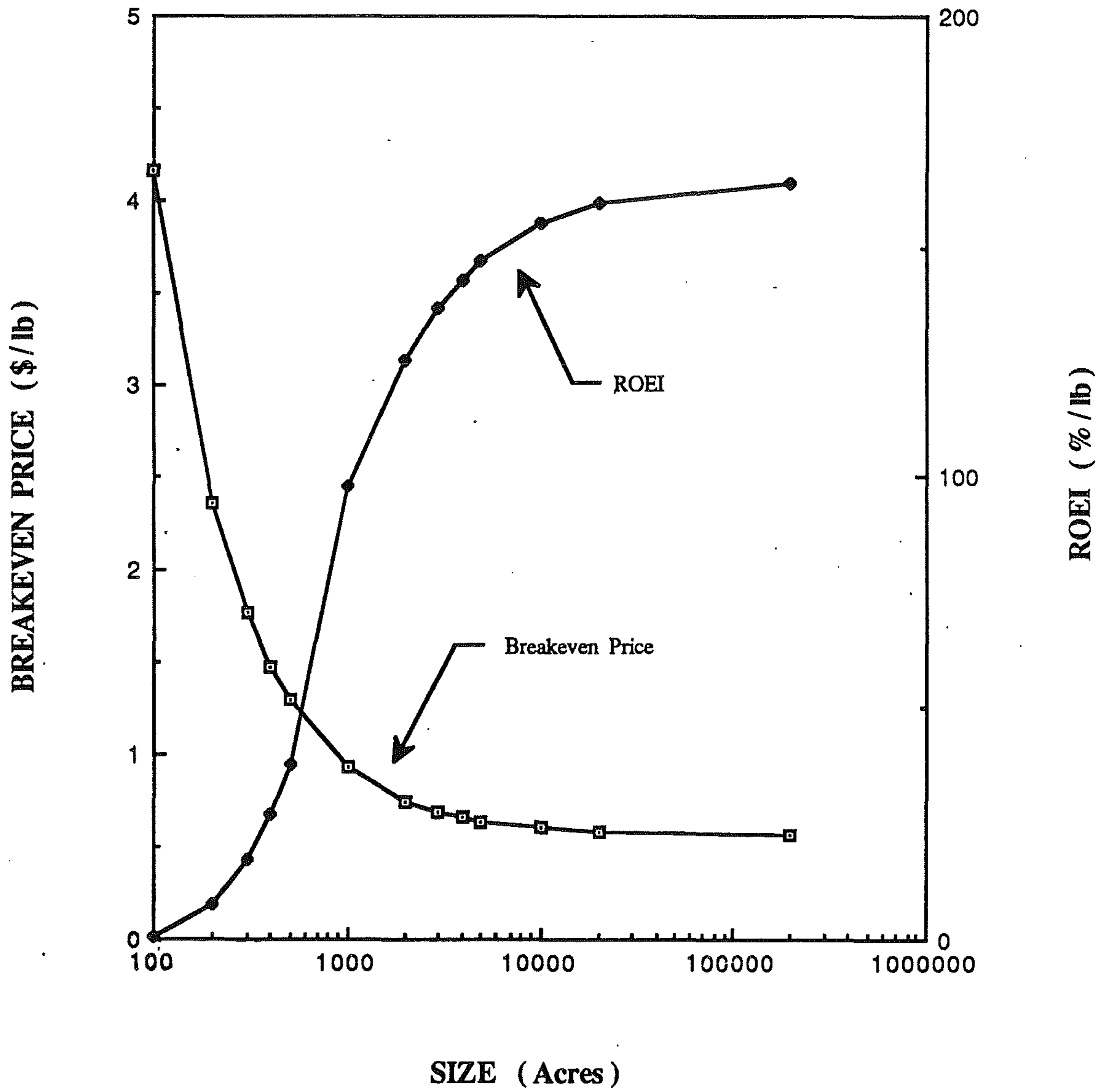

Figure 11 Breakeven Price and Return on Equity Investment (ROEI) for Extensive Sturgeon Culture (Selling Price = $2.55/lb)

Table 8 Extensive Sturgeon Culture - 20,000 Acres

Fry Price	$0.05
Sale Price	$2.55
Harvest Density	15.00 lbs./acre
Fry Survival	5 %
Adult Survival	50 %
Acres	20000

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
CAPITAL COSTS										
General										
truck(s)						20000				
boat						2500				
nets(fry)	1000				1250					
nets(adult)						200000				
miscellaneous	24500	20000	21000	22050	23153	24310	25526	26802	28142	29549
TOTAL CAPITAL COST	25500	20000	21000	22050	24403	246810	25526	26802	28142	29549
VARIABLE COSTS										
Fry Purchase	40000	42000	44100	46305	48620	51051	53604	56284	59098	62053
Utilities/Fuel	1000	1050	1103	1158	1216	3150	3308	3473	3647	3829
Labor	10000	10500	11025	11576	11000	11000	11550	12128	12734	13371
TOTAL VARIABLE	51000	53550	56228	59039	60836	65201	68461	71884	75479	79253
Invest. Required	76500	73550	77228	81089	0	0	0	0	0	0
Annual Finance	5960	12094	19071	27126	27126	27126	27126	27126	27126	27126
TOTAL COSTS	82460	85644	96298	108215	112365	339138	121113	125813	130747	135928
TOTAL REVENUES	0	0	0	0	765000	765000	765000	765000	765000	765000
NET REVENUE	-82460	-85644	-96298	-108215	652635	425862	643887	639187	634253	629072
TAXATION										
Income Tax	0	0	0	0	130527	85172	128777	127837	126851	125814
AFTER TAX REVENUE	-82460	-85644	-96298	-108215	652635	425862	643887	639187	634253	629072
ROEI (%)	159.7									

harvest area of 200 acres to breakeven assuming a price for the product of $1.25 (Figure 12). Only 50 acres would be needed for fertilized ponds, and only 25 acres for fed ponds (Figures 13 and 14). The ROEI (Tables 9, 10, 11) for the various size operations are:

Case	Size (acre)	ROEI(%)
Base case	200	17
Fertilized	50	24.3
Fed	25	8.7

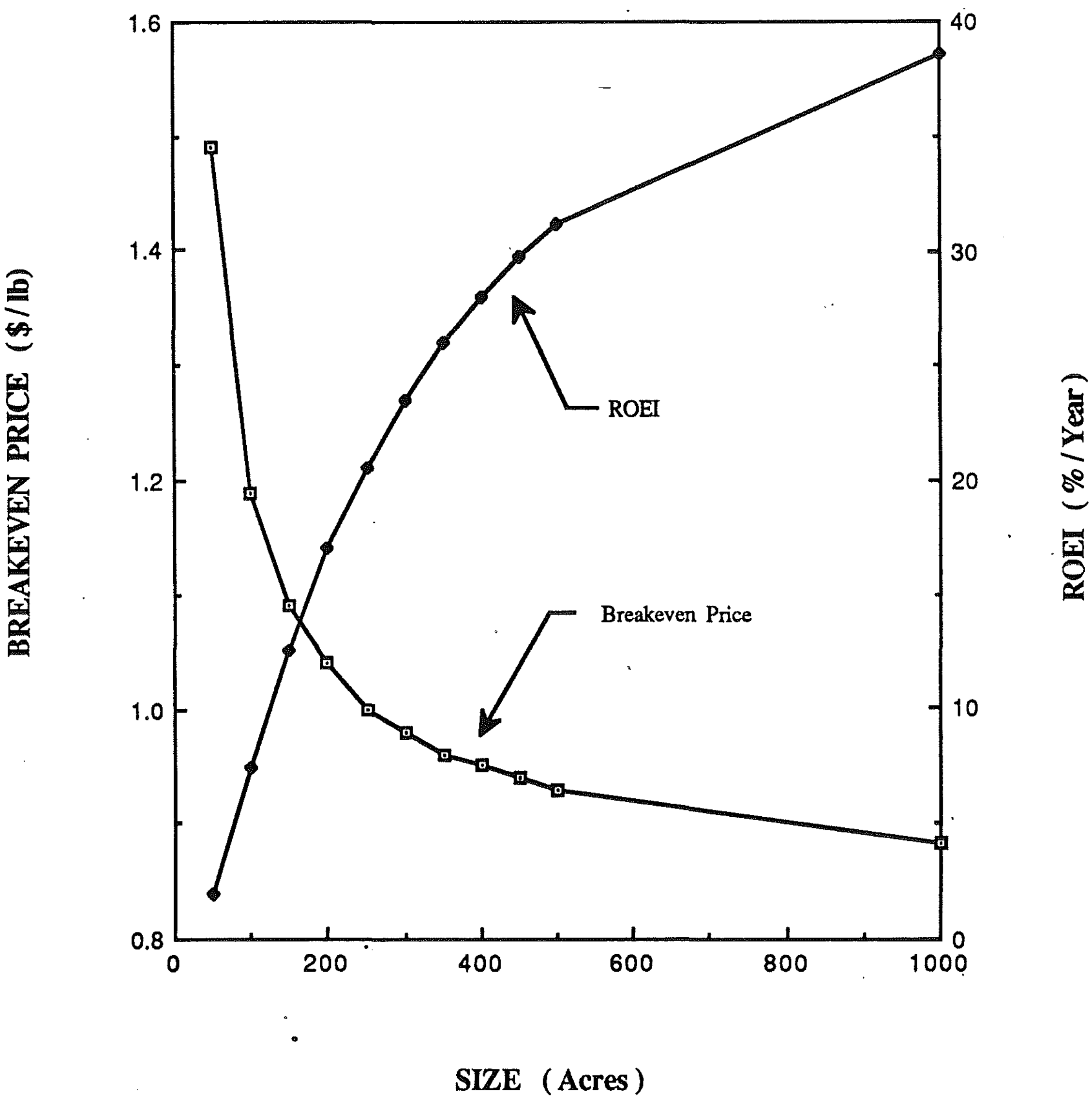

Figure 12 Breakeven Price and Return on Equity Investment (ROEI) for Extensive Minnow Culture (Selling Price = $1.25/lb)

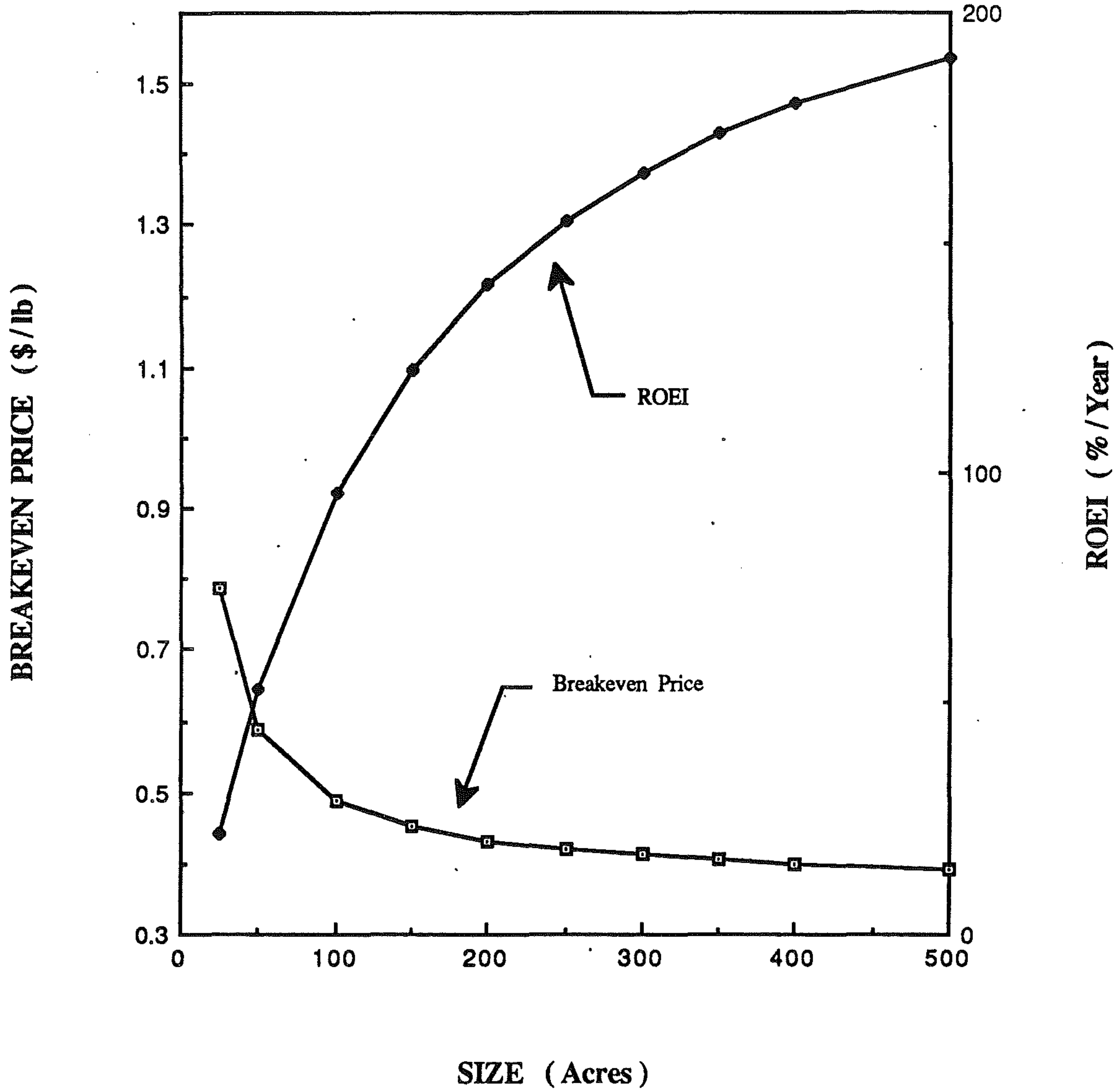

Figure 13 Breakeven Price and Return on Equity Investment (ROEI) for Fertilized Minnow Culture (Selling Price = $1.25/lb)

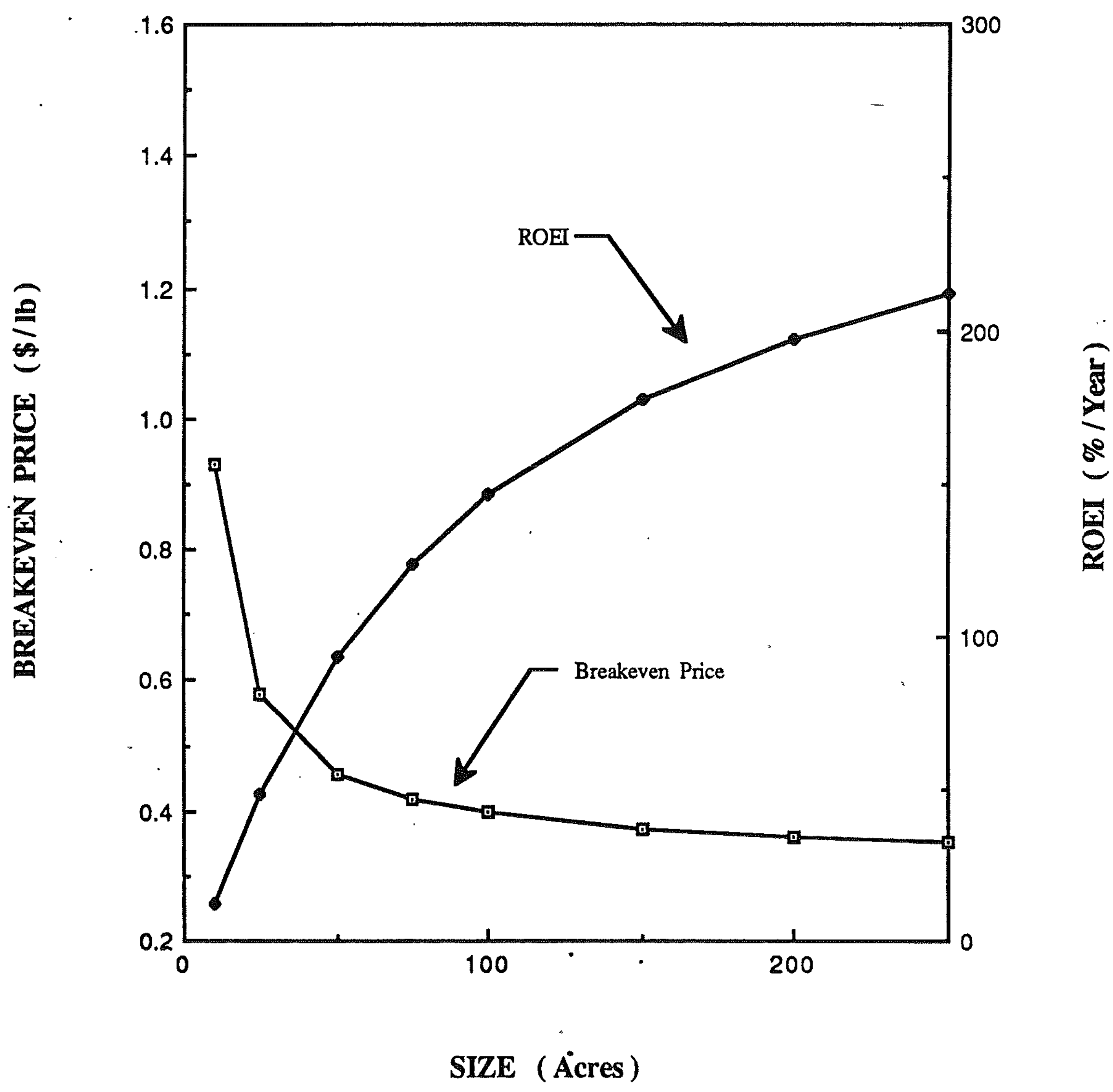

Figure 14 Breakeven Price and Return on Equity Investment (ROEI) for Intensive Minnow Culture (Selling Price = $1.25/lb)

Table 9 Extensive Minnow Culture - -200 acres

Brood Stock Price	$2.00	
Sale Price	$1.25	
Harvest Density	100	lbs./acre
Acres	200	
Acre Rental	$5.00	
Fert./Feed	$0.00	per acre

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
CAPITAL COSTS										
transport tank	3000									
boat	1500					1950				
nets	3000			3450			3967			456
holding tanks	3000									
miscellaneous	500	525	551	.579	608	638	670	704	739	77
TOTAL CAPITAL COST	11000	525	551	4029	608	2588	4638	704	739	533
VARIABLE COSTS										
Brood Stock Purchase	400	420	441	463	486	511	536	563	591	62
Utilities/Fuel	1000	1050	1103	1158	1216	1276	1340	1407	1477	155
Labor	2000	2100	2205	2315	2431	2553	2680	2814	2955	310
Transportation	2000	2100	2205	2315	2431	2553	2680	2814	2955	310
Fert./Feed	0	0	0	0	0	0	0	0	0	
Traps	8000	8400	8820	9261	9724	10210	10721	11257	11820	1241
TOTAL VARIABLE	13400	14070	14774	15512	16288	17102	17957	18855	19798	2078
Invest. Required	0	0	0	0	0	0	0	0	0	112
Annual Finance	0	0	0	0	0	0	0	0	0	
TOTAL COSTS	24400	14595	15325	19541	16896	19690	22595	19559	20537	2612
TOTAL REVENUES	25000	25000	25000	25000	25000	25000	25000	25000	25000	2500
NET REVENUE	600	10405	9675	5459	8104	5310	2405	5441	4463	-112
TAXATION										
Income Tax	120	2081	1935	1092	1621	1062	481	1088	893	
AFTER TAX REVENUE	480	8324	7740	4367	6484	4248	1924	4353	3571	-112
ROEI (%)	17.0									

Table 10 Minnow Culture (Fertilized) - 50 Acres

Brood Stock Price	$2.00	
Sale Price	$1.25	
Harvest Density	300	lbs./acre
Acres	50	
Acre Rental	$5.00	
Fert./Feed	$20.00	per acre

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
CAPITAL COSTS										
transport tank	3000									
boat	1500					1950				
nets	3000			3450			3967			456
holding tanks	3000									
miscellaneous	500	525	551	579	608	638	670	704	739	77
TOTAL CAPITAL COST	11000	525	551	4029	608	2588	4638	704	739	533
VARIABLE COSTS										
Brood Stock Purchase	100	105	110	116	122	128	134	141	148	15
Utilities/Fuel	250	263	276	289	304	319	335	352	369	38
Labor	500	525	551	579	608	638	670	704	739	77
Transportation	500	525	551	579	608	638	670	704	739	77
Fert./Feed	1000	1050	1103	1158	1216	1276	1340	1407	1477	155
Traps	2000	2100	2205	2315	2431	2553	2680	2814	2955	310
TOTAL VARIABLE	4350	4568	4796	5036	5287	5552	5829	6121	6427	674
Invest. Required	0	0	0	0	0	0	0	0	0	
Annual Finance	0	0	0	0	0	0	0	0	0	
TOTAL COSTS	15350	5093	5347	9064	5895	8140	10467	6824	7166	1208
TOTAL REVENUES	18750	18750	18750	18750	18750	18750	18750	18750	18750	1875
NET REVENUE	3400	13658	13403	9686	12855	10610	8283	11926	11584	666
TAXATION										
Income Tax	680	2732	2681	1937	2571	2122	1657	2385	2317	133
AFTER TAX REVENUE	2720	10926	10722	7748	10284	8488	6626	9540	9267	533
ROEI (%)	53.2									

Table 11 Intensive Minnow Culture (Fed) - 25 Acres

Brood Stock Price	$2.00
Sale Price	$1.25
Harvest Density	500 lbs./acre
Acres	25
Acre Rental	$5.00
Fert./Feed	$60.00 per acre

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
CAPITAL COSTS										
transport tank	3000									
boat	1500					1950				
nets	3000			3450			3967			456
holding tanks	3000									
miscellaneous	500	525	551	579	608	638	670	704	739	77
TOTAL CAPITAL COST	11000	525	551	4029	608	2588	4638	704	739	533
VARIABLE COSTS										
Brood Stock Purchase	50	53	55	58	61	64	67	70	74	7
Utilities/Fuel	125	131	138	145	152	160	168	176	185	19
Labor	250	263	276	289	304	319	335	352	369	38
Transportation	250	263	276	289	304	319	335	352	369	38
Fert./Feed	1500	1575	1654	1736	1823	1914	2010	2111	2216	232
Traps	1000	1050	1103	1158	1216	1276	1340	1407	1477	155
TOTAL VARIABLE	3175	3334	3500	3675	3859	4052	4255	4468	4691	492
Invest. Required	0	0	0	0	0	0	0	0	0	
Annual Finance	0	0	0	0	0	0	0	0	0	
TOTAL COSTS	14175	3859	4052	7704	4467	6640	8892	5171	5430	1026
TOTAL REVENUES	15625	15625	15625	15625	15625	15625	15625	15625	15625	1562
NET REVENUE	1450	11766	11573	7921	11158	8985	6733	10454	10195	536
TAXATION										
Income Tax	290	2353	2315	1584	2232	1797	1347	2091	2039	107
AFTER TAX REVENUE	1160	9413	9259	6337	8926	7188	5386	8363	8156	428
ROEI (%)	48.3									

VI. THE FUTURE POTENTIAL OF AQUACULTURE IN MINNESOTA

Intensive Culture

The study to this point has focused on the development of models to project the costs associated with various hypothetical aquaculture operations. Now, it is important to put the models to use and determine the overall potential of aquaculture in Minnesota.

Salmonid Cage Culture

In terms of economic viability, the indicators derived from the cost of production projections as a function of price, size, species, and breakeven prices, showed salmonid culture to have merit. However, as the biological potential of the Iron Range to sustain commercial production is presently untested, the actual potential of the area should be viewed as tentative.

Shaw and Rana (1985) estimated that the world-wide market for farm raised salmon was 75,000 metric tonnes in 1987, increasing to 87,500 metric tonnes in 1990. Considering the high level of demand for fresh farmed salmon, it is apparent that an estimated production of 2,900 metric tonnes in the state of Minnesota would easily find a place in the national market.

Assuming that quality control and grading standards are of the highest caliber, there is sufficient literature to suggest that this product will receive the same high prices as in Norway, British Columbia, and other salmon farming areas.

Examination of the cost of production models for salmonids indicates that two species which show the best promise are Atlantic salmon and Arctic charr.

Due to present restrictions on importation of potentially diseased Pacific salmon stocks, it is unlikely that land-locked stocks of chinook will be able to sustain a salmon farming industry in the state for a number of years to come. However, if importation conditions change, chinooks should be considered as a major culture species.

A system where multi-species are grown would provide the best operational plan. Atlantics and chinooks, grown in conjunction with steelhead or charr would provide some protection against price fluctuations of individual species, plus providing cash flows early in the start-up period. Atlantics and chinooks should, however, be considered as the primary market species because of their historical high level of consumer demand. The market for both these species is strong and should continue this way for the near future. Charr, while garnering a high price in the market, may require extensive price reduction if significant volumes are going to be sold.

The culture of these salmon and trout is economically viable, though the return on equity investment is considerably lower than one might expect from a high risk industry such as fish farming. This lower ROEI may be due to conservative assumptions used in the economic analysis; all costs were increased by 5%/year, while revenues remained constant.

The recommendation to utilize Atlantic salmon goes beyond the potential for high market prices. Minnesota's location places the product closer to the traditional markets to which Atlantic salmon has always been popular. To the well initiated Easterner "a Chinook is fine but an Atlantic is always finer". This traditional bias, plus the potential availability of eggs and smolt from sources within the state, make it economically attractive. It must be stated, however, that for the inexperienced fish farmer this species does present some difficulties in culturing, as it is far more difficult to grow than either rainbows or chinooks.

Of the four species, the culture potential of the Arctic charr is the least known. The present price, the rates of growth, apparent ease of culturing, and positive cost of production make it an attractive prospect. However, the availability of eggs or broodstock could be considered a negative factor. Most of the available domesticated broodstock are in Canada with much of that production spoken for. A potential source for eggs could be a Norwegian supply but, at the time of this writing, it could not be confirmed whether or not they were certified disease free.

A second potential negative factor in the culture of Arctic charr could be the relative lack of familiarity with the product in the U.S. In order for it to demand the high prices it now receives, due primarily to very low supply, an aggressive marketing campaign will likely be required if large volumes of the fish are to be produced by intensive culture. In Norway and British Columbia marketing programs have been funded by growers agencies with promotional assistance from provincial/state agencies. The programs usually involve some level of government assistance at trade shows and seminars, development of promotional literature, and visits to target markets. One factor which is likely to be a very positive influence on a promotional campaign for Arctic charr are recent newspaper reports citing the American Medical Association's support for the charr's low fat, low cholesterol, and high iron content.

Of the seventy plus mine iron pits which are now abandoned and potentially available for aquaculture development, discussion with some Minnesota respondents suggest that approximately one quarter (18 - 20) could meet all the criteria for successful salmon farming. Projecting further, it is unlikely that adequate private funding could be made available in the short term to support more than approximately one half that number (9 - 10). Therefore, the study team estimates that few more than this will be active in the next five years. Based on an average production size of 350 tons, annual production by 1994 is conservatively estimated to be approximately 3150 tons. In 10 years (1997), the full 18 -20 potential sites could have operating farms located in them.

<u>Hatchery/Smolt Production</u>

Assuming that intensive aquaculture does become a reality in Minnesota, history may be repeated. In every northern hemisphere location where salmon farming has started up, the major impediment to industry growth, next to lack of investment capital, has been an acute shortage of healthy eggs and smolt. In each case where the industry had a large availability of suitable sites, the number of farm start ups far exceeded the initial capability of hatcheries to keep up with the demand. Though it is unlikely that this same scenario will be as severe in Minnesota, it must be considered.

Based on the projections for the number of growout facilities listed in the previous section, at a minimum, one 4 million smolt production facility will be required immediately with the potential for a second operation after four years. Considering the ideal central location of the state and the presence of some disease free stocks of both Atlantic and Pacific species in the Great Lakes region, Minnesota could develop an egg and smolt distribution network.

However, before the mine pit sites can be seriously considered for hatchery sites, the impact of soluble iron on egg and larval development must be determined. Of particular importance were comments made by the B.C. Salmon Farmers Association who have been conducting experiments on the impact of iron on broodstock and egg development. Judging from the pH and dissolved oxygen concentrations in the iron pits, the solubility of iron should be low enough to not be a problem. Though facilities located near the pits would have relatively high utility costs, the cost of production models indicte that such facilities could be viable.

Extensive Culture

Paddlefish Culture

The fact that paddlefish culture looks reasonably attractive should not be overshadowed by the fact that at the present time there is only one area where this type culture is possible: the Red Lake Indian Reservation. The surface area of this lake is approximately 400,000 acres. Given that as few as a 1,000 acres can provide attractive cash returns, this option shows much promise. If as few as 20,000 acres were utilized, annual profits would be in excess of $300,000. Since there are no commercial sources of paddlefish fry in Minnesota, fry would have to be imported.

Assuming a 10 % conversion between zooplankton and paddlefish, 10 lb of zooplankton is required to grow 1 lb of paddlefish. This same 10 lb of zooplankton would produce 1 lb of minnows and only 0.1 lb of walleyes. Therefore, a harvest density of 30 lb/acre/year of paddlefish represents a loss of only 3 lb/acre/year of walleye. Assuming a productivity of 30 lb/acre/year of walleye, the harvest of 30 lb of paddlefish could reduce walleye productivity by 10 %. This analysis may not be valid for fry and fingerling walleye that feed directly on zooplankton. In that case, the paddlefish growth could reduce walleye growth on a 1:1 ratio. The impact of paddlefish on the growth of other important larval and juvenile fish (i.e, walleye, Northern pike, and Musky) must be determined experimentally prior to the start of any widespread stocking program.

Sturgeon Culture

The extensive culture of sturgeon holds the same limited promise as that offered by a paddlefish operation, again due primarily to the lack of available water area. The extensive culture of sturgeon is, also, limited to the Red Lake Indian Reservation. While the profitability of this type of operation is not staggering, it could offer significant employment during harvesting. Using the same reasoning given for paddlefish, a potential harvest density of 15 lb/acre/year could reduce walleye productivity by 5 %. Just like with paddlefish, the actual impact of stocking of sturgeon must be experimentally determined prior to the start of any wide-spread stocking program.

Minnow Culture

The culture of minnows, either as a fisheries or aquaculture enterprise, has excellent potential to supplement rural income. Minnows are easier and cheaper to raise than other species, especially if the land is already owned. If intensive culture methods are used, a viable operation could require as little as 25 acres. On a family owned farm, most if not all of the labor could be supplied by the owner, family, or close neighbors. It was anticipated that this labor would be provided during slack periods in the farming schedule. One possible impediment to further development of the minnow industry, in addition to availability of water sources, could be resistance from established harvesters. There appears to be a good market potential for minnows, though any further entry of new participants will necessitate development and implementation of defined marketing and transportation networks. Again, this would likely be provided initially by state or university extension personnel, and later, handled by an unified grower association.

Projected Production Levels and Employment Potential

The overall impact of aquaculture on revenues and employment are presented in Table 12 for all the various components discussed in this section. Using production levels for each operation type which were considered representative and an estimate of the number of facilities that can be supported, the total impact of each type of aquaculture venture was estimated. Detailed criteria and assumptions used in Table 12 are listed below:

<u>Intensive Culture</u>

Cage Culture. It is assumed that one farm goes into production in year 1, producing 350 tons/year by year 3. Two additional farms achieve full production during years 4, 5, and 6. The total number of farms is 9. Revenues are based on an average projected price of $2.60/lb from all salmonids with a yearly production of 350 tons/year per farm. Personnel requirements are estimated at 5 full-time employees for each farm. Total personnel requirements for the 9 farms is, therefore, 45.

Hatcheries. It is assumed that 1 hatchery goes into production during year 1, producing 4 million smolt/year during year 3. Manpower requirements are estimated at 3 full-time employees/hatchery. One additional hatchery would achieve full

Table 12 A Eight Year Projection of Economic Benefits from an Aquaculture Industry (Based on Present Regulations)

Type/Component	Year					
	3	4	5	6	7	8
Cage Culture						
Production (tons)	350	1050	1750	2450	3150	3150
Revenues (million $)	1.8	5.4	9.0	12.6	16.2	16.2
Labor (years)	5	15	25	35	45	45
Hatchery						
Production (million)	3	6	9	12	12	12
Revenues (million $)	1.6	3.2	4.8	6.4	6.4	6.4
Labor (years)	4	8	12	16	16	16
Paddlefish						
Production (tons)			300	300	300	300
Revenues (million $)			1.2	1.2	1.2	1.2
Labor (years)	0.5	0.5	2	2	2	2
Sturgeon						
Production (tons)				150	150	150
Revenues (million $)				0.8	0.8	0.8
Labor (years)	0.5	0.5	0.5	2	2	2
Minnows						
Production (tons)	150	300	450	450	450	450
Revenues (million $)	0.4	0.8	1.2	1.2	1.2	1.2
Labor (years)	5	10	15	15	15	15
Processing						
Production (tons)	350	1050	2050	2900	3600	3600
Revenues (million $)	0.3	0.9	1.6	2.3	2.8	2.8
Labor (years)	4	11	21	29	36	36
Equipment Manufacturing						
Revenues (million $)	0.4	0.9	3.0	5.0	5.0	5.0
Labor (years)	5	5	14	20	20	20
Marketing						
Revenues (million $)	0.04	0.04	0.04	0.08	0.10	0.10
Labor (years)	1	1	1	2	2.5	2.5
Fish Health						
Revenues (million $)	0.04	0.10	0.16	0.22	0.26	0.26
Labor (years)	1	2	3	4	5	5
Extension/Education						
Labor (years)	3	3	5	5	7	7

Table 12 (continued)

Type/Component	Year					
	3	4	5	6	7	8
Total Annual Revenues (million $)	4.6	11.3	21.0	29.8	34.0	34.0
Total Annual Labor (years)	29.0	56.0	98.5	130.0	150.5	150.5

Total Cumulative Revenue (Years 3 - 8) = 134.7 million dollars

Total Cumulative Labor (Years 3 - 8) = 614.5 years

production in years 5, 6, and 7, respectively, for a total of 4 hatcheries. It was assumed that any excess production beyond Minnesota's demand was sold out-of-state.

Extensive Culture

Paddlefish. It is assumed that stocking is started at year 1 and four years are required for growout. Therefore the first harvest will occur during year 5. Little labor will be needed until harvesting starts. The production area is assumed to be 20,000 acres at a production of 30 lb/acre/year, and a selling price of 2.00/lb.

Sturgeon. As with paddlefish, stocking is started during year 1 and harvest begins at year 6. The production area is assumed to be 20,000 acres at a production of 15 lb/acre/year, and a selling price of $2.55.

Minnows. Based on a production of 300 lb/acre, it is assumed that 1,000 acres reach full production in year 3, with an additional 1,000 acres in year 4 and 5. A selling price of $1.25/lb is used. A labor requirement of 5 person years per 1,000 acres is used.

Processing

The processing component of revenues and manpower requirements were computed using a cost of $0.39/lb, labor requirements of 1000 lb of production per day/person, and a 200 day working year. The processing volume in years 5 and 6 includes the additional production provided by paddlefish and sturgeon harvest.

Equipment Manufacturing

This component assumes that net pens, bleeding stations, and auxiliary equipment used in the fish farming and extensive aquaculture industries would be manufactured in Minnesota.

Marketing

It is assumed that initially one person will be employed in marketing, increasing to 2.5 persons in year 7.

Fish Health

This employment area will be required for diagnostic and preventative health care for the farmed fish. This position would probably be filled by an aquatic veterinarian ($50,000/year). It was assumed that the annual revenues from each pen system and hatchery was $20,000/year.

Extension/Education

This area will initially require 2 persons directly involved in farm design, operation, and market development at the extension level. One additional person will be needed during years 5 and 7. In the latter years of industry development, there will be a strong need at the college and university level to provide training in fish culture and marketing. It is assumed that 3 people will be needed (years 3, 5, and 7) to effectively train workers and farm managers.

Total Impact

At the end of 8 years, direct revenue from aquaculture is estimated to approach $34 million per annum. Cumulative revenue for the eight year period would be approximately $132 million for a commercial aquaculture industry operating under present regulatory conditions.

As a consequence of adhering to instruction 1 in the Introduction of this report, the findings of Phase II do not reflect the "actual" potential for aquaculture in the State of Minnesota, rather the aquaculture potential if no change to water use regulations are implemented within the State. Present water use regulations, restrict aquaculture development to only a fraction of the water resources which meet biological and economic criteria for intensive and extensive aquaculture.

VII. RECOMMENDATIONS AND CONCLUSIONS

Economic analysis presented in this report estimated that aquaculture in Minnesota can directly contribute up to $34.0 million in revenue within 8 years and up to 150.5 person years of employment. This includes production of bait and food fish, processing, and support industries.

Aquaculture development in most northern hemisphere regions has advanced due to involvement of government agencies from the onset. Traditionally, this involvement has come in the form of commercial oriented research, brood stock development, educational programs for aquaculture workers and management, and in the case of Norway, financial assistance.

Due to the relatively cold climate in Minnesota, the development of aquaculture will likely be more risky than in established areas such as British Columbia and Norway. Based on projections completed in Phase II of this study, salmon farming may be considered the most attractive from economic and marketing aspects. However, from the financial and investment standpoint, bank loans and investment capital may be difficult to obtain until one or two sites have been proven to be successful. Therefore, in order to ensure a rapid development of aquaculture in the iron range, some type of state loan or loan guarantee may be needed. The potential salmonid production in Minnesota is relatively small compared to the world-wide farmed fish production. Therefore, this increased production should not have a significant impact on the market price of these species. There will be a need for market development, product development, and crop insurance in the early phases of the industry. These functions may not be adequately supported by a developing industry, and it is likely that the state may have to initially undertake responsibility for these functions.

For the minnows, some type of pilot-scale rearing studies may be needed to clearly demonstrate economic viability. While the minnow industry is the largest aquatic rearing industry in Minnesota, little information is available on characteristics and economic returns of this industry. Additional research on this industry may be highly useful in planning and directing further expansion. This type of pilot project may not require major expenditure of money, but may require significant personnel time for monitoring and coordination.

Since both the paddlefish and sturgeon culture is currently limited to a single closed Indian Reservation, there is probably little the state can offer except general encouragement.

Another area where the state government can greatly assist the development of aquaculture is by making aquaculture development a recognized and significant part of future economic development. This could include the delegation of a particular department to act as a lead agency and assist in changes to regulations which will assist aquaculture while still protecting valuable water resources. As an example, the Ministry of Agriculture in British Columbia has taken on the responsibilities for commercial aquaculture. One major accomplishment of that agency was to fund the development of the B.C. Salmon Farmers' Association.

Based on the economic analysis performed in this report, the investment needed and return on equity investment for the operations considered were:

Species/ Operation	Total Investment Required (millon $)	Return on Equity Invested (%)
Chinook Salmon	2.0	26
Atlantic Salmon	1.6	35
Steelhead Trout	1.6	22
Charr	1.6	112
Hatchery Production of Smolts	0.8	19
Processing	0.2	82
Paddlefish	0.16	563
Sturgeon	0.30	160
Minnows - Base Case	0.04	17
Minnows - Fertilized	0.03	53
Minnows - Fed	0.03	48

Many of the desirable sites for aquaculture in Minnesota are unavailable for commercial development due to state and federal laws and policies. The development of commercial aquaculture may require some flexibility and regulatory change in the determination of available water resources. The present limitations represent a clear need for an in-depth and unbiased analysis of these regulations and their impact on aquaculture development. With appropriate regulatory control and monitoring, commercial aquaculture in Minnesota can develop in an environmentally responsible manner.

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Appendix A - Detailed Profitability Information

Table A-1 Breakeven Price, Required Investment, and Return on Equity Investment (ROEI) for Chinook Salmon (Selling Price = 2.60/lb)

Size (tons/year)	Breakeven Price ($/lb)	Investment[a] ($)	ROEI (%/year)
100	3.25	822,935	0.0
150	2.72	682,428	3.1
200	2.46	706,516	9.3
250	2.30	774,215	15.6
300	2.20	841,913	21.3
350	2.12	909,612	26.1
400	2.07	977,311	30.3
450	2.03	1,045,009	33.9
500	1.99	1,112,708	37.1
1000	1.83	1,789,695	55.7

[a] Required private investment, based on 50% of the total investment needed.

Table A-2 Breakeven Price, Required Investment, and Return on Equity Investment (ROEI) for Atlantic Salmon (Selling Price = $2.70/lb)

Size (tons/year)	Breakeven Price ($/lb)	Investment[a] ($)	ROEI (%/year)
100	3.23	757,479	0.1
150	2.70	612,381	5.5
200	2.44	656,816	13.6
250	2.29	712,090	21.7
300	2.18	767,363	28.6
350	2.10	822,637	34.6
400	2.05	877,911	39.8
450	2.00	933,184	44.5
500	1.97	988,458	48.6
1000	1.81	1,541,195	73.4

[a] Required private investment, based on 50% of the total investment needed.

Table A-3 Breakeven Price, Required Investment, and Return on Equity Investment (ROEI) for Steelhead Trout (Selling Price = $2.10/lb)

Size (tons/year)	Breakeven Price ($/lb)	Investment[a] ($)	ROEI (%/year)
100	2.87	811,904	0.0
150	2.35	684,953	1.1
200	2.09	662,061	5.8
250	1.93	718,370	11.3
300	1.83	774,899	16.9
350	1.75	831,429	21.8
400	1.70	887,959	26.1
450	1.66	944,489	29.8
500	1.62	1,001,018	33.2
1000	1.47	1,566,316	53.3

[a] Required private investment, based on 50% of the total investment needed.

Table A-4 Breakeven Price, Required Investment, and Return on Equity Investment (ROEI) for Arctic Charr (Selling Price = $3.50/lb)

Size (tons/year)	Breakeven Price ($/lb)	Investment[a] ($)	ROEI (%/year)
100	3.22	493,144	15.6
150	2.70	537,541	43.8
200	2.44	581,938	67.5
250	2.29	633,982	86.6
300	2.18	699,203	100.7
350	2.12	764,424	112.4
400	2.06	829,645	122.2
450	2.02	894,866	130.6
500	2.98	960,008	137.9
1000	1.83	1,612,299	178.1

[a] Required private investment, based on 50% of the total investment needed.

Table A-5 Breakeven Price, Required Investment, and Return on Equity Investment (ROEI) for Smolt Production (Selling Price = $0.40/smolt)

Size (million/year)	Breakeven Price ($/lb)	Investment[a] ($)	ROEI (%/year)
0.5	0.54	260,515	2.0
1.0	0.39	274,542	5.8
2.0	0.32	327,403	11.5
3.0	0.30	380,265	15.5
4.0	0.29	433,126	18.6
5.0	0.28	485,988	21.0
10.0	0.28	750,296	28.0

[a] Required private investment, based on 50% of the total investment needed.

Table A-6 Breakeven Price, Required Investment, and Return on Equity Investment (ROEI) Processing (Processing Charge = $0.39/lb)

Size (lb/day)	Breakeven Price ($/lb)	Investment[a] ($)	ROEI (%/year)
5,000	0.39	224,844	6.1
10,000	0.36	187,147	25.2
15,000	0.35	159,851	50.7
20,000	0.34	142,855	81.6
25,000	0.34	146,551	105.2
30,000	0.34	150,665	129.0

[a] Required private investment, based on 50% of the total investment needed.

Table A-7 Breakeven Price, Required Investment, and Return on Equity Investment (ROEI) for Extensive Paddlefish Culture (Selling Price = $2.00/lb)

Size (tons/year)	Breakeven Price ($/lb)	Investment[a] ($)	ROEI (%/year)
100	1.97	16,862	5.9
200	1.07	14,375	28.4
300	0.77	11,868	60.4
400	0.62	9,361	109.7
500	0.53	7,107	187.7
1,000	0.35	9,928	301.0
2,000	0.26	15,572	404.9
3,000	0.23	21,215	453.5
4,000	0.21	26,858	481.7
5,000	0.20	32,501	500.1
10,000	0.18	60,718	540.8
20,000	0.18	117,150	563.4
200,000	0.17	1,132,938	585.2

[a] Required private investment, based on 50% of the total investment needed.

Table A-8 Breakeven Price, Required Investment, and Return on Equity Investment (ROEI) for Extensive Sturgeon Culture (Selling Price = $2.55/lb)

Size (tons/year)	Breakeven Price ($/lb)	Investment[a] ($)	ROEI (%/year)
100	4.17	18,972	0.3
200	2.36	18,554	7.3
300	1.77	18,136	17.0
400	1.47	17,719	27.1
500	1.29	17,301	37.8
1,000	0.93	15,421	98.2
2,000	0.75	26,558	125.4
3,000	0.68	37,694	136.8
4,000	0.65	48,830	143.1
5,000	0.64	59,966	147.0
10,000	0.60	115,648	155.3
20,000	0.58	227,010	159.7
200,000	0.57	2,231,536	163.8

[a] Required private investment, based on 50% of the total investment needed.

Table A-9 Breakeven Price, Required Investment, and Return on Equity Investment (ROEI) for Minnow Culture (Base Case) (Selling Price = $1.25/lb)

Size (tons/year)	Breakeven Price ($/lb)	Investment[a] ($)	ROEI (%/year)
50	1.49	14,981	2.0
100	1.19	18,105	7.4
150	1.09	21,229	12.6
200	1.04	24,400	17.0
250	1.00	27,750	20.5
300	0.98	31,100	23.5
350	0.96	34,450	26.0
400	0.95	37,800	28.0
450	0.94	41,150	29.7
500	0.93	44,500	31.1
1,000	0.88	78,000	38.6

[a] Required private investment, based on the total expenses for the first year.

Table A-10 Breakeven Price, Required Investment, and Return on Equity Investment (ROEI) for Minnow Culture (Fertilized Case) (Selling Price = $1.25/lb)

Size (tons/year)	Breakeven Price ($/lb)	Investment[a] ($)	ROEI (%/year)
25	0.79	13,471	21.9
50	0.59	15,350	53.2
100	0.49	19,700	95.4
150	0.45	24,050	122.3
200	0.43	28,400	141.0
250	0.42	32,750	154.7
300	0.41	37,100	165.2
350	0.41	41,450	173.5
400	0.40	45,800	180.2
500	0.39	54,500	190.4

[a] Required private investment, based on the total expenses for the first year.

Table A-11 Breakeven Price, Required Investment, and Return on Equity Investment (ROEI) for Minnow Culture (Fed Case) (Selling Price = $1.25/lb)

Size (tons/year)	Breakeven Price ($/lb)	Investment[a] ($)	ROEI (%/year)
10	0.93	12,739	12.4
25	0.58	14,175	48.3
50	0.46	17,350	93.1
75	0.42	20,525	124.0
100	0.40	23,700	146.7
150	0.37	30,050	177.6
200	0.36	36,400	197.8
250	0.35	42,750	211.9

[a] Required private investment, based on the total expenses for the first year.

Appendix B - People and Agency Contact List

Table B-1 List of People and Agencies Contacted

Ian Angus, Sedwick Tomenson Inc., Aquaculture Insurance, Vancouver, British Columbia

Gary Arnold, Mariculture Products, Waterville, Maine
(207) 872-0664

Patty Burke, State Planning Agency, St. Paul, Minnesota
(612) 296-2888

Bruce Cady, Peterson Trout Farm, Peterson, Minnesota
(507) 875-2216

Jim Caufield, J. D. Caufield, Inc., Portland, Oregon
(503) 223-2764

Ken Beer, The Fisheries, Galt, California
(916) 687-7475

Roy Billing, Ministry of Environment, British Columbia
(604) 746-1425

Fred Binkowski, University of Wisconsin, Milwaukee, Wisconsin
(414) 227-3292

Michael Coon, Ministry of Agriculture and Fisheries, Victoria, British Columbia

Dennis Cork, Freshwater Fish Marketing Corp., Winnipeg, Manitoba

Sergei Doroshov, University of California, Davis, California
(916) 752-7603

Brian Egan, ScanTech Resources Ltd., Sechelt, British Columbia
(604) 885-7107

Steve Frank, WJF International, St. Paul, Minnesota
(612) 541-4700

Ron Gowan, Anadromous, Coos Bay, Oregon (503) 756-0465

Dave Holmbeck, Department of Natural Resources, Grand Rapids, Minnesota (218) 327-4430

Tom Hyland, Kemp Foods, Duluth, Minnesota (218) 728-4425

Jim Kahrs, Osage Catfish, Osage Beach, Missouri
(314) 348-2305

Terry Kayes, University of Wisconsin, Madison, Wisconsin
(608) 263-1242

Anne Kapaucinski, University of Minnesota, St. Paul, Minnesota
(612) 624-2720

Chuck Lepper, Ice Box Fisheries, International Falls, Minnesota (218) 283-3951

Ann Levi-Lloyd, Aqua Can Enterprises, Port Coquitlam, British Columbia

Michael McDonald, University of Minnesota, Duluth, Minnesota (218) 720-4264

William McKay, Ontario Sockeye Salmon Growers, Ontario (416) 781-7908

Carol Millar, Billingsgate Fish Market, Calgary, Alberta

Donald Millard, Great Northern Packers, North Vancouver, British Columbia

Ross Murray, Envirocon Pacific Smolt Farms, Burnaby, British Colombia

Robert Nelles, B.C. Salmon Farmers' Association, West Vancouver, British Columbia.

Mike Papst, Fresh Water Institute, Manitoba (204) 983-5211

Ron Parceval, Quadra Smolt Ltd., Quasiaski Cove, British Columbia (285) 326-3611

Dick Piefer, Morey Fish Company, Morey, Minnesota (218) 352-6345

George Reed, Ministry of Environment, British Columbia (604) 758-3951

Harry Rosefelt, Minnesota Department of Trade and Economic Development, St. Paul, Minnesota (612) 296-5010

Ray Svatos, IRRRB, Eveleth, Minnesota (218) 744-2993

James Taylor, Lynwood Acres Trout Farm, Ontario (416) 797-2484

Jack Wingate, Minnesota Department of Natural Resources, St. Paul, Minnesota (612) 296-0793