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The New Brunswick Atlantic Salmon Fisheries

Economic and Commercial Analysis Report No. 90

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The New Brunswick Atlantic Salmon Fisheries

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THE NEW BRUNSWICK ATLANTIC SALMON FISHERIES [1]

by

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ABSTRACT

This report examines the Atlantic salmon fisheries in New Brunswick from an economic perspective. It assesses the economic viability of the commercial fishery, describes the emerging salmon aquaculture industry, and estimates the value of the recreational fishery. The potential for maintaining joint recreational and commercial fisheries is evaluated for the Miramichi river.

Key Words: Atlantic salmon, aquaculture, commercial fishery, recreational fishery.

RÉSUMÉ

Ce rapport étudie la pêche au saumon de l'Atlantique au Nouveau-Brunswick selon une perspective économique. On y trouve une évaluation de la viabilité de la pêche commerciale pour cette espèce, une description de l'industrie en pleine croissance qu'est l'aquiculture du saumon ainsi qu'une estimation de la valeur de la pêche récréative. Finalement, on y évalue la possibilité de maintenir conjointement la pêche récréative et commerciale sur la rivière Miramichi.

Mots clés: saumon de l'Atlantique, aquiculture, pêche commerciale, pêche récréative.

THE NEW BRUNSWICK ATLANTIC SALMON FISHERIES

CHAPTER I - INTRODUCTION

1.1 BACKGROUND

This report examines economic aspects of the Atlantic salmon fisheries in New Brunswick. It assesses both the economic viability of the (currently closed) commercial fishery and the economic value of the salmon sportfishery. Policy options for these fisheries are discussed in light of the analysis.

Atlantic salmon (salmo salar) is an anadromous species which is spawned in the gravel beds of rivers. After spending a minimum of one year in the river, the juvenile salmon migrate to the ocean where they can spend from one to six years before returning to spawn. Salmon having a sea-life of only one year are known as grilse and return to their river of origin weighing only three to six pounds. More mature salmon average ten to twelve pounds when they return to their spawning streams. The first incoming run of fish begins in the spring. Usually the mature salmon make the first run into the river estuaries and they are followed soon after by the grilse. The runs of Atlantic salmon and grilse continue throughout the spring and summer, slackening off during August and ending in early fall. Some Atlantic salmon survive spawning and may return to the ocean before the winter freezeup of the rivers. Those that remain in the river throughout the winter months start their seaward migration in the spring. They are then known as black salmon (or kelt) and usually reach the ocean before the incoming salmon runs begin.

The Atlantic salmon is comprised of two main stock groups which spawn in North America and Europe respectively. The North American stocks originate in Canadian east coast rivers ranging from Ungava Bay in the northeast to the Canada-United States border in the southeast. New Brunswick rivers have historically produced large numbers of salmon. The most noted Atlantic salmon angling waters in Canada are found on New Brunswick's Miramichi River system. This river and its main tributaries, the Northwest, Little Southwest and Southwest Miramichi, the Dungarvon, Cains, and North and South Sevogle have historically yielded thousands of salmon annually. Another major New Brunswick river drainage which, in the past, has also provided large salmon catches is the Restigouche and its huge tributary, the Upsalquich. As well, the Saint John River and its main tributaries, the Tobique and the Nashwaak have also had significant salmon yields. Management of the fishery has been mainly concerned with maintaining stock abundance. The Government of Canada is responsible for management of the Atlantic salmon resource in eastern Canadian waters but property and civil rights matters pertaining to the resource fall under the jurisdiction of the provincial governments. Hence, the Government of New Brunswick through the Department of Natural Resources and Energy undertakes management directly as it concerns purchasing of angling rights, Crown angling waters allocations, licensing sport fishing and supplementing federal protective and biological services.

The sea migrations of Atlantic salmon remained undocumented until the 1950s. At that time, it was discovered that considerable concentrations of these fish could be found off the west coast of Greenland. Following the discovery of salmon stocks feeding in these waters, a fishery began in this area in 1960. Initially confined to local Greenland fishermen, it soon escalated to include other countries and the level of catch increased annually, peaking at 2700 tonnes in 1971. In conjunction with this, catches in New Brunswick declined in the late 1960s until, in 1971, the stocks collapsed. An international agreement on quota controls for the Greenland fishery was instituted immediately and commercial fishing in New Brunswick was closed over the 1972-1980 period. The recreational fishery remained open.

The commercial salmon fishery in N.B. has operated in the estuaries of the three major river systems. Effort controls were introduced into this fishery in 1971 with licenses issued to the 721 existing fulltime fishermen. The issuing of licenses removed a number of part-time fishermen from the industry since they were not given licenses. A further attempt at effort reduction was made through the introduction of a "buy-back" program whereby the Government of Canada made an offer to buy back the newly issued licenses. Thirty percent of those given licenses accepted a buy-back offer at that time, leaving 501 licenses operative when the 1972 ban was imposed. Over the period of the ban, some licenses disappeared due to the death of license-holders (since licenses were not transferable) and, in 1981, 260 chose to surrender their license in return for further compensation. Consequently, when the fishery reopened in 1981 only 225 fishermen took part: 25 on the Restigouche, 122 on the Miramichi, and 78 on the Saint John (Meagher 1981). A management plan was introduced with the 1981 reopening which consisted of landings quotas by river system with accompanying individual quota allocation by license. Of the 50,000 fish quota for all rivers in 1981, only 24,430 were landed. This catch of 103 tonnes was marginally smaller than the 124 tonnes taken in the last year before the ban (Table 1). The fishery continued to operate on all rivers in 1982 and 1983 and on the Saint John in 1984 but has been completely closed since 1985. Annual catches fell over the 1981-84 period and stocks were assessed to be at dangerously low levels (Canada, Department of Fisheries and Oceans 1980). As a result, the Government of Canada instituted another license "buy-back" program in 1985 and complete license removal has since occurred.

As a further conservation measure, legislation is now in place requiring that all salmon taken in traps, weirs, or gillnets of other fisheries are to be released alive. If this bycatch is "significant", fisheries officers have the authority to instruct relocation of these operations.

The recreational fishery in New Brunswick has also been regulated for many years. Although not restricted with respect to entry, controls on season length, gear and bag limit have been imposed. Angling on some rivers is restricted by private ownership of angling rights or lease of the waters, or by provincial ownership and control of waters. Residents and non-residents of New Brunswick are issued angling licenses for all designated salmon rivers for a minimal fee. While non-residents require a licensed guide when fishing, designated season lengths and bag limits apply to both user groups. Following the 1971 stock collapse, recreational fishermen were restricted by a season adjustment in some areas and a reduction in the daily bag limit to two fish. After the 1983 stock collapse, a "hook-and-release" program was introduced whereby anglers are not allowed to retain catches of adult salmon, although two grilse per day to a maximum of ten per season are allowed. For enforcement purposes, all salmon caught legally along with those imported into New Brunswick must be tagged.

The difficulties in the N.B. commercial and recreational salmon fisheries over the past decade have been accompanied by rapid growth in a provincial salmon aquaculture industry. Centered in the Bay of Fundy in the southwestern part of the province, it grew from a single experimental cage site in 1978 to thirty-six sites producing over 3500 tonnes by 1988. It supplies both domestic and eastern U.S. markets and has filled the void created by the closure of the commercial fishery. If the stocks were to recover sufficiently to enable the commercial fishery to reopen, it would face strong competition from the aquaculture sector.

1.2 OUTLINE OF REPORT

Given the above background, this study next undertakes an economic examination of the N.B. salmon fisheries. Chapter 2 deals with the economic viability of the commercial fishery on two of the three river systems prior to its closure; Chapter 3 describes the salmon aquaculture industry which is replacing the commercial fishery as a source of fish supply; Chapter 4 provides estimates of the value of the recreational fishery on the three New Brunswick river systems; Chapter 5 makes an economic assessment of joint commercial and recreational fisheries on a single river, the Miramichi; Chapter 6 discusses future directions for the N.B. salmon fisheries.

1.3 ACKNOWLEDGEMENTS

The authors are grateful to both commercial and recreational fishermen in New Brunswick for providing an invaluable information base through their positive response to our questionnaires. We are also indebted to Michael Chadwick and Robert Randall, Department of Fisheries and Oceans, Gulf Region, who provided us with biological information.

CHAPTER II - THE COMMERCIAL SALMON FISHERY[2]

2.1 ECONOMIC PERFORMANCE OF THE FLEET

The economic performance of the commercial salmon fleet is examined for the 1983 fishing season, its last full year of operation. The Restigouche commercial fishery operated under a global quota of 2400 salmon and 2400 grilse (one sea-year salmon). The Miramichi was also managed under a global quota with 3000 salmon and 2500 grilse allocated to trapnets and 7000 salmon and 1500 grilse to driftnets. The Saint John was managed on the basis of individual quotas with a total quota of 3700 salmon and 6450 grilse (Canada, Department of Fisheries and Oceans 1983).

The results we report are determined from a costs and earnings survey of 92 (out of 225) fishing enterprises for the 1983 season. Eighty-one useable surveys were obtained from the Restigouche and Miramichi, consisting of 50 driftnets and 17 trapnets on the Miramichi and 14 Restigouche trapnets.

Three gear types have been utilized in this salmon fishery. On the Restigouche, the trapnet has been the only gear used. Trapnets have either been strung out from shore or supported in the water by buoys and anchors. The nets then direct salmon to pounds where the salmon are collected. Traps are usually checked twice a day by a two-man crew in a small open boat. The second gear-type is the driftnet which has been used, along with trapnets, on the Miramichi and Saint John rivers. A driftnet is a floating gill net which is attached at one end to a boat. The boat, typically much larger than that used in the trapnet fishery, drifts with the current. Finally, there is a very limited fixed gill net fishery on the Saint John River.

The trapnet fishery generally uses small open boats while

[2]This chapter draws heavily from Cook and McGaw (1991).

driftnet vessels are more substantial as they are also used for catching other species. Since many of the driftnet vessels are multi-purpose, depreciation, loan payments, and repairs have been charged as fixed expenses to the enterprise in the proportion that salmon revenues account for total vessel revenues. (For example, one vessel valued at $25525 had a capital cost of $348, with depreciation taken arbitrarily to be 10% of the capital value, since only 13.6% of its revenue was derived from salmon.) Though the driftnet vessels are much more costly, they are nearly equivalent to trapnets in terms of fixed cost because they are multiple-use vessels. The variable costs of operation of the two gear-types differ considerably due to the different methods of fishing. The variable costs of a driftnet are significantly larger than those of a trapnet, accounted for principally by labour expenses and fuel. Here labour costs are assessed at the N.B. minimum wage.[3]

Revenue, variable and fixed costs, and economic surplus for the two gear-types are shown in Table 2. It can be seen that the average driftnet lost $336 while the average trapnet earned $1210. While driftnets had revenues that were some 10% higher than trapnets, the higher labor and operating costs of driftnets resulted in net revenues that were just slightly more than half those of trapnets. However, the use of averages here disguises the range of performance as 37 of the 81 vessels surveyed made a profit in 1983. Individual trapnets had an economic surplus ranging from from -$2722 to $14558, while that of driftnets ranged from -$5271

[3] All values in this analysis of the commercial fishery are in 1983 Canadian dollar terms. We evaluate the opportunity costs of the owner-operator's labor at the N.B. minimum wage but a number of options are possible in the assessment of opportunity costs. For example, opportunity costs might be taken to be near zero because local employment opportunities are very poor or, alternatively, these costs might be considered the average 1983 industrial wage in N.B. The minimum wage is approximately midway between these two extremes and we thus consider it an acceptable alternative.

to $6744. Thus while driftnets lost money on average, a number of them managed to do reasonably well. But from the perspective of economic performance, this survey clearly shows that the trapnet is the better gear for salmon harvesting, given current stock conditions.

This result is reinforced when the vessel performance is considered by location (river). While the Miramichi fishery is comprised of both trapnets and driftnets, the Restigouche fishery consists entirely of trapnets. On average, vessels earned an economic surplus on both rivers as seen in Table 3. However, the average surplus of $227 earned on the Miramichi was smaller than the $397 earned by Restigouche vessels. This discrepancy may be attributed to the mix of gear types on the Miramichi. While trapnets are the sole gear on the Restigouche, both trapnet and driftnet operations are undertaken on the Miramichi and the average surplus on the Miramichi is thus pulled down by the relatively poor driftnet performance.

In order to determine the aggregate contribution of the commercial salmon fishery, we apply the survey averages to the population of 138 driftnet and 87 trap licenses in N.B. in 1983. Multiplying the averages by the number of licenses, the net value of the 1983 season was estimated to be $58,900 on gross revenues of $1,212,500.

2.2 COST STRUCTURE OF THE INDUSTRY

Insight into the viability of the enterprises can be gained from estimating the vessel cost functions. Using cross-section data such as that available here provides an estimate of the long run cost function. A variety of functional forms were tested and the best fit was obtained from a double-log specification with slope and intercept dummies for the method of fishing:

$$\log(ATC) = 7.731 - 1.605*D - 0.9585*\log(H) + 0.4143*(\log(H)*D) \quad [1]$$
$$(13.67) \quad (2.12) \quad (8.39) \quad (2.77)$$
$$R^2=0.59$$

where ATC is the average total cost per salmon, D is a dummy equal to 1 for a driftnet and 0 for a trapnet, and H is the number of salmon caught. T-statistics for the coefficients (in parentheses) and the R^2 for the equation are reported. All coefficients are significant at the 95% level of confidence. This cost function can be decomposed into cost functions for trapnets and driftnets as follows (Koutsoyiannis 1977):

Trapnet: $\log(ATC) = 7.731 - 0.9585*\log(H)$ [2]

Driftnet: $\log(ATC) = 6.126 - 0.5442*\log(H)$ [3]

These cost functions indicate that the driftnet outperforms the trapnet only at very low levels of output (i.e., the intercept for the driftnet equation is smaller). The slope coefficient represents the relative decline in average cost as catch rises. For example, a 10 percent increase in catch will lower average cost by 9.6 percent for a trapnet and by 5.4 percent for a driftnet. Consequently, for catch levels of 50 salmon or more the trapnet acquires a cost advantage over the driftnet. Table 4 shows the average cost per salmon at selected output levels. Graphs of the cost functions are shown in Figure 1 where LRACd and LRACt represent the long run average costs of driftnets and trapnets respectively. There are very clear gains to be made (in terms of cost reduction) with an increase in the catch level per vessel from 200 to 400 salmon, but the gains are noticeably smaller in moving from 400 to 600. This reflects the scale economies defined by the cost function.

From our survey, the (weighted) average landed value per salmon was $29.50 for trapnets ($34.70 on the Restigouche and $25.50 on the Miramichi) and $26.70 for driftnets. The average revenues for Restigouche and Miramichi trap salmon catches are shown in Figure 1 as ARrt and ARmt respectively, while the average revenue for Miramich driftnet salmon is defined by ARmd. Given the estimated cost functions, it may be seen in Figure 1 that the break-even level of output for a trapnet is 79 salmon on the Restigouche and 109 salmon on the Miramichi. On the other hand, a driftnet requires 185 salmon in order to break even. For example, those trapnets with landings under 100 salmon are breaking even at best, with most losing money. On the other hand, a trapnet with landings of 500 salmon will earn a surplus of $24 per salmon. Similarly, a driftnet landing.100 salmon will lose about $11 per salmon while 500 salmon would bring a surplus of nearly $11 per salmon. Table 5 illustrates the wide differences in performance within each gear-type.

CHAPTER III - NEW BRUNSWICK SALMON AQUACULTURE

3.1 BACKGROUND

Salmon aquaculture in New Brunswick is still developing. It began seriously in 1978 when the Federal Department of Fisheries and Oceans, the New Brunswick Department of Fisheries, and a private firm jointly attempted to determine the commercial feasibility of cage culture for Atlantic salmon in the Bay of Fundy. A site with good water exchange, freedom from severe wave action and from lethal temperatures was chosen off Deer Island and 3500 salmon smolt were transferred to sea cages there. Over the next eighteen months, the salmon grew to a 3.3 Kg average weight and 6 tonnes were sold at that time at $7.70/Kg (dressed). The success of this project encouraged development of a salmon aquaculture industry which may be described over three loosely-defined time periods as follows:[4]

1978-82 was a period of experimentation where cages were initially anchored with pilings like those of the traditional herring weirs and the corners were attached using conveyor belting to allow flexibility. Feed content was varied and disease control unpredictable.

1983-86 was a period of implementation of tried and proven practices. Sea cage operations grew from five to twenty-eight.

1987- has been a period of innovation, exploitation and growth. The production season has expanded from six to ten months, heavy-duty mooring and anchorage systems have been perfected, the original wooden cages are gradually being replaced by steel cages, a new Aquaculture Act has been introduced, the number of hatcheries has grown and there has been a corresponding increase in smolt production, production and sales have increased dramatically, and the number of sea cage sites has expanded.

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[4] See Canadian Aquaculture, 1988, 4(4): B15 for further detail.

The industry has concentrated in the Bay of Fundy in the southwest region of the province because ice restricts the use of cages in northeastern New Brunswick during winter. Massive tidal ranges, some of the largest in the world (averaging 25 feet and peaking at 28 feet), result in strong tidal flows here. Temperature is a major consideration in this industry. Under ideal conditions, the growth of Atlantic salmon in the sea is determined simply by the temperature and the life stage of the fish. Salmon will die as their blood plasma starts to freeze and ice forms on their outer skin layers. The lower lethal temperature for Atlantic salmon is predicted at minus 0.7 deg. C. There is documented risk (Batbie et al. 1988) that winter surface seawater temperature may drop below the lethal limit in southwest N.B. waters. At the same time, oxygen and water flow conditions as well as toxicity of waste products can impact negatively on growth and the N.B. industry has experienced these effects as well. While the other biological effects can most likely be overcome with knowledge and experience, surface water temperatures which dip below one deg. C during February remain a very serious problem for salmon farmers. Water circulation can alleviate this difficulty to a certain extent but those operations located in areas with little tidal action are vulnerable.

These difficulties pose a continual challenge to salmon farmers. However, the salmon cage culture continues to thrive to the extent that the 1988 season saw established growers, operating from thirty-six cage sites, harvest 3500 tonnes valued at more than $40 million.[5] The industry has created more than 500 direct and 1,000 indirect jobs.[6] Three backward linkage industries have developed in N.B. in the form of fish feed suppliers, private hatcheries providing smolts, and the construction of hatchery holding units. The local feed market is dominated by two feed firms

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[5] See Fish Farming International, 1989, 16(7): 22.

[6] See Atlantic Insight, 1989, September.

with at least six other fish feed manufacturers, including a number of European and American companies supplying the N.B. aquaculture market.[7] Initially the federal government was the only supplier of smolts for the industry through its salmon enhancement programs but there are now four major (private sector) hatcheries each producing more than 100,000 smolts, two medium sized producers (federal) each providing 50,000-100,000 smolts and six smaller producers providing less than 50,000 smolts each.[8] The increase in the number of hatcheries provides more stability to the industry in that there is less vulnerability to disease outbreak at a given hatchery and the increase in smolt production removes a major constraint in the industry. Several companies are also involved in the production of steel cages and associated components for the industry. This includes those firms fabricating cages, producing concrete moorings, and providing custom-made styrofoam boxes and flotation blocks.

Most N.B. salmon farms are small privately owned-operations although there are a few large integrated operations in existence. There is some Norwegian influence in the industry. Some small firms are affiliated with Norwegian interests while one major firm is jointly owned by a large Norwegian firm and a large Canadian firm.

A marketing co-operative, Atlantic Silver, was established by a number of the independent growers in 1986. Individual member companies are assigned a percentage of total sales volumes based on their relative size. The co-operative supplies the Canadian market through various buyers in Montreal and Toronto and ships all salmon destined for the U.S. market through a single firm located in Boston. Some producers (including former members of Atlantic Silver) have begun entering into marketing agreements with

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[7] See Canadian Aquaculture, 1988, 4(2): 64.

[8] See Canadian Aquaculture, 1987, 3(5): 69.

established large companies in order to expand their market base.

3.2 ECONOMIC ASPECTS OF THE INDUSTRY

The basic requirement for a developing N.B. aquaculture industry is that it be capable of yielding an acceptable return on the required investment. This return is affected by many factors but major economic considerations include the efficiency of the operation and market conditions. Each of these considerations is discussed below.

3.2.1 Efficiency Considerations

According to some producers, it costs between $3.50 and $4.00/lb. to produce farmed Atlantic salmon.[9] Because of the infancy of the industry, economic analysis of the efficiency of N.B. sea-cage operations is sparse. An analysis of the cost structure of Atlantic salmon farm operations in Norway was undertaken by Kabir and Ridler (1987) in an attempt to fill this void by providing some approximations possibly relevant to the N.B. industry. Financial information from more than one hundred Norwegian farms was analyzed. Evidence in support of a conventional U-shaped average cost curve was found indicating that increasing economies of size exist at low production levels and then, as production expands, the farms experience constant scale economies followed by decreasing scale economies. While it is noted that the differences in climatic conditions, wage structure and costs of raw materials between Norway and Canada must account for cost variation, "...the information obtained on the economy of size (scale) should be useful for investors and policy planners, particularly as simulation studies using Canadian data confirm Norwegian experience".

A further analysis of industry efficiency was undertaken by Fiander-Good (1988). The study concluded that N.B. salmon farming

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[9] See Canadian Aquaculture, 1989, 5(3): 35.

operations are not particularly capital intensive because the total capital sums for an operation are lower than annual operating costs. While large sums of working capital are required, it was indicated that at prevailing salmon prices "...a well-managed salmon farm in southwestern N.B. would provide a lucrative return on investment." From this study, it appears that cage culture operations are relatively insensitive to changes in discount rates and smolt costs, moderately sensitive to changes in feed costs, and highly sensitive to smolt mortality rates in the cages and to salmon price changes.

3.2.2 Marketing Considerations

The demand for fresh seafood has increased in recent years and, as might be expected, sales of fresh Atlantic salmon have risen accordingly.[10] Estimates for the Canadian market put price elasticity of demand for fresh salmon at slightly greater than 10 and fresh-frozen at approximately 10 (Ridler and Kabir 1984). Income elasticites of fresh and fresh frozen salmon are estimated at approximately 4.[11] The high demand elasticity in the Canadian market indicates higher revenues can result from increased supply while the high income elasticity suggests that higher disposable income will increase the demand. However, the high demand elasticity implies a relatively large number of substitutes. And the high income elasticity suggests that the product is a strongly superior good so that any economic downturn would impact negatively on demand.

The above results relate to the domestic market. However, the U.S. market has grown in importance for the N.B. aquaculture industry. While initial sales of the Bay of Fundy product were

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[10] See Ridler (1984) for details.

[11] These high demand and income elasticities are supported in Lin (1988).

Canadian, forty per cent of production was exported to the U.S. in 1987 and this percentage is expected to increase significantly so that it becomes the Canadian farming industry's major market (Canada, Standing Committee on Fisheries and Oceans 1988). Hermann and Lin (1988) found that the demand for farmed (Norwegian) Atlantic salmon in the U.S. has demand elasticity of approximately 2 and income elasticity of 4.5. This suggets that Canadian salmon farmers face demand conditions in the U.S. market which are similar to those at home. However, the U.S. market is also extremely competitive.

Between August 1988 and April 1989, world prices for Atlantic salmon fell approximately 25% (Table 6). Increased production has created excess supply with an inevitable price reduction. A major source of supply is Norway, selling in some thirty markets worldwide.[12] Between 1983 and 1988, Norway expanded production approximately 500% from 17,298 to 85,000 tonnes (Table 7). The U.S. is a major Norwegian market. For example, in 1985 the U.S. accounted for over 30% of Norwegian exports. And over 73% of these Norwegian exports to the U.S. were landed in Boston and New York (Canada, Department of fisheries and Oceans 1989). Boston is the major destination for N.B. farmed salmon. Even as N.B. production has increased (Table 7), market competition in future is likely to squeeze profits through lower prices. Salmon farmers (including Canadian producers) must adjust to the transition to a buyers market as growth in the supply of pen-raised salmon from many countries continues.

Thus continued growth of the N.B. industry may be hindered by increasing competition in world markets. N.B., in fact, faces strong competition from British Columbia in the domestic market. However, it is clear that aquaculture currently has the ability to fill any market void created by the closure of the N.B. commercial

[12] See Fish Farming International, 1989, 16(9): 3.

fishery.

CHAPTER IV - THE RECREATIONAL FISHERY

4.1 OVERVIEW

Recreational fisheries create substantial management problems for governments because in most circumstances they do not generate the price signals that are necessary to determine the optimal allocation of resources. The Atlantic salmon sportfishery in New Brunswick is no exception as a large segment of this fishery has no operative price mechanism. Apart from a modest fixed fee for an angling licence, the existence of outfitters, and Crown lease and Crown reserve waters, the use of the resource itself is practically free. Even the Crown reserve prices are not market-based since the annual quantity demanded exceeds the quantity available and fishing rights are distributed by lottery at a minimal fee.

The stocks are currently depleted to such an extent that a "hook-and-release" program has been in effect since 1983. Very little analysis of the valuation of this fishery has been undertaken and if the fishery were to collapse there would be no measure of the loss. While a study measuring gross expenditures on salmon fishing and related activities has recently been completed (Tuomi, 1987), it is clear from the literature (eg. Crutchfield, 1962) that this is not a true valuation. These gross expenditures would simply be directed towards other goods and services if the fishery were to disappear. It is in fact the margin above the cost of sport fishing, i.e. consumer surplus, which measures the real monetary value which would be lost if the fishery were to disappear. As there has been no assessment of the net benefits of the New Brunswick Atlantic salmon sportfishery to date, we make such a consumer surplus estimate here.

4.2 VALUATION OF NON-PRICED RESOURCES

A number of methods have been used to evaluate non-priced resources. The three most common methods are the gross expenditure method, willingness to pay surveys, and the travel cost method. The gross expenditure method has been widely used in sportfisheries despite the fact that it is not a true measure of the value. This method simply totals the spending by users of the resource and designates this total as the value of the resource. It ignores the cost of inputs and merely records gross business volume. A recent example of this method reports that the value of gross expenditure and "investment" by salmon anglers in Atlantic Canada in 1985 was $84 million (Tuomi 1987).[14] (This method has a counterpart in the commercial fishery where proponents of that industry use the gross sales of fish rather than profit as the value of the industry.) The result of this approach is that the value of a particular sportfishery may be overestimated by a large factor.

Alternatively, willingness to pay surveys have been widely used in recreational fisheries and while the principle involved in surveying anglers about their willingness to pay is sound, it has often been found that there are large disparities in the results depending upon the nature of the questions asked. There continues to be disagreement over the appropriate way to ask the questions and the interpretation of the results.

For our purposes, we have chosen the travel cost method, which is an indirect approach. The underlying principle of the travel cost method is that since individuals are willing to incur travel expenses to use the non-priced resource, the benefit derived must be greater than or equal to the travel cost. Those who live closest and incur the least cost enjoy the greatest net benefit, and would be expected to use the resource in the greatest number. At some distance the cost will outweigh the benefit and there will be no users from beyond that distance. Consequently travel cost can be seen to be a proxy for price. At its simplest, the travel

[14] As well, the 1985 Survey of Sportfishing in Canada identified N.B.'s share of expenditures on Atlantic salmon to be $18 million (Canada, Department of Fisheries and Oceans 1987).

cost method involves estimating a relationship between the average travel cost from a zone and the per capita visits from that zone and imputing from that relationship a demand for the resource by adding hypothetical fees onto the known travel costs.

This basic model has undergone a number of refinements. Knetsch (1963) expanded the model to include consideration of travel time, income, congestion, and substitutes. This brought the model closer in line with conventional demand analysis, but created a problem since travel cost and travel time are highly collinear. This difficulty was overcome by combining time and money cost into a single variable. A problem remained however concerning how to evaluate the opportunity cost of time. Many chose arbitrary values, for example, setting the opportunity cost of time at some fraction of the wage rate. A model variation developed by McConnell and Strand (1981) allows the sample data itself to provide an estimate of the relative value of time spent travelling compared to time spent working, utilizing a two stage estimation. They showed that, except in very restricted circumstances, the marginal opportunity cost of time is less than the average, i.e. the wage rate. Thus the opportunity cost of time spent travelling is some fraction, k, of the wage rate and k can be estimated from:

$$\begin{aligned} V &= a + b(T + kAW) + cX \\ &= a + bT + bkAW + cX \qquad [4] \end{aligned}$$

where V is visits, T is travel cost, A is the time spent travelling, W is the wage rate, X represents other variables, and a,b, and c are parameters. Estimation of the model will give values for b and bk, hence the value of k can be found. With this, a composite value for travel cost, T + kAW, can be created, overcoming the problem of collinearity between travel cost and travel time.

In another refinement, Brown and Nawas (1973) and Gum and

Martin (1975) expanded the model to use individual observations rather than zone averages which increased the degrees of freedom considerably and allowed for much more variation in the variables. But the use of individual observations creates a bias because they do not reflect the lower participation rate of more distant population zones. If individual observations are used they must be adjusted to zone averages using a correction factor developed by Brown et al. (1983). The correction factor is the inverse of the sample size of the users in the total population multiplied by the number of observations in a zone divided by the zone population. The factor converts individual visits to individual visits per capita and removes the bias.

In a further development of the travel cost model, Ward (1984) shows that the travel cost coefficient is not in general an unbiased estimate of the price coefficient for which it is a proxy, and must be adjusted. The Ward model is a three equation system explaining visits, endogenous travel cost, and endogenous travel time, to be estimated using seemingly unrelated regressions. Travel cost and travel time include costs on site and time on site. One of the contributions of the Ward model is that it includes time on site as a cost, allowing for a trade-off between trip frequency and time spent on site per trip. Individual observations, rather than zone averages, are also used. Making the travel cost method a simultaneous system and endogenizing cost recognizes the opportunities that individuals have to make time or spending decisions to enhance utility. For example, Ward includes the opportunity cost of time on site in travel cost because this is a choice variable and trade-offs could be made between distance travelled and the amount of time spent on site. In order to compensate for greater distance individuals may choose to spend more time on site. This leads to a decomposition of costs into exogenous and endogenous components, where endogenous costs are those chosen to enhance utility, i.e. costs in excess of the minimum required.

4.3 THE MODEL

The Ward model was specified as:

$$VK = b_{01} + b_{02}(XTC) + b_{03}(CN) + b_{04}(AE) + b_{05}(AN) + b_{0i}(X_i) + e_0 \quad [5]$$
$$CN = b_{11} + b_{12}(XTC) + b_{1i}(X_i) + e_1 \quad [6]$$
$$AN = b_{21} + b_{22}(XTC) + b_{2i}(X_i) + e_2 \quad [7]$$

where VK is adjusted individual visits per capita, XTC is exogenous money cost of travel, CN is endogenous expenses per trip, AE is exogenous trip time, AN is endogenous trip time, X_i is other exogenous variables, and e is the error term. Following McConnell and Strand, this model would be estimated to obtain an estimate of k and then re-estimated using a composite travel cost variable, TC = XTC + CN + k(AE + AN), in (5). The second stage form of [5] is:

$$VK = b_{01} + b_{0c}(TC) + b_{0i}(X_i) + e_0 \quad [5a]$$

and all other equations remain unchanged.

Ward shows that the coefficient on price, b_p, is equal to the coefficient on travel cost, $b_{0c,}$ only if endogenous expenses are not affected by the level of exogenous expenses. In terms of the system above it can be shown that:

$$b_p = b_{0c}[1 + b_{12} + kb_{22}] \quad [8]$$

and $b_p = b_{0c}$ only if b_{12} and b_{22} are both equal to zero. It is expected, however, that these coefficients will be positive.

Estimates of this model for the New Brunswick case were not satisfactory and two modifications were introduced. First, the Ward model is linear and we estimate the visits equation in semi-log form.[15] Second, we extend the model, as suggested in a footnote by Ward, to five equations. Ward defined travel cost and travel time to include costs incurred both while travelling and on site. He suggested that costs might be further segmented to separate on site costs from travel costs. The extended model model is:

$$\log(VK) = b_{01} + b_{02}(XTC) + b_{03}(AE) + b_{04}(CNT) + b_{05}(CNS) + b_{06}(ANT) + b_{07}(ANS) + b_{0i}(X_i) + e_0 \quad [9]$$

$$CNT = b_{11} + b_{12}(XTC) + b_{1i}(Xi) + e_1 \quad [10]$$

$$CNS = b_{21} + b_{22}(XTC) + b_{2i}(Xi) + e_2 \quad [11]$$

$$ANT = b_{31} + b_{32}(XTC) + b_{3i}(Xi) + e_3 \quad [12]$$

$$ANS = b_{41} + b_{42}(XTC) + b_{4i}(Xi) + e_4 \quad [13]$$

where CNT is endogenous money cost of travel, CNS is endogenous money cost on site, ANT is endogenous time cost of travel, and ANS is endogenous time cost on site. In terms of the Ward model, CN=CNT+CNS and AN=ANT+ANS. The signs of the coefficients on XTC in equations [10]-[13] are expected to be positive to reflect the substitution of endogenous expenditures when higher exogenous travel costs are experienced. However, it is possible for b_{32} to be negative since a longer trip might cause individuals to spend less discretionary time in transit. The composite travel cost variable is TC=XTC+CNT+CNS+k(AE+ANT+ANS).

Rather than estimate this system in two stages to find an estimate of b_{0c} we re-specified [9] as a nonlinear (in the parameters) equation and constrained the parameters on the cost variables to be equal, thus estimating b_{0c}, k, and all other parameters simultaneously:

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[15] Graham-Tomasi et al. (1990) concluded that "...the literature contains substantial empirical support for the semi-log form..."

$$\log(VK) = b_{01} + b_{0c}(XTC) + b_{0c}\cdot k(AE) + b_{0c}(CNT) + b_{0c}(CNS) + b_{0c}\cdot k(ANT) + b_{0c}\cdot k(ANS) + b_{0i}(X_i) + e_0 \quad [9a]$$

The system [9a]-[13] was estimated using seemingly unrelated regressions and the nonlinear system procedure in SAS.

Because the visits equation is semi-log, the relationship between the coefficient on the composite travel cost variable, $b_{0c,}$ and b_p is:

$$b_p = VK\cdot b_{0c}[1+b_{12}+b_{22}+k(b_{32}+b_{42})] \quad [14]$$

4.4 APPLICATION TO THE NEW BRUNSWICK SPORTFISHERY

The model outlined above was estimated and the demand function was then defined in terms of the parameter estimates. The consumer surplus value of the fishery was established by integrating the demand function from zero to the highest observed travel cost, using 15 cents per mile as the operating cost of an automobile.

The data used to estimate this model were obtained from a survey of the resident anglers in New Brunswick for the 1984 salmon angling season. In 1984 there were 12641 resident angling licences sold. At the end of the season 784 surveys were mailed and 260 usable responses were returned. Respondents were asked to report trip details along with a variety of socioeconomic variables. The money cost of travel was the trip distance at 15 cents per mile (Statistics Canada 1984). The counties of New Brunswick were defined as zones for purposes of converting the individual responses to visits per capita. There are three major salmon river systems in New Brunswick, the Restigouche, the Miramichi, and the Saint John. All tributaries were classified with respect to the appropriate drainage system and some small number of salmon rivers which did not fall in any of these drainage systems were grouped as "other". The X_i variables of the model are:

R1, R2, R3 = river drainage dummies

YM, YH = income dummies

SA = salmon catch per rod-day
WK = weeks worked per year
The results of the model estimation are shown in Table 8.

Three of the four coefficients on XTC in equations [10]-[13] are positive and significant, as expected. Only the sign in [12] is negative, which means that the higher the money cost of travel the less discretionary time is spent in travel. The estimate of k is 0.597, suggesting that the cost of time spent travelling and on site is 60% of the wage rate. Using [14], the value of b_p can be found:

$$b_p = 0.0612\cdot(-0.0012)\cdot(1 + .74 + 1.567 + 0.597(-0.342 + 5.471)) = -0.000468$$

where 0.0612 is the average value of VK. This estimate of b_p is used to estimate the consumer surplus value of the fishery:

$$CS = V_0[\exp(b_p\cdot TC_{max})-1]/b_p \qquad [15]$$

where CS is consumer surplus, V_0 is total visits, and TC_{max} is the maximum observed travel cost. This is a truncated estimate of consumer surplus because of the functional form (Smith and Koop, 1980). For example, the estimated number of visits to the Miramichi is 7163 and the maximum observed travel cost is $1242, yielding a consumer surplus of $6.75 million. The Miramichi had the largest of the total estimated net benefits of $12.64 million. The consumer surplus estimates for each river system is found in Table 9. (A sample calculation is shown in the Technical Notes.)

4.4 VALUING A SALMON

This model also allows us to estimate the value of a salmon on the Miramichi which is used in the following chapter. This is accomplished by establishing the increased consumer surplus attributed to an increase in catch rate. For an arbitrary 10%

increase in catch rate, the increase in visits is predicted from the model to be 1.1% (which effectively means the demand curve shifts to the right). With an estimated 7163 visits of 2.23 days at an average catch rate of 0.79 salmon per day, a 10% catch rate increase will generate 82 additional trips and a total of 1420 additional salmon.[16] (This same calculation may be made for any arbitrary increase in catch rate using the model parameters.) It is then found that the consumer surplus per additional salmon caught is $57. (See Technical Notes.) This compares favorably with an estimate of $46 from Gillen and McGaw (1984), where the marginal willingness to pay for salmon on the Miramichi was estimated for 1979 using data from the Crown Lease auction carried out by the Province of New Brunswick. Considering the time difference and the likely lower catch rates generally when compared to the Crown Lease waters, the estimate of $57 appears reasonable.

[16] This is an interesting result because it could be used to calculate the marginal consumer surplus of policy actions such as enhancement programs designed to increase the catch rate. See Loomis et al. (1985) for further elaboration.

CHAPTER V - JOINT ALLOCATION: THE MIRAMICHI FISHERIES

5.1 INTRODUCTION

Fisheries with both commercial and recreational use are sometimes characterized by conflict over stock allocation between the competing groups and when such conflicts exist, the appropriate allocation between sectors is not always obvious and can pose a difficult problem for the policymaker (McConnell and Sutinen 1979). A theoretical economic analysis by Bishop and Samples (1980) addresses this type of problem by adding a recreational sector to the standard commercial fishing optimal control model (Clark and Munro 1975). Given the current situation in the New Brunswick salmon fisheries, i.e. the closure of the commercial fishery and the retention of the recreational fishery, we utilize the Bishop and Samples framework in order to evaluate the situation from an economic perspective. In our analysis, we examine the fisheries on New Brunswick's most prolific salmon river system, the Miramichi.

5.2 THE MODEL

The Bishop and Samples framework cannot be adapted perfectly to the Miramichi salmon fishery because their logistic production model is not applicable to an anadromous species such as salmon. However, the introduction of a stock-recruitment function allows for an amended version of their analysis.[17] In salmon species, recruitment is the primary factor influencing the size of the yearly stock so that the size of a salmon population in any one period is a function of the number of spawners from the previous period (escapement). When there is no harvesting by man, this relationship may be defined as

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[17] Two population models apply to fisheries depending on the type of species. The surplus production type associated with Schaefer (1954) treats the population as a single entity described effectively by its size or biomass. The analytic models associated with Ricker (1958) and Beverton and Holt (1957) consider age structures and population is defined as the sum of individual age classes.

$$dS/dt = G(S) - S \qquad [16]$$

where G(S) is the growth or recruitment and S the spawning stock or escapement. Escapements which produce year classes (recruits) greater than needed for replacing the parent year class provide surplus growth available for harvesting. With commercial and recreational harvesting by man, this relationship becomes

$$dS/dt = G(S) - S - H - R \qquad [17]$$

where H is the harvest of the commercial fishery and R the recreational harvest. Thus while the biological model used by Bishop and Samples required the growth per time period to equal the harvest in order to maintain a steady state (i.e., $dS/dt=0$), the biological model used here requires the growth to equal the parent stock plus the harvest for a steady state.

In the commercial fishery, a constant price, P, is assumed for each salmon harvested.[18] Following the Clark and Munro (1975) format for clarity, C(S) defines the harvest cost with $C'(S)<0$, and S the salmon stock. The net benefit per salmon caught commercially is then P-C(S). H represents the commercial salmon harvest with $0 \leq H \leq Hmax$. In the recreational fishery, R represents the recreational catch with $0 \leq R \leq Rmax$. The net benefits per recreationally caught salmon are defined by B(S) with $B'(S)>0$.[19]

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[18] Bishop and Samples examined both constant and variable price situations. The demand for Atlantic salmon in Canada has been shown to be downward sloping (Kabir and Ridler 1984). However, we examine a small fishery where fishermen are essentially price takers and the constant price assumption is considered more applicable in this case.

[19] It is assumed that net benefits and salmon stocks are positively related. The second order condition is unknown in general although it is sometimes assumed that the net benefits function increases at a decreasing rate because a a good part of the value of the salmon fishing experience can be attributed to factors other than success-rate. For a discussion of this issue,

The model attempts to establish the optimal stock level when rent maximization is the goal. The maximization of the present value of the rents from the fish population by the respective fisheries is defined as

$$\max J(H,R) = \int_0^\infty e^{-\delta t} [(P-C(S))H + (B(S)R] \, dt, \qquad [18]$$

subject to

$$dS/dt = G(S)-H-R-S,$$

$$0 \le H \le Hmax,$$

$$0 \le R \le Rmax,$$

$$S(0) = So.$$

The Hamiltonian function is

$$\mathcal{H} = e^{-\delta t} [(P-C(S))H + (B(S)R)] + \lambda(t)[G(S)-H-R-S], \qquad [19]$$

where $\lambda(t)$ is the adjoint variable and δ is the discount factor. Necessary conditions for the solution are:

$$\partial\mathcal{H}/\partial H = 0 = (P-C(S))H \, e^{-\delta t} - \lambda, \qquad [20]$$

$$\partial\mathcal{H}/\partial R = 0 = B(S)R \, e^{-\delta t} - \lambda, \qquad [21]$$

$$-\partial\mathcal{H}/\partial S = d\lambda/dt, \qquad [22]$$

$$dS/dt = G(S)-H-R-S. \qquad [23]$$

Both [20] and [21] hold simultaneously at the singular

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see Felder (1984). In our analysis, B'(S) is a (positive) constant.

solution, S*, only when the net benefits of the commercial and recreational fisheries are equal at the margin. This is unlikely to be true except by accident. If it is true, each fishery should be allocated its appropriate share of the optimal catch. What is more likely is that [20] and [21] are not equal at the margin and that either H or R must go to zero. This is the so-called "bang-bang" control of the linear model (Clark and Munro, 1975). This means that if [P-C(S*)] exceeds [B(S*)], then the commercial fishery should be the sole fishery. The opposite is true if [P-C(S*)] is less than [B(S*)]. However, the path to the steady state may temporarily allow for both fisheries to be operative. The path is determined by the stock level, So. If So>S*, it is possible that both fisheries should operate at H=Hmax and R=Rmax until S* is reached. Then the remaining fishery (i.e., the one with the largest net benefits or rents) takes [G(S*)-S*], allowing for stock replacement.[20] On the other hand, if S*<So, neither fishery should operate (i.e., H = R = 0) until S grows to S* and then only the fishery with the largest net benefits is allowed to function, taking either H* or R*, depending on which fishery makes the greater contribution.

In establishing the singular solution, S*, the time derivative of either [20] or [21] is calculated (depending on whether the commercial or the recreational fishery is to be retained) and combined with [22] to give [22]'. The singular solution is then established from [22]' and [23] as

$$G'(S_1) + [(C'(S_1)S_1 - C(S_1)G(S_1))/(P-C(S_1))] = 1+\delta, \qquad [24]$$

when [20] is relevant. When [21] is relevant, S* is defined by

$$G'(S_2)+[(B'(S_2)G(S_2)-B'(S_2)(S_2))/(B(S_2))] = 1+\delta. \qquad [25]$$

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[20] See Clark (1976:210-255) for a good discusssion of the economics of metered models.

5.3 ESTIMATION OF THE BIOLOGICAL FUNCTION

A stock-recruitment relationship for Atlantic salmon in the Miramichi river was estimated for the period 1971 to 1986. Egg depositions were used as an index of spawning stock and fry densities as an index of recruitment.[21] The functional form of the salmon stock-recruitment relationship is the subject of much debate in the literature.[22] It was specified here as

$$G(S) = Z = 1/(a+b/S) \qquad [26]$$

where a and b are parameters. This is a Beverton-Holt (1957) type function having an asymptote, (1/a).[23] The initial regression equation took the form

$$1/Z = a + b/S. \qquad [27]$$

However, the fit was improved when a dummy variable was introduced to account for the years 1972-80 and 1984-86 when the commercial fishery was closed. A time trend variable was also found to be

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[21] The biological data were obtained in unpublished form from the Department of Fisheries and Oceans sampling results on the Miramichi river system. Egg depositions (Year i) represent the stock index while recruitment is derived from mean densities of fry (Year i+1) based on annual sample data for the period 1970-1987. The sample statisitics were scaled up for the entire river system and may thus be overstated.

[22] A major issue in the debate is the shape of the stock-recruitment curve and this issue is discussed extensively in, for example, Solomon (1985) who concludes that a dome-shaped curve is not the most appropriate basis for explaining observed results for stream salmonids. On this river system, indications are that Ricker's (1975) dome-shaped curve is not necessarily applicable. See, for example, Chadwick (1987) and (1985) and Chadwick and Randall (1986).

[23] Other functional forms including logarithmic, quadratic, and Ricker were tested with a much poorer fit than the hyperbola used here. The Beverton and Holt (1957) form assumes density dependent mortality begun early in the life cycle which is relevant here, given the indices used for stock and recruitment.

significant in the estimation. The regression results are indicated below (t-statistics in parentheses):

$$1/Z = 0.000056 + 0.002737/\ S - 0.000004\ M + 0.000040\ D \qquad [28]$$

$$(3.5) \qquad (2.7) \qquad (-3.3) \qquad (2.5)$$

$$R^2 = 0.79 \qquad d\text{-}w = 2.20$$

where X is an index of recruits ('000 fry) in time "t", S is an index of spawning stock (millions of eggs) in time "t-1", M is a time trend variable ranging from 1 to 16, and D is a dummy variable which assumes the value 0 when the commercial fishery was not operating and 1 when it was operating. R^2 is the coefficient of correlation and d-w the Durbin-Watson statistic.

According to the estimation results, recruitment was affected by the operation of the commercial fishery and by some other undefined exogenous factors which occurred within this timespan (e.g., increasing stock interceptions by fisheries in Greenland and Newfoundland).[24] The undefined exogenous effects impacted negatively on (1/Z) and hence positively on Z. This is reasonable because quota agreements with Greenland and cutbacks in Newfoundland catches were achieved during this time. The commercial fishery was in operation in only 4 of the 16 years of the analysis and each time it was reopened, biologists felt that the stocks had increased during this time. The positive sign of the dummy coefficient indicates that when the commercial fishery was in operation, Z fell. The positive signs of the constant and stock coefficient are as expected in the biological function. The economic performance of the commercial fishery was assessed in 1983. This means values of M=13 and D=1 are inserted in [28] resulting in an adjusted constant term. The stock recruitment

[24] A discussion of the problems of interception of the New Brunswick stocks over this period may be found in Cook and McGaw (1986).

function, [26], is then defined as

$$G(S) = Z = 1/[0.000044 + (0.00274/S)]. \quad [29]$$

5.4 ECONOMIC ASPECTS OF THE MIRAMICHI FISHERIES

The commercial salmon fishery on the Miramichi has been carried out at the mouth of the river and historically utilized two gear types: trapnets and driftnets. As indicated in Chapter 2, the average total cost per vessel-year in the 1983 trapnet fishery was found to be $3844, while in the driftnet fishery it was $5936. The weighted average for the two gear types was $5223 per vessel-year. The vessel-year for the salmon fishery on this river constituted 27 actual vessel-days of operation which results in average costs per vessel-day of $193. In 1983, commercial fishermen on the Miramichi received approximately $2.80 per pound (and the salmon weighed 10 pounds on average). Since this is a very small fishery with the fishermen acting as pricetakers and having no influence over the market, it is assumed that demand is perfectly elastic at $28 per salmon in the calculations which follow.

The valuation of the recreational salmon fishery described in Chapter 4 assumed visits to be a function of trip costs, salmon caught, and various socioeconomic variables. The salmon caught (along with the socioeconomic variables) acted as shift variables for the demand curve. By establishing the change in the consumer surplus associated with a change in caught salmon, the value of a salmon taken in the 1984 Miramichi recreational fishery was calculated to be $57 (see Technical Notes).

In establishing the optimal values for the commercial fishery, equation [24] was solved for S_1*. A discount rate of 10% was used.[25] Cost per unit of fishing effort was defined as C(S)=c/S where c is the cost of a vessel-day and estimated to be $193. Then using a price of $28 per salmon, the optimal population for the commercial fishery was found from [24] to be 1134 ($*10^6$) eggs with a 10% discount rate.

The optimal population for the recreational fishery was found using [25]. However, net benefits of the recreational fishery are defined in terms of the stock in [25]. In order to value the recreational salmon fishery in this manner, catch was first estimated as a function of the stock and then transformed into value by the scale factor, v (= $57 per salmon). The net benefit function is then defined as $B(S) = v \cdot R$ where R=R(S) is the relationship between the angled catch and the stock.

The R=R(S) relationship was estimated for the period 1971 to 1986 (t-statistics in parenthesis) as[26]

$$A = \underset{(3.7)}{0.0049} + \underset{(7.5)}{0.000083}\, S \qquad [30]$$

$R^2 = 0.69$ d-w = 2.1

where R is the recreational catch per year ($*10^6$) and S the stock index ($*10^6$ eggs). Given v=$57 per salmon, $B(S) = v \cdot R(S)$ simplifies to

$$B(S) = 0.28 + 0.0047\, S \qquad [31]$$

[25] A 10% rate is used because it is the specified "real" social rate of the Canadian government (Canada, Treasury Board Secretariat 1976).

[26] The catch depends upon many factors including weather, predation, season length, the angling "catchability coefficient", and the native Indian food fishery to name a few. Lack of information in this respect helps to explain the relatively low coefficient of correlation in the estimation. Catch statistics were obtained from O'Neill et al. (1984-1987).

Using [31], it is possible to solve [25] for S_2*. Given a discount rate of 10%, S_2* is found to be 10,790 (*10^6) eggs.

The policy decision is to choose between S_1* and S_2*. At the margin, B(S_2*) is calculated to be $52 (in 1984 $) and p-C($S_1$*) is $27.83 (in 1983 $). Even with p-C($S_1$*) inflated at 5% to 1984 terms at $29.22, B($S_2$*) > p-C($S_1$*). This means the recreational fishery would be more valuable at the margin than the commercial fishery, given these optimal populations. S_2* is thus the desired population.

This result must be qualified, however. Higher stock levels will most likely result in higher success rates and an associated increase in rod-days. It would be unlikely that a salmon would maintain a constant value of $57 in these circumstances. Congestion externalities and reduction in the angling challenge among other factors will have a negative impact on the value of a landed salmon. If the valuation of a recreationally caught salmon were not constant (and enough data were available to provide this information), it is possible that B(S^*) would be less than $52 and the conclusions of this analysis would require modification. This is an area for further research.

CHAPTER VI - DISCUSSION

6.1 THE COMMERCIAL FISHERY

The 1983 N.B. commercial salmon fishery is estimated to have produced an economic profit, based on averages, of $59,600 on gross revenues of $1,212,500. While the performance of individual vessels was highly varied, 44 of the 81 vessels surveyed failed to make a profit. From the estimation of the long run cost function for the industry, it can be seen that the main reason for this lies in the level of catch. Long run average cost declines substantially for landings up to 200 salmon but over one-half the vessels could not achieve this level of catch and thus failed to take advantage of the economies associated with a larger scale of output. For an enterprise to break even, a catch of between 80 and 110 salmon per season was required and many did not achieve this level. A driftnet on the Miramichi would have required a catch of 185 salmon.

Even though the performance of individual enterprises is highly varied, it appears unlikely that the commercial fishery overall can ever be economically viable unless salmon stocks rejuvenate substantially. This is not anticipated in the near future. Cutbacks in the Newfoundland commercial fishery have not been nearly as dramatic as in N.B. and the interception problem remains at both the domestic and international levels (Table 1). Meanwhile, the N.B. salmon aquaculture industry has grown over the 1980s to the extent that domestic market demand is met even with the closure of the commercial fishery. Competition from this source is likely to impact negatively on any renewed commercial fishery. The license buyback program might thus be considered in the long term best interests of the commercial fishermen.

6.2 AQUACULTURE

In examining the N.B. aquaculture industry, it appears to have survived initial start up difficulties. It is now under government management. Agreement between both levels of government through a

Memorandum of Understanding (MOU) provides for federal-provincial co-operation in the interests of an orderly development of the industry and for aquaculture licensing and leasing procedures administered by the provinces. N.B. signed such a MOU with the federal government in April 1989 which clarified federal and provincial responsibilities and introduced a simplified licensing service in a single centralised provincial operation.

The industry has been aided by government financing made available under the Canada-New Brunswick Subsidiary Agreement on Fisheries Development through the "Salmonid cage-culture program" which gave $2.1 million in grants for selected capital and operating expenditures to 21 companies in the Bay of fundy between 1985 and 1988 (Canada, Standing Committee on Fisheries and Oceans 1988). A moratorium was imposed on the number of new leases for aquaculture sites in 1986 in order to slow the growth of an industry which had doubled output annually since 1980. It also allowed time for the development of smolt facilities as a lack of smolt had been a constraint on the industry since its inception. Provincial legislation in the form of an Aquaculture Act was introduced in December of 1988, effectively lifting the ban on the granting of new site licenses for cage operations while controlling the growth in the number of licenses. The industry is now viable and able to meet market demand. In this regard, one may conclude that it is valuable to N.B. in that it has been able to effectively substitute for the lost commercial fishery. As well, spin-off effects are notable in terms of employment and new industry.

6.3 THE RECREATIONAL FISHERY

The recreational fishery is also very valuable to N.B. No matter what value is used for the commercial fishery, it quite simply does not compare in value to the sportfishery. In terms of consumer surplus, we estimate the sportfishery to be worth about $12 million. Consumer surplus is of interest here because it tells us how much consumers value the resource over and above the amount which they actually pay for it. In effect, it is a measure of the net benefit received from the resource and in the case of this fishery, it is the full value of the resource since there are no market prices.[25]

The marginal value per salmon of $57 found here compares favorably with a value estimated from Crown Leases where salmon waters are auctioned, thus creating a price effect. In one sense this goes far enough. The marginal gross value of a commercially caught salmon would be $28 if costs were zero. Add to this the statement by Tuomi (1987) that the government expenditure per salmon caught in Atlantic Canada is about $47 and it appears that the correct policy decision was made when the commercial fishery was closed.

6.4 CONCLUSIONS

When the commercial and recreational information is considered more formally in the context of a theoretical model of joint allocation applied to the Miramichi, the overall conclusion that the sportfishery is more valuable is unchanged. Here, if one fishery must be chosen over another because of diminished stocks, the recreational fishery is deemed more valuable at the margin.

Current management of the fisheries seems appropriate, with the commercial fishery closed and a significant part of the sportfishery effectively closed through a hook-and-release program. Salmon stocks are well below the optimum levels and if stocks rebuild, we believe preference should be given to the sportfishery. Based on what appears to be happening in the salmon aquaculture industry in its early years, the non-fishing public can have its demand for salmon quite reasonably satisfied through this source.

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[25] There are many difficulties involved in estimating values when there is no price system but to reverse our conclusion would require substantial bias or error.

At the same time, the government might reasonably consider extracting some of the surplus value from recreational users if the cost to taxpayers is as high as $47.

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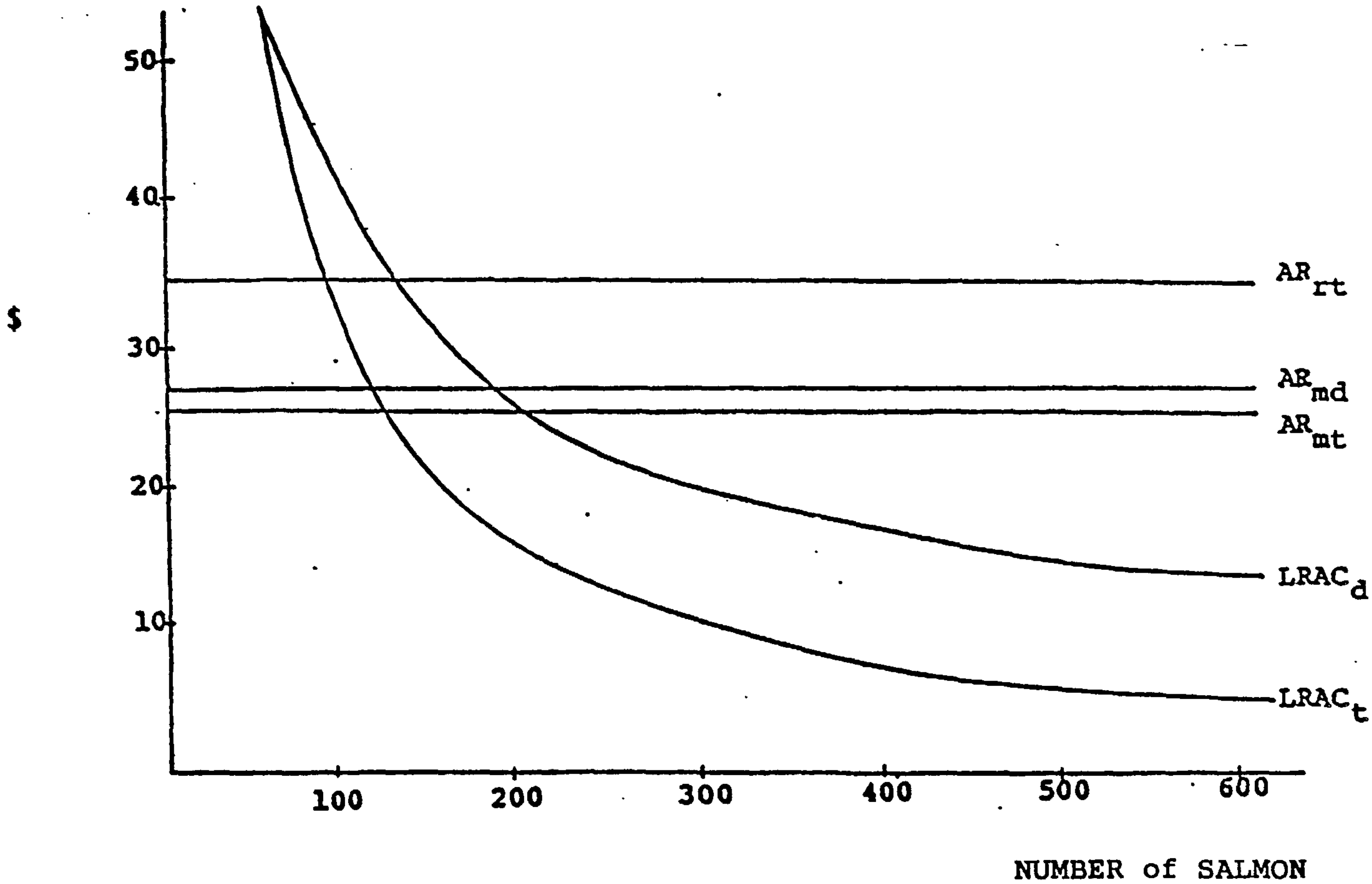
FIGURES

Figure 1. Average Cost and Average Revenue Curves for Trapnet and Driftnet



TABLES

Table 1. Commercial Salmon Landings (tonnes)

YEAR	NEW BRUNSWICK	NEWFOUNDLAND	GREENLAND
1967	656	1822	1601
1968	375	1445	1127
1969	268	1441	2210
1970	263	1595	2146
1971	124	1576	2689
1972*	-	1395	2113
1973*	-	2008	2341
1974*	-	2011	1917
1975*	-	2044	2030
1976*	-	1175	1175
1977*	-	1939	1420
1978*	-	1179	984
1979*	-	986	1395
1980*	-	2104	1194
1981	103	1895	1204
1982	87	1314	1077
1983	75	1017	285
1984**	14	796	297
1985*	-	881	857

* Commercial fisheries closed on all three N.B. river systems.
**Commercial fisheries closed on two of three N.B. river systems.

Source: North Atlantic Fisheries Organization, Statistical Bulletin. Vols. 32-35. Dartmouth N.S., Canada.

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Table 2. Costs and Earnings by Vessel Type (Vessel Averages)

	DRIFTNET		TRAPNET	
Revenue		$ 5600		$ 5054
Labour	1908		325	
Fuels and oil	652		245	
Nets and equipment	438		581	
Clothing	34		70	
Food	374		4	
Maintenance	146		63	
Owner's labor	909		1254	
Freight	36		108	
Other	108		42	
Variable Cost		4605		2693
Net Revenue		995		2361
Repairs	79		37	
Loan payment	198		0	
Fees	283		65	
Depreciation	771		1049	
Fixed Cost		1331		1151
Economic Surplus		$ (336)		$ 1210

Note: Numbers may not add precisely due to rounding.

Table 3. Costs and Earnings by River (Vessel Averages)

	RESTIGOUCHE		MIRAMICHI	
Revenue		$5115		$5449
Labour	$ 390		$1493	
Fuels and oil	193		559	
Nets and equipment	511		489	
Clothing	68		44	
Food	0		281	
Maintenance	66		125	
Owner's labor	1476		950	
Freight	191		37	
Other	13		97	
Variable Cost		2908		4075
Net Revenue		2207		1374
Repairs	32		69	
Loan payment	0		147	
Fees	85		223	
Depreciation	1692		708	
Fixed Cost		1809		1148
Economic Surplus		397		227

Note: Numbers may not add precisely due to rounding.

Table 4. Average Cost per Salmon by Fishing Method

Number of Salmon	TRAPNET	DRIFTNET
50	$53.60	$54.40
100	27.60	37.30
200	14.20	25.60
300	9.60	20.50
400	7.30	17.60
500	5.90	15.50
600	5.10	14.10

Table 5. Output Distribution of Vessels

Number of Salmon	Trapnet	Driftnet	Total
0-99	11	7	18
100-199	15	18	33
200-299	1	9	10
300-399	1	12	13
400-499	1	0	1
500+	2	4	6

Table 6. Wholesale Price Trends*

	Aug./88	Oct./88	Dec./88	Feb./89	Apr./89
Chinook & Coho (4-6 lbs) (B.C. farmed)	$4.70	$4.50	$4.40	$4.25	$3.90
Chinook & Coho (6-9 lbs) (B.C. farmed)	5.50	5.20	5.35	5.10	4.25
Atlantic (4-6 lbs) (N.B. farmed)	5.95	5.70	5.00	5.00	4.45
Atlantic (6-9 lbs) (N.B. farmed)	6.45	6.20	5.25	5.25	4.85
Atlantic (9+ lbs) (N.B. farmed)	6.55	6.30	5.40	4.85	4.90
Atlantic (4-6 lbs) (Norway, CIF)	5.90	5.40	4.85	4.90	4.50
Atlantic (6-9 lbs) (Norway, CIF)	6.40	5.95	5.25	5.00	4.70
Atlantic (9+ lbs) (Norway, CIF)	6.60	6.10	5.65	5.30	4.80

* All prices in Cdn. $. Price per lb. for the fresh fish market, FOB price, major city.

Source: Canadian Aquaculture, Vol. 4(6), Vol. 5(1), Vol. 5(3).

Table 7. Farmed Salmon Production (tonnes)

Year	New Brunswick[a]	Norway[b]
1979	6.4	4,389
1980	11.4	4,312
1981	20.9	8,910
1982	38.2	10,266
1983	68.2	17,016
1984	222.7	22,300
1985	350.0	28,655
1986	636.4	45,675
1987	1,318.2	47,000
1988	3,200.0[c]	85,000[d]

a Fiander-Good Associates. 1988. Economic assessment of salmonid cage culture in SW New Brunswick. p.12.

b Canada, Department of Fisheries and Oceans. 1989. Long term production outlook for the Canadian Aquaculture industry. Economic and Commercial Analysis Report No. 13.

c Canadian Aquaculture. 1989. Vol.5(3): 35.

d Fish Farming International. 1989. Vol.16(7): 68.

Table 8. Regression Model Estimate

Equation	Parameter/X_i Variable	Estimate	T ratio
9a	b_{01}	-4.228	19.65
	b_{0c}	-.0012	1.91
	k	.597	1.47
	R1	-.384	1.11
	R2	1.273	5.37
	R3	-.055	0.17
	SA	.144	2.31
10	b_{11}	13.773	1.47
	b_{12}	.74	3.54
	R1	31.578	2.09
	R2	-10.258	1.00
	R3	-2.033	0.14
11	b_{21}	-42.049	1.44
	b_{22}	1.567	4.26
	R1	65.489	2.47
	R2	18.138	1.01
	R3	5.721	0.23
12	b_{31}	8.70	5.55
	b_{32}	-.342	7.15
13	b_{41}	371.74	4.85
	b_{42}	5.471	5.87
	YM	140.0	2.32
	YH	390.6	6.34
	WK	-7.924	4.82
	SA	-26.607	2.06

Table 9. Consumer Surplus Estimate ($ millions)

Restigouche	2.09
Miramichi	6.75
Saint John	1.36
Other	2.44
Total	12.64

TECHNICAL NOTES

Establishing the Price Coefficient

The travel demand equation of the Ward model is:

(1) $VK=f(C+kA)=f(TC)$

where $C=CX+CN$, $A=AE+AN$, $CX=XTC+P$, and P is the unobserved (and nonexistent) price of the resource. All other variables remain as previously defined. TC can be expressed as:

(2) $TC=CX+CN(CX,X)+k(AE+AN(CX,X))$

The travel cost model attempts to measure $b_p=\partial VK/\partial P=\partial VK/\partial CX$ but actually measures $b_{0c}=\partial VK/\partial TC$. The relationship between b_p and b_{0c} can be determined from:

(3) $$b_p=\partial VK/\partial P=\partial VK/\partial TC\cdot \partial TC/\partial P$$
$$= b_{0c}[\partial CX/\partial P+\partial CN/\partial CX\cdot \partial CX/\partial P+k\cdot \partial AN/\partial CX\cdot \partial CX/\partial P]$$
$$= b_{0c}[1+\partial CN/\partial CX+k\cdot \partial AN/\partial CX]$$

In terms of the Ward model this is:

(4) $b_p=b_{0c}[1+b_{12}+kb_{22}]$.

Since we have estimated this as a semi-log model, (1) becomes:

(5) $VK=e^{f(TC)}$.

(2) remains unchanged, and (3) becomes:

(6) $$b_p=\partial VK/\partial P=e^{f(TC)}\cdot \partial VK/\partial TC\cdot \partial TC/\partial P$$
$$=VK\cdot b_{0c}[1+\partial CN/\partial CX+k\cdot \partial AN/\partial CX]$$

In our model this translates to:

(7) $b_p = VK\cdot b_{0c}[1+b_{12}+b_{22}+k(b_{32}+b_{42})]$

Expressing the Demand Equation

The travel demand equation, with a hypothetical price, can be expressed as:

(8) $\ln(V_0)=b_0+b_p(TC+P_0)+b_i(X_i)$

where $P_0=0$ and V_0 is the number of visits with a zero price.

With a price $P_1>0$, the demand is:

(9) $\ln(V_1)=b_0+b_p(TC+P_1)+b_i(X_i)$

Subtracting (9) from (8) and rearranging eliminates all variables other than visits and price:

(10) $V_1=V_0\cdot \exp(b_p\cdot P_1)$

Calculation of Consumer Surplus

The value of consumer surplus is found by integrating (10) for P ranging from zero to the maximum observed travel cost:

(11) $CS = V_0[\exp(b_p \cdot TC_{max}) - 1]/b_p$

For example, the calculation for the Miramichi is as follows:

(12) $CS = 7163\ [\exp(-0.000468 \cdot 1242) - 1]/[-0.000468]$

$= \$6.75$ million

Establishing the Value of a Salmon

In establishing the value of a landed salmon, the change in consumer surplus is calculated by replacing visits with the change in visits, and then dividing by the additionally caught salmon. This gives the marginal consumer surplus per salmon on the Miramichi as:

$\Delta\ CS = 82\ [\exp(-0.000468 \cdot 1242) - 1]/[-0.000468 \cdot 1420]$

$= \$57$