SMALL-SCALE ARCTIC CHARR PRODUCTION IN MAN-MADE PRAIRIE PONDS

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ABSTRACT

Arctic charr, Salvelinus alpinus L., has become more popular in recent years as a common food source for many Canadians. Although charr aquaculture is relatively new in Canada, intensive culturing of market-size charr (≥200 g) in tanks and raceways has been implemented with success.

The purpose of this practicum was to investigate the biological and economic feasibility of rearing pan-size, Arctic charr in man-made, prairie ponds as an income supplement for individuals living in rural communities. The biological assessment provided data on growth and survival of charr, in two ponds located at Garson, Manitoba, over two production cycles (May to October). Changes in water quality were also investigated. The economic assessment introduced a model which provided information on the investment potential for small-scale, pond aquaculture. A financial statement (which included capital expenses and all cost components involved in the operation of one rearing pond and a hypothetical four-pond system over one production cycle) was formulated and break-even analysis was applied to various pond culturing conditions (both observed and hypothetical). Financial ratios and investment analysis were also used to determine the overall financial performance.

At the end of each production period (in both years), the majority of charr harvested from pond A reached market size. Charr harvested from pond B (during the first year) did not attain target size and after overwintering in the same pond, continued to grow at a slow rate over 1.5 years. Large size variations were noticed among charr populations from both ponds.

Because of high water temperatures and ineffective predator control measures, low survival of charr in ponds A and B occurred in the first year. Improvements in pond operations and the culture method were made during the second year which increased survival. Because of reductions in algal populations, problems, such as deterioration of water quality, and evidence of muddy flavour in sampled fish from the first year, were not noticeable in the second year.

The financial statement indicated that the operation of one pond, with stocking densities of 1000 and 6000 charr, was not economically viable. The operation of a hypothetical four-pond rearing system produced a net profit ($2,000) and its break-even level of production was shown to be 1500 kg of market-size charr (32% recovery rate). Break-even analysis suggested that profits could be obtained at low recovery rates in this four-pond system despite high production costs ($22,000) as long as wholesale prices for charr remained high (between $8 to $11 per kg) and production costs did not increase substantially. Investment analysis showed that the operation's internal rate of return was 8% in the short term and approximately 25% in the long term indicating that this pond rearing system was economically feasible for part-time fish producers.

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CHAPTER 1

Introduction

1.1 Background

Aquaculture can be referred to as "man's attempt through inputs of labour and energy to improve the yield of useful aquatic organisms by deliberate manipulation of their rates of growth, mortality, and reproduction" (Reay, 1979). The culturing of fish fills an important role in the food and nutrition of many countries, and is particularly significant in integrated rural development. Subsistence-level or commercial-scale aquaculture can improve rural economies and often, under economic and social conditions prevailing in many rural areas, it can be more feasible to develop pond or lake culture operations instead of high cost, intensive tank or raceway culture (Pillay, 1973).

On a global scale, earth ponds (or plastic-lined ponds) are the most common holding facility (82% are fed by freshwater) and they are cheap and easy to construct if the ground is soft (Reay, 1979). However, major characteristics/differences, listed in Table 1, between intensive rearing of fish in tanks or raceways, semi-intensive, pond-rearing of fish outdoors, and extensive pond/lake culture shows that there are risks which must be carefully considered before developing an aquaculture business.

A recent trend has been to turn to aquaculture as a means of supplementing the production from commercial fishing and by meeting the demand for some of the highly-valued species. Arctic charr, Salvelinus alpinus L. is one species of fish that may be commercially cultured in Canada.

1.2 Problem Statement

Arctic charr is a coldwater fish species with limited information available on its commercial culture in Canada. Pilot experiments have shown that this species can be reared successfully to

Table 1

Major Differences Between Pond Culture vs. Intensive Tank or Raceway Culture for Salmonids (Bardach et al. 1972; Leitritz and Lewis, 1980; Stechey, 1990)

	Advantages	Disadvantages
Intensive Tank or Raceway Culture	- more control over feeding, disinfecting, water quality - low predation rate - can raise more fish per cu. m. of water due to high flushing/ exchange rates - fish densities > 15 kg/m^3	- labour intensive - reliance on artificial food - expensive (feed, generator, tanks) - high water flow rates required - high capital costs
Semi-Intensive Pond Culture	- natural food available - less stressful (more natural environment) - less labour involved - less expensive - fish densities 5-10 kg/m^3 - active exchange of water	- high predation rate - muddy flavour problems - less control - water quality problems (algae) - high water temperatures
Extensive Lake Culture	- natural food for growth - labour is minimized - fish densities <2 kg/m^3 - low capital costs	- high predation - summerkill possibilities - water exchange is minimal (passive) - low harvest percentage - muddy flavour

market size (200 + g) under intensive indoor culture conditions. However, no controlled studies, involving the culturing of this species in outdoor, artificial ponds, have been conducted. In addition, no information is available on the economic feasibility of outdoor charr culture operations.

1.3 Project Objectives

The purpose of this study was to conduct a biological and economic assessment of a small-scale pond culture operation (utilizing Arctic charr) over two production periods. Specific objectives of the above study were:

1) To determine growth and survival of Arctic charr in two prairie dug-out ponds.
2) To evaluate changes in water chemistry during the culture operations.
3) To assess costs and potential revenues from a small-scale pond culture operation.
4) To recommend strategies for the development of a small-scale Arctic charr production system which may be utilized as an income supplement for individuals in rural communities.

1.4 Justification

The establishment of a hatchery brood stock program at the Rockwood Fish Hatchery, located north of Winnipeg, has provided an incentive for the private sector to become involved in the commercial rearing of charr (to meet a growing market demand throughout Canada). Hathaway (1987) determined that producers would receive a top price of $11.03 /kg for fresh Arctic charr (≥200 g) and $ 8.82 /kg for frozen charr. It was also reported that fresh, cultured Arctic charr had good consumer acceptance in the Winnipeg area.

Generally, factors such as high production costs and foreign competition have provided barriers to development of the aquaculture industry in many Canadian provinces. Further progress and development of the industry will not take place until commercial aquaculture is profitable and yields a reasonable return on invested capital.

1.5 Limitations of the Study

1. In order to reduce handling stress and because of the difficulty in sampling fish (due to weather extremes and pond configurations), a minimal number of samples were taken. Therefore, estimates of growth rates could only be approximated.

2. Survival estimates of charr in year 2 were limited because of movement of some fish from one pond to another (pond overflowed its banks due to a plugged outlet).

3. Water quality data (oxygen, ammonia, secchi disc transparency, etc) were limited because of time constraints and difficulty in obtaining monitoring equipment.

4. Other biological and economic data (fish mortalities, estimates of heron predation, effects of pigmented food on flesh colour) were limited due to manpower, budget, and time constraints.

5. Maximum production from each pond was estimated (due to shortages of fish for initial stockings) and based on water quality criteria and past performance of trout under similar rearing conditions. As a result, potential revenue from each pond is an approximation.

6. Exchange rates of ponds were below optimum levels for salmonid rearing because of restricted flow rates due to low pump capacities.

1.6 Study Area

The practicum research was conducted over a two year period (two summers) approximately 35 km northeast of Winnipeg near Garson, Manitoba (Figure 1). Two rectangular, clay-bottomed, dug-outs (approximately 26 x 18 x 2.5 m and 53 x 15 x 2.8 m) were supplied with a limited amount (27 to 54 lpm) of pumped well water (5 to 7 C) which was aerated (Figure 2). Each rearing pond can be considered a flow-through system whereby water enters and leaves the pond through screened outlet pipes. Groundwater seepage into these ponds has provided additional flows during the early spring (water table in this area is unusually close to ground surface) however, this is only a temporary feature.

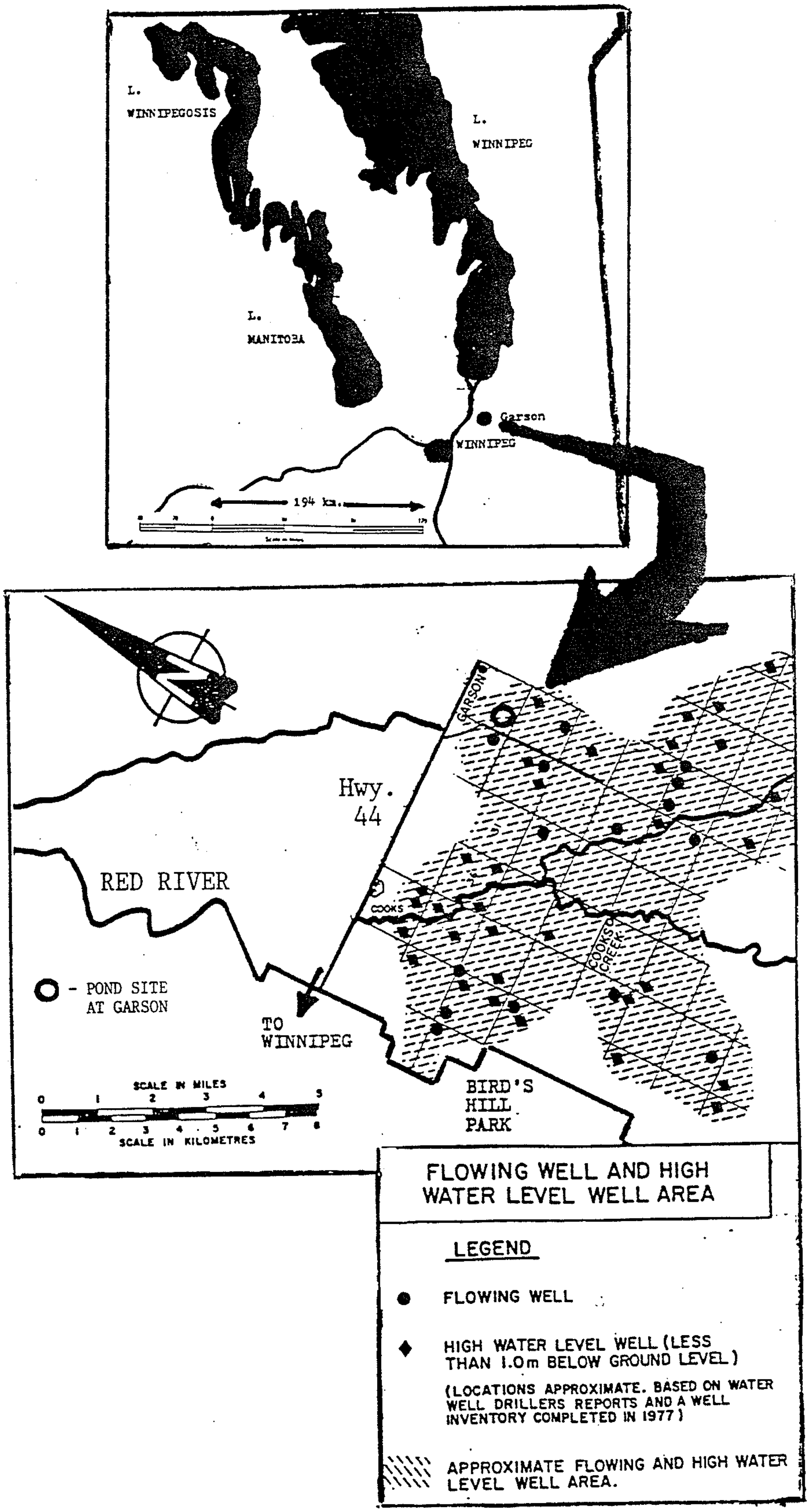
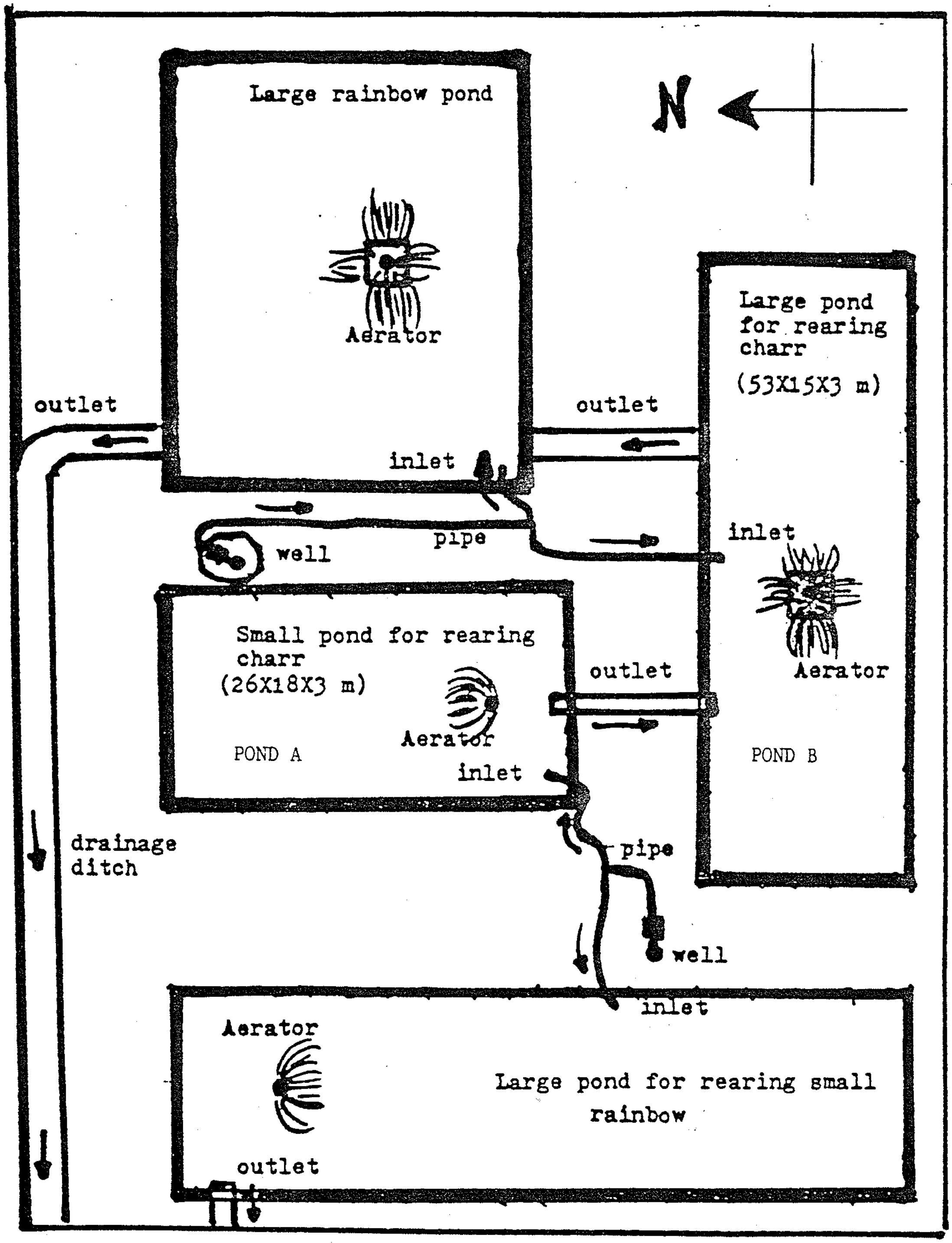


Figure 1: .. Location of Study Area in Southern Manitoba

Figure 2: Schematic Diagram of Pond Arrangement at Garson



Two additional, older dug-out ponds on site have been used successfully to rear fingerling rainbow trout and chinook salmon, and therefore, these new ponds (for rearing Arctic charr) may be considered as adequate rearing units for salmonids. A small assemblage of invertebrate fauna and rooted aquatic plants have been observed in both ponds.

CHAPTER 2

Review of Related Literature

2.1 Introduction

In the northern hemisphere, the Arctic charr has a circumpolar distribution and is frequently migratory, spending part of its life in the sea. Landlocked forms of this species are native to cold, deep mountain lakes of central Europe, northern Britain, and eastern parts of Canada and the United States. Within its range, Arctic charr has been of considerable economic importance (Johnson, 1980). During the last 20 years there has been a general decline in charr landings from commercial fishing in northern Canada, although public interest in this species as a food delicacy has increased (Iredale, 1984).

Freshwater culture of charr is managed in Norway and the U.S.S.R. and, in Iceland, charr have recently been reared at one government station and two private fish farms (MacCrimmon and Gots, 1980). In the U.S., the Sunapee charr, Salvelinus alpinus oquassa, a landlocked strain, is reared at state hatcheries in Maine and New Hampshire. However, very little culturing is being done in Canada with some charr being reared at one government hatchery at Fort Qu'Appelle, Saskatchewan (MacCrimmon and Gots, 1980). At present, private commercial culture of this species, in North America, is still in the experimental stages.

Arctic charr are naturally gregarious and, as noted by Johnson (1980), their social structures are not rigid, with territorial displays of young charr fry being limited to only a few dominant fish. Because Arctic charr are native to polar regions throughout the northern hemisphere, one would assume that this species is specifically adapted for living in very cold waters, however, Holeton (1973) could find no difference in the respiration rate of charr that would indicate a special adaptation. Weatherley (1976) reported that evolutionary adaptation can allow fish species that are adapted to polar regions, to grow rapidly under a wide variety of thermal conditions. McCart and Bain (1974), in studying a population of Arctic charr inhabiting a warm mineral spring, reported that this species thrived in water temperatures of 14 to 16 C, oxygen concentrations of 0.2 to 6.8 ppm, and levels of dissolved solids approaching 2600 ppm. McCauley (1958), investigating two stocks of European landlocked Arctic charr, found that the upper lethal temperature was lower (24 C) than has been observed for other salmonids.

2.2 Growth of Arctic Charr

Swift (1964), Gjedrem and Gunnes (1978), Wandsvik and Jobling (1982), Uraiwan (1982), Baker (1983), and Papst and Hopky (1983) studied growth of Arctic charr or rainbow trout, Oncorhynchus mykiss, under intensive conditions and at different water temperatures (Table 2). Optimum temperature for growth of charr was 10 to 16 C compared with 13 to 19 C for rainbow trout. Generally, maximum specific growth rates for Arctic charr were approximately 2.0 percent day^{-1} at 14 C and maximum rations. Maximum specific growth rates for rainbow trout were somewhat higher, 2.5 percent day^{-1} at 14 C and similar rations. Gjedrem and Gunnes (1978) grew charr (15 to 65 g) at a rate of 1.45 percent day^{-1} under farming conditions. Growth rates of Arctic charr, reported by Wandsvik and Jobling (1982) and Gjedrem and Gunnes (1978), were lower compared to growth rates recorded by both Uraiwan (1982) and Baker (1983).

Papst and Hopky (1984) reared charr in one year from 15 to 211 grams in indoor tanks at water temperatures ranging form 8 to 17.4 C. Gjedrem and Gunnes (1978) reared charr to 100 grams in one year at temperatures ranging from 10 to 15 C. Jobling (1982) also reported that Arctic charr increased in weight from 18 to 135 grams at 10 C over a period of six months.

Wandsvik and Jobling (1982) and Papst and Hopky (1983) observed a significant degree of variation in size and growth rates of Arctic charr which was attributed, in part, to precocious maturity among the smallest males. Papst and Hopky (1983) found evidence of cannibalism on smaller charr which could be highly detrimental to commercial culture. This problem could possibly

TABLE 2

Comparisons of Growth Rates Between Arctic charr and Rainbow Trout Reared Under Optimum Conditions

	Arctic charr			Rainbow Trout		
Author	Opt. temp for growth	Max spec ific growth	Max ration	Opt temp for growth	Max spec ific growth	Max ration
Swift (1964)	12 to 16C	2.0+%/day	---			
Gjedrem & Gunnes (1978)	10.0 C (av)	1.45%/day				
Uraiwan (1982)	10 to 13C	2.0%/day	4.7% body wt/day	13 to 19C	2.1%/day	4.6% body wt/day
Wandsvik & Jobling (1982)	13.1 C	1.4%/day				
Baker (1983)	14 C	2.0%/day	4.48-5.2% body wt/day	14 C	2.5%/day	3.85-5.7% body wt/day
Papst & Hopky (1983)	13 C	1.9%/day	150% of ration in published tables	13 C	1.9%/day	
Tabachek (1984)	12 C	2.0%/day	---	12 C	1.8%/day	

be overcome by selectively breeding for fast-growing charr however, at present, further research in this area is needed.

Sawchyn (1984) reported that rainbow trout, reared in cages, grew from a mean weight of 41 to 205 grams over a period of 145 days and that successful rearing of trout could be obtained at final cage densities of 13 to 19 kg fish/m^3/cage. Baker and Ayles (1984) found that Arctic charr growth rates responded favourably at higher densities (40 kg fish/m^3) compared with rainbow trout.

An observation was made by Papoutsoglou and Papaparaskeva-Papoutsoglou (1978) who showed, from growth equations, that Arctic charr, reared at an optimum temperature of 14 C, could attain growth rates of 7.5 percent day^{-1} and therefore, was one of the fastest growing salmonid species.

2.3 Food Requirements and Conversion Ratio

The food requirement of any fish species is always an important factor to consider if maximum growth is to be achieved within a certain time period. Feeding experiments have shown that natural food was superior to commercial food in the development and growth of young charr (Steiner, 1984). Arctic charr are naturally wide-ranging, opportunistic feeders utilizing whatever is available to them. Jobling and Wandsvik (1983) found that the protein and lipid requirements of Norwegian charr were 35 to 45 percent and 11 to 15 percent, respectively, which was similar to rainbow trout requirements.

Tabachek (1984) reported that charr fingerlings originating from Nauyuk Lake, N.W.T., required higher protein and lipid levels, 44 to 54 percent and 15 to 20 percent, respectively. In the above experiment, growth rates for both Labrador charr and rainbow trout were excellent after feeding for twelve weeks on a commercial diet (Martin's Feed Mills M.N.R. Trout Feed) which was manufactured in Ontario.

Food conversion (amount of food fed: amount of wet fish gain) was lower (1.17:1) for Labrador charr compared to Sunndalsora charr (2.60:1) after being fed the same diet under similar rearing conditions (Tabachek, 1984). Robertson et al. (1986), in rearing lake trout backcross fingerlings in cages from 2 to 58 g, reported that conversion ratios were high during the first year (2.2:1) compared to the second year (1.6:1). They suggested however, that a conversion ratio of 1.5 to 2.5:1 is acceptable for commercial cage culture operations.

Sawchyn (1984), in the first year of rearing rainbow trout in cages, used 236.9 kg of food to produce 139.7 kg of trout (836 fish) to give a net conversion ratio of 1.7:1 in a control cage. This compared with 231.3 kg of food used to produce 121.7 kg of trout (680 fish) with a net conversion of 1.9:1 in an experimental cage. During the second year, conversion ratios of 1.99:1 (632 fish) and 1.76:1 (587 fish) were reported for trout reared in two cages.

2.4 Fish Production

Total production from an aquaculture operation refers to the total amount of fish produced (usually expressed in weight) over one production cycle. In extensive aquaculture, productivity is expressed as standing stock or the total weight of fish produced for a given unit of lake or pond area (kg ha^{-1}). Hunter (1976) determined that the standing stock of Arctic charr in Keyhole Lake, N.W.T. was 2113 kg or 43.5 kg ha^{-1} with a turnover time of 6.7 years for the harvestable portion of the stock. Rigler (1975) estimated the standing crop of Arctic charr in Char Lake, Cornwallis Island, as being 104 kg ha^{-1}. However, it was suggested that this may be too high considering that the turnover time is between 10 to 15 years.

Lawler et al. (1974) showed production figures for rainbow trout cultured in prairie ponds over a period of four years (1969 to 1972). Total production averaged 53.0, 45.6, 79.8, and 80.3 kg ha^{-1} respectively. It was reported that the highest yield from a prairie lake was 313 kg ha^{-1} and that yield increased with increasing stocking rate up to an optimum limit.

2.5 Economics of Arctic Charr and Rainbow Trout Culture

In recent years, Arctic charr have been processed in northern Canada and utilized by local people and tourists, however, any surplus frozen-dressed adult fish from the Arctic is shipped to the Freshwater Fish Marketing Corporation in Winnipeg for distribution to various Canadian markets (Iredale, 1984). Previous marketing surveys in Manitoba and Canada have also shown that there is a special market for pan-sized charr which has prompted some private aquaculturists to take interest in this species as a commercial prospect.

However, despite incentives to commercially culture exotic fish species such as Arctic charr, aquaculturists continue to be plagued with various problems (Cauvin and Thompson, 1977; Industry Task Force on Aquaculture, 1984; Pfeiffer and Jorjani, 1986). Constraints facing charr aquaculture are: a) inadequate supplies of broodstock, b) insufficient refinement of techniques for rearing charr, c) size variability of the end product, d) lack of research into appropriate feed mixtures, e) a relatively long grow-out period and, f) lack of market recognition for the fish (Price Waterhouse Management Consultants, 1990). Also one of the major concerns facing the aquaculture industry as a whole, has been the lack of adequate returns on invested capital.

Published information, dealing with the economic aspects of trout and charr culture, is limited. Cauvin and Thompson (1977) report that investment in rainbow trout farming, as a commercial venture in non-algal collapse lakes in Manitoba, should not be considered because of wide variations in annual recovery of fish (unless the fish farmer wanted to ignore wages and the cost of investing in aquaculture).

Data gathered from one survey of larger Ontario trout farms suggested that the basic investment in production facilities and fish inventories should equal 1.5 to 2.0 times the annual gross sales if the farms produce at full capacity (Blum, 1979). Today, Ontario trout farms produce 4 kg trout/year/1pm and it has been estimated that as much as 12 kg trout/year/1pm could be produced with improved culture methods and production planning (Castledine, 1986).

Results from a private feasibility study, implemented for the owner of the Garson fish farm has shown that market demand exists for both pan-size charr and the 1 to 3 kg fresh-farmed product (Bentley, 1989). It was also established that demand for either wild or farmed Arctic charr clearly outstrips available supplies and that the target price range at the wholesale level would be $8.00 to $11.00 per kg (CDN $). Retail prices for charr in Winnipeg (1989) are listed in Table 3. Recent wholesale prices for pan-size, aquacultural charr varies between $10.45 to $11.22 per kg. As production of the pan-size charr exceeds 90 to 100 tonnes per year, it was suggested that the prices will decrease for this size, eventually levelling about $1.00 per pound above the price for trout (Smith, 1989). It was concluded that farmed charr production would increase annually over the next five to ten years and that by 1994 and 1999, farmed charr sales could be 454 tonnes and 907 to 1361 tonnes, respectively. Manitoba charr production was approximately one tonne in 1987 with projected estimates of five tonnes in 1990 and 28 tonnes by the year 2000.

Hypothetical fish farm models were constructed by Blum (1979) and Castledine (1986) in order to serve as guidelines for determining equipment requirements and the costs/prices that might be expected in establishing a typical, large-scale fish farming operation in Ontario (Tables 4, 5). In both cases, capital investment and operating expenses were high. Under these conditions, net returns can be low. However, the above models reflect the costs involved in developing a large, indoor fish culture operation and therefore, should not be compared to a small-scale, outdoor, pond-rearing system where operating and capital costs are relatively low.

Most successful commercial trout farms in Ontario were originally small hobby farms that gradually developed into larger production units following more intensive utilization of water and favourable legislation (Blum, 1979).

Table 3

Current or Recent Retail Prices for Arctic
Charr in Winnipeg (Bentley, 1989)

Safeway	steaks(fresh)	$1.99/100 g
	whole (farmed) (fresh)	$1.69/100 g
	whole (frozen)	$1.59/100 g
Eaton's	whole (frozen)	$1.49/100 g
	dressed, head-off (frozen)	$1.82/100 g
Neptune Fisheries	whole (fresh)	$1.37/100 g
Produce Plus	fillets (fresh)	$1.99/100 g

Table 4

An economic Model of a Trout Farming Operation in Ontario Showing
Total Capital Investment, Fixed and Variable Costs
(Blum 1979)

Capital Investments	Dollars
2-hectare parcel of land at $7500/ha	15,000
Building to house trout production facilities, 372 m^2	15,000
Installation of pumps to produce 3000 lpm, well points, and electric wiring	20,000
75 kw. standby generator (used)	15,000
Circular tanks, raceways, and ponds	40,000
Aeration equipment	16,000
Landscaping, digging settling pond, roadways	3,000
Contingency capital to cover cost overruns	20,000
Pick-up truck for general use	6,000
TOTAL CAPITAL INVESTMENT	150,000
Revenue	Dollars
Sales of:	
Fingerlings, 10,000	4,000
Trout, wholesale, 90,000	94,500
TOTAL	98,500
Variable Costs	
Fish purchases, 125,000	12,500
Fish feed	36,238
Labour, 1200 hrs. at $4 plus benefits of $400	5,200
Property taxes after farm tax rebate	250
All risk insurance, $73,600 at 3.25%	2,392
Energy, hydro at $18/day	6,570
Repairs & maintenance by contractors	1,000
Office supplies	120
Chemicals	150
Gas, oil, & diesel fuel	200
Telephone	150
Contingency expense	600
TOTAL	65,370
Fixed Costs	Dollars
Depreciation:	
Buildings and hatchery facilities, generator and landscaping, 5% per year on invested capital	3,650
Pumps, well points, wiring, aeration, truck, 20% per year on invested capital of $42,000	8,400
Owner-manager salary, 5% of gross revenue	4,925
Interest on land investment & contingency reserves	3,150
TOTAL VARIABLE & FIXED COSTS	85,495

Expected return on investment would be 8 to 9%/year(13005/150000 x 100).
The model covers a period of one calendar year.

Table 5

An Economic Model of a Trout Farming Operation in Ontario Showing Total Capital Investment, Fixed and Variable Costs (Castledine 1986)

Capital Investments	Dollars
4-hectare parcel of land (with 1125 lpm) @$5000/ha	20,000
Construction of building (uninsulated) for production facilities, concrete floor	30,000
Building wiring, plumbing, pipes	6,000
Electrical service to site	8,000
Tanks for rearing and growing	9,500
Excavation and preparation of head (1), settling (1), waste (1), and earth ponds (6)	10,000
Standby generator (10 hp.) including installation	7,500
6 aerators	3,000
Purchase & installation of pump to handle 1125 lpm	3,500
Used one-ton truck	8,000
Construction of transport trailer	2,000
8-inch concrete pipe, concrete work	2,500
TOTAL CAPITAL INVESTMENT	110,000
Revenue	**Dollars**
Farm sales, 20% of production @ $6.60/kg live wt	30,000
Sales to Guelph Co-op, 60% of production @ $3.40/kg live wt	46,500
Stocking sales, 20% @ $8.80 kg live wt	40,000
TOTAL	116,500
Variable Costs	**Dollars**
Fingerlings (10 cm), 67,000 @ $ .35 apiece	20,100
Feed including delivery	19,400
Mortality and culling (.008%/month	2,500
Labour, one-half man year @ $7/hr	6,500
Insurance, 5% of fish value	6,900
Repairs and maintenance, 5% of total investment	5,500
Hydro	2,000
Interest on working capital, @ 13-1/2 %	9,300
Transportation (including depreciation, repairs, gas	4,000
Chemicals and drugs	500
Office supplies and telephone	600
Accounting fees	500
TOTAL	77,800
Fixed Costs	**Dollars**
Depreciation: Buildings, $30,000 @ 5%	1,500
Pumps, electrical wiring, aerators, 28,000 @ 20%	5,600
Ponds and tanks $19,500 @ 20%	3,900
Interest on long-term debt 12% of $77,000	9,200
TOTAL VARIABLE & FIXED COSTS	98,000

Expected return on investment is 16 to 17%/yr. This model reflects revenue and costs of rearing 22,700 kg of trout over 12 month period.

2.6 Summary

Freshwater culturing of Arctic charr is carried out in Europe, U.S.S.R., and, to some extent, the northeastern U.S. Comparisons of different strains or stocks of Arctic charr have shown that certain characteristics are inherent in some individual populations which allow them to survive in sub-optimum environments.

Growth rates of Arctic charr are lower than growth rates recorded for rainbow trout when reared at optimum water temperatures. Growth equations indicate that Arctic charr may be a fast growing fish species. Also, certain strains of charr will grow at different rates when reared at similar temperatures in the same environment.

Variation in size has been reported in populations of Arctic charr that were reared under intensive culture conditions. Variability in growth can be attributed to aggressiveness and intraspecific competition, genotype, precocity in males, and environmental factors (water temperature, fish density and metabolites, flow rates and oxygen levels, water quality, and food ration).

Food requirements can differ between strains of charr. Charr fingerlings from the N.W.T., reared in optimum water temperatures, required higher protein and lipid levels than Norwegian charr reared under similar conditions. A commercial pelleted diet (Martin's Feed Mills - M.N.R. Trout Feed) was used to achieve optimum growth in the N.W.T. strain of charr.

Limited supplies of frozen-dressed adult Arctic charr from the Eastern Arctic are shipped to the Freshwater Fish Marketing Corporation for distribution to Canadian markets. Marketing surveys have revealed that special markets in Manitoba and Canada also exist for pan-size charr.

In North America, fish farming is growing at more than 7 percent each year. The percentage of cultivated fish is growing faster than any other part of the human diet. Highly-valued, exotic species, such as Arctic charr and salmon, may give individuals the incentive to commercially culture these species. However, a lack of adequate returns on invested capital is one major obstacle which has prevented rapid development of the aquaculture industry in Canada.

Private profitability analyses, which were conducted on large, intensive trout farming operations in Ontario have shown that capital costs and operating expenses were extremely high in comparison to net returns. By investing in small pond culturing operations, overhead costs may be substantially reduced allowing for greater profits and possible expansion of the business.

CHAPTER 3

METHODS

3.1 Physical Data

3.1.1 Arctic Charr Stocks

Arctic charr fingerlings were obtained from a single source, the Rockwood Experimental Fish Hatchery. During the first year, two strains of Arctic charr were used, Nauyuk Lake (N.W.T.) domestic charr and Fraser River (Labrador) charr. Nauyuk Lake charr, an anadromous cross, were hatched on September 6, 1984 and originated from parent stock captured in November 1978. Fraser River charr were hatched on October 31, 1984 and originated from parent stock captured in October 1980.

All fish were ungraded (with large size variations) and approximately 1.5 years old when released into the pond. Mean initial weight of the Nauyuk Lake charr population was approximately 39.8 g per fish. Mean initial weight of the Fraser River charr population was 32.3 g per fish. One hundred fish of each strain were placed into one small pond (Pond A) on May 20, 1986. Additionally, another 1000 Nauyuk Lake charr were released into one large pond (Pond B) on June 11, 1986 (mean initial weight - 45.3 g per fish).

During the second year, 1000 graded (small size variations) Nauyuk Lake charr fingerlings hatched September 1985, (mean initial weight - 43.1 g per fish) were released into Pond A on June 1, 1987. Low stocking rates were used for both ponds because of a shortage of fish. All fish (from both years) were overwintered in the ponds.

3.1.2 Pond Construction & Description

Arctic charr ponds at Garson were carved from clay soils during the first week of May 1986. A large excavator (on tracks) was used to dig both large and small ponds. A bulldozer was used to level and build up sides and ends of each pond (approximately 1.0 m). Pond sides were sloped at 45 degrees while the middle portions had relatively even bottoms.

Because the water table at the Garson site was relatively close to the ground surface (4.2 to 6 m), one small area (of the pond bottom) at the end of each pond was dug deeper in order to tap into the groundwater supply. This provided a fast and simple method of filling each pond. Also, groundwater seepage into each pond contributed to the overall flow of water through each pond and allowed pond temperatures to reach optimum levels for growth of Arctic charr. However, groundwater seepage was only temporary (lasting approximately 5 weeks) due to lower water table levels during summer months.

Steel pipes (25.4 cm diam) were positioned at outlets of each pond. Plastic screens were also placed across outlet pipes to prevent fish from escaping. Water from the small pond was allowed to flow into the large pond and eventually into a drainage ditch.

Total time (machine hours) involved in pond construction and landscaping are listed in Table 6.

Ponds averaged approximately 2.5 (Pond A) to 2.8 m (Pond B) in depth although middle sections approached 4.0 m. In order to accurately determine total pond volumes, various depth measurements were taken at 1.5 m intervals across the pond width using a metered pole. Measurements were also taken along the full length of each pond (every 4 m) and an average depth was determined by adding individual depths at each location and dividing by the number of measurement locations. Figure 3 shows how the volume of Pond A was calculated. Surface area of Ponds A and B was 0.047 and 0.079 ha, respectively.

Table 6

Total Machine Time Used in Pond Construction and Landscaping at Garson, Man. 1989

	Time (Machine hrs)	Machinery Used	Machine Purpose
Pond B	18	backhoe (excavator) $75/hr.	digging pond & pond outlets
	12	bulldozer (D6C) $65/hr	levelling pond sides; building up edges
Pond A	12	backhoe (excavator)	digging pond & outlets
	4	backhoe (excavator)	digging drainage ditch & levelling sides
	8	bulldozer (D6C)	levelling pond edges

Both ponds are situated in open fields and some agricultural activities such as fertilizing and herbicide spraying were conducted during the research. However, necessary steps were taken (spraying limited to calm days) to ensure that fish ponds were not contaminated. Ponds generally remained ice-free from May 1 to the end of October (approximately 180 days).

3.1.3 Water Source

Water used in the pond culture operation at Garson was obtained from two sources: a) groundwater seepage and, b) pumped well water. Groundwater seepage into ponds was a temporary feature only. Water flow was obtained from two shallow wells dug in close proximity to the ponds. Each well (with 12.7 cm diam casing) was drilled to a depth of approximately 18 metres.

Figure 3: POND A VOLUME MEASUREMENTS

18m

	1.31	1.41	1.52	1.60	1.78	1.83	1.80	1.78	1.42	1.39	1.28
	O	O	O	O	O	O	O	O	O	O	O
	1.27	2.86	3.14	3.23	3.20	3.11	3.10	3.01	2.73	1.80	1.32
	O	O	O	O	O	O	O	O	O	O	O
	1.30	2.89	3.41	3.60	3.65	3.65	3.58	3.54	3.39	2.55	1.26
	O	O	O	O	O	O	O	O	O	O	O
26m	1.21	2.96	3.76	3.81	3.88	3.90	3.67	3.40	3.15	2.71	1.31
	O	O	O	O	O	O	O	O	O	O	O
	1.29	2.83	3.61	3.70	3.95	3.97	3.92	3.80	3.72	2.60	1.22
	O	O	O	O	O	O	O	O	O	O	O
	1.25	1.30	1.60	1.69	1.75	1.93	1.71	1.54	1.50	1.33	1.29
	O	O	O	O	O	O	O	O	O	O	O

Dimensions 26 x 18 x 2.46 m

(1150 m3)

O - measurement location

Average Depth = <u>162.18 m</u>

66 (measurement locations)

= 2.5 m

*Note: Pond Width Measurements Taken every 1.5 metres
Pond Length Measurements Taken every 4 metres

Water levels rose to about one metre from the ground surface (within the well casing) and were maintained at that level for most of the summer.

During the first year, one well provided a limited flow of water for both ponds. A small capacity well pump (54 1pm) was lowered into the well shaft (approximately 7.5 to 9 metres down). Plastic well pipe (3.2 cm diam) was attached to the pump and serviced both ponds.

During the second year, another well was drilled at the pond site and two new, electric surface pumps (capacity 450 lpm) were put into operation. Pumps were installed at each well. Both charr ponds were serviced by 3.8 cm diameter plastic well pipe. A "Y" connector (with individual flow control valves) was installed in the well pipe line so that water flow into each pond could be adjusted periodically in order that pond surface temperatures be maintained at optimum levels for Arctic charr growth (12 to 16 c). Water from both pumps serviced four ponds (two charr ponds and two rainbow trout ponds). Volumes of Pond A and B were 1150 and 2230 m^3 respectively. Flow rates were maintained at 148 to 157 lpm in both ponds during the summer. This allowed pond water temperatures to remain below 18 C during summer. Arctic charr become inactive and die as temperatures approach 22 C (Jobling, 1982).

Pond exchange rates were low and estimated to be one exchange every 5 days (Pond A) and one exchange every 10 days (Pond B).

3.1.3.1 Evaporative Losses

Evaporation, or the loss of water from a moist surface or a body of water, will vary in rate, depending upon climatic conditions present in the immediate area. An increase in temperature and wind movement (up to a certain value) are two major factors which can increase evaporation rates (Knight, 1965). The use of surface spray aeration may also contribute to evaporative losses from water bodies.

At Garson, ponds were situated in open fields where there is little protection from winds or the sun. Observations of pond A during both years (by observing water level marks on aerator casing which was attached to long pole anchored into pond bottom) showed that water levels fluctuated greatly throughout the summer. However water levels never dropped more than 0.3 m (at one time) over the production cycle and it was not apparent if these reduced levels resulted from a reduction in groundwater levels (groundwater is close to surface at Garson) or an increase in pond evaporation rates. Pumped well water was redirected from one pond into another in order to refill them if water levels dropped substantially in Garson ponds.

Predictive modelling was used by Stechey (1990) to determine monthly net heat flux at the air-water interface at the Garson put-and-take fishing ponds. This thermal modelling approach assumed that the water was continuously mixed (via aeration). Climatological data were obtained from Canadian Climate normals (Canada Dept. of Transport, 1982) and information required for thermal budgeting was taken from the weather station at the Winnipeg airport.

3.1.4 Aeration

Two types of surface spray aerators (1/3 hp) were used in the Garson ponds, a) floating type (on styrofoam pads) and, b) "fresh flow" type (attached to a metal pole that was anchored in pond bottom). Both electric aerators provided aeration for ponds. Water was drawn up the aerator casing (via an impeller blade) and distributed across the pond surface as a fine spray (Figure 4). Aerators were operating 24 hours per day to ensure that oxygen concentrations within ponds were not reduced to critical levels during summer months. Spare aerators were available for use in emergency situations if pond aerators malfunctioned.

3.1.5 Feeding

Arctic charr, during both years, were fed pelletized, artificial fish feed (both floating and sinking) from Martin's Feed Mills, Elmira, Ontario. Food was administered by hand once or twice daily (depending on how active the fish were) and total weight of food used was recorded on a daily basis. In order to provide charr with additional natural food, an incandescent light was set up at one end of pond A (during both years) to attract flying insects. A 100 watt bulb was positioned approximately 0.3m above the pond surface and was attached to a rope which had been stretched across both sides of the pond. Similarly a light was positioned in Pond B during the first year, however, charr did not feed actively in this pond.

A strict feeding regime was not warranted since both artificial and natural food were available to the fish. In addition, Arctic charr do not feed actively on the surface compared to rainbow trout. However, for the first few weeks, charr were fed according to a rainbow trout feeding guide (Hilton and Slinger, 1981) based on a water temperature of 12 C at approximately 100% of the recommended ration for trout (2% body weight per day). The amount of food fed after this initial period was estimated and gradually increased over the production period according to how active the charr were.

In their natural environment, Arctic charr are mid-water feeders although Mills (1971) reports that European charr, impounded in lakes, were also littoral feeders and fed on surface insects. Because of this, both sinking and floating food were given to charr to ensure that these fish would receive adequate food supplies (depending on feeding behaviour).

In the second year, pigmented food (containing a colouring agent canthaxanthin, a bacteriologically produced pigment) was given to charr to improve flesh colour after they had obtained a weight of 100 grams or more (usually during the last two months of the production cycle). Smaller fish (less than 100 grams) show little improvement in flesh colour after being fed a pigmented diet. Also, during the second year, Gammarus lacustris were introduced. The natural pigments found in these crustaceans should also enhance the flesh colouration of charr.

3.2 Biological Analysis

Biological information that was needed to provide an accurate assessment of the Arctic charr's performance in man-made pond environments included:

a) Growth performance data

b) Survival/mortality data

c) Water quality data

3.2.1 Biological Data (Year 1)

3.2.1.1 Growth Performance

Two strains of Arctic charr (Labrador and N.W.T.) were branded differently using an electrical brand (hot wire) to investigate possible differences in growth. In order to develop a more accurate representation of growth, some fish were tagged at the base of the dorsal fin.

Before sampling fish, pond levels were lowered by pumping water out of each pond (using a 2 hp centrifugal pump) (Figure 5). A fine-meshed seine net (17 m long, 2.5 m deep) was dragged from one end of the pond to the other and fish were dip-netted at random, weighed in batches, counted, and then placed into aerated tanks until sampling was completed (approximately one-sixth of the population (200) that was initially stocked) (Figure 6). The number of sampling periods was kept to a minimum in order to reduce the effects of stress and allow fish to grow at a steady rate.

In this study, specific growth rates were used to determine growth performance. Specific growth was calculated as the difference in mean ln (initial wt) and ln (final wt) over a given period of time (t) days x 100.

$$\text{S.G.R.} = \frac{\ln(W\ \text{final wt}) - \ln(W\ \text{initial wt}) \times 100}{dt}$$

Total Yield (Production)

The amount of water in a static pond will determine the intensity of production. Reay (1979) suggests that in an unmodified system, the first limiting factor will probably be food supply however, in ponds where artificial feeding or fertilization is used the effective limiting factor will be oxygen

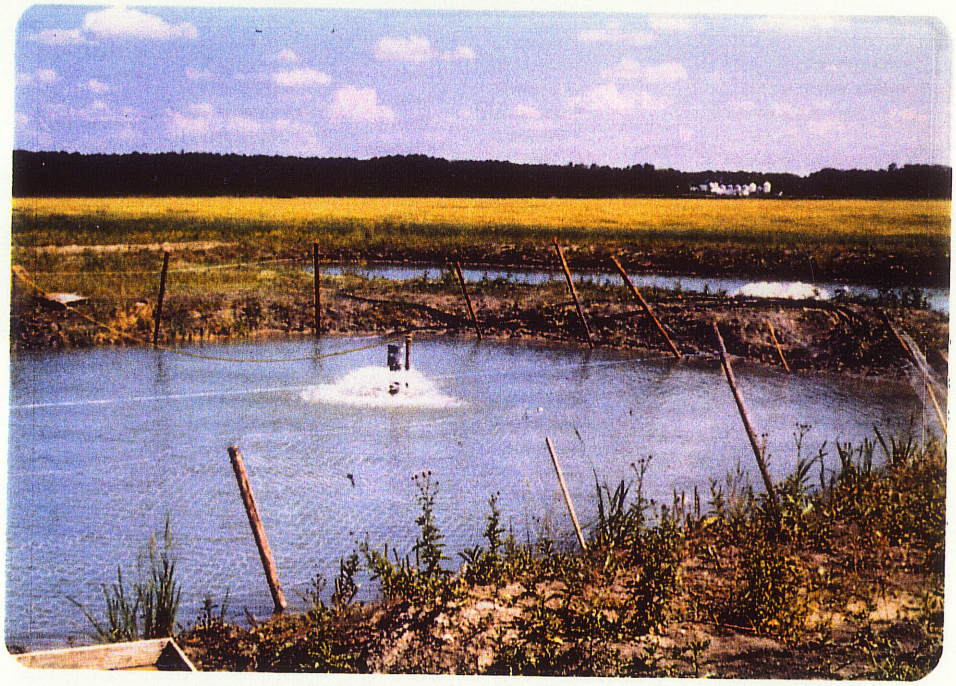


Figure 4: Pond A Showing Surface Spray Aerator And Wire Fence For Protection From Herons

Figure 5: Water Level In Pond A Was Lowered For More Efficient Harvesting Of Arctic Charr (2 HP Floating Pump Is Shown Here)

Figure 6: Seine Net Used To Harvest Charr At End Of Production Cycle

Figure 7: Initial Size Of Nauyuk Lake Arctic Charr Fingerling At Spring Stocking

depletion or self-pollution with waste products (ammonia, etc.). In continuously flowing water situations, the rate of volume flow becomes the decisive factor.

An estimate of total yield per pond at Garson, expressed in terms of fish biomass over one production cycle, was also used to measure growth performance. Since the total weight of fingerlings was known at the time of stocking, total production for each pond was determined by the following formula:

$$\text{Total Production (kg/ha) or (kg/m3)} = \frac{\text{No. fish recovered x mean wt at harvest}}{\text{Pond Area (Volume)}}$$

$$\text{Total Biomass Fish Produced} = \frac{\text{(No. fish recovered x mean wt. at harvest) - total wt. stocked fingerlings}}{\text{Pond Area (Volume)}}$$

Food Conversion

Feed conversion was calculated on the basis of total fish weights and total weights of artificial food consumed over one production cycle. Bardach et al (1972) have suggested that an acceptable food conversion ratio for salmonid culture is 1.5 - 2.0:1 (1.5 -2.0 kg food consumed for every 1 kg of wet fish weight gained).

3.2.1.2 Survival/Mortality

Ponds were monitored once every two days for fish mortalities. Dead fish were removed and a record was kept of all mortalities from each pond. Because the numbers of fish initially being planted into ponds was known, mortality rates can be determined by the following formula:

$$\text{Mortality (M)} = \frac{nS - nH}{nS} \times 100 \text{ where:}$$

nS = total no. fish stocked

nH = total no. fish harvested

Survival rates (%) can be found by subtracting M from 100%.

Bird Predation

One of the most difficult problems to overcome in relation to outdoor pond culture is heavy predation of fish by various birds including herons, Ardea herodias, and cormorants, Phalacrocoras auritus. In order to increase fish survival in ponds, control methods were implemented. During the first year, methods used to control predation were:

a) nets stretched across ponds

b) ribboned line across ponds

c) guard dogs on long leash

d) gun shots to scare birds

Numbers of birds that visited ponds were recorded during morning periods every second day over the summer. A rough estimate of bird use was provided by comparing the number of days birds were observed to the total number of days in one production cycle. This would be, at best, a minimum estimate since observations were made only during the morning and not every day.

3.2.1.3 Water Quality

Monitoring of water quality criteria during the first year included:

1. measurement of surface water temperature, using a calibrated thermometer, at least once every two days during the production cycle
2. measurement of well water temperature at least once every two days
3. measurement of dissolved oxygen, using a Sentry 3 Temp./Oxygen meter, once every two weeks from the end of September to the end of October (when fish biomass is the greatest, total oxygen uptake can be maximized under certain conditions).
4. collection of water samples from Garson ponds and wells for analysis of major ions, pH, conductivity, ammonia, nitrite, and nitrate levels.

Results were compared with recommended water quality guidelines (Sigma Resource Consultants Ltd., 1979; Daily and Economon, 1983) for successful salmonid culture (Table 7). Water samples were collected during October (when water quality problems may exist due to increased fish biomass) and brought to the Freshwater Fisheries Institute laboratory for analysis.

3.2.2 Biological Data (Year 2)

Biological information gathered during the second year of operation included the data collected in the first year (water quality, growth performances, and survival/mortality data). An attempt was made to improve survival of charr in pond A by introducing two control methods, a) the operation of a mechanical man (with swinging arms) and, b) the erection of a wire fence (slanting inwards) around pond edges. From observations of bird movements/behaviour, the effectiveness of each method was examined.

Additionally, water flows were adjusted accordingly and recorded throughout the summer in order to maintain pond surface water temperature at optimum growth levels for Arctic charr. Also, secchi disc transparency tests were made once per week (during October) to detect changes in water clarity (brought about by algal blooms and a build-up of suspended solids). Water quality problems were minimized by pumping approximately 1.5 metres of water from each pond (once or twice per month) using a 2 hp centrifugal pump.

The Coefficient of Variation (C.V.) was calculated as an index of size variation within a population of fish. Because individual fish within the population were not measured initially (before stocking), C.V. could not be determined, however, initial size of charr (at stocking) (Figure 7) was fairly uniform (fish were graded before introducing them into ponds). Individual fish, at the end of the production cycle, were weighed and recorded.

Table 7

Water Quality Criteria for Salmonid Culture in North America
(Sigma Resource Consultants Ltd., 1979)

PARAMETER	VALUE (mg/1)		
	Optimal	Recommended	Toxic
Temperature		>2-3 C; <18-25 C	
pH	7.2	6.5-8.5	<5, >9
D.O.	100% sat.	>6.8	
Gas pressure (total)	100% sat.	<103%	>110%
Alkalinity (total)	20-300		
Ammonia-NH_4 (total)		- unionized <.002 for incubation - unionized <.005 for rearing	.08
Chlorine		<.002	.006
Conductivity		150-2000 uS/cm	
Hardness as $CaCO_3$		20-400	
H2S		<.002	>.004
Nitrite (NO_2)		<.012	.2
Nitrate (NO_3)		<.12	
Pesticides & herbicides		0	
Phosphate (total)		<.05	
TDS (mineral content)		500-1000	15000
Calcium	<52	4-150	300
Iron		<.3/<1 for f.w. life	
Magnesium		<10	100
Phosphorus		<.0001 for saltwater life	

3.3 Economic Analysis

Three general opportunities for profit exist for owners of commercial fish ponds: firstly, the sale of recreational angling based usually on a daily angling fee or a charge for fish taken; secondly, the live sale of fish reared in ponds for stocking other private waters; and thirdly, the production of fish for sale as food. This economic assessment was conducted during the second year of operation at Garson and was designed to provide some indication of the capability of this culture method (utilizing Arctic charr) to generate a net economic return on investment from the sale of market-size fish. The assessment was based on the fish farm's capital investment, operating costs, and production revenue, and incorporated four types of analysis a) a financial statement, b) break-even analysis, c) financial ratios and, d) investment analysis (internal rate of return).

Information relating to initial capital investment and operating costs was supplied by the owner of the fish farm (Mr. P. Palaschuk).

3.3.1 Financial Statement

The financial statement covered four different areas 1) capital investment, 2) revenue generated, 3) variable costs and, 4) fixed costs. The above will be considered as an economic model for a small-scale fish farm at Garson, Manitoba. A dollar value (1990) was placed on all cost and income generating components. Fixed and variable cost components, associated with the construction and operation of one pond rearing unit, were determined. Profitability (return an assets, return on equity), efficiency (capital turnover), and liquidity (current capital) ratios were utilized to determine overall performance of the pond culture operation.

3.3.1.1 Capital Investment

Initial capital expenses consisted of the following purchases:

a) land

b) pump (capacity 450 lpm) 2 hp

c) well (installation)

d) pond (construction and landscaping)

e) aeration equipment (1/2 hp) including spares

f) used 1/2 ton truck (1981)

g) electrical service to site (including erection of small storage building and panel box)

h) wiring, plastic pipe, fittings

i) 25.4 cm diam. steel pipe (used) - 7 m

j) 2 hp. floating pump (used)

k) 3.8 m diam. holding tank

l) fence material

m) canoe or rubber dinghy

n) mechanical man

o) seine net (25m x 2.5m)

p) Oxygen meter (Sentry 3)

q) miscellaneous items (dipnet, plastic tubs, pails, twine, screen, extension cord, thermometer, waders)

3.3.1.2 Revenue

Total revenue generated from production and sales of Arctic charr from one pond was estimated based on the current producer's price for fresh-dressed charr (pan-size). Sales were also included for charr reared under hypothetical conditions (different loading rates and pond numbers). Marketable charr were those fish reaching harvest weights of 200 grams or more (Figure 8).

3.3.1.3 Variable Costs

Variable costs, associated with the operation of the Garson fish farm, were as follows:

a) fingerling purchases*

b) fish food (artificial)

c) freshwater shrimp (fish food supplement)

d) labour (part-time) for harvesting, processing

e) risk insurance

f) repairs and maintenance of equipment

g) hydro

h) interest on working capital

i) transportation (repairs, gas)

j) property taxes

k) ice

l) ammonia test kit

m) water quality aids (Bacta-Pur, Aquashade)

n) contingency expense

* Fingerlings used for this operation were approximately 1½ yrs. old and were provided (free of charge) by the Department of Fisheries and Oceans. A local supplier could supply Arctic charr fingerlings (12.7 cm long) for $0.40 /fingerling if eggs were available in the fall.

Figure 8: Average Size Of Nauyuk Lake Charr At End Of Production Cycle

3.3.1.4 Fixed Costs

Fixed costs were those costs which remained constant over the life of the project. In this project these costs included:

a) fish farming licence

b) Depreciation: ponds, pumps, well point, aerators, truck, nets, canoe/dinghy

3.3.2 Break - Even Analysis

Break-even analysis, as shown by Cauvin and Thompson (1977), was used at Garson to:

a) determine the level of annual harvest at which revenue from the sale of fish will equal the fixed and variable costs of annual production (Figure 9).

$Q = F/P\text{-}V$ at break-even Q

where P = sales price per unit ($/kg)

Q = quantity produced and sold (kg)

F = fixed costs ($)

V = variable cost per unit ($/kg)

The above analysis was based on a proposed loading rate of 6000 charr per pond.

b) compare the effect of fingerling size on profits

c) compare the effect of market prices for Arctic charr on profits. Market prices could fluctuate depending on quantity of fish produced, consumer acceptance, and seasonal availability.

* It should be noted that approximately 6 ponds (1150m^3 in volume) could be constructed on one acre of land at Garson.

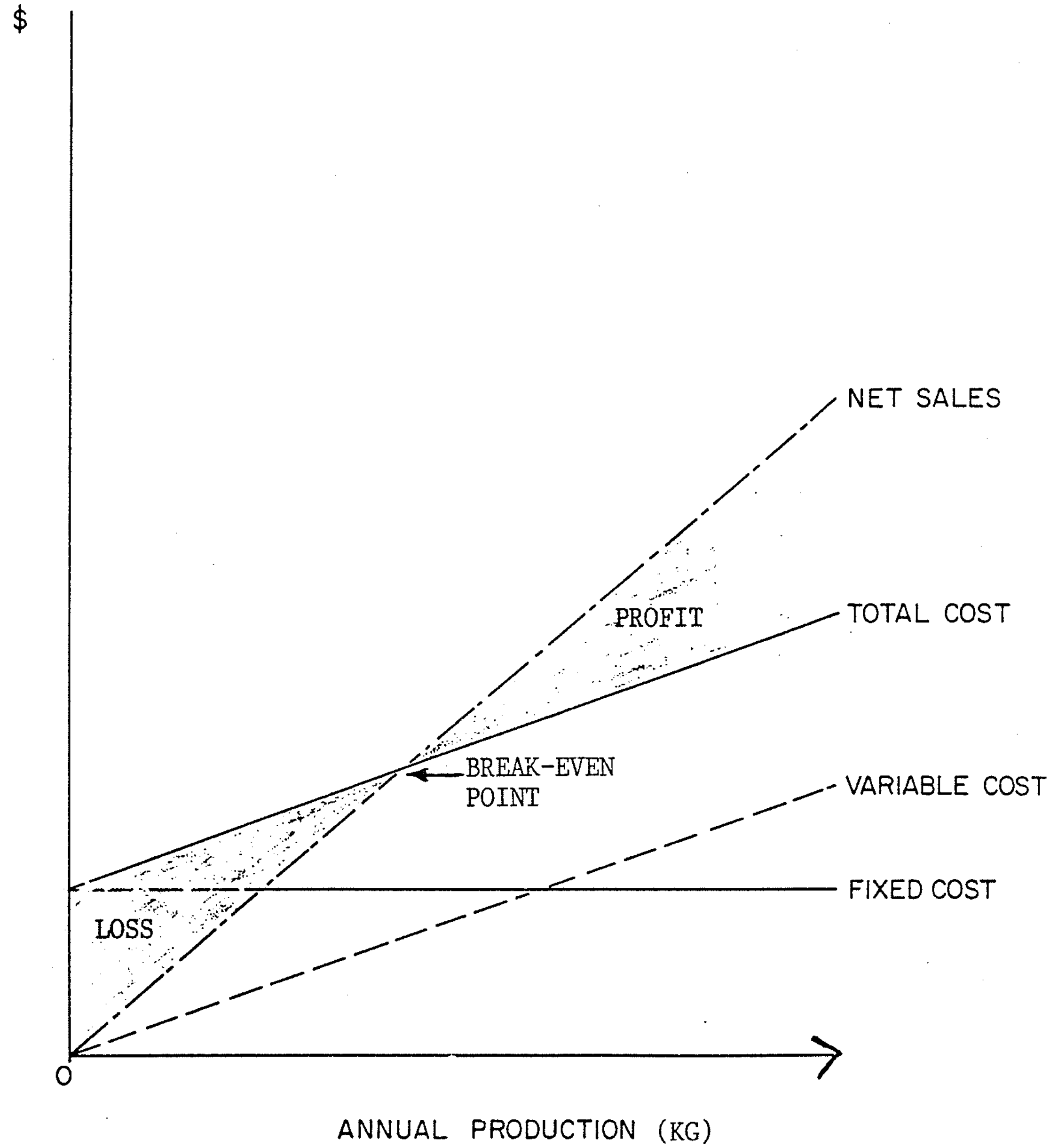


Fig 9 Break-even analysis: Annual production

3.3.3 Investment Analysis (IRR)

Investment analysis, or capital budgeting, is the process of determining the profitability of an investment. Pfeiffer and Jorjani (1986) have suggested that a thorough analysis requires information concerning a) net cash revenues from the investment, b) the cost of making the investment (including interest on borrowed capital), c) the terminal or salvage value of the investment, and d) the real interest (or discount) rate which relates the rate of return of the investment to the general rate of return to capital in the economy. Depreciation is not included as an expense when determining net cash revenues since it is a non-cash expense.

The internal rate of return (IRR) of an investment (the discount rate that equates the Net Present Value of the investment to zero) is one method of analyzing investments which reflects the time value of money over the investment period (see equation below). Pfeiffer and Jorjani (1986) used this procedure to determine the investment potential for small and large - scale fish culture facilities in southern Ontario.

$$NPV = \frac{P_2}{(1+i)^1} + \frac{P_2}{(1+i)^2} + \ldots + \frac{P}{(1+i)^n} - C$$

where: NPV = net present value   i = discount rate
P = net benefit   c = cost of investment

The above equation is solved for i, the discount rate. Investing in a business such as aquaculture, should be undertaken only if the internal rate of return (discount rate i) exceeds the prescribed discount rate. An alternative method of solving this equation involved the use of annuity tables for present value (taken from a general accounting textbook) given the net farm income and total investment costs.

The economic viability of the Garson pond culture operation was investigated using the above method of investment analysis (for scenario (C)). The prescribed discount rate for this analysis was 7% (the difference between the current prime lending rate (12%) and inflation rate (5%)). The economic viability of pond culture depends on whether or not the operation's internal rate of return exceeds the above discount rate of 7%.

CHAPTER IV

Biological Results

4.1 Biological Data (Year 1)

4.1.1 Growth

An early fall snowstorm delayed the final fall inventory of charr in both ponds until the following spring. All fish therefore, were overwintered. Aerators were used to oxygenate ponds, as well as to open up a small area of each pond in order to feed charr throughout the winter. However, charr fed sporadically for four days only (when the weather was mild) and it was assumed that growth for the winter period was minimal or non-existent. Johnson (1980) reports that wild stocks of European and Nauyuk Lake (N.W.T.) charr undergo a marked reduction in metabolism over winter and little feeding takes place. In some cases, Nauyuk Lake charr had experienced negative growth.

Initial growth inventories were conducted during September 1986 in both ponds at Garson. Final inventories were also recorded and these results are listed below.

4.1.1.1 Final Inventories

For pond A, a final growth inventory, representing one production cycle, was conducted on May 14, 1987. (Table 8). A total of 44 Arctic charr (from an initial population of 200) were recovered (22% survival). Factors, such as high water temperatures and bird predation, contributed to a low survival of charr. Twenty-three N.W.T. charr grew from an initial mean weight of 39.8 g to a mean harvest weight of 242.0 g (range: 142.0-327.0 g) over a period of 361 days (including winter months). Twenty-one Labrador charr grew from an initial mean weight of 32.3 g to a mean harvest weight of 310.7 g (range: 244.1-348.0 g) over the same period.

For pond B, a final growth inventory, representing one production cycle, was conducted on May 10, 1987 (Table 8). One thousand N.W.T. charr grew from an initial mean weight of 45.3 g to a mean harvest weight of 190.1 g (range: 108.1 - 237.2 g) over a period of 355 days (including winter months).

4.1.1.2 Tagged Charr

A total of 14 charr were tagged in Pond A at Garson during September, 1986. Fifteen charr were tagged in Pond B during the same month. Tag retention was poor because of problems in tying solid knots when anchoring tags to dorsal fins. Numbers of tag returns were also influenced by predation from herons.

Only three tagged individuals were recovered after one production cycle. One N.W.T. charr (tag #105), from Pond A, grew from a weight of 198.1 g on September 26, 1986 to 280.0 g by May 14, 1987. This fish was blind at the time of recovery (both lenses were opaque).

Another N.W.T. charr (tag #101) from Pond B grew from a weight of 127.4 g on September 13, 1986 to 350.0 g by May 10, 1987 (after overwintering). One other N.W.T. charr (tag #154) grew from a weight of 254.7 g on September 13, 1986 to a final weight of 1410.0 g by October 18, 1987 (Figure 10).

4.1.1.3 Population Growth Rates

From May 20, 1986 to May 14, 1987, specific growth rates for N.W.T. and Labrador charr (in Pond A) averaged 0.50 and 0.63 percent day^{-1}, respectively (if both summer and winter periods are included).

N.W.T. charr (in Pond B) had specific growth rates averaging 0.41 percent day^{-1} if both summer and winter months are considered in growth calculations.

Additionally, specific growth was calculated for N.W.T. and Labrador charr (Pond A) for the growth period from September 26, 1986 to May 14, 1987. Specific growth rates for N.W.T. and

Table 8

Final Growth Inventories (Year 1)

Pond Volume	Date Sampled	Strain + Initial Wt.	Batch No.	No. Fish in Batch	Mean Batch Wt. (g)	Average Sample Wt. (g)	No. Days of Growth	Specific Growth (%/day)
Pond B (2230 m^3)	May 10, 1987	N.W.T. 45.3	1	14	199.0	190.1	355 including winter	0.41
			2	12	237.2			
			3	12	219.4			
			4	17	203.0			
			5	6	108.1			
			6	4	175.0			
Pond A (1150 m^3)	May 14, 1987	N.W.T. 39.8	1	4	288.8	242.0	361 including winter	0.50
			2	5	327.0			
			3	9	142.0			
			4	5	210.0			
	May 14, 1987	Labrador 32.3	1	10	340.0	310.7	361 including winter	0.63
			2	3	348.0			
			3	8	244.1			

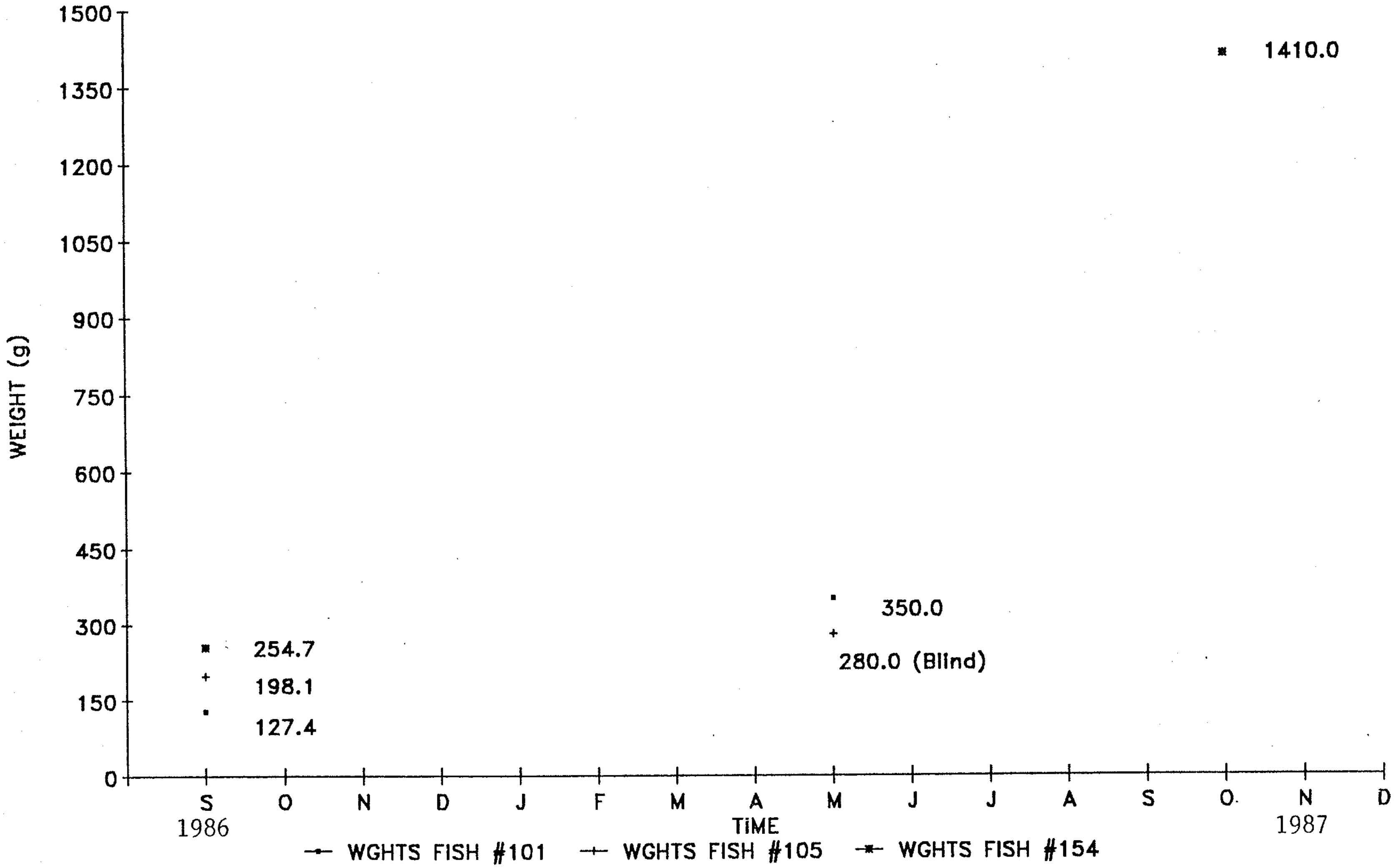


Figure 10: Growth of Tagged Charr in Garson Ponds

Labrador charr were 0.25 and 0.27 percent day^{-1}, respectively, for this period. Similarly, specific growth was calculated for N.W.T. charr in Pond B from September 13, 1986 to May 10, 1987. The specific growth rate was 0.28 percent day^{-1}.

4.1.1.4 Growth Rates of Tagged Charr

Over a period of 230 days, tagged fish #105 (Pond A) grew at a rate of 0.15 percent day^{-1}. Tagged fish #101 (Pond B) grew at a rate of 0.42 percent day^{-1} over a period of 239 days. This compares quite differently with a tagged individual #154 (Pond B) which grew at a relatively fast rate of 0.43 percent day^{-1} over a period of 400 days.

Tagged fish #105 was blind and therefore, grew at a slower rate (0.15 percent day^{-1}) compared to an overall population growth rate in Pond A for N.W.T. charr of 0.50 percent day^{-1}. Tagged fish #101 grew at a faster rate (0.42 percent day^{-1}) compared to an overall population growth rate in Pond B of 0.41 percent day^{-1}. Tagged fish #154, which was reared in Pond B for 1½ years (2 production periods), grew at a fast rate (0.43 percent day^{-1}) compared to overall population growth rates (in both production periods) of 0.41 and 0.18 percent day^{-1}, respectively.

4.1.1.5 Total Yield (Production)

Total yield and biomass was determined for Pond A only at Garson. Forty-four charr, from an original population of 200 fish, were recovered and produced a yield of 12.16 kg fish per pond A or 258.7 kg ha^{-1}. Total biomass of fish produced from Pond A (over one production cycle) was 4949 g fish per 1150 cubic metres of water volume or 4.3 g fish per cubic metre of water.

Because of equipment failures, which led subsequently to inefficient harvesting of Pond B, only a small portion of the total population of charr was recovered (65 fish from original population of 1000). Therefore, an accurate estimate of total yield could not be made.

4.1.1.6 Conversion Ratio

Arctic charr were fed at 2% body weight per day (approximately 150 grams food per day) for three weeks according to a feeding rate developed by Hilton & Slinger (1981). After this period, charr were fed according to how active they were. Most of active feeding occurred at sunset (approximately 200 grams food was fed per day) because daytime water temperatures were high which led to reduced feeding activity.

From May 20, 1986 to May 14, 1987, charr from Pond A were fed pelletized food for approximately 100 days (once or twice per day). A total of 18.92 kg food fed was used to produce 4.95 kg fish (total biomass) for a conversion ratio of 3.8:1. Extensive overfeeding (due to a lack of knowledge of numbers of fish predated upon) coupled with the fact that high water temperatures were evident in Pond A (which can reduce feeding activity and assimilation efficiency) are factors which may have contributed to a high conversion factor (3.8:1).

During June to August, Arctic charr were observed feeding on terrestrial, flying insects around lights at night and this natural food supply could have affected the conversion ratio. However, the conversion factor, as listed above, was based solely on the amount of artificial food fed over one production period.

4.1.2 Survival/Mortality

Observed mortalities were recorded from ponds A and B during 1986 and are listed in Table 9. High water temperatures during mid-July to mid-August may have contributed to the above mortalities. Although only 20 mortalities (pond A) were observed and recorded, some fish were highly stressed and also showed signs of abnormal behaviour (lethargy, swimming near surface, erratic swimming movements) however, these fish were not recovered. It is believed that this weakened condition allowed charr in both ponds to become more susceptible to predation from fish-eating birds over the summer. In pond A, the differences between observed (20) and total (156) mortalities of charr could possibly be attributed to heron predation.

Table 9

Observed Summer Fish Mortalities, 1986 (Garson)

Date	Pond A Mortalities	Pond B Mortalities
June 22		1
July 10		1
18	2	
19	1	
20	1	
24	2	3
25		3
27	2	3
30	4	7
31		2
Aug 1	1	2
4	1	1
9	1	
10		1
11	2	1
15		2
16		1
17		1
25	1	1
Sept 3		1
Total	20	29

4.1.2.1 Bird Predation

Various methods of controlling predation at Garson (nets across ponds, ribboned lines, guard dogs, scare tactics) were attempted during the first year. However, birds still continued to use ponds (especially from mid-July to end of September). Nets stretched across ponds were awkward to handle (ponds too wide). It was also difficult to obtain netting that was wide enough to cover ponds completely. If ponds were narrower (10-12 m), nets likely could have been used effectively against bird predators. This method is widely used in British Columbia where chinook and coho salmon, Oncorhynchus kisutch, are reared in narrow earth ponds (author, pers. obs.).

Ribboned line, stretched across ponds at 0.6 m intervals, appeared to prevent cormorants and fish-eating ducks from landing on pond surfaces. This method however, was not effective against herons. These birds were observed on numerous occasions feeding in shallow waters (close to shore) between the ribboned lines.

Guard dogs tied on long leashes, as well as various scare tactics, proved to be temporary controls only. Herons avoided dogs initially and did not come near the charr ponds however, after 2 or 3 weeks, they got used to the dogs' movements and were able to feed uncontrolled at the ends of each pond. Similarly, scare tactics such as gun shots and the use of loud bangers (supplied by Department of Natural Resources) were not effective over the long term. Herons would be scared off only to land a short distance away from ponds and remain there for a short period. This continued until they got used to the noise (this control method was ineffective once herons became accustomed to noises).

Herons first arrived at ponds on July 27, 1986. They were seen on numerous occasions from July 27 to October 2, 1986. Over a production period of 165 days, the total number of days in which herons were observed at the Garson ponds was 30. Since ponds were checked every second day (mornings only), the frequency of bird use was estimated to be at 18% of the production period. This, at best, is a minimum estimate of use.

It was also noticed that heron parents often brought their young to the ponds, especially during the latter part of August. This behaviour pattern may have contributed to mortalities in both ponds since the young birds were able to catch fish.

4.1.3 Water Quality

4.1.3.1 Well Water/Pond Surface Temperatures

Well water and pond surface water temperatures were recorded throughout the production period (Figure 11). Well water temperatures ranged from 5 to 7 C for most of the summer. Pond surface temperatures fluctuated from month to month, from 10 C at initial stocking up to 22.5 C in mid-summer (air temperatures approached 33.0 C and were high for prolonged periods), and a low of 1.5 C at harvest. Optimum temperatures for growth (12 to 16 C) were maintained for most of the period between May 20 to June 30, 1986.

Water temperatures in Pond B were generally consistent with Pond A temperatures (fluctuating 1 or 2 C).

4.1.3.2 Dissolved Oxygen and pH

Because pond loading rates were low and artificial aeration was used continuously during the first year, dissolved O_2 levels were not monitored closely. On June 18, 1986, DO (surface) from Pond B registered 9.6 mg l^{-1}. DO (surface) from Pond A was 9.4 mg l^{-1}. Oxygen levels on September 13, 1986 remained high (9.0 mg l^{-1}) in Pond A and well within the recommended range for successful salmonid culture (6.8 to 9.5 mg l^{-1}).

Table 10 shows pH levels found in well and pond water samples taken during October. All levels were within the recommended pH range for successful salmonid culture (6.5 to 9.0).

4.1.3.3 Ammonia,Nitrate, Nitrite, Conductivity, Ions

Water quality results were obtained for Pond A, Pond B, and well water samples during October, 1986. Ammonia, nitrite, nitrate, conductivity and some major ion concentrations were

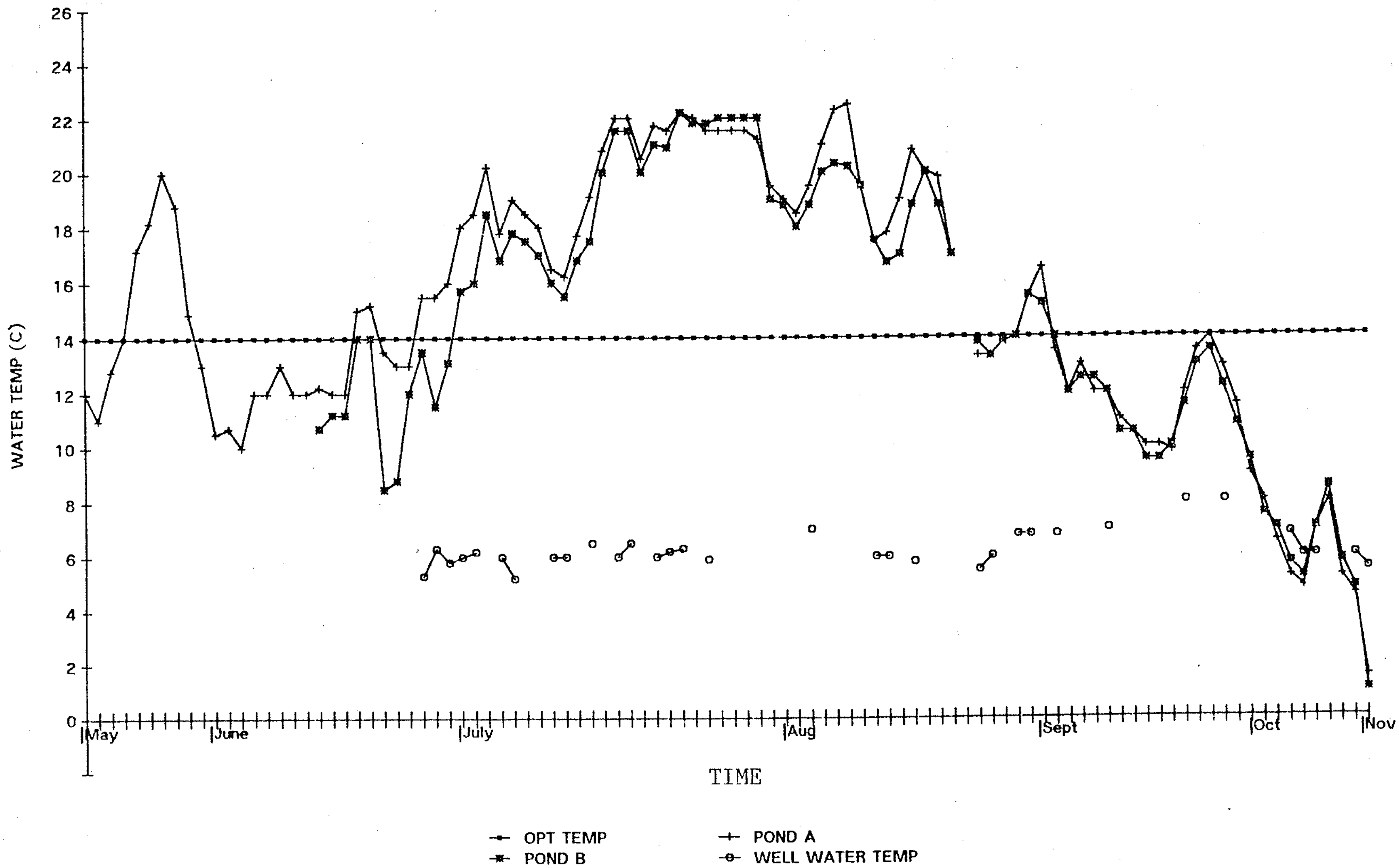


Figure 11: Pond and Well Water Temperatures at Garson, Manitoba (1986)

within recommended water quality guidelines for successful salmonid culture (Tables 10, 11). An NH_{4-N} concentration of 0.15 mg l^{-1} on October 9, 1986 in Pond A was high according to recommended water quality quidelines for salmonid culture (Sigma Resource Consultants Ltd., 1979). This problem occurred because well water was redirected from Pond A to Pond B for approximately one week in order to lower pond temperatures. As a result, ammonia levels were allowed to build up. Also, nitrate levels were high for both ponds however, salmonids suffer no harmful effects from nitrates unless they appear in concentrations of 800 to 1300 mg l^{-1}(Westin, 1974).

4.2 Biological Data (Year 2)

4.2.1 Growth Performance

In order to reduce stress and allow charr to grow at a more steady rate during summer, only one inventory was conducted on October 21, 1987 (at the end of production cycle). Charr were individually weighed after 143 days of growth (June 1 to October 21). One thousand graded N.W.T. charr grew from an initial mean weight of 43.1 g to a final mean harvest weight of 198.2 g (Table 12). A total of 728 fish were recovered from an initial population of 1000 charr. From this population, 362 fish ranged in weight from 15 to 195 g while 366 fish ranged from 200 to 450 g (Figure 12).

During the second year, one inventory of Pond B was conducted on October 18, 1987 to determine growth and survival rates for an initial population of 1044 Arctic charr (1000 N.W.T. charr stocked on June 11, 1986 + 44 N.W.T. and Labrador charr from Pond A stocked on May 14, 1987) over a period of 161 days.

All fish were approximately three years old at the time of sampling. A total of 387 charr were recovered from an original population of 1044. These fish grew from a mean weight of 211.7 g to a final mean harvest weight of 280.5 g from May 14, 1987 to October 18, 1987 (Table 12). Out of the total population of 387 fish, 211 ranged in weight from 35 to 165 g and 170 charr ranged

Table 10

pH, NH_{4-N}, NO_2-N, Conductivity Measurements, Garson, 1986

Sample Location	Date	pH	NH_{4-N} (mg/l)	NO_2-N (mg/l)	Conductivity (uS/cm)
Pond A (1150m3)	Oct. 9	8.47	0.15	0.048	657
Pond B (2230m3)	Oct. 9	8.47	0.080	0.028	647
Well	Oct. 9	8.31	0.060	0.003	657

pH, NH_{4-N}, NO_2-N, NO_3-N, Conductivity Measurements, Garson, 1986

Sample Location	Date	pH	NH_{4-N} (mg/l)	NO_2-N (mg/l)	NO_3-N (mg/l)	Conductivity (uS/cm)
Pond A (1150m3)	Oct. 23	8.37	0.050	0.017	1.52	639
Pond B (2230m3)	Oct. 23	8.36	0.080	0.021	2.03	664
Well	Oct. 23	7.69	0.010	0.002	7.00	695

Table 11

Dissolved Ions (Ca, Mg, Fe) Garson 1986

Sample Location	Date	Ca (mg/l)	Mg (mg/l)	Fe (mg /l)
Pond A	Oct. 23	42.9	61.7	< .04
Pond B	Oct. 23	43.9	61.7	< .04
Well	Oct. 23	43.4	62.2	< .04

in weight from 170 to 1425 g (Figure 13A). Six fish escaped back into the pond and were not weighed. A large size variation was evident within this population of charr.

Table 12

Final Growth Inventories (Year 2)

Pond Volume	Date Sampled	Strain + Initial Wt	No. of fish sampled	Mean pop. Wt (g)	No. Days of Growth	Sp. Growth (%/day)
Pond A	**Oct 21**	**N.W.T.**	**728**	**198.2**	**143**	**1.07**
(1150 m^3)		**43.1**				
Pond B	**Oct 18**	**N.W.T.**	**387**	**280.5**	**161**	**0.18**
(2230 m^3)		**211.7**				

4.2.1.1 Specific Growth Rate

During the second year, Arctic charr in both ponds (A & B) were sampled and weighed (individually) only once at the end of one production cycle. Therefore, overall specific growth rates have been calculated for a long period of growth (143 days for Pond A, 161 days for Pond B).

Specific growth rate for N.W.T. charr in Pond A was 1.07 percent day^{-1} for the period June 1 to October 21, 1987. Growth rate for a population of N.W.T. and Labrador charr in Pond B was 0.18 percent day^{-1} for the period May 14, 1987 to October 18, 1987 (Table 12).

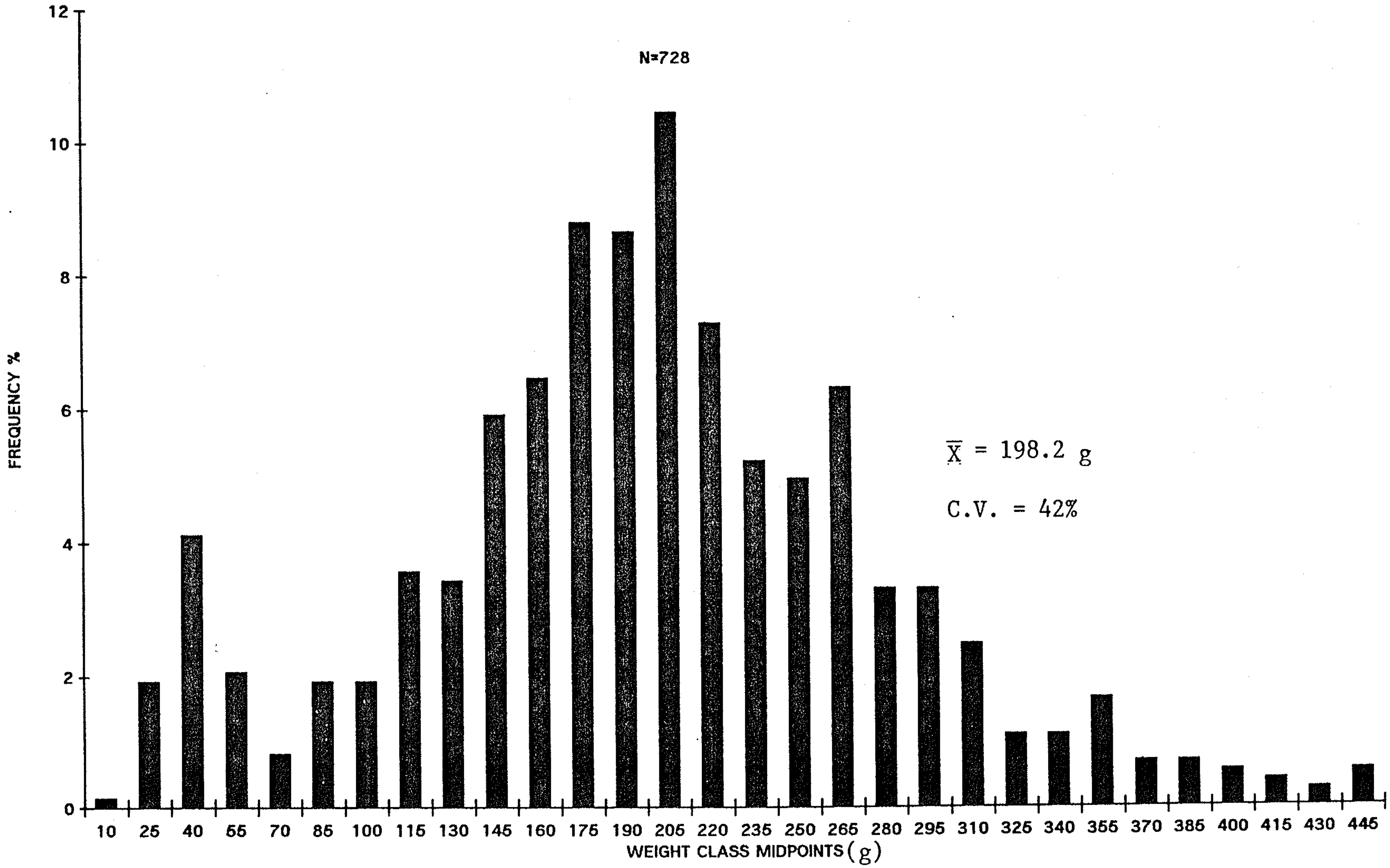


Figure 12: Size Distribution of N.W.T. Charr From Pond A at Harvest (Oct. 21, 1987)

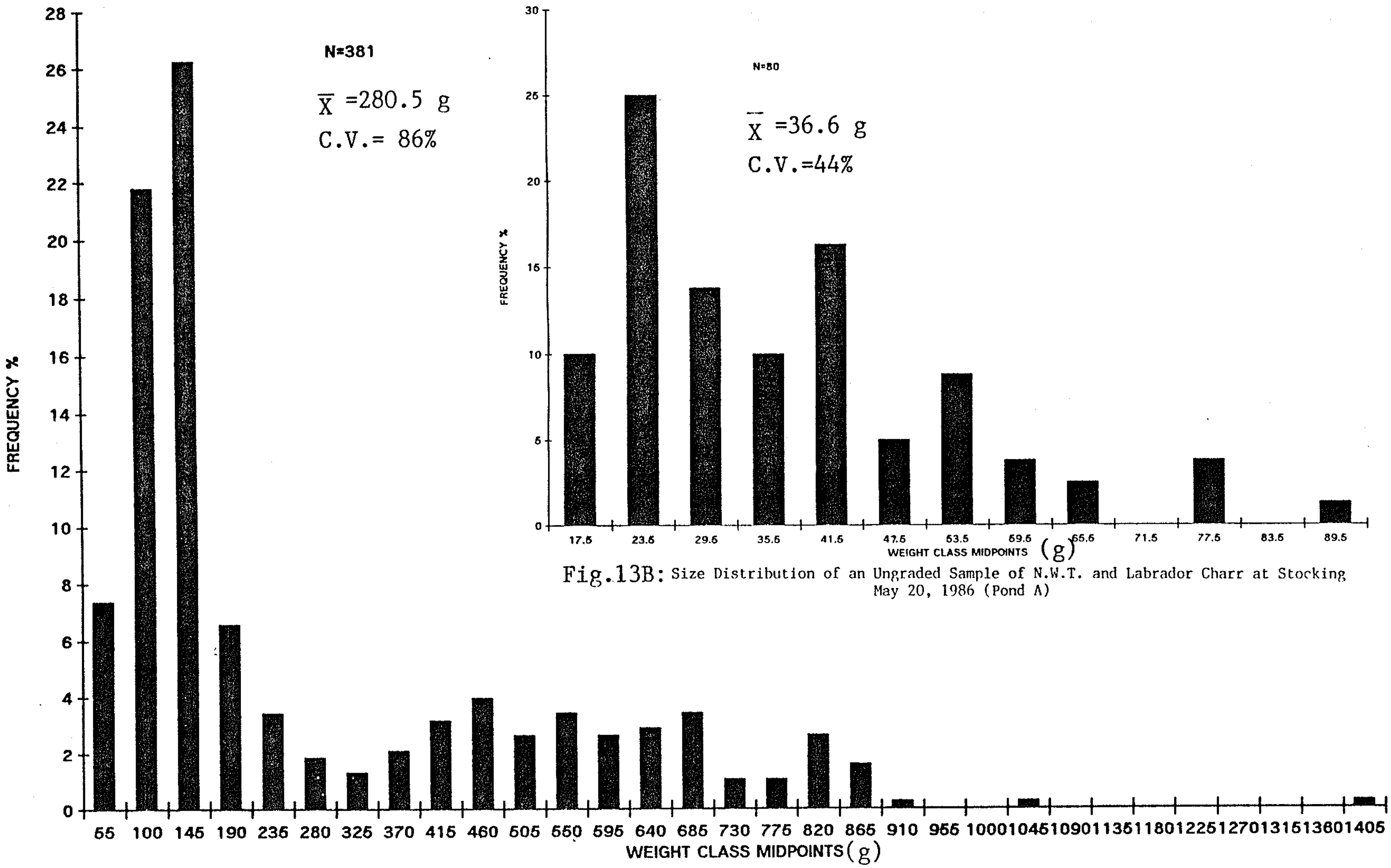


Fig.13B: Size Distribution of an Ungraded Sample of N.W.T. and Labrador Charr at Stocking May 20, 1986 (Pond A)

Figure 13A: Size Distribution of N.W.T. and Labrador Charr From Pond B at Harvest (Oct. 18, 1987)

4.2.1.2 Growth Model

Surface water temperature data that was collected from Pond A was used to develop a model of rainbow trout growth (from ponds at Garson, Manitoba) by using a growth model devised by Papst et al (1982). This model expressed specific growth as a function of temperatures and weight and could be used to estimate growth of salmonids at water temperatures ranging from 5 to 24 C. The initial size of fingerlings at stocking, the temperature of the pond over a specific growth period, and a scaling factor (a6) must be known before specific growth can be estimated. The scaling factor (needed to adjust the growth equation for different culture conditions) was determined to be 0.031 by experimenting with different scaling factors to obtain growth close to that of observed growth at Garson (from past growth records).

The effect on growth of stocking three different sizes of fingerlings (43 g, 25 g, 10 g) was simulated using the model developed by Papst et al (1982) at Garson pond conditions (Figure 14). The 43 g fingerlings achieved market size after approximately 125 days. The 25 g fingerlings achieved this same size after approximately 150 days. It was determined from this model that fingerlings stocked at 10 g would not achieve market size within the specified growing period (May to October) and therefore should not be used in commercial pond culture operations.

4.2.1.3 Total Yield (Production)

Production was determined for Pond A during the second year. A total of 728 charr were recovered from an original population of 1000 fish. Total yield was 144.3 kg per 0.047 ha (3070 kg per ha). Biomass of fish produced in Pond A was 101.2 kg per 1150 m^3 (87.9 g per m^3).

Production was also determined for Pond B during the second year. A total of 387 charr were recovered from an original population of 1044 charr. Total yield for Pond B was 108.6 kg per 0.079 ha or 1374.1 kg per ha. Biomass of fish produced in Pond B was 51.1 kg per 2230m^3 or 23.0 g per m^3.

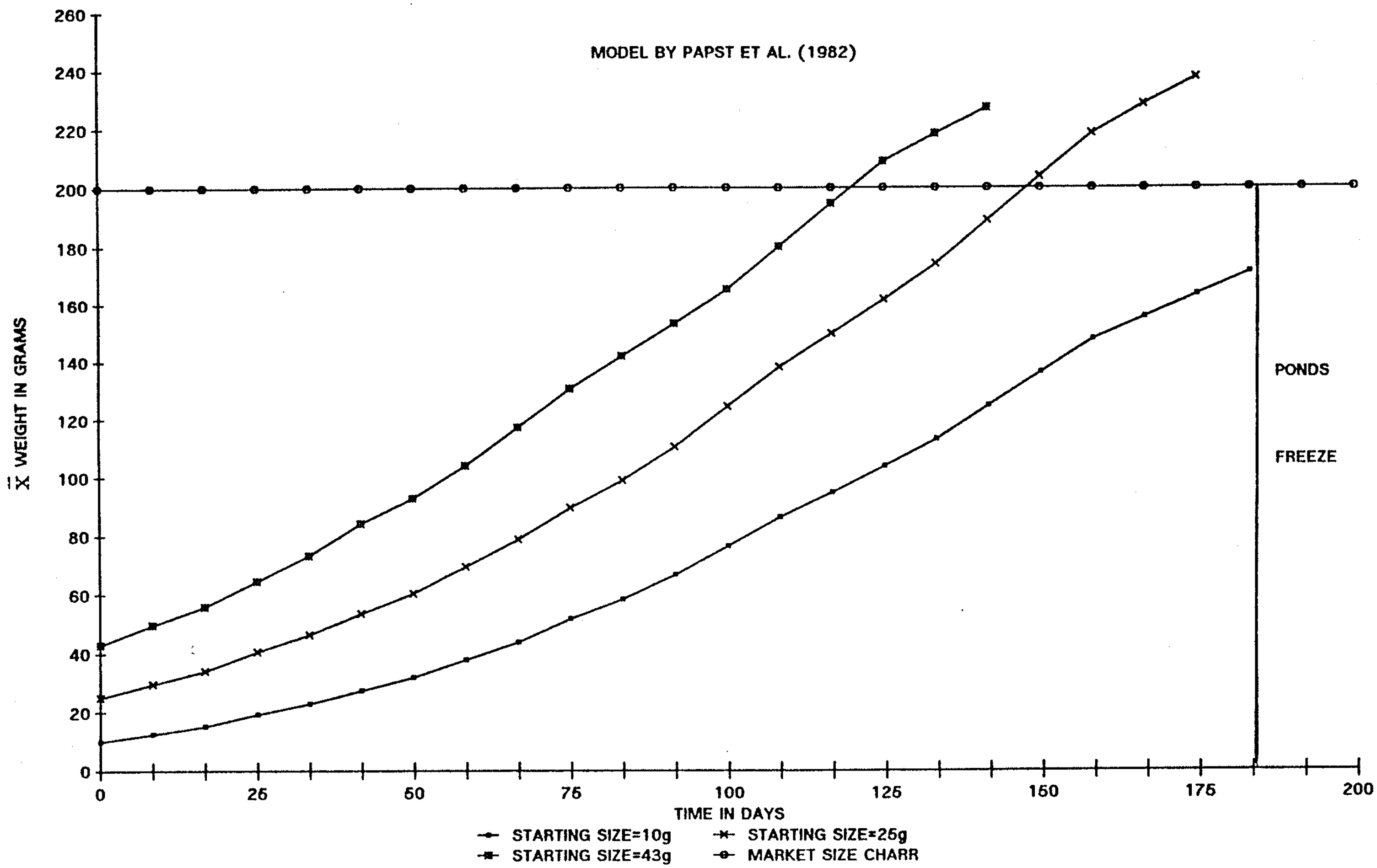


Figure 14:Effects of Starting Size on Growth of Arctic Charr at Garson Pond Temperatures

Production figures for Pond B represents one production cycle. Total yield and biomass were determined for a period between May 14, 1987 and October 18, 1987.

4.2.1.4 Conversion Ratio and Feeding

Feeding behaviour varied considerably depending on pond temperatures, weather patterns, time of day, and availability of natural food (flying insects, shrimp). During sunny days, Arctic charr concentrated on the pond bottoms and remained inactive. On cloudy days, charr were more active and were observed feeding on pond bottoms and mid-water areas (this necessitated the use of sinking pelleted food). Surface feeding occurred at sunset and at night around lights. Generally, as water temperatures cooled to 6 C (in October), feeding activity on surface decreased.

Because Arctic charr fed more actively on the surface in the evenings (after sunset), artificial food was administered by hand mostly during this period. Feeding occurred once per day (amounts varied from 850 to 1150 grams per feeding). Feed charts/schedules were not used during the second year of operation.

Charr were fed for approximately 104 days during the production period (June 1 to October 21, 1987) in Pond A. Feed conversion values were derived on the basis of total weights of feed provided and the total fish biomass less stocking weight calculated from samples weighed at harvest. A total of 134.7 kg of food fed produced 101.2 kg of fish biomass which provided a conversion ratio of 1.33:1. Although natural food was available to charr (insects, Gammarus), conversion ratios again were based solely on the amount of artificial food fed.

An attempt was made during the second year to provide optimum rearing conditions for Arctic charr in Pond A. Optimum water temperatures and water quality as well as more efficient use of artificial food fed (because of high survival rates of charr in the pond) were possible factors which led to an improved conversion value compared to the first year.

4.2.1.5 Coefficient of Variation

A population of graded N.W.T. charr reared in Pond A at Garson, over a period of 143 days, showed a "normal" distribution pattern. However, the high Coefficient of Variation (42%) indicated a large variation in size throughout the entire population (despite "size-grading" procedures before stocking).

Large size variation was again noticeable in a population of ungraded three year old charr (Labrador and N.W.T.) reared in Pond B over a period of 495 to 518 days (depending on strain). The Coefficient of Variation (C.V.) was very high (86%) with smaller charr being more numerous within the population. Two size groups were evident here - one group of small fish (mean weight approx 125 g) and one group of larger fish (mean weight approx 550 g). This growth pattern is similar to wild charr populations having both immature and mature fish.

The size distribution for an ungraded sample of Labrador and N.W.T. charr (which were stocked into Pond B along with other ungraded charr) is shown in Figure 13B. The Coefficient of Variation for this sample population was initially high (44%) at stocking and therefore, it is not surprising that the final C.V. was higher (86%) at harvest (these charr were reared over a period of 1.5 years).

4.2.2 Survival/Mortality

Because of increased efforts during the second year to minimize predation and to provide optimum temperatures for growth, mortalities of fish were significantly reduced. Only ten fish mortalities were observed during summer and most of these resulted from being caught in the wire fence that surrounded the pond.

Approximately 260 charr escaped from Pond A on August 16, 1987 after the pond overflowed its banks because of a clogged outlet screen and heavy rainfall.

Survival rates were calculated based on the final number of fish harvested form Pond A. Survival in Pond A was 73% however, it should be noted that this rate could have approached 100% if charr had not escaped from the pond.

4.2.2.1 Bird Predation

During the second year, bird predation was controlled by two methods: a) a wire fence erected around pond edges and, b) the operation of a mechanical man.

Cormorants were seen on one occasion during summer (in an unprotected pond containing rainbow trout). Herons were observed at the ponds on five different occasions. Tell-tale tracks around fenced ponds showed that these birds could not effectively predate upon charr (as long as fences were slanted inwards towards deep water). Wire fences, used in conjunction with other control methods (ribboned line across ponds) may be a deterrent to most bird predators visiting outdoor ponds at fish farms.

The mechanical man was not effective at controlling bird predators. Herons were seen fishing in unprotected ponds (used for rainbow trout) in full view of the mechanical man (while in operation).

The number of birds observed visiting the ponds was low (5) during the second year compared to the first year (30) (although ponds were checked every second day and usually only in the mornings) therefore, the frequency of bird use was estimated to be at 4% of the production period. However, again, this was a minimum estimate only. It was not known if the reduction in bird use during the second year was due to the effectiveness of the bird control methods or some shift in feeding behaviour which allowed birds to search for food less frequently outside their home territory.

4.2.3 Water Quality

4.2.3.1 Well Water/Pond Surface Temperatures

Well and pond surface water temperatures were recorded throughout the production period in Ponds A and B. (Figure 15). Well water temperatures ranged from 5 to 7 C during summer. Pond surface temperatures varied from month to month however, fluctuations were not as extreme compared to the first year. Temperatures ranged from 10 to 17 C in Pond A for most of the summer although during that time, optimum temperatures for growth prevailed (13 to 15 C). From August 13 to October 21, cooler pond temperatures were recorded because of lower air temperatures (4 to 11 C).

Water temperatures in Pond B deviated approximately 1 to 3 C from Pond A temperatures during one production period. Air temperatures were high (maximum temperature recorded was 34 C) however, they occurred rather infrequently and only for short periods during the second year.

4.2.3.2 Dissolved Oxygen and pH

Because a moderate loading rate (1000 charr) was used compared to the volume of Pond A, and also because artificial aeration was used continuously during the second year, DO levels were not monitored closely. DO (surface) in Pond A registered 8.5 mg l^{-1} on September 25, 1987. On October 20, 1987, DO (surface) was 8.2 mg l^{-1}. These levels were within the recommended DO range for successful salmonid culture (6.8 to 9.5 mg l^{-1}) (Sigma Resource Consultants Ltd., 1979).

4.2.3.3 Ammonia, Nitrite, Nitrate, Conductivity, Ions

Ammonia, nitrite, nitrate, conductivity, and major dissolved ion concentrations from Pond A were measured during October only. Table 13 shows readings for all water quality parameters listed above in both well and Pond A water samples taken on October 1 and October 16, 1987. Measurements are well within recommended water quality guidelines for salmonid culture.

Table 13

pH, S.R.P., NH_{4-N}, NO_2-N,$N0_3$-N, Conductivity Measurements, Garson, 1987

Sample Location	Date	pH	S.R.P (mg/l)	NH_{4-N} (mg/l)	NO_2-N (mg/l)	NO_3-N (mg/l)	Conductivity (uS/cm)
Pond A (1150m3)	Oct 1	8.92	0.020	0	0.017	4.300	679
Well	Oct 1	8.86	-	0	<0.001	4.400	689
Pond A (1150m3)	Oct 16	8.77	-	0.030	0.011	-	682
Well	Oct 16	8.83	-	0.030	<0.001	-	693

Dissolved Ions (Ca, Mg, Fe) Garson 1987

Sample Location	Date	Ca (mg/l)	Mg (mg/l)	Fe (mg/l)
Pond A	Oct 1	59.5	51.8	<.01

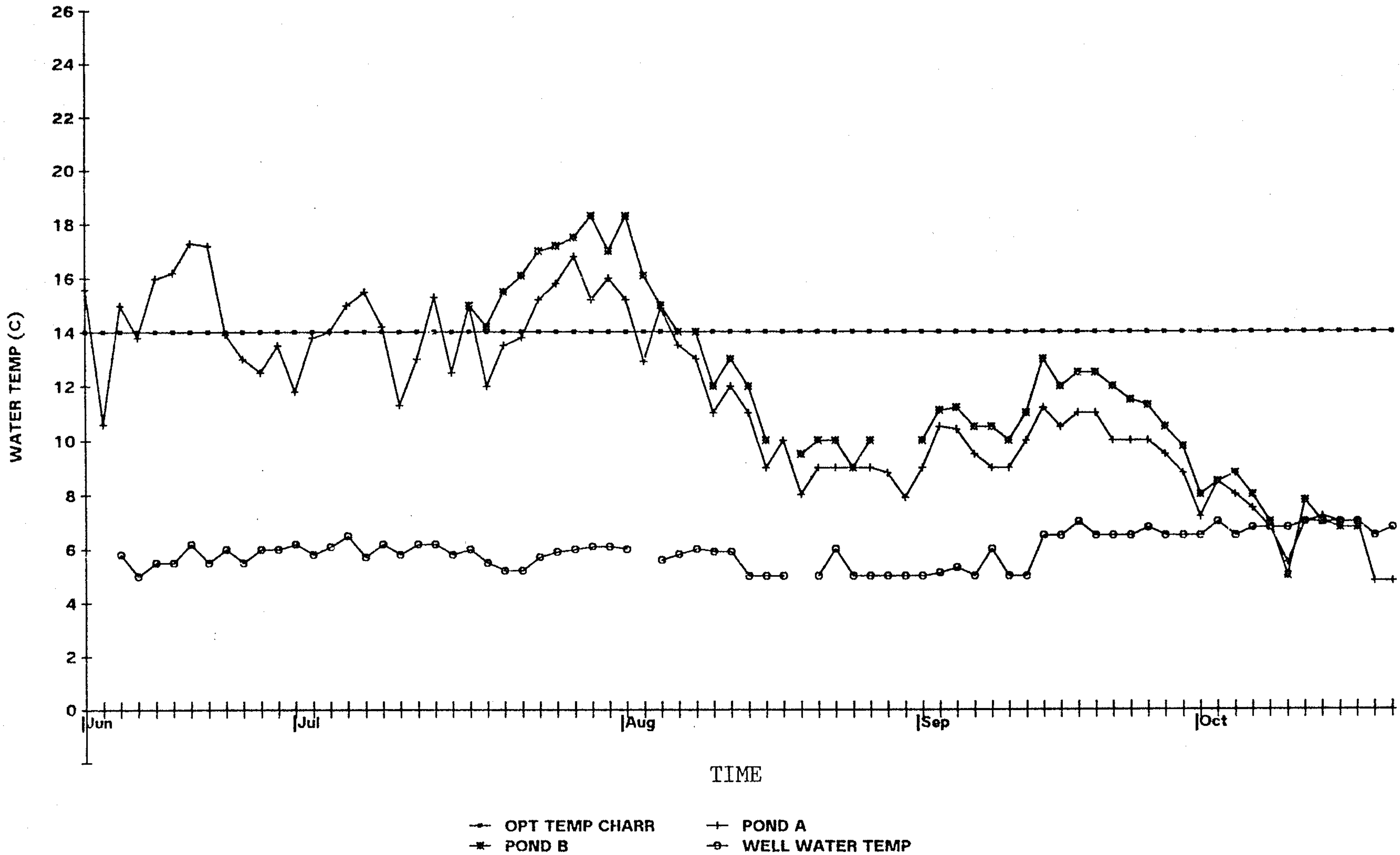


Figure 15: Pond and Well Water Temperatures at Garson, Manitoba (1987)

4.2.3.4 Secchi Disc Transparency

Secchi disc measurements were taken during October only. Throughout the production period, suspended solids (fine clay particles) in Pond A provided water clarity problems. This resulted from higher water flows which stirred up bottom material and also because of continuous aeration by surface spray aerators. Arctic charr however, did not seem to be adversely affected by murky water and continued to feed actively on surface in the evenings. In order to alleviate the above problem, the inlet hose of Pond A was elevated above pond surface (1.3m) so that well water could be dispersed across pond surface instead of towards the bottom of pond. Also, it was necessary occasionally to pump ponds down (1 to 1.5m) and turn aerators off for a few hours (to allow suspended solids to settle).

Secchi disc readings for October 4, 6, and 12 were 0.25, 0.20, and 0.60 m, respectively. These low readings reflect the presence of large quantities of suspended solids in the water column. Algae growth was not a factor in the second year of operation (possibly because of continuous aeration and lower pond temperatures compared to the first year).

CHAPTER V

Biological Discussion

5.1 Introduction

Experimental stocking of a limited number of charr fingerlings (provided by the Freshwater Fisheries Institute) into artificial ponds near Winnipeg, Manitoba in 1985 revealed negative results based on Arctic charr growth and survival performance as shown in Table 14 (Papst, pers. comm.). In all cases, results showed that few charr survived summer months in man-made ponds. However, because most of the ponds were not patrolled at regular intervals by the owners, poor survival rates could possibly be attributed to bird predation. High water temperatures may have also been a factor.

By assessing various limiting factors during the first year at Garson, adjustments and improvements in pond culture techniques were made during the second year of research which improved survival but did not affect growth.

5.2 Growth

Ayles (1975), Weatherley (1976), and Ayles and Baker (1983) have shown that differences in growth of salmonids can be attributed to both internal and external factors. Some of these factors are listed below.

a) Competition - certain fish are more competitive or aggressive and therefore can obtain more food for growth.

b) Genotype - some strains or stocks of a certain species of fish grow at a faster rate. Reinitz et al (1979) reared six strains of rainbow trout in a constant environment (11 C) and fed them an experimental diet for 180 days. Both growth

Table 14

Results From the Department of Fisheries and Oceans Stocking of Arctic Charr Fingerlings into Private Artificial Ponds in Southern Manitoba (1985)

	Location	St. Laurent, Manitoba	----	Winnipeg Area	Winkler, Manitoba	Winnipeg Area	Winnipeg Area	Carman, Manitoba
FISH DATA	No. Fish Stocked	100	2400	300	220	50	pond 1 (120) pond 2 (650)	250
	Initial Size	12.5 - 15 cm	1.08 g	11.0 - 15.0 cm	12.5 cm	17.5 cm	pond 1 (25 g) pond 2 (650)- 16-26 g	33-61 g
POND DATA	Area	21 m diam.	60,702 m^2	4046 m^2	121,404 m^2	66.9 m^2	#1-14,164 m^2 #2-6070 m^2	1.6 ha
	Depth (av.)	2.8 - 3.2 m	7.5 m	3.2 m	6.5 - 12 m	1.8 m	3.5 - 4.0 m	4.3 m
	Fresh-water added?	well	spring	spring	spring	run - off	----	----
HARVEST DATA	Date	----	Oct. 14	----	Aug. 7	Sept.28	Nov.	Oct. 31
	No. Fish	none	30	----	none	5	4	none
	Fish Size	----	12.5 - 15 cm	too small to seine	----	28 cm	35.5 cm	----

and feed conversion differed significantly among strains giving strong support to the hypothesis that the variation in body composition of rainbow trout was influenced by genotype. The Labrador strain of Arctic charr, as reported by Baker (1983), had growth rates similar to that of the Norwegian strain at 7 and 10 C however, Labrador charr growth rates were significantly higher at 14 and 19 C.

Table 14

c) Age - rate of protein increase is frequently related to age, being characteristically greater in older fish.

d) Precocity among males - Papst and Hopky (1983) found evidence of Arctic charr growing very little over a period of time and attributed this reduced growth to early maturation (food protein was being assimilated into energy for the production of sex products).

e) Temperature - optimum temperatures usually provide optimum growth and each species has a temperature preference (Hilton and Slinger, 1981; Leitritz and Lewis, 1980).

f) Food ration and composition - most species of salmonids will grow better on a natural diet. Sawchyn (1984) suggests that insects may provide essential trace elements or amino acids which are not available in artificial feed and which may serve to improve the digestibility of artificial food. However, some commercial diets are adequate and are formulated specifically for a particular species. Maximum growth can be obtained when fish are fed approximately 25 to 30 percent more than the optimum diet (based on feed tables). This procedure is ideal for commercial culture where target weights must be reached within a short period of time although special attention must be given to water quality management.

g) Fish density and metabolites - fish that are overcrowded will be subjected to increased stress and therefore will maintain poor growth rates (Daily and

Economon, 1983). In describing the intensive cage culture of rainbow trout in farm dug-outs, Sawchyn (1984) reports that a relatively safe stocking rate for pond culture operations (where artificial aeration is provided) is 1 fish per m^3 pond volume (1500 fish stocked into a 1500 m^3 pond).

Growth of Labrador and N.W.T. charr (reared together in Pond A) was influenced by high water temperatures (up to 22.5 C) during the first year. Both strains continued to feed in the evenings during hot summers. However, growth of charr is severely retarded when water temperatures exceed 18C (Swift, 1964; Jobling, 1982). Although Labrador charr were stocked at a smaller size (mean 32.3 g) compared with N.W.T. charr (39.8 g), their overall growth performance was greater at the end of one production cycle (mean 310.7 g for Labrador charr and mean 242.0 g for N.W.T. charr). Despite the fact that only 44 charr were harvested from an initial population of 200 the majority of these fish were marketable ($\geq$ 200 g).

Growth of N.W.T. charr, reared in Pond B during the first year, was also influenced by high water temperatures. Because these fish were stocked at a later date (June 11), the final mean harvest weight of the charr population was lower (190.1 g) compared to mean harvest weights from Pond A.

Since there was more control over predation and high water temperatures during the second year in Pond A, charr were allowed to grow under more optimal conditions (and displayed a normal distribution) over one production cycle. Approximately one-half (50.3%) of the total population of charr that were harvested (728) reached final weights of 200 g or more. However, because initial stocking of charr was late (June 1) and also because charr were harvested early (Oct. 21), the growth period could have been extended for another 37 days (from 143 to 180 days). This would have possibly allowed an additional 127 fish (in the size range from 170 to 195 g) to reach market size within the production period. Approximately 68% of the total charr population would have then been marketable.

Results from a final inventory of charr in Pond B showed that approximately 45% of a total population of 387 charr reached weights of 170 to 1410 g. From the same population, another 48% reached weights of only 80 to 165 g. which indicates that growth was restricted in large numbers of charr reared over long periods of time (two growing seasons). Milligan (1987) reported similar results for Arctic charr taken from a cold, deep lake near Lynn Lake, Manitoba. A harvestable size (200 g) was achieved after two growing seasons (470 days) although large size variations occurred within the lake population. These fish grew as fry from a mean weight of 1.34 g to a mean harvest weight of 181.5 g.

Difficulties in feeding charr, because of pond size and depth, a low stocking rate used, and the fact that charr did not feed actively on the surface, were possible reasons for differences in growth of fish in Pond B compared with pond A. There was also evidence that two different size groups had developed within this population of charr. Johnson (1980) reports that the seaward migrating Arctic charr stock from Nauyuk Lake, N.W.T. consisted of two distinct size classes, one of small fish (modal length 220 mm) and a larger class (modal length 600 mm). He suggested that if this bimodal length distribution represents a true condition then an increase in growth rate is implied. Fraser and Power (1984) reported that allopatric, landlocked Arctic charr from subarctic Quebec, had a bimodal length frequency distribution with modal values at 15 to 20 cm and 40 to 45 cm. The occurrence of two distinct size categories was attributed to possible changes in density dependent factors.

It is interesting to note that Labrador charr matured at 3 years of age in the Garson ponds while N.W.T. charr remained immature. This may be an important factor to consider if aquaculturists require brood stock.

5.2.1 Specific Growth Rate

Growth rates in this study were lower than those reported for Arctic charr reared under intensive culture conditions (Swift, 1964; Uraiwan, 1982; Baker, 1983; Papst and Hopky, 1983).

However, specific growth rates for charr reared in both ponds were similar to growth rates reported by Milligan (1987) who reared Arctic charr in a deep, northern prairie lake and by Gjedrem and Gunnes (1978) who grew European charr under Norwegian fish farming conditions (fluctuating temperatures). Also, Sawchyn (1984) reared rainbow trout (200 g) in prairie dug-out ponds at 1.1 percent day^{-1} over a period of 145 days. Growth rates of Arctic charr, reared in dug-out ponds at Garson, were similar, and therefore, indicated that this species was capable of growing as well as domesticated rainbow trout under pond culture conditions.

Specific growth rates were low for charr populations in ponds A and B over the winter period (during the first year) as well as for charr reared in Pond B over a total growing period of 1½ years. This compares with the growth pattern of Arctic charr at Nauyuk Lake as reported by Johnson (1980) where there is a minimal gain or considerable loss of weight over winter. However, despite the low growth rates, as described above, some tagged fish in the same ponds (over the same period of time) displayed higher growth rates. There may be some indication here of the adaptability or hardiness of certain individual fish within a population that allows them to attain larger sizes compared to other fish. Mills (1971) and Johnson (1980) indicate that there are four sub-species or forms of Arctic charr which may represent genetically distinct races or variations due to different habitats. These four forms display different growth patterns and include:

a) a predatory, fast-growing form feeding on fish and attaining weights of 4.5 kg,

b) a normal, medium-size form feeding on plankton and benthos,

c) a "dwarf" characteristic of alpine lakes and feeding mainly on plankton, and

d) a deep-water form living at depths of 33 to 115 metres and growing to a length of 10 to 20 cm.

It should be noted that because specific growth rate determinations were summed over long periods of time (in both years at Garson), it was imperative that a growth model be used to obtain a more accurate relationship between weight increase and time. This model, although originally developed for estimating growth of cultured rainbow trout, can also be used to determine Arctic charr growth under various culture conditions (Papst, pers. comm.).

It was found that Arctic charr, stocked initially at 43.0 and 25.0 grams (in Garson ponds) could grow to market size (200 g) at approximately 1.2 and 1.4 percent day^{-1}, respectively. These estimated growth rates were similar to observed growth rates for rainbow trout (Sawchyn, 1984). Growth rates for Arctic charr reared in deep, northern Manitoba lakes and prairie pothole lakes, were estimated by Milligan (1987) using the same growth model. Model comparisons have shown that growth rates of Arctic charr, reared in prairie potholes, were similar to Arctic charr growth under Garson pond culture conditions. However, growth rates for this species were considerably slower in deep, northern Manitoba lakes and therefore, market size could not be achieved in one production cycle under these conditions.

5.2.2 Fish Production

Biological, chemical, and physical factors control production in natural lakes or ponds. Lake/pond size and depth, the amount of littoral area and shoreline development, winter kill and summer kill phenomena, water temperatures and water quality, predation, etc. are all important in determining the amount of fish that can be supported or produced under natural conditions. Milligan (1987) reported that Arctic charr production was 4.4 and 4.9 kg ha^{-1} from two lakes in central Manitoba although survival was low (1% and 5.7%, respectively).

Sunde et al (1970) found that rainbow trout could be reared in natural prairie lakes up to 131.8 kg ha^{-1} however, the interaction of weather, lake morphometry, and water quality provided variable production results over two years in different lakes.

Because of greater control over various limiting factors, production (per unit area) from man-made ponds may be substantially increased over natural lake/pond production. Sawchyn (1984) was able to produce 353.7 kg of rainbow trout ($\geq$ 200 g) in cages from a dug-out pond of approximately 0.1 ha in size which represents 3537 kg ha^{-1} total production. Total biomass produced from this same pond was 261.4 kg per 1500 m^3 pond volume (or 174.3 g per m^3). Standing crop densities in ten Ontario rainbow trout pond production facilities ranged from 0.13 to 2.54 kg fish per m^3 of pond volume (average 0.85 kg per m^3) (Stechey, 1990).

At Garson, during the first year, production of charr was marginally better (in relative terms) than extensive aquaculture production from central prairie lakes as reported by Milligan (1987). Despite the high water temperatures in ponds A and B, water quality parameters were generally well within the "safe" limits for aquaculture production. Because of this, production was increased substantially in Pond A during the second year.

Production from Pond B, over a period of 1.5 years, was low considering that this pond was almost twice as large as Pond A. This low yield however, was understandable since heavy predation from herons occurred during the first summer.

Production from Pond A was similar (in year 2) to rainbow trout production from a prairie dug-out pond as reported by Sawchyn (1984). Again, water quality parameters were within "safe" limits for aquaculture production. Sawchyn (1984) suggested that a dug-out pond (1500 m^3 in volume) may support as many as 3400 rainbow trout ($\geq$ 200 g) without water recirculation if careful monitoring of pond conditions prevails.

With limited water flow (67.5 lpm) and two aerators operating, 5000 rainbow trout up to 400 g have been reared at La Broquerie, Manitoba, over the summer months in a prairie dug-out pond (similar volume) (author, pers. obs.). However, signs of environmental stress were evident as fish congregated around aerators during the late afternoon periods.

Since the maximum production from each pond is, in part, directly related to the initial loading rate, the number of charr stocked into the Garson ponds (1000) can be regarded as less than optimal for the pond size and conditions (having aeration and a flow-thru system). It was suggested that pond A (using a standing crop of approximately 1 kg per m^3 pond volume) could easily support approximately 6000 charr if water temperature averaged 15c (over one production period), flow rates were maintained at 157 lpm, and aeration was provided by a 4 - airstone manifold hooked up to a 3/4 hp compressor (Stechey, pers. comm.).

5.2.3 Food Conversion and Feeding

A conversion ratio of 3.8:1, within the first year at Garson, was high and could possibly be attributed to heavy predation, high water temperatures (which reduced feeding activity), and poor feeding practices.

Grayton and Beamish (1977), in comparing feeding frequencies of rainbow trout from one meal every second day to six meals per day, found that maximum daily food intake occurred with two feedings to satiation per day. Landless (1976) determined that stomach evacuation and return of appetite returns after eight hours. During the second year, improvements in feeding practices provided a minimum of food wastage (floating food was used at sunset when fish were actively feeding on surface while sinking food was used on cloudy days). Because of time constraints, it was often not possible to feed fish by hand more than once per day. To compensate for this loss of feeding time/frequency, lights at night were used in Pond A to encourage night feeding on insects. As well, an examination of stomach contents from a few sampled charr at harvest (in Pond A) showed that freshwater shrimp was being utilized as a food source.

Combined factors such as a minimum of food wastage, and the fact that freshwater shrimp, aquatic and flying terrestrial insects were available to charr, were possible reasons for an improved conversion ratio(1.33:1) in the second year. However, Sawchyn (1984), who measured the quantity of flying insects captured in insect traps (mounted over rainbow trout ponds at night), found that the amount of supplemental food (flying insects) was insignificant when compared to the total food intake of the fish (quantity of insect biomass was 5.0 grams day^{-1} over a period of 64 days).

In many aquaculture facilities, the use of automatic or demand feeders is a common operational procedure for rearing salmonids. Since the feeding of fish can be a time-consuming task, feeders may effectively eliminate some auxiliary staff or they can allow workers to concentrate on other tasks. The use of demand or automatic feeders in this study was not possible because of the difficulty involved in obtaining them.

Landless (1976) found that demand feeders worked efficiently (no food wasted) only if a large number of trout were reared together. Rainbow trout were conditioned to feed together in one area of a pond (at LaBroquerie, Manitoba) by using demand feeders (author, pers. obs.) although this feeding method (despite adjustments to rate of food dispensed) had a tendency to waste food (food accumulated on pond bottoms). Since charr school naturally and have been observed congregating en masse around lights at night, the possibility exists for this species to be attracted to feeders in one large group. However, it is not known if using automatic feeders on a regular basis at Garson would have improved Arctic charr growth rates.

5.2.4 Size Variability

In a commercial fish farming operation, it is important that fish grow at relatively uniform rates to market size so that a favourable yield can be obtained. This provides the aquaculturist with the potential for maximum cash earnings from sales over one production cycle. However, often when fish are reared together, their size range increases with age. This is, in part, due to natural variation but may also be due to size hierarchy effect (in which competition between fish suppresses the growth of certain individuals) or factors such as precocious maturation of males.

Wandsvik and Jobling (1982) found that the formation of hierarchies within various populations of Norwegian charr, reared at different temperatures, caused the suppression of growth of smaller individuals. Over a period of 115 days, C.V. increased from 11.73 to 32.57% and 12.56 to 31.45% for populations of charr reared at constant temperatures of 8.4 and 13.1 C, respectively. Jobling and Wandsvik (1983) compared growth rates of groups of Norwegian Arctic charr reared under conditions simulating "size grading" which was often used in fish farming operations. Results showed that there was an increase in C.V. with time which suggested that dominance hierarchies were established.

Papst and Hopky (1983) reared Arctic charr at 13 C under intensive culture conditions and found that a graded population, after 84 days of growth, developed a Coefficient of Variation of 59%. They also found that C.V. increased from 26 to 39% for a graded population of "small" charr (range 10.0 to 70.0 g) over a period of 48 days.

Populations of "medium" and "large" charr, reared over the same period, did not show any marked increase in C.V. It was concluded that the occurrence of early maturation (precocious maturity) amongst the smallest males was a factor contributing to the large variation in size. Therefore, it may be possible to provide some growth stability within populations of charr by "weeding" out smaller charr at an early stage in the production cycle. This would inevitably lead to reductions in feed costs. Also, selective breeding programs could possibly be implemented which selected for positive growth characteristics that are found in medium or large-sized charr. All of this could eventually lead to improved yields and higher profits.

In northern Norway, Johnson (1980) reports that non-migratory Arctic charr stocks contained "big" and "juvenile" or "dwarf" charr which were bimodally distributed. The larger charr were pelagic feeders while the smaller charr were littoral feeders. Immature fish showed a normal distribution for length with a mode at 250 mm while mature charr developed a modal value at 160 mm (with a long tail on the right-hand side of curve). It was suggested that in a slow-growing stock the juveniles, suppressed for many years, eventually undergo hormonal changes that allow reproduction to occur before they become normal adults.

5.3 Survival/Mortality

In wild charr populations, cannibalism causes high mortalities among the smaller fish of landlocked stocks however, competition for food is likely to play a greater part than predation in regulating numbers of charr in a particular system (Dept. of Fisheries & Oceans, 1984). It was suggested that food shortages restrict the growth of all fish within a lake and impinge on the survival of young charr.

In aquaculture, "natural" mortality refers to all losses of fish from abiotic factors, diet, predators, and pathogens. Reay (1979) reports that fish in captivity are susceptible to natural mortality for three reasons: (1) their artificial environment may be unsuitable because of inadequate understanding of requirements; (2) they cannot usually move away from any cause of potential mortality which would be the initial reaction of wild fish; and (3) at high densities there will be a tendency for a natural regulation of numbers to occur through mortality.

Eipper (1960), in comparing the survival and weight of trout in an unprotected, man-made pond at various times after stocking (over a three year period), reports that with natural food available only, few fish were left for harvesting. Numbers of trout in the pond had fallen from 600 to 230 per 0.4 ha after one year because of natural mortalities and only 45 per 0.4 ha after two years. He suggested that artificial feeding may improve survival.

Ayles (1977) found that survival of rainbow trout in prairie pothole lakes was variable, ranging from 0 to 50%, with an average of 30 to 40%. Mortalities varied depending on the techniques of planting, size of fingerling, strain of trout used, and the type of lake stocked. It was reported that heavy mortalities occurred shortly after stocking and were caused, in part, by predation from gulls (Larus argentatus) and terns (Sterna hirundo) and also by unidentified factors associated with the environment of a particular lake. Lawler et al (1974) found that survival in prairie ponds is not correlated with stocking rates below 2500 fish ha^{-1}, although at rates above 4500 fish ha^{-1}, survival was significantly lower.

Schramm et al (1987), in determining potential problems of bird predation for fish culture in Florida, found that from a possible 35 avian species which could have adverse effects on fish production, 20 bird species had estimated summer food consumption rates exceeding 100 grams day^{-1}. Great blue herons had one of the highest consumption rates of all birds visiting fish culture facilities in northern Florida depending on time of year (305 to 340 grams day^{-1}). Because of additional metabolic requirements for thermoregulation, food consumption would be greater in colder climates. It was also reported that in a Florida channel catfish (Ictalurus punctatus) grow-out pond, 13 double-crested cormorants consumed an estimated 246 fingerlings (7 to 16 mm/long) daily and it was determined that the abundance of cormorants increased almost four-fold in one year. Quantity of food required increases considerably when the adult birds are rearing young and therefore bird predation has the potential to become a significant factor affecting aquacultural production of fish.

During the first year at Garson, fluctuating, high, water temperatures (maximum temperature in small pond was 22.5 C) and heavy predation by herons contributed to poor survival rates of Arctic charr. McCauley (1958) determined that European landlocked Arctic charr could survive in water temperatures lower than 24 C. However, Hokanson et al (1977) reported that fluctuating temperatures in excess of the physiological optimum caused increased mortality rates of rainbow trout during the first 20 days of the experiment.

Dug-out ponds, with limited water flow (22.5 lpm) and maximum depths of 2.6 m were used experimentally to rear Arctic charr over the summer months near Steinbach, Manitoba (author, pers. obs.). Pond surface temperatures ranged from 18 to 24 C from June 15 to Aug 15, 1986. Heavy mortalities occurred as surface temperatures approached 23 C with subsequent loss of all fish.

The operation of a larger pump at the Garson ponds during the second year, provided higher water flows which lowered pond temperatures considerably (maximum temperature recorded in small pond was 17.3 C). Survival of charr improved from 22 to 72.8% compared to the first year. Additionally, the wire fence surrounding Pond A may have played an important role in reducing bird predation.

In both years, no mortalities were observed in the Garson ponds after initial stocking was completed.

Fish eating mammals, mink (Mustela vison) and otters (Lutra canadensis), were not seen at Garson during both years possibly because all ponds were located in open farmland and not close to wooded areas. However, on one occasion during the winter, a muskrat, (Ondatra zibethicus) was observed in Pond B feeding on charr that had become trapped in a screened, outlet pipe.

5.4 Water Quality

5.4.1 Pond Water Temperatures

Because of prolonged periods of hot weather during summer, it is often difficult to maintain outdoor pond water temperatures at ideal growth conditions for different fish species. Unless there are large reserves of well/spring water available, optimum temperatures, especially in ponds containing large volumes of water, cannot easily be achieved. If artificial aeration is not used and pond depths approach 5 m, thermal stratification may occur which can provide fish with cooler bottom water during summer. Continuous operation of aerators over a 24 hour period has the tendency to stabilize temperatures by mixing surface water with bottom water. The net effect of using artificial aeration (which allows the aquaculturist to grow more fish per unit pond volume) is the elimination of the cooler layer of bottom water to give a warmer, uniform temperature throughout the entire pond in summer.

Sawchyn (1984) reported that aerated ponds with an operating depth of 3.4 metres, developed constant temperatures on cloudy days however, temperatures fluctuated from 1 to 3 C (from top to bottom) on sunny days.

Heavy algal blooms in natural ponds during hot summers can create summer kill problems due to a sharp reduction in oxygen levels at night from plant respiration and decomposition. This problem seldom occurs in ponds that are artificially aerated on a regular basis.

Lawler et al (1974) and Ayles (1977) found evidence of muddy flavour in rainbow trout from prairie ponds. This off-flavour was attributed to substances such as geosmin and 2 - methylisoborneol which were found in algae such as Oscillatoria and Lyngbya sp. Ayles (1977) suggested that muddy flavour could be removed from fish if they could be harvested live and held in clear water for one to two weeks.

High water temperatures produced blooms of algae in Ponds A and B at Garson and provided a deterioration of water quality in the first year. Evidence of muddy flavour was noticed in some fish (after cooking) that were sampled once harvesting was completed. Because water flow was increased considerably into Pond A during the second year, pond temperatures were lowered sufficiently enough so that algal blooms were not a problem. Arctic charr that were sampled showed no evidence of muddy flavour in the second year. However, as a precautionary measure, aquaculturists may want to have a large tank available for holding live fish after harvesting (with seine nets) to ensure that muddy flavour is not a problem. Stechey (1990) has recommended that overall pond water quality can be enhanced with the application of beneficial bacterial supplements (eg. Bacta-Pur) which reduces the concentration of particulate and dissolved organic compounds. He also suggested that a water dye (Aquashade) should be applied to ponds in limited amounts to effectively reduce algae populations. Observations, following treatment of ponds with the above substances in subsequent years at Garson, have shown that water quality does improve.

5.4.2 Dissolved Oxygen and pH

To ensure the general health of fish, it is a common practice in salmonid culture to never allow oxygen levels in rearing units to drop below 6 mg l^{-1}. Salmonids can become stressed below this level with heavy mortalities occurring when oxygen concentrations are 4 mg l^{-1} for prolonged periods. Generally, as water temperatures increase, dissolved oxygen levels will decrease. It is extremely important therefore, that artificial aeration be used continuously during hot summers if large numbers of fish are going to be reared in outdoor ponds.

Sawchyn (1984) reported that heavy mortalities of rainbow trout occurred in dug-out ponds (from mid to late August) due to low oxygen concentrations brought about by high water temperatures and the fact that artificial aeration was only used during evening periods. He also found that oxygen gradients developed throughout the vertical profile of the ponds with fluctuating low oxygen levels (0.2 to 6.0 $mg.l^{-1}$) being recorded at pond bottoms. Gradients appeared to be less extreme when continual aeration was used in September with bottom DO levels never reaching critical levels.

Several factors, including the size of fish, total fish weight, species involved, and activity level of fish, determine how much oxygen is consumed over a specific period of time. At Garson, oxygen concentrations did not reach critical levels during summer since continuous aeration and low to moderate stocking rates were utilized in both ponds. Oxygen levels recorded in the latter parts of the production cycle in both years (September to October) were generally high (8.2 to 9.0 $mg\ l^{-1}$). However, Arctic charr showed signs of environmental stress during the first year as water temperatures approached 23 C. No behavioral signs were displayed (lethargy, crowding along pond edges, poor feeding response) during the second year which indicated oxygen deficiencies or other environmental problems.

Normal pH values for freshwater fish culture range from 6.7 to 8.6 with toxic effects being displayed at values below 5 and above 9 (Sigma Resource Consultants, 1979). Generally, waters slightly on the alkaline side support more fish than water on the acid side (Leitritz and Lewis, 1980). The pH values for the Garson ponds were slightly alkaline (there are large deposits of limestone below ground surface in this area). It should be noted that rainbow trout have been reared over the past 6 years (in one pond) at Garson with excellent growth (up to 5.5 kg) and health being achieved and therefore, it is reasonable to assume that pH of the water is appropriate for salmonid culture.

5.4.3 Water Chemistry

Ammonia in the water is mainly a biological by-product and in its un-ionized form (in low concentrations) it is extremely toxic to fish. Ammonia and CO_2 both affect pH in water which is not adequately buffered (buffering of ponds can be achieved by adding either alkaline or acidic substances to raise or lower pH). Reay (1979) also suggests that the combination of temperature and pH can affect the proportion of total ammonia which is in the toxic, un-ionized form and that a lower pH in combination with a lower temperature is beneficial and can reduce toxic effects if total ammonia is high. For example, if a total ammonia concentration is 12 mg l^{-1}, the un-ionized ammonia would be 0.01 mg l^{-1} (non-toxic) at a pH of 6.5 and water temperature of 10 C compared with 0.49 mg l^{-1} (toxic) of un-ionized ammonia at a pH of 8.2 and water temperature of 15 C.

At Garson, it was necessary, at times, to pump ponds down and refill them with well water in order to maintain water clarity. This procedure may jeopardize the health of all fish in ponds if maximum stocking rates are used. Ammonia and NO_2 concentrations may become more concentrated if water levels drop substantially in pond (either through evaporative loss or via pumping) after fish have been fed. Large volumes of water can be lost through evaporation in a relatively short period of time. Evaporation rates (obtained from the Winnipeg airport) for small lakes in Southern Manitoba have shown that approximately 0.9 metres of water evaporated into the air during 1988 from May to October (in each lake system). Therefore, it is important (especially on hot, summer days) to ensure that pond levels are maintained at normal operating levels throughout the production cycle. Ponds can be "topped up" periodically by temporarily re-directing well water from one pond to another.

Iron and manganese are detrimental to fish culture in both the ionized and un-ionized forms (Daily and Economon 1983). The development of insoluble hydroxide precipitates on gill filaments can seriously impair respiratory functions in alkaline waters.

High suspended solids in the water column can also interfere with feeding and may block or seriously irritate the gills of fish causing faulty respiration, poor growth, stress, and susceptibility to infections (Redding and Schreck, 1987). Food wastes, fine clay particles, and other debris settle on pond bottoms and are stirred up by fish. Because of this it is essential (in outdoor pond culture) that wastes and accumulated mud/debris be removed from pond bottoms at the end of each production cycle. This can be achieved by using a 2 hp gas-operated, trash pump (rented) with a flexible 4" hose (33 m) mounted in a small boat or canoe.

It is imperative that monitoring of water chemistry (especially pH, NH_4, NO_2) be done on a regular basis and preferably before ponds are drawn down. In this study, water quality analyses were limited due to time constraints and a lack of access to testing equipment.

5.5 Summary

Growth of Labrador and N.W.T. charr was affected by fluctuating, high water temperatures during the first year. Results from one pond showed that Labrador charr may grow better than N.W.T. charr over one production cycle under pond culture conditions. The majority of Labrador and N.W.T. charr from Pond A grew to a market size (200 g) over one production cycle. Mean harvest weights of N.W.T. charr (raised in Pond B) were lower than mean harvest weights for Labrador and N.W.T. charr (reared together) in Pond A. The majority of charr from Pond B did not reach market size over one production cycle. Factors such as high water temperatures, late stocking date, and difficulty in feeding fish may have been responsible for lower harvest weights.

Approximately 50% of the total charr population (728) reached market size during the second year in Pond A. Two-thirds of the charr population could have reached market size if initial stocking had been one month earlier and charr had been harvested one week later. A final inventory of charr in pond B (during the second year) showed that over a growing period of 1.5 years (summer and winter), Arctic charr (N.W.T.) grew at a slow rate with large size variations present.

Labrador charr matured in Pond B at three years of age while N.W.T. charr remained immature. This is an important consideration if aquaculturists require brood stock for future operations.

Even though only three tagged charr were recovered after 29 fish had been initially tagged and released, results showed that some fish may grow faster or slower than others under similar rearing conditions. It was suggested that perhaps the adaptability or hardiness of some individuals allow them to grow at a fast rate.

Arctic charr growth rates in Garson ponds were lower than those reported for charr reared under intensive culture conditions. However, growth rates were similar to growth rates from charr reared under Norwegian fish farming conditions and from northern prairie lakes.

Because there was greater control over various limiting factors (water quality, predation, etc.), production (per unit volume) from man-made ponds may be substantially increased over natural lake or pond production. During the second year, Pond A production was similar to rainbow trout production from prairie dug-out ponds. Total production from Pond B, over a period of 1.5 years, was low however, results may have been influenced by heavy predation from herons.

Food conversion was high for charr reared in Pond A during the first year and this was attributed to a combination of heavy predation, high water temperatures which reduced feeding activity, and poor feeding practices. Food conversion was low in the same pond during the second year. Improvements in feeding practices and the availability of natural food were suggested as possible reasons for this low value.

Size variation of Arctic charr reared in man-made ponds was discussed in relation to wild charr populations and charr reared under intensive and extensive culture conditions. Large variations in size of Arctic charr seemed to be quite common in all populations regardless of origin. A graded population of N.W.T. charr reared in Pond A showed a normal distribution pattern with large variation in size. Distribution was heavily "skewed" to the right in a population of ungraded charr reared in Pond B over 1½ years. Smaller charr were more numerous than larger individuals and it was evident that two distinct size groups had developed.

Survival was low in both ponds during the first year. High water temperatures and predation from herons played a key role in lowering survival of charr. During the second year, survival improved and it was concluded that increased water flow into Pond A (which lowered pond temperatures) and the construction of a wire fence around the pond edges were major factors contributing to increased survival of charr. However, growth rates remained similar in both years.

Water quality was also discussed in relation to pond/well temperatures, pH and dissolved oxygen concentrations, and water chemistry (NH_4, NO_2, NO_3, major ions). Pond surface temperatures were sub-optimal for growth of charr. This was attributed to high air temperatures at the Garson site and low water flows during the first year. A deterioration of water quality (produced by algal blooms) was brought about by high water temperatures. Observations showed that periodic pumping of one metre of water from ponds and refilling them with well water improved water clarity. It was suggested that regular monitoring of water quality must be implemented and feeding of fish should be discontinued in those periods before ponds are pumped down. Lowering of water levels could be lethal to fish since NH_4 and NO_2 concentrations may become more concentrated especially if fish have fed previously.

Muddy flavour was detected in fish from both ponds during the first year and was attributed to bacteria found in algae. It was suggested that this problem could be overcome if fish could be harvested live and held in clear water for one to two weeks. Muddy flavour problems were not evident during the second year.

Dissolved oxygen measurements were taken infrequently during both years. Measurements recorded in the late stages of growth showed that oxygen concentrations were high in both ponds.

Overall, water chemistry met the requirements for successful salmonid culture and was well within recommended guidelines. However, suspended solids in Pond A during the second year provided minor problems which were alleviated by pumping water from the pond periodically. As a routine procedure, it was recommended that waste should be removed from pond bottoms at the end of each production cycle by using a gas-operated trash pump.

CHAPTER VI

Economic Results and Discussion

6.1 Introduction

An economic model for a small-scale fish farm at Garson, Manitoba (utilizing man-made ponds for rearing Arctic charr to market size) was used and included a financial statement and a break-even analysis. Capital investment and operating costs were determined for one rearing pond and this data was extrapolated for a four-pond rearing system. Past experience at Garson, Manitoba has shown that four ponds can be managed efficiently by one person on a part-time basis. Revenue generated from sales of Arctic charr was estimated based on wholesale prices ($8.00 to $11.00 per kg.) that producers would receive for fresh, dressed charr from Winnipeg supermarkets (Bentley, 1989).

The economic model outlined should not be interpreted altogether as being representative of the costs and revenue generated for small-scale aquaculture in Manitoba. Development costs of any two farm sites can vary greatly (Castledine, 1986). The Garson site had some excellent features for aquaculture production in that it was situated close to available markets in an area where large groundwater reservoirs were relatively close to the ground surface. Since all of the Garson area is composed of clay soils, construction and operation of outdoor ponds as rearing units was desirable because of the excellent water-holding capacity of clay. The financial statement was developed for the Garson fish farm which displayed the following characteristics:

a) one rearing pond (1150 m^3) with a flow-thru system

b) well water pumped at 450 lpm (water flow to service three ponds)

c) farm site is within 35 km of markets in Winnipeg, Manitoba

d) all equipment was purchased new except for a 2 hp centrifugal pump (for lowering pond levels), old sewer pipe used as pond outlet pipes, and a large tank for holding fish alive for one to two weeks in well water (to remove off-flavours).

e) Arctic charr fingerlings were stocked at 12.7 to 15.2 cm and could be purchased for $0.40 per fingerling if they were available from local suppliers in the fall

f) labour costs involved part-time work for harvesting/processing of charr only. All other work was done by the owner/operator.

6.1.1 Economic Assumptions

- Costs associated with pond construction are paid for in total during the first year. However, it should be emphasized that capital investment could be reduced to $17,532.00 (in year 1) if the above costs were distributed over a three year period.
- The economic assessment does not reflect G.S.T. costs. Fish producers initially must pay the above tax on various items purchased, however, they can claim these expenses as deductions on their income tax form at the end of the year.
- A 12% interest rate is assumed over a 5 year period.
- Whole, dressed charr would be sold at a future, predicted wholesale price of $9.50 per kg.
- Capital investment includes the high cost of purchasing a used vehicle for transportation of fish to markets as well as for routine farm use. It is assumed that the fish farmer does not have a vehicle and must purchase one.
- The economic analysis reflects prices for materials and services based on 1990 dollars.

6.2 Financial Statement

The financial statement for the Garson fish farm was formulated using similar methods of Blum (1979) and Castledine (1986) for Ontario trout farms. Revenue, capital investment, and cost components were calculated for three different scenarios:

(A) actual production of 98 kg of market-size (200 g) Arctic charr from one pond (pond A) with 73% survival. Stocking density was low due to a lack of available fingerlings. Total costs (fixed and variable) for this scenario was $3,396.00.

(B) a more efficient utilization of one pond with an estimated production of 714 kg of market-size charr (which is based on 70% recovery of market-size fish from an optimal stocking density of 6000 fish and 85% survival). Total costs for this scenario amounted to $8,718.00.

(C) an efficient operation of a four-pond rearing system with an estimated production of 2856 kg of charr (each pond similar in size/volume to pond A) based on an optimal stocking rate of 6000 fish/pond, 85% survival, and a 70% recovery of market-size fish. Total costs for this scenario amounted to $22,385.00.

6.2.1 Capital Investment

Initial capital expenses, outlined in Table 15, were incurred during the development of the fish farm at Garson. Because all start-up costs (for land and equipment) were paid for in cash by the owner of the Garson property, the variable cost (interest on working capital) is not listed under scenario (A), however this expense is included under scenario (B) and (C).

Under scenario (A), one well pump, two fresh-flow aerators (including one spare), and one holding tank would be needed. Scenario (B) is similar to (A) except for the use of a 3/4 hp air compressor (and an additional spare) with a four airstone manifold which increases stocking densities (compared to fresh-flow, spray aerators). Under scenario (C) four ponds would be

Table 15

Capital Investment for Different Pond Culturing
Scenarios at Garson, Manitoba

Capital Investment	1990 Scenario (CDN $)		
	A	B	C
a) land	300.00	300.00	300.00
b) pump (2 hp)	513.00	513.00	1539.00
c) well (installation) 24 m casing	1080.00	1080.00	1080.00
d) pond construction & landscaping	1720.00	1720.00	6880.00
	surface-spray	compressor	compressor
e) aerators (including spares)	1473.00	445.00	700.00
		small pick-up	
f) used 1/2 ton truck	4500.00	3000.00	3000.00
g) electrical service to site	500.00	500.00	950.00
h) plumbing fixtures	150.00	210.00	360.00
i) sewer pipe (used) 6 m long	180.00	180.00	720.00
j) floating 2 hp pump + 15 m lay-flat hose	1100.00	1100.00	1100.00
k) holding tank (3.65 m diam)		1500.00	3000.00
l) canoe or small boat	350.00	350.00	350.00
m) mechanical man	150.00		
n) seine net (25 m x 3 m)	260.00	900.00	900.00
o) 0_2 meter (Sentry III)	540.00	540.00	540.00
p) fence material (wire)	100.00	100.00	400.00
q) miscellaneous items (dipnets, plastic tubs, pails, twine, screen, extension cord, waders, knives, thermometers)	200.00	250.00	300.00
Total Capital Investment	13,166.00	12,688.00	22,119.00

operating and therefore three well pumps (2 hp) (including one spare), three compressors (including one spare and four manifolds), as well as two holding tanks would be required. Two pumps operating from one well could easily service four ponds. Under scenario (A), materials for seine net construction were purchased at a supply shop in Winnipeg and the net was assembled by the author for a total cost of $260.00. This manufacturer has now ceased operations and therefore pond seine nets (with floats and lead line) can be purchased from Pacific Net and Twine in British Columbia. Under scenarios (B) and (C), seine nets could be constructed and purchased for $900.00 (including freight charges).

Actual machine costs involved in the construction of pond A and a drainage ditch (including levelling around pond) amounted to $1720.00

A used 2 hp floating pump was purchased for $1100.00 (including lay-flat hose) and was used primarily for pumping ponds down periodically for water quality improvements. This pump was also used, at harvest time, to decrease pond water levels so that fish could be captured more efficiently with a seine net.

A mechanical man was constructed for $150.00 and was used to scare herons and other predators away from fish ponds. This device, however, proved to be ineffective for the above purposes and therefore, was not included under scenarios (B) or (C).

Large holding tanks (3.65 m diam) are used at the end of each production period to keep fish alive in well water for one to two weeks (without feeding) in order to remove off-flavours and firm up flesh. New plastic tanks can be purchased from Bonar Plastics in Winnipeg for $1500.00. Two tanks would be required under scenario (C).

6.2.2 Revenue

Under scenario (A), actual production from pond A in 1987 was 98 kg of market-size charr. Milligan (1987) reported that the dressing of charr entails a weight loss of less than 10%. Therefore total production of dressed charr would be 88 kg. Since Arctic charr could be sold in

Winnipeg for $8.00 to $11.00 per kg (average $9.50 per kg) (fresh-dressed), total revenue generated from potential sales would be $840.00. Under scenario (B) an estimated production from Pond A was 714 kg. Total production of dressed charr would be 643 kg. Revenue generated from sales would be $6105.00. Under scenario (C), an estimated production from four ponds (stocked initially with 6000 charr each) was 2856 kg. Total production of dressed charr would be 2570 kg and revenue generated would be $24,419.00

6.2.3 Variable Costs

Variable costs are those costs involved in the operation of one or more pond rearing units at Garson for the production of charr (over one production cycle). Processing and marketing costs are also included here (Table 16).

Fingerling Costs:

Although Arctic charr fingerlings were supplied free of charge (by the Dept. of Fisheries and Oceans) for this study, the economic assessment was based on purchased fingerlings, approximately 30 to 40 grams each. This size proved to be adequate for pond culture operations at Garson since the majority of charr reached target weights (200 g) over one production cycle. However, it should be noted that earlier estimations of growth using a growth model suggested that similar weights may be achieved (over the same period) if smaller fingerlings (25 g), purchased at lower prices, were stocked into ponds. Field studies with this size of charr should be implemented to determine conclusively if market size can be achieved under pond culture conditions.

Presently, there are no regular suppliers of Arctic charr fingerlings in Canada, however a few private suppliers in Manitoba offer limited quantities and would sell charr at a price slightly above the current price for rainbow trout fingerlings.

Under scenario (A), fingerlings were provided free of charge and therefore are not included as a cost item in the economic analysis. Under scenarios (B) and (C), fingerling costs reflect a commercial price of $0.40 per fingerling and therefore total costs for 6000 and 24,000 fingerlings

Table 16

Revenue and Variable Costs for Different
Pond Culturing Scenarios at Garson, Manitoba

Revenue	1990 Scenario (CDN $)		
	A	B	C
Charr Sales	750.00	5425.00	24,419.00
Variable Costs			
a) fingerling purchase		2400.00	9600.00
b) Fish food (artificial)	125.00	795.00	2645.00
c) Gammarus lacustris	15.00	60.00	240.00
d) labour (part-time)		180.00	790.00
e) water quality aids		227.00	320.00
f) all-risk insurance			595.00
g) repairs & maintenance of equipment	180.00	300.00	420.00
h) hydro	340.00	370.00	745.00
i) transportation (repairs, gas)	230.00	230.00	450.00
j) property taxes (1 acre)	27.00	27.00	27.00
k) ice	28.00	200.00	800.00
l) ammonia test kit		64.00	64.00
m) contingency expense		100.00	200.00
n) U.I.C., C.P.P.		8.00	35.00
Total Variable Costs	945.00	4961.00	16,931.00

would be $2400.00 and $9600.00, respectively. Delivery charges of $1.00 per km would be added costs. Since fingerlings could be purchased in Garson at Arctic Aquafarms Inc., delivery fees are not applicable for this assessment.

Food Costs:

Artificial - food costs were determined for the second year of operation only. Pelleted food consisted of regular sinking and floating food (sizes 3PT, 4PT, 5PT) as well as pigmented floating food (sizes 4PT, 5PT). Prices per bag (25 kg) of regular sinking and floating food averaged $17.20 with additional shipping costs (from Elmira, Ont.) of approximately $2.75 per bag. Pigmented floating food averaged $18.75 per bag (25 kg) with additional shipping costs of $2.75 per bag. A total of 135 kg of food was used over one production cycle (scenario (A)). Total feed costs during the second year was approximately $125.00. Under scenarios (B) and (C), it was estimated that approximately 810 and 3240 kg of food would be required for a total food cost of $793.00 and $2645.00, respectively.

Natural - A total of 5.45 kg of freshwater shrimp was purchased from a supplier (Erickson, Manitoba) on July 29, 1987 at a price of $11.00 per kg. Total costs were $60.00. Because the shrimp were distributed evenly amongst all four ponds at Garson, approximately 1.4 kg were stocked into Pond A. Therefore, costs for Pond A was $15.00. It was estimated that under scenarios (B) and (C), approximately 5.5 and 22 kg of shrimp, respectively, would be required to provide food supplements for charr (because of stocking densities and numbers of ponds).

Labour Costs:

Labour costs would involve the harvesting, dressing, and cleaning of charr at the end of one production cycle. The number of man hours required was based on actual times recorded for harvesting and dressing rainbow trout at Garson in previous years. It was also suggested by staff at the Freshwater Fish Marketing Corporation (in Winnipeg) that an individual with average experience could gut and clean approximately 130 fish per hour. In all scenarios, the owner/operator would not receive a wage for his/her work and additional workers would be paid $8.00 per hour. Also, U.I.C. and Canada Pension Plan contributions would be extra costs.

Under Scenario (A) all charr were harvested from pond A and released into a larger pond for overwintering (they were not marketed). Under scenario (B), a total of 3570 charr (initially 6000 charr - 85% survival and 70% recovery of market-size fish) would require approximately 22 man hours (not including owner's time) for harvesting, dressing and cleaning fish. This represents $180.00 in labour costs for one additional worker, as well as U.I.C. and C.P.P. costs of $8.00. Under scenario (C) a total of 14,280 charr (3570 charr per pond for 4 ponds) would require 98 man hours for harvesting, dressing, and cleaning fish. This represents $790.00 in labour costs for two additional workers. U.I.C. and C.P.P. costs would amount to approximately $35.00.

Hydro

Hydro costs at Garson (under scenario (A)) involved the operation of one 2 hp well pump, one 1/2 hp surface-spray aerator (operating for twenty-four hours) and one 100 watt light bulb (for 8 hours) over a period of 143 days. Extra power would also be required to operate a 2 hp floating pump (periodically) during the production cycle under scenarios (A), (B), and (C). Winnipeg Hydro charges $1.80 for a 2 hp motor operating over a twenty-four hour period and $0.04 for a 100 watt bulb operating for an eight hour period. Total costs were $340.00 (scenario (A)).

Hydro costs for pond A (scenario (B)) were $370.00 (operating of one bulb, one 3/4 hp compressor, one 2 hp well pump). Under scenario (C), four ponds (similar to pond A) would be in production which would require a total of two 2 hp well pumps, two 3/4 hp compressors and four 100 watt light bulbs. Total costs would be $745.00.

Transportation Costs:

Transportation costs would involve the operation and maintenance of a 1/2 ton truck mainly for the purpose of transporting fish to markets in Winnipeg and surrounding areas. The truck would also be used periodically for hauling equipment and materials to and from pond sites and for making trips into Beausejour (for servicing equipment & for purchasing miscellaneous items). A return trip to Winnipeg is approximately 70 km. Gas can be purchased for $0.50 per litre in Winnipeg and the truck averaged 8.8 km per litre of gas. Total cost per trip was $4.00. A return trip to Beausejour (14 km) was approximately $0.80. Estimated total gas costs for the operation of a truck over one production cycle was $80.00 for scenarios (A) and (B). Repairs to the truck would also be included here. These costs are estimated to be $150.00. Because of more fish to process and transport to Winnipeg, it was estimated that transportation costs (under scenario (C)) would increase to $450.00.

Repairs and Maintenance of Equipment:

Actual equipment repair costs amounted to $180.00 (for rewiring a 2 hp floating pump motor). However, the financial statement also includes potential costs that should be considered such as servicing of aerators and pumps (which can break down periodically after extended use.). This would involve rewiring of motors and the replacing of impeller blades, bearings, bushings etc. which can be purchased separately and installed by the owner/operator of the ponds. These additional costs are estimated at approximately $300.00 (scenario (B)). Because of the use of more equipment under scenario (C), it was estimated that repair costs would increase to $420.00 over one production cycle.

Water Quality Aids:

Maintaining a high standard of water quality is an important consideration in outdoor pond culture operations. Both Aquashade (controls algae) and Bacta-Pur (reduces bottom sediment) can be used to enhance water quality in ponds. These substances were not used under scenario (A) because of budgeting constraints however, they have been included in scenarios (B) and (C). In subsequent years at Garson, both Aquashade and Bacta-Pur have been used regularly and have proven to be effective for the purposes described above. Aquashade can be purchased in Ontario (Aquafarms Canada Ltd.) for $92.00 per gallon (4.55 l). Bacta-Pur can be purchased from Canadian Aquaculture Systems for $125.00 per four gallons (18.2 l) and should be injected directly into pond bottom sludge via a pipe or hose.

Ice:

Ice sells for approximately $0.32 per kg in Winnipeg and it is estimated that one kg of ice is required for every kg of dressed charr being transported to local markets. Under scenarios (A), (B), and (C), ice costs amounted to $28.00, $200.00, and $800.00, respectively.

Risk Insurance

All-risk insurance for fish farming enterprises covers all loss of fish stocks from predation, summerkill, disease, and equipment malfunctions. This kind of insurance is offered by only a few brokers in Canada. One international insurance broker located in British Columbia (Sedgwick Tomenson Inc.) indicated that they could insure charr reared in outside ponds (for 2-3% of total fish value) however, this would only be considered if fish value was $100,000 or more. In southern Ontario, brokers charge $1.30 per 100 dollars of fish value however, their coverage is restricted to the province of Ontario only. One insurance company indicated that they would insure charr being reared in prairie ponds if regulations permitted them to do so. Under scenario (C), a four-pond rearing system could be insured for $595.00 provided that the ponds were not isolated and were protected by a six foot fence.

6.2.4 **Fixed Annual Costs**

Commercial Fish Farming Licence:

A licence is required by aquaculturists who wish to develop a fish farming enterprise. In Manitoba, licences are available from the Fisheries Branch of the Department of Natural Resources (for $15.00) and must be renewed each year. This cost is included in all three scenarios (Table 17).

Depreciation Expense

Fish farm assets (listed below) were depreciated at a rate that is consistent with the Federal Income Tax Act, Small Business Guide, and the Farmer's and Fishermen's Guide (1990). Depreciation is a system of accounting that distributes the value of an asset over its working life.

a) Pumps: Two pumps would be required under scenarios (A) and (B). A 2 hp impeller-driven pump (new) and a 2 hp floating pump (used) cost approximately $1615.00. Pumps are categorized as a class 8 asset and are depreciated at 20% per year. Therefore, the depreciated cost is $323.00. Under scenario (C), three 2 hp pumps and one floating pump would be required to service four ponds. Total costs would be $2640.00 and the depreciated cost would be $528.00.

b) Aerators: Under scenario (A), two fresh-flow aerators were depreciated at 20% per year (class 8 asset) and therefore, expenses amounted to $295.00. Under scenario (B), two air compressors would also be depreciated at 20% per year for a total depreciated cost of $90.00. Three compressors (including one spare), under scenario (C), would be depreciated at $140.00.

Table 17

Fixed Costs for Different Pond Culturing Scenarios at Garson, Manitoba

Fixed Costs	1990 Scenario (CDN $)		
	A	B	C
a) fish farming licence	15.00	15.00	15.00
b) depreciation expenses			
pumps (20%)	323.00	323.00	528.00
well (20%)	215.00	215.00	215.00
aerators (20%)	295.00	90.00	140.00
truck (30%)	1350.00	900.00	900.00
seine net (20%)	52.00	180.00	180.00
O_2 meter (20%)	108.00	108.00	108.00
canoe\boat (15%)	53.00	53.00	53.00
tanks (20%)		300.00	600.00
miscellaneous (20%) - (tubs, pails screen, fencing, waders, wiring etc)	40.00	50.00	60.00
c) Interest on working capital (12%)		1523.00	2654.00
Total Fixed Costs	2451.00	3757.00	5454.00

c) Well: Wells are categorized as class 8 assets and depreciated at 20% per year. Therefore, depreciated cost amounts to $215.00 for one well.

d) Truck: A used 1/2 ton truck depreciates at 30% per year and is regarded as a class 10 asset. Depreciated cost is $1350.00 per year.

e) Seine Net: Nets are categorized as class 8 assets and depreciated at 20% per year for a total cost of $52.00 under scenario (A) and $180.00 for scenarios (B) and (C).

f) O_2 meter: Oxygen meters are categorized as class 8 assets and are depreciated at 20% per year or $108.00.

g) Canoe/dingy: Boats are categorized as class 7 assets and are depreciated at 15% per year or $53.00.

h) Tanks: Under scenario (B) one tank would be required to hold fish alive. Tanks are categorized as class 8 assets and depreciated at 20% per year. Depreciated costs under scenarios (B) and (C) are $300.00 and $600.00, respectively.

i) Tubs, pails, fencing, waders, wiring, etc.: Miscellaneous items are depreciated at 20% per year and categorized as class 8 assets. Total depreciated costs for scenarios (A), (B), and (C) are $40.00, $50.00, and $70.00 respectively.

*Note: Pond construction and landscaping is regarded as a local improvement to land and these costs are usually regarded as land costs. Fish ponds are relatively permanent in nature and can be maintained indefinitely therefore, they cannot be depreciated. Improvements to land with <u>limited</u> lives should be depreciated over their estimated lives.

Table 18

Summary of Financial Statement for Small-Scale
Pond Culture at Garson, Manitoba (1990)

	Scenario (CDN $)		
	A	B	C
Total Capital Investment	13,166.001	12,688.00	22,119.00
Revenue (Charr Sales)	840.00	6105.00	24,419.00
Total Variable Costs	945.00	4961.00	16,931.00
Total Fixed Costs	2451.00	3757.00	5454.00
Total Variable & Fixed Costs	3396.00	8718.00	22,385.00
Net Profit	-2556.00	-2613.00	+2034.00

6.2.5 Analysis of Financial Statement

6.2.5.1 Net Profit\Loss

Net losses were recorded for scenarios (A) and (B) (Table 18). Under scenario (A), all expenses were paid for in cash and cost factors, such as fingerlings and labour expenses, were not included. However, the pond operation was still not profitable at a low stocking density of 1000 charr (net loss of $2556.00). Under scenarios (B), when all costs are included in the economic assessment (for one pond operating over one production period), there was also a net loss of $2613.00 (despite stocking pond with 6000 charr). Food and fingerling costs were major expense items under both scenarios (B) and (C). A four-pond system (Scenario (C)) obtained a net profit of $2034.00 (with all cost factors being considered). Net income (after taxes) amounted to

$1688.00 and this compared similarly with small-scale extensive aquaculture in northern Manitoba (Milligan, 1987).

It should be noted that there is a possibility of increasing net income under scenario (C) because the non-marketable portion of the charr population (at end of production cycle) can be overwintered in the same pond with one aerator running continuously throughout the winter. For example, if 30% of the surviving charr population are not marketed (6120 fish) and approximately one half of these are immediately culled because of their small size (7" or less), then the remaining half should be overwintered and allowed to grow to market size during the second year. Fingerling purchases (in year two) could be reduced by about $1200.00. Increased hydro costs (for the operation of two compressors over winter) would be approximately $250.00. Therefore, net income (in year 2) if all components of the operation are the same, would increase to $2460.00. Productivity and efficiency ratios for the overall operations would also increase.

6.3 Break-Even Analysis of Production

Break-even analysis is used to determine the level of harvest whereby sales revenue (from Arctic charr) will just cover fixed and variable costs of fish production. Variable costs are those costs that fluctuate in direct proportion to changes in output. Fixed costs are those costs that remain constant in spite of changes in output.

Break-even level of production can be determined by the following formula:

$$Q = \frac{F}{P-V}$$

where:

Q = quantity produced (kg)

P = sales price per unit ($/kg)

V = variable cost per unit ($/kg)

F = fixed cost ($)

The above formula was used to calculate the break-even level of production for 24,000 charr and for fish weighing 200 grams under scenario (C) (Table 19). The price here ($9.50/kg) is based on the future average wholesale price for charr in Winnipeg as determined by Bentley (1989). Results of the analysis showed that with variable costs reaching $5.93 per kg of market-size charr produced, the level of production required to break-even was 1528 kg or a 32% survival/recovery rate.

Table 19

Break-Even Level of Production

Variable	Scenario (C)
Fixed Costs ($ CDN)	$ 5454
Variable Costs ($ CDN)	$ 5.93 / kg
Price	$ 9.50 / kg
Q	1528 kg market-size
Fish (200 g)	7640
S (24,000 fish)	32%

(Q = break-even production, S = survival rate)

A break-even table was formulated for scenario (C) to determine net profit or loss received if different recovery rates of charr were obtained. Production levels, net income, variable and fixed costs were calculated and outlined in Table 20 and Figure 16.

Net income from fish sales increases dramatically with increased recovery rates and a maximum profit of $11,682 can be realized if there was 100% recovery of market-size charr. Total costs (variable and fixed) are high and this has resulted in net losses if recovery rates are low (less than 32%). Above this point, net profit increases steadily reflecting the high income from fish sales which is directly related to the high wholesale price paid for dressed charr.

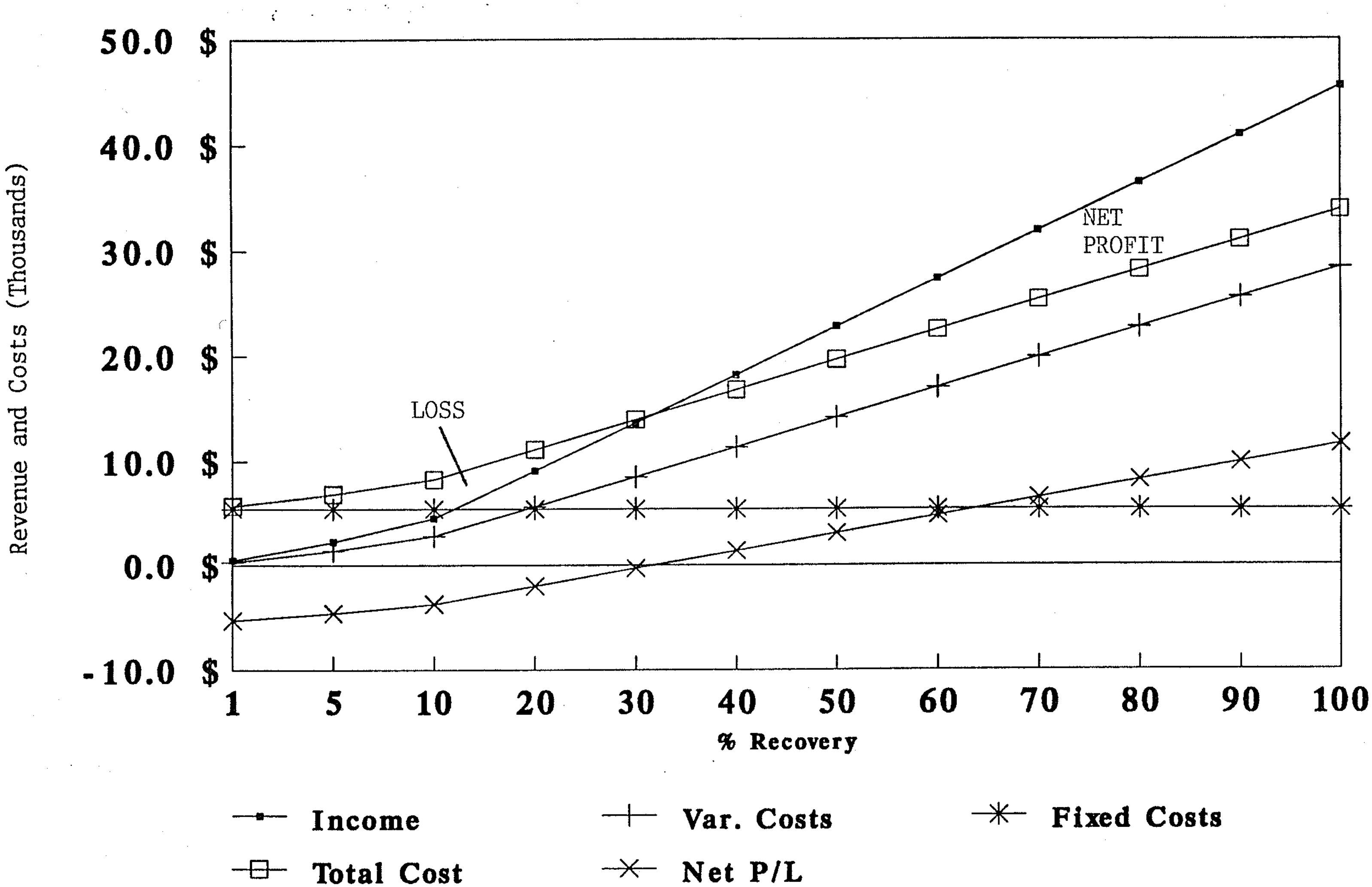


FIGURE 16: BREAK-EVEN ANALYSIS SHOWING NET PROFIT OR LOSS

Table 20

Break-Even Table

Rec (%)	Prod (kg)	Income ($)	Var C ($)	Fix C ($)	Total C ($)	Net P/L ($)
1	48	456.0	284.6	5454.0	5738.6	-5282.6
5	240	2280.0	1423.2	5454.0	6877.2	-4597.2
10	480	4560.0	2846.4	5454.0	8300.4	-3740.4
20	960	9120.0	5692.8	5454.0	11,146.8	-2026.8
30	1440	13,680.0	8539.2	5454.0	13,993.2	-313.2
40	1920	18,240.0	11,385.6	5454.0	16,839.6	+1400.4
50	2400	22,800.0	14,232.0	5454.0	19,686.0	+3114.0
60	2880	27,360.0	17,078.4	5454.0	22,532.4	+4827.6
70	3360	31,920.0	19,924.8	5454.0	25,378.8	+6541.2
80	3840	36,480.0	22,771.2	5454.0	28,225.2	+8254.8
90	4320	41,040.0	25,617.6	5454.0	31,071.6	+9968.4
100	4800	45,600.0	28,464.0	5454.0	33,918.0	+11,682.0

Total costs involved in the production of 2856 kg of market-size charr (representing 85% survival of an initial population of 24,000 charr and a 70% recovery of market-size charr) under scenario (C) were $7.85/kg. Milligan (1987) reported that extensive aquaculture in northern Manitoba lakes could produce market-size charr with total costs approaching $7.93/kg (initial population per lake was 7500 with a 30% recovery of marketable fish). Price-Waterhouse (1990) indicated that total costs involved in the operation of a large intensive trout grow-out facility in southern Ontario amounted to $4.31/kg of trout produced (after interest expenses which assumed 70% debt). It was not known however, if this low cost reflected the total costs for production of market-size fish only or for all fish (both marketable and non-marketable). Under scenario (A), it was estimated that approximately 68% of charr within the total population (from pond A) could have reached market size if there was a full six-month growing period. The break-even analysis for production was approximately 1528 kg (32% recovery) under scenario (C) however, because of the large size variability found within charr population a 48% recovery rate (marketable and non-marketable fish) would be a more realistic objective in order to achieve a break-even level of production. From the analysis, as long as survival is high and the non-marketable portion of fish within a total population is 30% or less, then reasonable profits can be obtained from this method of culture.

The effect of fish price and size of stocked fingerlings will be analyzed in the following pages using break-even analysis as described above.

6.3.1 Effect of Price on Profit

As previously indicated, the average wholesale price paid for charr (in the future) would most likely be between $8 and $11 per kg of dressed charr. However, it was emphasized by Western Management Consultants (1989) that the eventual price for dressed charr **may level off to approximately $1.00 above the price paid for trout** in Canada ($6.26/kg trout). Profits are directly related to prices received for charr as well as the total costs involved in the operation. Prices fluctuate with supply and demand and, since there is only limited production of Arctic charr in Canada presently, wholesale prices for charr will remain high until production of this species increases substantially.

The following prices have been used to determine the effect of price on break-even level of production (Table 21).

a) $7.26/kg ($3.30/lb.) - all charr sold at $1.00 above the current price paid for rainbow trout in Ontario

b) $8.80/kg ($4.00/lb)

c) $9.50/kg ($4.30/lb)

d) $10.56/kg ($4.80/lb)

e) $11.70/kg ($5.30/lb)

Table 21

Effect of Price on Break-Even Point

Variable	$7.3/kg	$8.8/kg	$9.5/kg	$10.6/kg	$11.7/kg
Fixed Cost	$5454	$5454	$5454	$5454	$5454
Variable Cost	$5.93/kg	$5.93/kg	$5.93/kg	$5.93/kg	$5.93/kg
Price	$7.30/kg	$8.80/kg	$9.50/kg	$10.60/kg	$11.70/kg
Break- Even Point	3981 kg	1900 kg	1528 kg	1168 kg	945 kg
Fish (200 g)	19,905	9500	7640	5840	4725
Survival	83%	40%	32%	24%	20%

Using the lowest price ($7.30/kg) received for Arctic charr ($1.00 above rainbow trout price), the break-even level of production was high (83%) with only a small profit being achieved at 100% recovery of charr. As the price received for dressed charr increases to $11 per kg, the break-even level of production gradually decreases to a point where low survival/recovery rates (22%) are required to cover all costs (variable and fixed). Throughout a price range of $8 to $11 per kg of charr, recovery rates for break-even production are quite reasonable and therefore, the potential for earning profits is good.

The effect of price on net profit or loss has been determined using break even tables and the results are graphed (Figure 17).

The analysis showed that net profits were <u>highly sensitive to price</u> and that if wholesale prices for charr remained high (approximately $11/kg), fish culturists could earn as much as $10,000 - $16,000 over one production cycle with a 70-80% recovery rate. Pond culture (at Garson) is still viable at lower wholesale prices for charr ($8.80 - $9.50/kg) with 70% recovery rates. Profits are reasonable ($4,000 - $8,000) and could be sufficient enough to be used as income supplements for individuals living in rural areas. If prices of charr decrease below $8 per kg, a small profit can be realized only if recovery rates are high (90%). Therefore, it would not be practical to develop this kind of operation if wholesale prices for charr drop below this level.

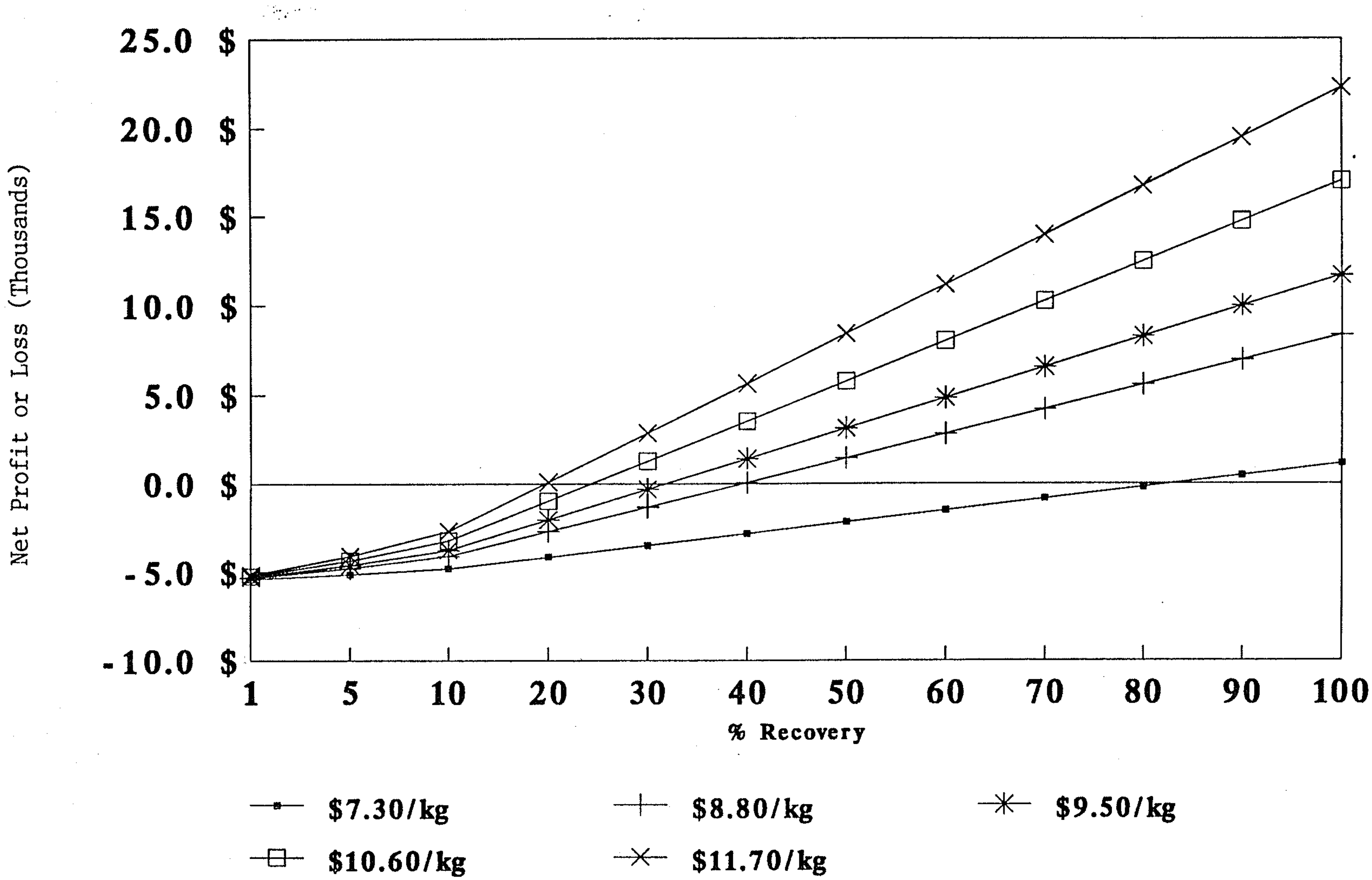


FIGURE 17: EFFECT OF PRICE ON PROFIT

6.3.2 Effect of Fingerling Size on Profit

Under ideal growth conditions (ie. optimum water temperatures and water quality), rainbow trout can achieve growth rates of approximately one inch (2.54 cm) per month. Growth performance of Arctic charr can be similar to rainbow trout if reared under ideal conditions. Final harvest weights of charr are directly related to initial size of fingerlings at spring stocking as well as other biological and environmental factors.

For this analysis, 30 to 40 gram charr (5.5") were initially stocked into pond A with a mean harvest size of approximately 200 grams being achieved at the end of one production cycle. The effect of starting size of fish on growth was demonstrated by a growth model in the biological analysis. It was found that 10 gram charr would never reach marketable size under Garson pond conditions however, 25 and 43 gram charr were capable of reaching target size during this time period. Taking into consideration the size variability within each charr population, it is possible under ideal conditions that five inch fish (approximately 22 grams) may reach a final mean harvest size (after 6 months growth) of 11 inches (or approximately 200-250 grams). Six inch charr (40 grams), initially stocked into ponds, could reach a final mean harvest size of 12 inches (or approximately 250-300 grams). Seven inch charr (62 grams) could also reach a final mean harvest size of 13 inches (or approximately 350-400 grams). In order to produce more marketable fish, it may be appropriate to stock larger fingerlings in spring however, there is a trade-off between a higher cost for larger fingerlings and an increased number of market-size fish.

With 100% of the recommended ration being utilized by charr (based on actual feed tables used for rearing rainbow trout), it was estimated that, over one production cycle at 14 C, five inch charr would require 30% less food than seven inch fish. As well, six inch charr would require 20% less food than seven inch charr.

The financial effect of stocking both smaller and larger fingerlings into the Garson ponds is analyzed in the following pages. Differences in variable costs can be attributed to: a) changes in fingerling costs and, b) changes in feed costs. Five inch Arctic charr fingerlings (23 grams) could be purchased for $0.30 each. Thirty to forty gram charr (5.5" to 6") and sixty gram charr (7") could be purchased for $0.40 and $0.70 each, respectively. Fingerling costs would decrease if 23 gram charr were stocked into Garson ponds ($7200 for 24,000 fish compared to $9600 if 30-40 gram charr are required). Purchasing costs would increase for sixty gram charr ($16,800 compared to $9600 for 30-40 gram fish). Arctic Aquafarms Inc. in Garson, Manitoba could supply charr fingerlings and transportation of fish would be free for large orders if location of ponds is within 50 km of hatchery.

Feed costs at Garson, over one production cycle, (for charr initially stocked at 40 grams) would amount to $2645 under scenario (C). If 23 gram charr were stocked, feed costs would decrease to approximately $2314. Feed costs would increase to $3305 if 60 gram charr were stocked into ponds.

Changes in variable costs (outlined above) were incorporated into the financial statement (under scenario (C)) and the effect of fingerling size on break-even level of production was determined (Table 22)(Figure 18).

Table 22

Effect of Fingerling Size on Break-Even Point

Variable	5 inch (23 gram)	6 inch (40 gram)	7 inch (60 gram)
Fixed Cost	5454 (CDN $)	5454 (CDN $)	5454 (CDN $)
Price	$9.50/kg	$9.50/kg	$9.50/kg
Variable Cost	$4.97/kg	$5.93/kg	$8.68/kg
Break-Even Point	1204 kg	1528 kg	6651 kg
Fish (200 g)	6020	7640	33,255
Survival	25%	32%	138%

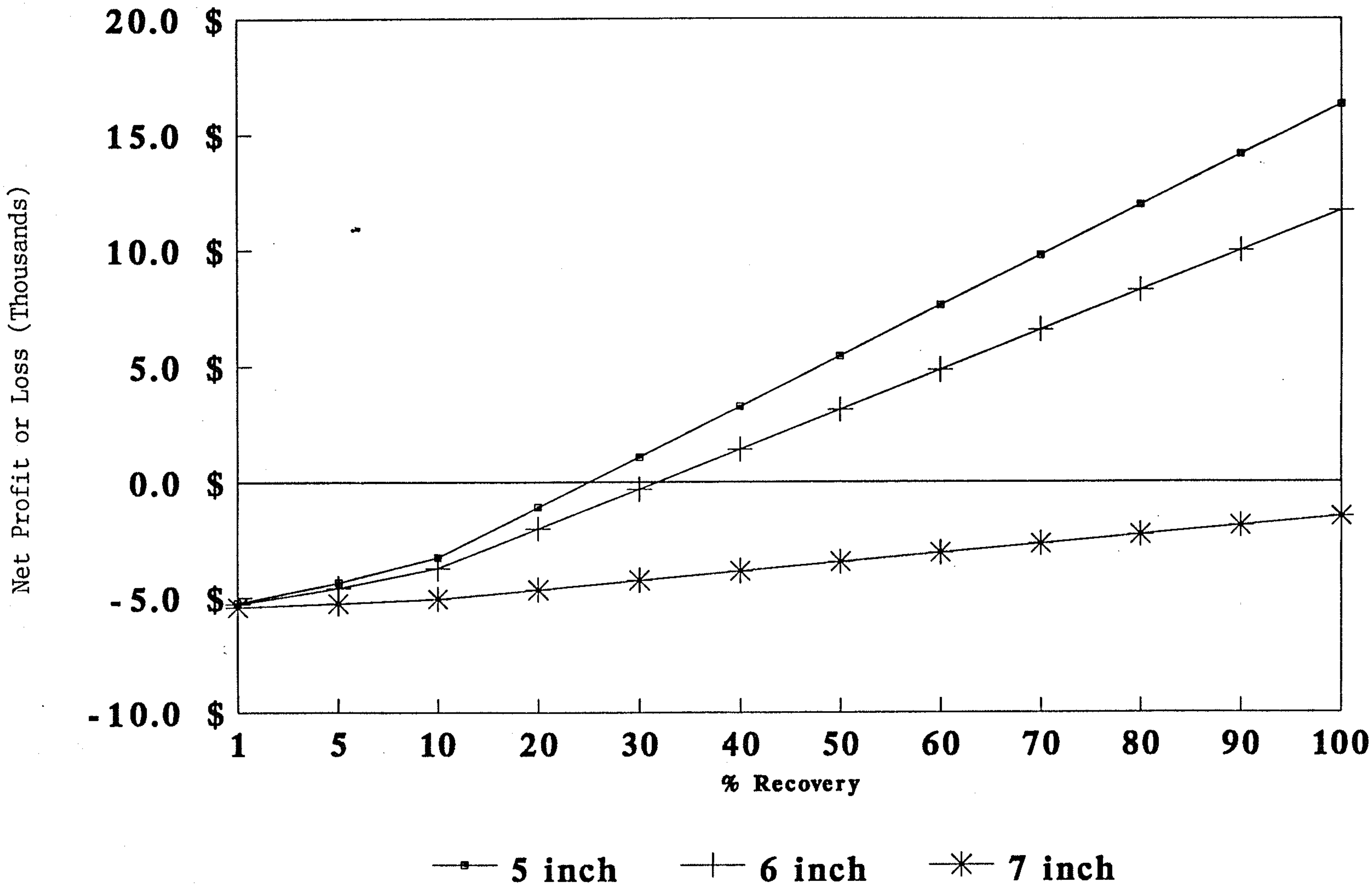


FIGURE 18: EFFECT OF FINGERLING SIZE ON PROFIT

Variable costs, associated with the stocking of seven inch charr into the Garson ponds, were high ($8.68/kg) and resulted in total costs exceeding total revenue generated from charr sales. Because of this, the pond culture operation would never break even despite a 100% recovery rate. When charr are stocked at 5 and 6 inches, the recovery rates that are required for a breakeven level of production are low, 25 and 32%, respectively. Although smaller charr seem to be a reasonable choice for stocking the Garson ponds, the difference in survival rates for break-even production between 5 and 6 inch charr is small. However, it is impossible to estimate the final harvest size of initial stockings of smaller and larger fish because of the many environmental, physical, and genetic factors which can influence growth of fish under intensive or semi-intensive culture conditions. Due to the large size variability within each charr population, it is also impossible to know what percentage of non-marketable fish would likely occur in populations of 5 inch charr compared to populations containing 6 inch fish initially. This can only be determined conclusively by stocking different size fingerlings into ponds (preferably starting with smaller 4 inch fish).

6.4 Analysis of Financial Ratios

Financial ratios are used as "vital" signs of any business and can indicate current financial stability or future financial problems. Measures of profitability (productivity of assets, % of return to equity), efficiency (capital turnover), and liquidity (current capital ratio) ratios were used to determine the overall economic performance of the Garson pond culture operation. These ratios were calculated from figures extracted from the financial statement.

6.4.1 Profitability Ratios

Profit should be viewed in relation to the value of assets or equity which were employed to produce it and therefore profitability ratios are better indicators of economic performance than profit. If a particular asset is profitable, it will earn more than it costs in any given time period.

a) Productivity of Assets: measures the rate of return on the assets of the business and is calculated by dividing net income (after tax) by tangible net worth or total depreciated fixed assets.

Cauvin and Thompson (1977) suggest that a relationship of at least 10% is required as a desirable objective for providing dividends plus funds for future growth. Under scenario (C), total depreciated fixed assets amounted to $17,970.00 (assets such as land and ponds were non-depreciable and therefore their full values were included in the calculation of tangible net worth).

Productivity of the pond culture operation (scenario C) was 9.4% and this suggested that the earning potential of the assets employed in fish farming was below standard levels of other commodity producers such as: grocery stores (11.5%), wholesale dairy products (13.3%), and meat products (11.6%). Cauvin and Thompson (1977) and Milligan (1987) indicate that extensive lake culture of rainbow trout and Arctic charr produced high productivity of assets ratios (59%) and (40%), respectively. This method of culture however, utilizes a minimum number of assets for fish production and therefore, high ratios can be expected especially if wholesale prices paid for charr are at premiums. Net income, as reported by Milligan (1987), reflected the high price paid for charr ($11 per kg) as compared to the Garson pond culture operation where prices of charr were lower ($9.50 per kg)). The higher cost of production and a lower (more realistic) wholesale price for charr were two reasons why pond culture at Garson achieved a lower rate of return on assets. Pfeiffer and Jorjani (1986) indicated that an average return on assets of 7% is traditional for extensive (crop and livestock) agricultural enterprises however, for more intensive agricultural operations (greenhouses, small-scale orchards), a ROA over 12% was considered satisfactory and would likely guarantee long-term success.

b) % Return to Equity - describes the returns per dollar of equity invested in the fish farming business. It is useful as a basis for comparing the profitability of the farm business relative to other investment alternatives (providing that assets and equity are valued at current market prices).

$$ROE = \frac{\text{Net Farm Income}}{\text{Equity}}$$

Claims on assets (acquired from cash purchases) held by the owner/operator are referred to as equity. Claims on other assets that are held by individuals who are not part of the fish farm operation (banks who lend money to fish farmers) are known as debts or liabilities. A basic accounting equation (outlined below) indicates that the value of claims in the form of liabilities plus the value of claims in the form of equity must be equal to the value of assets.

$$\text{Assets} = \text{Liabilities} + \text{Equity}$$

At Garson, under scenario (C), it is assumed that the owner/operator takes out a short-term loan ($22,119) to pay for all capital expenses and pays cash for all operating expenses ($19,600). Terms of the loan are such that interest payments are paid annually with the principle amount being paid at the end of the loan period. In addition, the owner/operator acquires assets (at the end of one production cycle) in the form of table-size fish worth $24,419.

Rate of return to equity was calculated at 8.6% which was higher than the current real interest rate but lower than the return on assets (9.4%). This result was similar to findings reported by Pfeiffer and Jorjani (1986) although ROE was much higher (24%) for large-scale fish farms in southern Ontario. Investment in pond culture may not be profitable if either the return on assets or equity was lower than the interest costs. As the real interest rate rises, the present value of all potential investment projects will decrease to a point where investment will no longer be equitable. Funds used to purchase equipment could be used to purchase some other income-earning asset, such as bonds. The return that can be earned on bonds is equivalent to the real interest rate and therefore, as the real rate of interest increases, the earning potential of a bond will also increase.

Other investment alternatives, such as savings accounts, money market funds, or G.I.C.'s, have current annual interest payments of 4.25, 8.6, and 8.25%, respectively. Under present economic conditions, it appears that investing money in a charr culture operation would be similar to or better than other forms of bank investment opportunities.

6.4.2 Efficiency Ratios

Efficiency ratios indicate the operator's ability to transform available resources into valuable output with a minimum waste of effort or resources. The capital turnover ratio indicates the number of years of cumulative gross income required to achieve the same value of invested capital. The more physically efficient the production is, the fewer years are required. Capital turnover ratios describe farm earnings in relation to the size of investment employed:

$$\text{Capital Turnover} = \frac{\text{Total Farm Investment}}{\text{Gross Farm Income}}$$

For the Garson operation, the above ratio was 0.91 years and indicated a strong rate of earning relative to the capital investment which was made to sustain the business. This fast turnover time was similar to efficiency indicators as reported by Pfeiffer and Jorjani (1986) for large fish culture operations in Ontario.

6.4.3 Liquidity Ratios

Liquidity involves the operation's capacity to generate enough cash to meet financial obligations as they fall due. Current working capital provides an absolute measure of liquidity and is calculated as follows:

Current working capital = Current assets - Current liabilities

The current capital ratio is a relative measure of liquidity that indicates the vulnerability to change in asset values. This ratio is calculated as follows:

$$\text{Current Capital Ratio} = \frac{\text{Current Assets}}{\text{Current liabilities}}$$

It should be emphasized that current assets do not refer to all assets acquired by the fish farm but instead, involves such things as cash on hand, bank deposits, accounts receivable, and the value of fish currently being reared. Current liabilities similarly refers to those liabilities such as: operating loans payable, accounts payable, interest, and principal payments due within one year.

At Garson, current assets ($24,419) and current liabilities ($19,585) provided a current capital ratio of 1.25. Pfeiffer and Jorjani (1986) report that current ratios of 1.25 - 1.75 are sought by agricultural lenders therefore, it would appear that lenders might provide credit to aquaculturists involved in a pond culture business similar to the Garson operations.

6.4.4 Internal Rate of Return

Table 23 shows calculated IRR's over a short (5 years), medium (10 years), and long term (20 years) period for the Garson pond rearing system (scenario (C)). In all periods, the internal rate of return exceeded the prescribed discount rate (real interest rate) which indicated that investment in pond culture is viable for the short term and considerably better for the medium and long terms as long as market prices for Arctic charr remain high and production costs do not substantially increase.

Table 23

Internal Rate of Return for a Four-Pond Rearing System at Garson, Manitoba
(Scenario C - wholesale price = $9.50 per kg)

Investment Cost (including interest on borrowed capital)	Net Farm Income (not including depreciation)	IRR Short Term (5 yrs)	IRR Medium Term (10 yrs)	IRR Long Term (20 yrs)
$24,773	$6202.59	8.0%	21.5%	25%

6.5 Summary

The financial statement for the Garson pond culture operation indicated that, under scenario (A) and (B), the operation of one pond (1150m^3 volume), with stocking densities of 1000 and 6000 charr, respectively, was not economically viable despite high survival rates of charr. Net losses were recorded for both scenarios and was attributed to high variable costs (fingerlings, interest, and food expenses) in relation to the amount of revenue generated from Arctic charr sales. Under scenario (C), the hypothetical operation of four ponds, having similar survival rates and stocking densities of 6000 fish per pond, produced a net profit despite high costs of production. It was suggested that net income could improve in the second year if residual fish, that did not reach market size after the first growing period, were overwintered and reared to proper size over the second production period.

Break-even level of production for scenario (C) was investigated and shown to be 7640 charr or 1528 kg of market-size fish (with a survival rate of 32%). Net income from charr sales increased dramatically as recovery rates increased because of the high wholesale price paid for charr. Total costs of production (variable and fixed) were high ($7.85 per kg charr produced) however, this compared similarly with production costs associated with extensive (lake) culture of charr in Northern Manitoba.

Using the lowest future wholesale price predicted for Arctic charr ($7.26 per kg), the break-even level of production was high (83%) with only a small profit being achieved. However, when wholesale prices fluctuated from $8.80 to $11.70 per kg, break-even production decreases steadily from 1900 kg to 945 kg of charr or a 20% survival rate. Earning potential for part-time charr producers was considered to be good if market prices remained high.

The financial effect of stocking both smaller and larger fingerlings into the Garson ponds was also investigated. It was found that small charr (23 gram), when compared to 40 and 60 gram fish, would be less expensive to purchase and feed (over one production cycle) and therefore, would be the logical size to stock into ponds. Sixty gram charr proved to be too costly to stock and therefore, should not be used in this type of culture. It was suggested however, that producers could experiment with different sizes of charr (starting with 10 gram fish) in order to determine conclusively if specific sizes reach market size (in ponds) over one production period.

Additional criteria (financial ratios and investment analysis) were used to determine the overall economic viability of the four-pond rearing system at Garson. Productivity of assets (9.4%) was close to the recommended level of return on assets (10%) which is necessary for providing funds for future growth. However, this result was substantially lower than productivity of assets reported for extensive culture of charr and rainbow trout in northern lakes (due to the high start-up costs for pond culture compared to lake culture). Efficiency and liquidity ratios indicated that the operation provided a fast turnover of invested capital and a strong rate of earning relative to the total investment. They also provided evidence which suggested that lenders of money may provide assistance to aquaculturists who wish to develop this type of fish-rearing system.

Investment analysis was conducted for the Garson operation in order to determine its financial viability. Internal rates of return (generated from the business) were high in the short and long terms which indicated that pond culture of charr could provide adequate supplemental income for part-time aquaculturists.

CHAPTER 7

Conclusions and Recommendations

Biological and economic conclusions drawn from the results of the research at Garson, Manitoba are summarized below. It should be emphasized however, that these findings may not necessarily apply to other areas within the province since each potential aquaculture site has its own unique characteristics, some of which may not be appropriate for successful rearing of Arctic charr. As well, additional conclusions have been listed which relate to the above research and are based on recent experience (over the past four years at Garson, Manitoba) rearing salmonids in outdoor ponds (including Arctic charr).

7.1 Biological Conclusions

- Man-made ponds in southern Manitoba were able to produce market-size, Arctic charr (200 g) over one production cycle (May to October) when initially stocked with 30-40 gram fish.
- Growth of Arctic charr in dug-out ponds was similar to growth rates (reported in the literature) for charr reared in northern Manitoba lakes, and for rainbow trout cultured in prairie ponds. However, charr reared under intensive culture conditions (in tanks and raceways) grew faster.
- Limiting factors which influenced survival of charr were water temperature and heron predation. Increased water flows, and erection of fences around ponds, improved survival rates in the second year. Ammonia, nitrite, and oxygen concentrations did not limit fish production in this system with a stocking density of 1000 fish.
- Specific growth rates of approximately 1.0%/day can be achieved in this culture system when ponds are stocked initially with $\leq$1000 fish (30-40 g each). Arctic charr grow better when stocked at heavier densities and therefore, growth rates could improve with increased stocking rates in ponds.

- Microscopic examination of stomach contents from sampled charr (harvested from ponds at the end of one production cycle), as well as observations of charr feeding on terrestrial, flying insects at night (around lights), provided evidence that this species was utilizing natural food (freshwater shrimp, aquatic and terrestrial insects) as a diet supplement.
- Size variability was common among charr populations reared in this system over two production cycles. Similar findings were reported for charr reared under different culture conditions. "Grading" the unmarketable portion of the fish population at harvest and holding them (alive) for the next production period could be beneficial.
- A minimum flow rate of 159 lpm in a pond (26x18x2.5 m) 1150 m^3 in volume is sufficient enough to maintain water temperatures below 18 C during summer as long as hot weather does not persist for extended periods. Arctic charr become inactive and will not feed above this temperature. The above flow rate was important in reducing mortalities during the second year.
- Observations of herons around ponds showed that wire fences, surrounding ponds, (with posts slanting inwards towards deep water) prevented these birds from predating upon fish.
- Observed water quality parameters (NH_3, NO_2, O_2) from pond A suggest that a standing crop of 1000 charr was low. The utilization of density loading formulas, as well as consultation with an aquaculture specialist (in subsequent years at Garson) have indicated that as many as 6000 to 10,000 (200+ g) fish can be reared in pond A if water flows were maintained at 158 lpm and a compressor (with a 4-airstone manifold) was used to aerate the water on a continual basis.

Other Conclusions:

- Marked improvements in water quality can be achieved with periodic use of Aquashade, a harmless food dye for algae control, and Bacta-Pur, a bacterial supplement for pond sludge/sediment reduction.
- Reductions in numbers of aquatic, rooted vegetation can be achieved around pond edges (which can interfere with the harvesting of fish via seine nets) using thick layers of plastic (in 8 foot widths) positioned along the pond periphery and out towards deeper water. The extra costs for purchasing rolls of plastic is minimal.

7.2 Economic Conclusions

Conclusions from the economic analysis can be summarized under the following points:

- The operation of one pond rearing unit at Garson, Manitoba was not profitable with initial stockings of 1000 fish. High operating costs (fingerlings, feed, interest expense) were considered to be the main factor affecting profitability in this system. The hypothetical operation of one pond, with an optimal stocking density of 6000 fish was also shown to be unprofitable for similar reasons.
- Despite high production costs, a four-pond rearing system (containing 6000 fish/pond) would become profitable at low recovery rates of market-size charr (22% or greater). Net income increased dramatically as recovery rates improved even at a lower future wholesale price predicted for charr ($9.50 per kg).
- Profits were shown to be highly sensitive to price, recovery rate, and fingerling size. The four-pond rearing system could obtain profits at a price range from $8.80 to $11.70 per kg of charr. However, the operation would never realize a profit if Arctic charr wholesale prices decreased to a value of $1.00 above the current price paid for rainbow trout (dressed, whole) ($6.26 per kg). The analysis showed that five inch charr would be the most economical size to stock into ponds. If seven inch charr were stocked, there was a strong possibility that more harvestable fish would be available at the end

of one production period however, the added food and fingerling costs would never allow the operation to make a profit even at a 100% recovery rate.

- Overall, the economic assessment indicated that this operation has good potential for earning profits and was economically viable for part-time aquaculturists as long as market prices for Arctic charr remained high and operating costs did not substantially increase.

7.3 Perspectives

Although Arctic charr is a relatively new aquacultural species in Canada, positive culture traits such as the ability of charr to grow under heavy densities, growth rates for charr similar to rainbow trout at optimum temperatures, and the hardiness of charr, make the commercial culture of this species very promising. As well, results from previous studies have shown that the intensive and extensive culture of Arctic charr is biologically feasible. However, many areas of its culture should be further investigated and improved upon before this species is reared in large quantities on a regular basis. From a producer's perspective, two major problems (shortage of fingerlings for stocking and non-uniform growth of charr) must be addressed in the near future.

In central Canada, aquaculture has become a cottage industry with the majority of fish farmers being "hobbyists" (rearing fish for their own consumption or selling small qualities of fish to local people and/or businesses). This industry will remain small and inconspicuous unless there is a concerted effort by independent producers to form an aquaculture association and/or co-operative in Manitoba. To date, there has been some expressed interest, from various producers in this province, to develop an aquaculture association (which would provide more clout in dealing with federal and provincial representatives and establishing regulations that would better suit the needs of aquaculturists).

Also, with more people becoming interested in the commercial culture of Arctic charr in this province the impetus for developing a Fish Producer's Co-operative (similar to southern Ontario) has never been greater. Total production from each aquaculture site can be collected, processed together, and then distributed to markets in various cities throughout the Prairies and Canada. The formation of the only Co-op in central Canada would provide easier market forecasting, lessen the problems associated with seasonality in supply, and eliminate the need for producers to undercut one another in order to sell their fish. It ensures that each producer is paid a reasonable price for his/her product without having to worry about unpredictability of sales. However, the effectiveness of a co-operative will hinge on the willingness of each producer to provide a quality product. Quality control is an important consideration and therefore, fish would have to be supplied with undamaged fins, firm and nicely-coloured flesh, as well as no off-flavours.

Total capital investment and operating costs for small-scale, charr culture in ponds is relatively low compared to intensive rearing of fish indoors (in raceways, tanks). The return on investment is reasonable and profits can be achieved if ponds are stocked adequately (6000 fish) and fish survival is high. However, because this culture method can be labour-intensive, and provides seasonal production only, it should be implemented preferably (in rural localities) as a means of supplementing one's income and not for large-scale fish production.

Market prices for grain crops have declined over the past few years in Canada and future conditions may not sufficiently improve. At the same time, demand for farmed fish has gradually increased. This may provide new incentives for farmers to diversify their operations and develop fish-rearing units on some land previously utilized for grain crops.

With so many unknown variables involved with commercial fish production, it is imperative that individuals take a cautious approach when deciding to invest in this kind of business. Large-scale, intensive rearing of fish can be both challenging and rewarding, however, it is an expensive undertaking and can often lead to financial disaster if not properly managed. A collective effort from small-scale fish producers in Manitoba (in association with a Fish Producer's Co-op) is a logical step towards the rejuvenation of an otherwise static industry.

7.4 Recommendations

Major drawbacks to commercial culture of Arctic charr in ponds at Garson, Manitoba were: large size variability of charr, reduced operating efficiency of ponds, high production and capital costs, and difficulties associated with the marketing of fish in Winnipeg due to the unwillingness of retail outlets and wholesalers to buy charr from individuals producing small quantities of fish without a guarantee of steady supplies on a regular basis. It is recommended that the following procedures be implemented to increase pond culture potential yields and net profits.

- a marked difference in size of charr was noticed at the end of each production cycle and this seems to be a common characteristic of charr populations. Because of this, it is recommended that size grading be tested in order to separate the small fish from larger (marketable) individuals. These small fish should be overwintered and reared through the second production period. Hydro costs, for operating two compressors (servicing four ponds), are minimal for the winter period and operating expenses can be reduced because of less fingerlings to purchase in the second year. Stunted fish should be removed (culled) after the initial production period.
- It is recommended that artificial ponds be constructed so that widths and depths are of a manageable size. Large rearing ponds should not be used for the following reasons: a) large, deep ponds require enormous amounts of well water to lower pond water temperatures to optimum levels for charr, b) large ponds are awkward to work around and there is less control of fish production, feeding, and harvesting and, c) exchange/flushing rates of large, deep ponds are low and therefore ammonia levels can build up and severely limit fish production.
- It is recommended, as a routine procedure, that ponds be pumped down approximately 1.5 metres (twice per month). This prevents a deterioration of water quality brought about by heavy algal blooms during hot summers. As well, water quality aids such as,

Aqua Shade (for algae control) and Bacta-Pur (for sludge reduction) should be administered according to manufacturer's guidelines throughout the production period.

- Growth rates of charr in this system were similar to growth reported for Arctic charr and rainbow trout reared in northern Manitoba lakes. However, growth rates were below levels recorded for charr reared indoors under intensive culture conditions. Studies should be implemented to determine conclusively if increased stocking densities, the use of automatic feeders and feed tables, as well as the availability of large quantities of natural food in ponds has a positive effect on growth rates of charr.
- High production and capital expenses resulted from the development and operation of a four-pond rearing system at Garson, Manitoba. The possibility exists however, for substantially reducing these costs by finding practical and innovative ways of doing things and by acquiring cheaper, used materials whenever there is an opportunity. Flawed holding tanks, for instance, can sometimes be obtained for considerably less money than new tanks. It may not be necessary to purchase a farm truck if the aquaculturist already has the use of a vehicle and this would again reduce capital expenses. Fish producers should always be looking for ways of cutting costs without adversely affecting his/her production capability or jeopardizing the health of fish. The net result of such actions can provide increased profits and/or benefits.

Future consideration should also be given to the following points:

- To reduce the build-up of food wastes on pond bottoms as well as to maintain a high level of water quality, floating food should only be used for feeding charr and these pellets should be <u>screened</u> to remove fine particles.
- Poor performances in the past, (due to off-flavours and inconsistent harvests) by fish farmers in Manitoba have resulted in rather low returns and this has caused local fish buyers as well as government personnel to view aquaculture as nothing more than a

hobby or for recreational value. If small fish producers want to be taken seriously and establish some credibility with retail and wholesale fish buyers, it is imperative that a Fish Producers Co-op be established in Winnipeg (within the near future) to ensure that there are reliable supplies of fresh charr available on a regular basis. Because of this, it is recommended that a Co-op be developed before small or part-time aquaculturists invest in a fish farming business in order to eliminate risks associated with unpredictability of sales and unreliable supplies of charr.

. Ground water reservoirs in some areas of Manitoba may contain poor water quality and therefore would not be appropriate for aquaculture. It is imperative that a thorough water quality analysis be conducted on area wells or springs before deciding to develop a potential site for rearing fish.

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