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Economic Aspects of Salmon Aquaculture in Atlantic Canada

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ECONOMIC ASPECTS OF SALMON AQUACULTURE IN ATLANTIC CANADA

by

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ABSTRACT

Ridler, N. B., and M. Kabir. 1988. Economic aspects of salmon aquaculture in Atlantic Canada. Can. Ind. Rep. Fish. Aquat. Sci. 188: iv + 13 p.

Farming of Atlantic salmon has expanded rapidly in Europe, and with a lag also in Atlantic Canada, particularly New Brunswick. Salmon farming can be profitable; it is also a growth industry in the southwest region of New Brunswick which presently has the highest unemployment rate in the province. The industry has already generated approximately 300 person-years of work and further job creation will occur as the industry expands. This report examines these socio-economic aspects of salmon farming. Complementary to, rather than competitive with, the commercial fishing of Atlantic salmon, the report analyzes the impact of aquaculture on the commercial fisheries. Profitability is demonstrated using actual Norwegian data and hypothetical data for Canada. Concern over imminent market saturation is examined by estimating price and income elasticities of demand; the results indicate a strong domestic market with some potential for exports. Overall, the prospects for expansion appear promising, with attendant socio-economic benefits for the Atlantic economy.

RÉSUMÉ

Ridler, N. B., and M. Kabir. 1988. Economic aspects of salmon aquaculture in Atlantic Canada. Can. Ind. Rep. Fish. Aquat. Sci. 188: iv + 13 p.

L'élevage du saumon de l'Atlantique s'est répandu très rapidement en Europe, et avec un peu de retard, il prend de plus en plus d'essor dans les provinces de l'Atlantique, plus particulièrement au Nouveau-Brunswick. L'élevage du saumon peut être rentable. Il représente une industrie en pleine croissance dans le sud-ouest du Nouveau-Brunswick, où sévit actuellement le taux de chômage le plus élevé de la province. Cette industrie a déjà engenfré la création d'environ 300 années-personnes et on estime qu'elle en créera d'autres à mesure qu'elle prendra de l'essor. Le présent rapport se penche sur les aspects socio-économiques de l'élevage du saumon. Il analyse les incidences de l'aquaculture sur la pêche commerciale du saumon de l'Atlantique, et il estime que ces deux activités sont complémentaires plutôt que compétitives. La rentabilité de l'aquaculture y est démontrée, à l'aide des données réelles empruntées à la Norvège et des données hypothétiques estimées pour le Canada. On examine le problème de la saturation imminente des marchés en estimant l'élasticité de la demande par rapport aux revenus et aux prix. Les résultats de cette analyse laissent voir en marché intérieur fort et quelques possibilités sur le plan des exportations. Dans l'ensemble, les perspectives d'expansion semblent prometteuses et les provinces de l'Atlantique devraient en retirer des avantages socio-économiques.

INTRODUCTION

As a common resource, the commercial fisheries have experienced overfishing to the extent that 11 ocean fisheries face biological collapse. Among the species involved is Atlantic salmon. Both world and Canadian landings have been declining; the world wild catch of Atlantic salmon has declined from 14,800 t in 1973 to less than 10,000 t by 1983. Canadian landings over the same period fell from 1894 t to 1221 t.

The decline in commercial landings of a high value species created ideal opportunities for farming. Initially in Norway, and later in Scotland, Ireland, Iceland, the Faroes and Canada, farming of Atlantic salmon attracted private investment because of its potential profitability. By 1980, output of farmed Atlantic salmon, principally from Norway, was 4900 t; by 1986, output was more than 59,000 t. World production of farmed Atlantic salmon is now four times the wild catch of Atlantic salmon.

Still in its infancy in Canada, farming of Atlantic salmon has also shown exponential growth. From a total output of 6 t in 1979, output grew to 163 t in the calendar year 1984 and approximately 297 t in 1986. Some 33 salmon farms are now operating in New Brunswick alone. In addition, Atlantic salmon is being cultivated in the Pacific off British Columbia.

This report examines certain economic aspects of farming Atlantic salmon. It focuses particularly on Atlantic Canada, although the general framework could include other parts of Canada, and even other species. The initial chapter will examine the economic interrelationship between the commercial fisheries and aquaculture. The second chapter examines the profitability of salmon farming, using both actual and hypothetical data, and the potential contribution of salmon farming to Atlantic Canada. The third chapter analyzes the market for Atlantic salmon. Given the projected output of farmed salmon in Canada and elsewhere, will there by an over-supply and subsequent deterioration of farm income? Any conclusion must be tentative, but estimates of demand elasticities encourage a relatively sanguine outlook.

THE COMMERCIAL FISHERIES

A MODEL OF THE COMMERCIAL FISHERIES

The wild Atlantic salmon catch has declined but, as Table 1 shows, Canadian landings of 1200 t in 1986 were still more than four times the 297 t output of farmed Atlantic salmon. This section provides a brief review of the traditional fishery model. Management of individual river systems requires an escapement model for salmon but, for the species as a whole, the traditional models of Gordon (1954) and Schaefer (1957) are applicable. In their theoretical models the rate of growth of the fish stock (biomass) is assumed to be a function of its size:

$$dx/dt = F(x) - H(t) \qquad (1)$$

where x is the fish stock, F(x) is the growth rate

Table 1. Canadian landings and exports of Atlantic salmon 1973-86.

	Landings			Exports					
			Real	Fresh		Frozen		Real export price index	
Year	Volume[1] (t)	Value ($000)	landing price index[2]	Volume (t)	Value ($000)	Volume (t)	Value ($000)	Fresh	Frozen
1973	1894	3470	100.0	79	264	621	2193	100.0	100.0
1974	1931	3658	93.3	125	420	292	974	80.8	85.3
1975	1929	3618	83.3	82	338	467	1714	100.4	84.6
1976	1909	4270	92.5	57	295	596	3554	117.2	127.9
1977	1856	5488	113.3	73	437	575	3434	125.8	118.7
1978	1217	4455	128.7	83	494	363	2067	114.8	103.9
1979	943	3713	126.8	103	870	175	1347	162.9	128.7
1980	2393	8966	109.5	129	927	474	3681	127.0	84.9
1981	2074	7608	95.2	198	1521	402	2667	123.0	89.4
1982	1464	5606	89.8	124	988	267	1534	113.6	69.9
1983	1221	4833	87.8	152	1392	147	761	111.4	59.6
1984	816	3152	82.1	52	399	39	222	89.4	62.8
1985[3]	826	3530	87.3	45	455	80	628	113.3	83.2
1986[3]	1209	4685	76.02	143	1176	116	942	88.6	82.7

Source: Calculated from the Department of Fisheries and Oceans, Annual Statistical Review of Canadian Fisheries, Ottawa: various issues; Statistics Canada, Exports by Commodity and Country, Catalogue Nos. 65-202, Department of Fisheries. Canadian Fisheries-Landings (various issues).

[1]Dressed or round weight.
[2]Landing price index divided by the Consumer Price Index (all items).
[3]1985-86 preliminary landing volume and value.

of the biomass and H(t) is the rate of harvest. It is commonly assumed in the literature that fish stock follows the logistic growth model, which is as follows:

$$F(x) = rx(1 - x/k) \qquad (2)$$

In the above equation, r is the intrinsic growth rate of the fish stock and k is the environmental carrying capacity of the stock. In the absence of any harvesting, there are two values for x (0 and k) for which the rate of growth of the biomass will be zero. Equation 2 yields a parabola if F(x), the growth in fish stock, is plotted against x, the fish stock itself. It implies that if the fish stock is small, the biomass will grow quite rapidly. Growth rate will reach a maximum and then decline gradually until the biomass reaches its carrying capacity.

Fish harvesting can be expressed as a function of fishing effort (standardized units of fishing time or fishing activity). Assuming a proportional relationship between harvest and effort, the following equation can be written:

$$H(t) = aEx \qquad (3)$$

where a is the constant of proportionality (the catchability coefficient) and E is total effort. For the sake of simplifying the exercise, we can normalize units of effort by setting a = 1. The biological equilibrium is defined as a situation where the natural growth rate is equal to the industry harvest rate. In other words, the rate of change in the fish stock is zero:

$$dx/dt = F(x) - H(t) = 0 \qquad (1a)$$

Substituting from (2) and (3) to equation (1a), and setting a = 1, we have the following:

$$dx/dt = rx(1 - x/k) - Ex = 0 \qquad (4)$$

Equation (4) can be solved to obtain a biological equilibrium stock size, x*:

$$x^* = k(1 - E/r) \qquad (5)$$

For any $E < r$, the equilibrium is unique. The equilibrium harvest H* (sustainable yields), corresponding to a given level of E is given by the following:

$$H^* = kE(1 - E/r) \qquad (6)$$
$$\partial H^*/\partial E > 0 \text{ for } 0 < E < E_m$$
$$\partial H^*/\partial E < 0 \text{ for } E_m < E$$

E_m is the maximum sustainable yield. The sustainable yield curve is basically the long run production function of the industry. The traditional analysis is a long run analysis because it assumes complete stock adjustment to changes in the level of effort.

Assuming that the price of fish (P) and the unit cost of effort (c) are constant, the profit function can be written as below:

$$\Lambda = PH^* - cE \qquad (7)$$

The unregulated fishery will reach an equilibrium where rents are equal to zero. As long as some positive rents exist, more fishermen will enter the fishery and utilize the stock. Thus, the unregulated common-property equilibrium occurs where total revenue (TR) is equal to total cost (TC). This equilibrium is inefficient.

Figure 1 summarizes the basic points of the traditional theory. The total revenue curve is the "monetized" sustainable yield curve. If the price of fish is set equal to unity, then the corresponding total revenue curve becomes the yield curve. Total cost curve has been drawn as a linear function of effort. The common-property equilibrium is obtained at E_2 because at the level of effort, the TR = TC condition is satisfied. The economic-efficient equilibrium is at E_e, where the marginal cost of effort is equal to the marginal revenue. The common property equilibrium can also be biologically inefficient if the equilibrium is at a lower level of stock than the maximum sustainable yield (MSY) stock.

The above analysis can be used to derive the steady-state long-run supply curve of the open-access fishery. In Fig. 1, panel (a), a family of total revenue curves has been drawn for different unit- prices of fish. As fish prices increase, the TR curve is blown out. The TR_1 curve is for a price level of unity and thus it becomes the yield curve. The point of intersection between the TC and TR curves indicates the common-property equilibrium. For an equilibrium effort level, the supply of fish (harvest) is read along the yield curve. Once the maximum sustainable yield is reached, further increases in prices will lead to greater effort and reduced catch.

The relationship between price of fish and the resulting harvest has been graphed in panel b (Fig. 1). The steady-state supply curve of fish from the open-access fishery is a backward-bending one. It is possible that the demand curve could shift to the right far enough to intersect the supply curve at its backward-bending portion. This will lead to overfishing.

THE IMPACT OF SALMON AQUACULTURE ON THE COMMERCIAL SALMON FISHERIES

In this section, market interactions between common-property fishery and aquaculture are examined for a single species, say Atlantic salmon. It is assumed that farmed fish and wild fish are perfect substitutes. The fish are produced by a large number of commercial operations which can be divided into two groups based on the technology employed. The first group of firms belongs to the traditional fishery and these apply fishing effort to the common-property stock to obtain their harvests. Their behavior has been evaluated in the previous section.

The second group of firms belongs to the commercial aquaculture and produces fish under managed conditions. These firms use factor inputs in a way which is the same as in the private-property case. The economics of production and supply for an aquaculturalist is much the same as discussed in any intermediate microeconomics text. A typical fish farm will equate marginal cost to the marginal revenue to maximize profit. The supply curve of the firm is the marginal cost curve above the average cost curve.

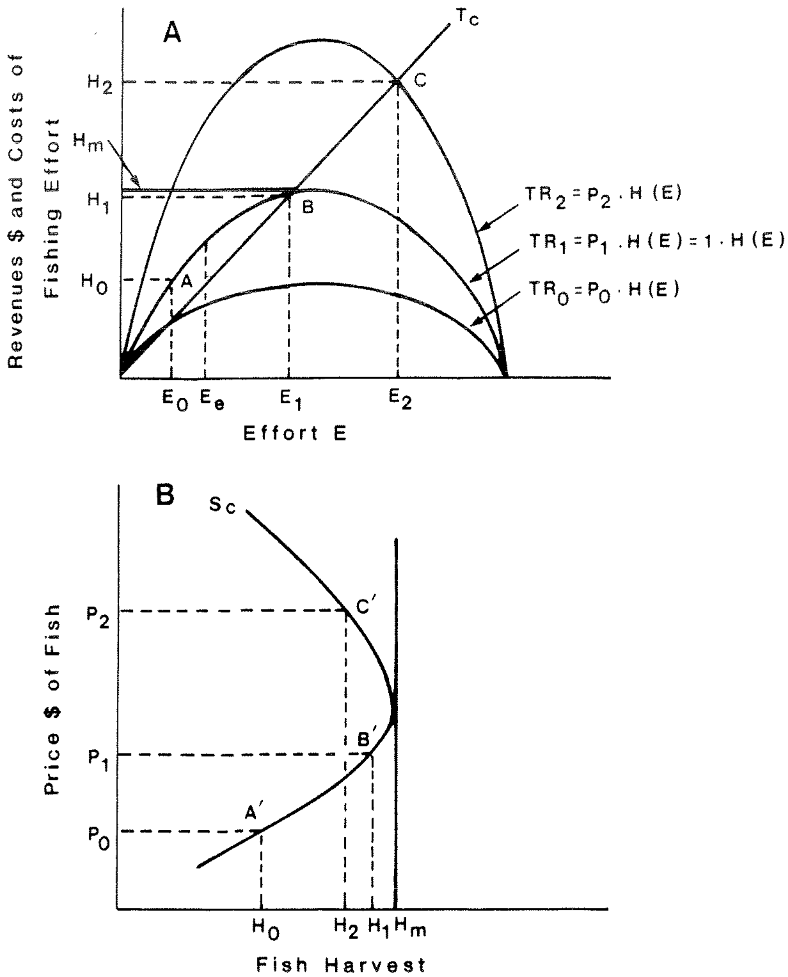


Fig. 1. Derivation of a steady-state supply curve for the common-property fishery.

The Atlantic salmon industry's supply curve is the horizontal sum of the individual supply curves of all firms producing the same fish. The shape of the aggregate supply curve will depend on the relative weights of aquacultural and traditional supplies. The relative weights, and hence the shape of the supply curve, will not be constant given the unpredictability of the commercial fisheries (e.g. the world catch of Atlantic salmon ranged between 9300 t in 1982 and 12,400 t in 1984). In Fig. 2, we have derived the aggregate supply curve of the industry (S_a+c) which is a horizontal sum of the aquaculture supply S_a and the common-property supply S_c. In the absence of aquaculture, the common-property equilibrium output will be Q_1 and the price will be P^1. Biological overfishing takes place at such a high price and the introduction of aquaculture supply in this market lowers equilibrium price to P_2 (assuming constant demand), raises equilibrium quantity to Q_4 and lowers the incentive to overfish. At price P_2, the open-access fishery is harvesting at a level which is lower than the maximum sustainable yield.

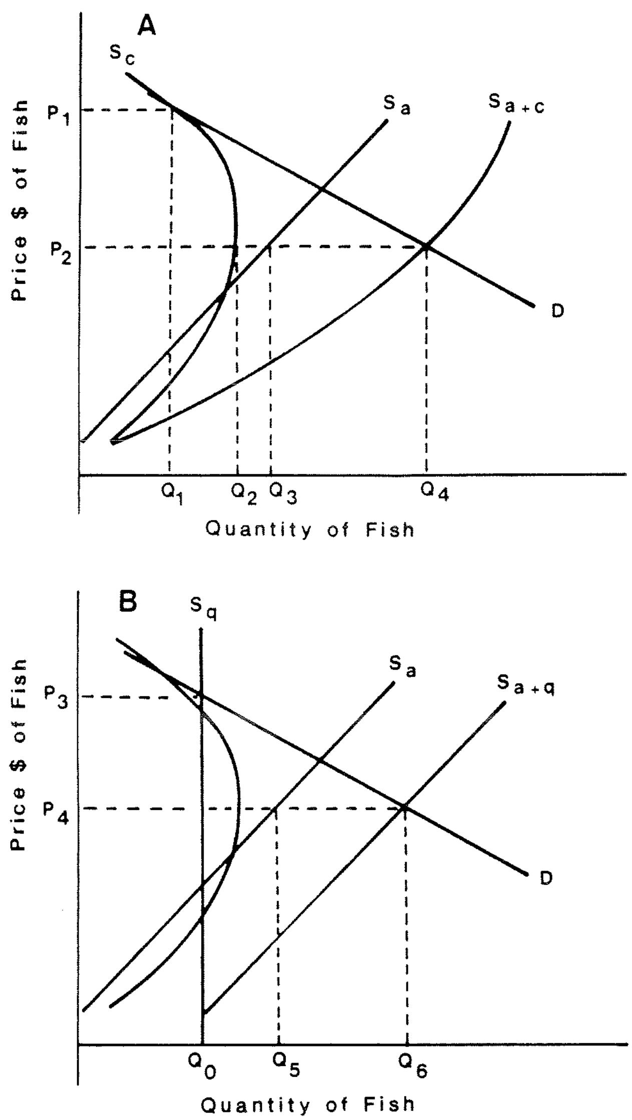


Fig. 2. Market interaction between common-property fishery and aquaculture.

The implications of a quota on the open-access fishery harvest is explained in Fig. 2b. Let Q_0 be the quota on fish harvests. Because of the quota, the supply from the open-access fishery becomes perfectly inelastic at the quota level. The vertical supply curve S_q is now added to the supply curve from aquaculture (S_a) and the resulting supply S_{a+q} is drawn. Introduction of aquaculture to an open-access fishery with quotas lowers equilibrium price and raises the quantity exchanged. The lower market price reduces the incentive to violate the quota.

The additional supply from aquaculture and consequent downward pressure on prices generates opposition to aquaculture from the capture fishermen. This is particularly so when aquaculture threatens to dwarf the output from the capture fisheries. Internationally, cultivation of Atlantic salmon is forecast to expand so rapidly that by 1990 the capture fisheries may account for less than 10% of total supply. Canadian output of cultured Atlantic salmon could equal the Canadian commercial landings of Atlantic salmon in 1987; in 1982, farmed output was only 5% of the commercial catch. The threat of lower prices clearly is of concern to the commercial fisheries. However, paradoxically the net effect may be beneficial. If the current stock is below the MSY because of overfishing (as with Atlantic salmon internationally), lower fish prices will reduce fishing efforts. Fish stocks can then be replenished, with higher fish yields later. The effect of aquaculture on the commercial fisheries is therefore ambiguous, with lower prices initially, but ultimately increased landings. It should be noted that consumers will benefit through lower prices. Taxpayers will also benefit as lower prices reduce the incentive to overfish and violate quotas where they exist. This should mean tax savings in fishery management (such as buy-outs and policing). Thus, aquaculture may cause initial hardship in the commercial fisheries, but consumers and taxpayers benefit, and perhaps in the long run even the commercial fisheries.

SOCIO-ECONOMIC VARIABLES

FINANCIAL FEASIBILITY

The purpose of commercial aquaculture is to make profits. Experience from Norway indicates that farming Atlantic salmon is profitable. In 1982, a survey of 104 Norwegian farms was undertaken by the Norwegian Department of Fisheries; for the first time, data were available on a large number of farms actually in production (Ridler and Kabir 1987). In all, more than a quarter of all farms were surveyed with a higher proportion sampled from the larger farms. In addition, the size distribution of salmon farms, and the regional distribution, make the data singularly interesting. Four size groups are differentiated with an average for each group. The last column shows the national average for all farms. The results of the survey are given in Table 2.

Table 2 shows that the average farm makes profits. This is consistent with the Gerhardson and Berge (1978) study and with the unsatisfied demand for farming licenses. When annual revenues are compared against annual costs, the average profit (row 8) per farm exceeded $100,000 in 1982, with the amount varying from $29,000 for the smallest to more

Table 2. Costs and revenues of Norwegian salmon and trout farms in 1982 (in Canadian dollars at 6.37 N.K.KR = C $1).

Item							
1	Group size (m³)	<3000 m³	3-5000 m³	5-7000 m³	7-15,000 m³	>15,000 m³	National average
2	Mean size (m³)	1,999	3,550	5,534	8,080	29,309	5,886
3	Mean output (kg)	23,129	51,261	80,131	128,391	225,386	79,989
4	Production income ($)	102,202	223,603	365,386	652,696	1,110,088	353,107
	Sales	85,990	181,254	290,890	543,853	987,339	293,841
	Stock changes	16,212	42,349	74,986	108,843	122,749	59,266
5	Fixed costs ($)	19,045	48,721	80,004	115,474	305,757	74,698
	Rent	9,020	20,908	37,281	45,696	155,641	33,510
	Interest	4,768	16,158	21,949	21,826	35,660	16,530
	Depreciation	4,003	9,275	16,432	34,537	86,970	18,623
	Imputed interest on owner's capital	1,254	2,380	4,342	13,415	27,486	6,035
6	Variable costs ($)	54,108	121,921	187,000	281,782	575,547	173,744
7	Total costs ($)	73,153	170,642	267,004	397,256	881,304	248,442
8	Gross profit ($)	29,049	52,961	98,872	255,440	228,784	104,665
9	Person-years	1.17	2.10	3.20	5.20	11.20	3.19
10	Capital stock ($)	26,368	59,785	76,082	259,644	543,325	
11	Capital-labor ratio (K/L)	22,537	28,469	23,776	49,932	48,511	37,798
12	Capital-output ratio (K/Q)	1.14	1.17	0.95	2.02	2.41	1.51
13	Output-labor ratio (Q/L)	19,768	24,410	25,041	24,691	20,124	25,075
14	Average total cost ($/kg)	3.16	3.33	3.33	3.09	3.91	3.10
15	Marginal cost ($/kg)		3.46	3.34	2.70	4.00	

Sources: Calculated from Fiskeridirektorat, Lonsemdundersokingar for Fiskeoppdretsanlegg 1982. No 8/84, Bergen 1984; Fiskaren. Tuesday, 7 August 1984, p. 26.

than a quarter of a million dollars for farms between 7,000-15,000 m³. Compared with the Norwegian commercial fisheries, these profits are very high. Profits of commercial fishing boats over 13 m were $15,000 in 1982, barely $8000 for boats between 8-13 m (Fiskerodirektoratet 1984). For some farm sizes, annual profits exceeded fixed investments. It should be emphasized that because of the licensing requirements, the salmon farmers are enjoying some economic rent. Thus, the profit figures reported in row 8 include profits as well as rents.

The profit figures reported in Table 2 are averages for farms of a certain size. Actual profits earned depend on such factors as the location of farms and management skills. While the average surplus per worker on the most profitable sized farm (7,000-15,000 m³) was $49,123, the range within the group of 20 farms surveyed went from -$1500 to almost $100,000. The two most profitable farms per worker were in the smaller group; there the maximum profit per worker exceeded $175,000. Similarly, while the average profit per worker in the smallest group of less than 3000 m³ was substantial (at least compared with the commercial fisheries), four within the group suffered losses (the largest loss being $42,000).

Atlantic salmon farming in Canada has not yet reached the degree of profitability of Norway, partly because Canada began later than Norway, also because the rate of expansion has been slowed by lack of smolt and access to credit. However, the prospect of profits has been sufficient to entice new farmers. The number of salmon farmers in New Brunswick has increased from about six in 1982 to 33 in 1986. In British Columbia, the number of salmon farms (mostly of coho and chinook, but also Atlantic salmon) has increased dramatically. At the end of May 1986, there were 54 active grow-out facilities; by the middle of November, a further 47 licenses had been issued, and for the 1987/88 season, a total of 254 farms are forecast. Financial profitability is illustrated by a hypothetical farm. Clearly any conclusions must be tentative. Financial and technical coefficients have been based on 1986/87 New Brunswick data; profits of actual farms vary according to such variables as site, management, etc. Detailed worksheets and software (using Lotus) are available from the authors on request.

The farm in April of Year 1 is assumed to buy 10,000 smolt (at $3.20), and each April thereafter purchase 30,000 smolt. Given the estimated growth and mortality rates, this farm would produce from Year 3 an approximate output of 100 t. This, as the Norwegian data suggest, is an optimum size. At present, producer prices for Atlantic farm salmon exceed $6.00/lb; however, a conservative price of $5.00/lb was assumed. No inflation factor is included in the model on the assumption of unchanged relative prices. Table 1 shows that the landing price in real terms (net of inflation) has been falling since 1978 and by 1986 was 25% below that of 1973. A similar decline in real salmon prices has occurred in Europe (Irish Sea Fisheries Board 1986). Hence it was thought plausible for long-run projections to use a price lower than the present retail price. Results are shown in Table 3.

Table 3. A hypothetical sea cage Atlantic salmon farm (100 t annually by year 3).

	Year 1	Year 2	Year 3	Year 4	Year 5
Capital investment	124,900	84,000	77,000	-	-
Cash flow analysis					
Net sales @$5/lb	70,000[1]	361,760	1,082,080	1,082,080	1,082,080
Cost of sales					
Variable	126,331	480,805	616,341	616,341	616,341
Fixed (excl. dep)	15,951	15,951	15,951	15,951	15,951
Depreciation	30,912	50,388	68,232	68,232	68,232
Total	173,194	574,144	700,524	700,524	700,524
Gross profits	(103,194)	(185,384)	381,556	381,556	381,556
Administration	4,704	4,704	4,704	4,704	4,704
Marketing	-	43,410	129,849	129,849	129,849
Net income (before tax)	(107,898)	(233,498)	247,003	247,003	247,003
* (Tax 50%)[2]	-	-	-	76,035	123,501
Net income	(107,898)	(233,498)	247,003	170,698	123,502
Depreciation	30,912	50,388	68,232	68,232	68,232
Net cash flow	(76,986)	(183,110)	315,235	238,930	191,734

[1]Government cash grant.
[2]Tax payable after accumulated losses.

Internal rate of return over 10 yr = 32%.
Payback period = 4 yr.
Labor capital ratio over 10 yr = 11%.

The table illustrates net income and cash flows of the hypothetical farm during its initial 5 yr of operation. Revenues and costs are similar from year 3 onwards but, because accumulated losses of the first 2 yr can be carried forward for tax purposes, the table projected 5 yr to illustrate after tax net income. As can be seen, variable costs are more important than capital investment; over the first 3 yr fixed investment is less than $300,000 while variable costs exceed $1,000,000. It conforms to Norwegian experience as shown by rows 5 and 6 in Table 2. The principal component of variable cost is that of feed (approximately 50% of variable cost), with most of the remainder shared between labor (18%), marketing/processing (17%) and smolts (13%). The proportions are similar to those experienced by salmon farms in British Columbia (DPA Group Inc. 1986).

The table illustrates the potential profitability of sea cage salmon farming. The internal rate of return over 10 yr is 32%, the payback period is 4 yr. It should be noted that this assumes a low ($5/lb) price of salmon. With a current price of $6/lb, the rate of return exceeds 40%, and the payback period is reduced to 2 2/3 yr. That Table 3 is a conservative estimate is indicated by Norwegian experience. Table 3 shows after-tax net income of $123,500. The Norwegian data in Table 2 show 1982 profits of farms with a mean output of 80 t average $99,000, those of 128 t farms averaged $255,000.

However, no allowance has been made for imputed wages of the owner and family. Moreover, mortality rates clearly affect profitability. The hypothetical farm assumes 9% mortality rate over the 18 mo. However, predators, disease or lethally cold water temperatures could increase that rate sharply. Sensitizing for mortality rates, a 10% increase in mortality almost halves the return on investment (Henderson 1984). Similarly, the price of salmon dramatically influences profitability. At $4 per lb, net income is reduced to $30,500 from year 3 onwards. To some extent, therefore, profitability depends on exogenous forces. Water temperatures and market prices for an internationally traded commodity, such as salmon, are outside the control of an individual farmer. Yet as Norwegian experience shows, good management and strict quality control, while not sufficient, can produce profits.

It should be noted, as Table 3 shows, that net income is negative in the early years. Given the long growth phase of salmon in seawater and the need to feed them for 18 mo before they can be harvested, salmon farms can face a severe cash-flow squeeze. For the first 18 mo, the cash flow is consistently negative; for the first 2 yr, this 100-t farm accumulates losses of over 300,000. Thus salmon farmers must rely on credit. In practice, equity financing is important, if only as condition for debt financing. Banks have been reluctant to lend, partly because of the newness of industry and partly because of the risks unless there is fish mortality insurance. To provide a high estimate of costs, the hypothetical farm assumes reliance on bank financing. The extent of the cash-flow problem and the need for (banks) credit is illustrated in Fig. 3.

The top diagram shows that even in full operation the cash flow is seasonal, but for the first 18 mo, the cash flow is consistently negative. Hence there is reliance on bank financing. The lower diagram in Fig. 3 shows that bank loans will exceed one million dollars ($1,118,201) in October of the third year. Not until the fifth year does the closing balance on the bank loan reach zero; not until the eleventh year is access to bank credit no longer needed. Thus, while potentially very profitable, salmon farming is financially risky and unprofitable during the initial years. To ease the cash-flow shortage, the New Brunswick government has provided a cash contribution (of $70,000) to assist new growers. They have also provided loan guarantees.

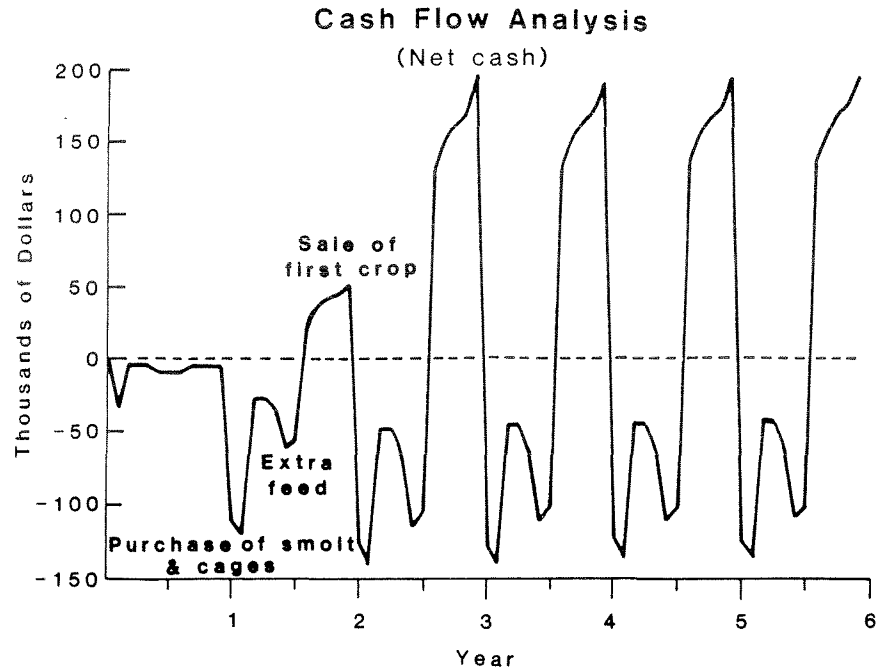
EMPLOYMENT

One of the attractions of salmon farming to governments concerned about unemployment is its potential for providing jobs. New Brunswick has higher unemployment than the national average (3 percentage points higher in August 1987) and the region where much of the salmon farming occurs, higher unemployment rates than the provincial average (the highest rate in the province in August 1987). The employment impact of salmon farming is both direct and in support industries. Whether measured by capital-labor ratios or cost per job, salmon farming shows moderate labor absorption. Using the hypothetical farm data in the Appendix and the notation C = total cost, and CLt = total labor cost, the labor-capital ratio:

$$\sum_{t=1}^{10} CLt/Ct = 11\% \qquad (8)$$

Even incorporating an allowance for supervision from the initial year does not increase the capital-labour ratio beyond 18%. Smaller farms of 50 t a year show similar ratios (Ridler 1984). In terms of cost per job $\sum_{t=1}^{10}$ Ct/man-years, each man-year of employment costs approximately $160,000. The low labor absorption is confirmed by Norwegian data. As Table 2 shows, the average farm in Norway only provides three man-years of work, the largest group of farms eleven.

On the positive side it should be noted that the aggregate impact on employment can be significant. In 1982 Scottish salmon farming employed almost 300 people directly, in Norway approximately 2000. New Brunswick's projected output of 1100 t in 1987/88 should provide direct, on cage site employment for 180 people. This is small compared with the more than 3000 in New Brunswick's commercial fisheries. The employment is, however, year-round and not seasonal as in the commercial fisheries. Moreover, it is in isolated communities. Labor force participation rates in New Brunswick are the second lowest in Canada; by providing jobs in rural communities, salmon farming enables those communities to earn income. The regional aspect of salmon farming is emphasized in Norway, with the northern provinces given preference in the granting of licenses. An additional aspect of salmon farming, relevant in Norway but not in Canada, is that of providing alternative employment to the fisheries and agricultural sectors; in Norway almost two-thirds of salmon farmers and their employees come from the fisheries or agriculture.



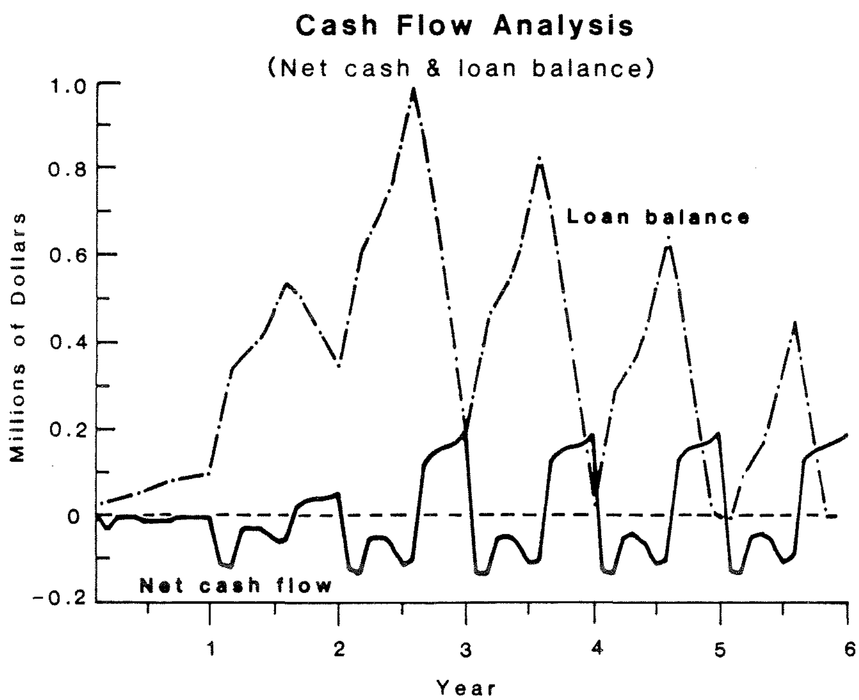


Fig. 3. Cash flow analysis.

NET FOREIGN EXCHANGE EARNING

Atlantic salmonid exports from eastern Canada in 1985 earned more than a million dollars as Table 1 shows; among these exports were 70,000 farmed rainbow trout and Atlantic salmon marketed through Atlantic Silver in New Brunswick. Eventually, half or three-quarters of cultured salmon may be exported (Woods-Gordon 1983). Even assuming one-third is exported and that certain equipment is imported, sea cage salmon farming appears to be a net earner of foreign exchange and one that is efficient. One criterion merely compares the foreign exchange earned with the amount spent on imports. Using the notation C_M as the cost of imported inputs, C_D, the cost of domestic inputs, Z_X as the revenues from exports, and i the discount rate, the foreign exchange criterion can be written:

$$\sum_{t-1}^{t=10} Z_{Xt} \geq \text{or} \leq \sum_{t=1}^{t=10} C_M t \qquad (9)$$

The hypothetical farm of 100 t a year, assuming an export coefficient of one-third, earns net foreign exchange - in excess of two million dollars over 10 yr. The second criterion is more sophisticated in that it discounts foreign exchange earned, and takes into account the domestic cost of earning foreign exchange; it can be written:

$$\sum_{t=1}^{t=10} \frac{C_L t + C_D t}{(1 + i)^t} \bigg/ \sum_{t=1}^{t=10} \frac{Z_t - C_M t}{(1 + i)^t} \qquad (10)$$

Again, assuming one-third of output is exported, the criterion is positive. Using a 15% discount rate, the internal exchange rate is below parity with the US dollar, this is below the official exchange rate, and hence indicates efficiency. These results are only to be expected of an industry which relies on few imported inputs.

LINKAGES

Seasonal unemployment in fishing and fish processing industries can be moderated by making farmed salmon available for processing and marketing in the off-peak period. Salmon farming will also provide indirect jobs by creating demand for various inputs required for fish farming (such as cages and food for salmon, smolt production, processing, transportation, etc.). Metal (rather than the traditional wood) cages are being built in Saint John, dry feed is being manufactured in Fredericton and moist feed in Beaver Harbour. Additional income generated by the production process will have a multiplier effect on the fishing communities. In 1982, the Scottish salmon farms produced 2151 tonnes of salmon and directly employed 297 people with another 200 indirectly employed in related activities. Using the same ratio of two-thirds of an indirect job per direct job, total employment in Atlantic salmon aquaculture in 1986 was approximately 300. This does not include the more than 40 government and university personnel involved in research, education, training, technical extension service and related activities.

THE MARKET

SUPPLY

Individual Farm Supply

From a microeconomic perspective, farm supply is the marginal cost curve. As a price taker, the producer will set output where marginal cost (above average variable costs in the short-run) equals price.

Unfortunately, the individual responses by 104 Norwegian fish farmers surveyed are not available. The data were grouped by farm sizes before making these available to the public. Thus, our cost analysis is based on the group sizes which have been chosen by the Norwegian Department of Fisheries.

Since the salmon farming industry is well established in Norway, it may be argued that the farms are in their long-run equilibrium position. Thus, there are no fixed factors of production. Although, for accounting reasons, fixed and variable costs are always recorded separately for economic analysis, all costs should be treated as variable costs in the long run. The long-run cost is a function of production levels and may be written as follows:

$$C = g(Q) \qquad (11)$$

where C and Q are costs and volume of production, respectively.

The above cost function is based on the standard neoclassical production function, which may be specified as follows:

$$Q = f(K, L, M) \qquad (12)$$

$$\partial Q/\partial K > 0,\ \partial Q/\partial M > 0,\ \partial Q/\div\partial K < 0,\ \text{etc.}$$

where Q is the maximum amount of output which can be produced with any given combination of labor service L, capital service K, and raw material M. The production function is assumed to be such that the marginal products of factors of production are positive but diminishing. Thus, the production function shows the so-called law of diminishing marginal productivity. The size of K usually determines plant size and in the long run the plant size is variable.

Both the average total cost (C/Q) and the marginal cost ($\Delta C/\Delta Q$) will be convex from below if the production function exhibits increasing returns to scale when the output level is low, then passes through a stage of constant returns, and finally exhibits decreasing returns to scale when the output level becomes larger and larger.

The average total cost and the marginal cost computed are reported in rows 14 and 15 of Table 2, respectively. If one excludes the smallest two groups of farms, then for the rest of the farms the average total cost seems to be somewhat U-shaped.

The smaller farms produce two species of fish - trout and salmon - to alleviate their cash-flow problems in the early years of operation. The cost of production of trout is considered to be lower than that of salmon, thus lowering the overall cost of production for the smaller farms. If the entire output consisted of salmon alone, then the actual cost of production would be higher than the reported cost. Since only the smaller farms produce both salmon and trout, the cost figures reported in Table 2 should be adjusted upward for these farms. The corrective factor should be highest for the smallest group size and then decline as the farm size increases (Ridler and Kabir 1987).

This correction should make the average cost curve U-shaped for the entire range of output, thus suggesting increasing returns to scale followed by constant returns and eventually decreasing returns as output level expands. The above correction will also change the marginal cost of production. If average cost is falling when the output level is low but expanding, then the marginal cost will always be below the average cost.

It should be noted that our computed marginal costs are quite crude in the sense that they were not calculated on the basis of marginal changes in output. In fact, the variations in output and costs between successive groups were substantial.

Aggregate supply

The supply of farmed Atlantic salmon has increased dramatically as shown in Table 4. In recent years, total world output has grown at an average annual rate of 40%. With wild landings constant or even declining, the total harvest of cultured Atlantic salmon has risen from just over 10,000 t in 1981 to approximately 60,000 t in 1986.

Norway remains the dominant producer, with 690 salmonid farms in 1986 yielding about 45,656 t of salmon (and a further 4310 t of trout). Scotland is a distant second with output of 9700 t in the same year; Ireland's 12 major farms produced 1500 t in 1986, up from only 35 t in 1981. The remaining producers, namely Iceland, Canada, Sweden, Spain and the Faroe Islands, did not begin farming until the 1980's and thus have yet to reach comparable levels of output.

Table 4. Actual and forecast supply of Atlantic salmon.

	1980 actual tonnes	1986 actual tonnes	1990 forecast tonnes
Farmed			
Norway	4,150	45,657	100,000
Scotland	600	9,700	25,000
Ireland	21	1,500	10,100
North America	-	500	7,000
Other	-	1,750	11,000
Total	4,771	59,107	153,100
Wild (avg.)	11,300	11,200	11,200
TOTAL	16,071	70,307	164,300

Source: Irish Sea Fisheries Board. The Atlantic Salmon Farming Industry, Dublin, 1986.

An expansion of the industry is predicted for all producing countries. Owing to the 3- or 4-yr growth cycle of the salmon, reasonably accurate forecasts of production are possible. Also, the availability of smolt has proven to be the limiting factor in the production process; current smolt production can therefore be considered a good indicator of future salmon output. Projections for total output of farmed Atlantic salmon in 1990 range from 153,000 to 177,000 t, with Norway probably accounting for close to 100,000 t, Scotland 25,000 t, Ireland 10,000 t and North America perhaps 7000 t (Irish Sea Fisheries Board 1986).

In Atlantic Canada, given present technology, the biological maximum production of cultivated salmon has been conservatively estimated at 5,000-10,000 t in the Bay of Fundy alone (Anderson 1980). The Southern New Brunswick Aquaculture Development Committee, a federal-provincial industrial advisory body, has proposed that the Bay of Fundy salmonid industry alone could account for 5000 t by 1990. Currently, one small farm operates in Newfoundland and seven in Nova Scotia combine salmon and trout cultivation, but the center of production is clearly in the Bay of Fundy where some 30 farms contain more than 1,000,000 fish. Output has increased dramatically in both volume and value from 48 t worth $522,000 in 1982 to 297 t worth $3,602,000 in 1986. In 1987, output should surpass 1100 t.

The main constraints to production are the lethally cold water in much of Atlantic Canada which restricts output of the Bay of Fundy, and the existence of a limited number of protected sites in that area. In 1986/87 one farm in New Brunswick and two in Nova Scotia lost fish because of cold water. Output here has also been restricted by a lack of smolt so that existing farms have been prevented from expanding and obtaining economies of scale. During the early years, the federal government helped make up the short-fall by supplying smolt, but increasingly in New Brunswick the private sector is able to meet the demand. Three hatcheries are now being developed and run by Sea Farm Canada Ltd., a Norwegian-Canada Packers subsidiary, with total production capacity of over one million smolt. In addition, Connors Brothers Ltd. at Lake Utopia and a number of smaller hatcheries should eventually provide sufficient smolt, enabling growout facilities to meet their potential.

In addition to Atlantic salmon, output of cultured Pacific salmon is projected to increase. Of the six species, two (coho and chinook) are farmed in British Columbia, the state of Washington and various Pacific countries. Though Canada and the United States contained 40 and 10 Pacific salmon farms, respectively, in 1984, they are becoming overshadowed by Japan where the industry, which produced 6800 t of coho in 1985, has been experiencing an annual growth rate of about 50%. Twenty-five farms in Chile accounted for an estimated 1300 t in 1986 and New Zealand's three farms, supplied by a state-run hatchery, produce about 250 t annually. While total production of farmed Pacific salmon was approximately 10,000 t in 1985 and has been projected to be as high as 22,000 t by 1990, the industry will probably remain dwarfed by the traditional fishery; landings of coho and chinook alone exceeded 50,000 t in 1984 and total landings of Pacific salmon (all species) was close to 575,000 t (Irish Sea Fisheries Board 1986).

DEMAND

Domestic

Atlantic salmon caught by the Canadian commercial fisheries is generally sold domestically. Table 1 shows that of the 1209 t landed in Canada in 1986, only 259 t or 21% were exported. Similarly, the bulk of farmed Atlantic salmon sold by (the marketing co-op) Atlantic Silver is marketed within Canada.

Since Atlantic salmon is traded internationally, ideally a simultaneous system of equations describing the international market (mainly the U.S. market) as well as the local market should be estimated (Kabir and Ridler 1984). However, lack of sufficient observations on U.S. production, imports and prices precludes estimation of such a model. Rather, a system of simultaneous equations was developed that consisted of a domestic demand equation, an export demand equation, a supply equation and a market clearing identity which equated the total demand to the supply. This four-equation model determines the value of four endogenous variables which are price, domestic demand, exports and supply. The domestic demand equation was overidentified and the method of two-stage least squares was used to estimate this equation. Two versions (one for fresh salmon and the other for fresh and frozen salmon combined) of this equation are reported below:

$$\underset{}{Ln\ P_f} = \underset{(3.711)}{-3.451} + \underset{(3.407)}{0.376}\ ln\ I - \underset{(2.144)}{0.088}\ lnQ_f \;\; \underset{(0.110)}{-0.176}\ ln\ S_m \qquad (13)$$

$$R^2 = .83 \qquad DW = 1.39 \qquad F = 38.46$$

$$(2)\ Ln\ P_t = \underset{(3.69)}{3.890} + \underset{(3.46)}{0.380}\ ln\ I - \underset{(2.05)}{0.092}\ lnQ_t - \underset{(0.146)}{0.018}\ ln\ S_p \qquad (14)$$

$$R^2 = .82 \qquad DW = 1.49 \qquad F = 38.42$$

where P_f = price index of fresh Atlantic salmon;
P_t = weighted average of prices of fresh and frozen Atlantic salmon;
I = per capita disposable income;
Q_f = per capita consumption of fresh Atlantic salmon;
Q_t = per capita consumption of fresh and frozen Atlantic salmon;
S_m = price index of meat; and
S_p = price index of Pacific salmon.

All nominal variables were deflated by the consumer price index to ensure that the demand function is homogeneous of degree zero. The data for this study were collected from various Statistics Canada publications. The data period extends from 1955 to 1982. A log-linear version gave decidedly better results and hence only this version has been reported. There were no serious problems of multicolinearity and autocorrelation. The t-values are included in the parentheses. The equations were estimated in inverted form because this form often gives a better fit for commodities whose supplies do not adequately respond to the current price. The price of Pacific salmon was tested to see if there was any degree of substitutability between the two varieties of salmon.

Using the estimated parameters, one can compute the price elasticity, income elasticity and cross price elasticity. Price elasticity measures the responsiveness of quantity demanded to changes in the price of the product. As the chapter on aggregate supply illustrated, both world and Canadian supplies of Atlantic (and Pacific) salmon are forecast to increase sharply. Price elasticity enables one to estimate how much that increase in supply will cause the price of Atlantic salmon to fall. Where demand is elastic extra production causes prices to decline, but because the quantity demanded is very responsive, only a small decline in price is needed to restore equilibrium. Not only would the price decline be small, but incomes of salmon farmers would be higher as the small decline in prices is offset by increased output. The opposite would occur with low price elasticity of demand. The increase in supply would produce a large fall in prices and farm incomes would decline. The concept of income elasticity compares how demand for a product changes as consumers' incomes change. This concept is particularly important in determining the potential market for a product over a long period. The higher the income elasticity, the more responsive demand is to changes in income. Cross price elasticity in this context compares how the demand for Atlantic salmon is affected by changes in the price of meat (in equation 13) and by changes in the price of Pacific salmon (equation 14).

Since the equation was estimated in its inverted form, the estimated coefficient of the quantity variable measures the direct price flexibility. The inverse of the direct price flexibility forms the lower limit, in absolute terms, of the own price elasticity. However, if the cross elasticities are not significantly different from zero, then the reciprocal of price flexibility will be equal to price elasticity. The estimated price elasticities are quite high. The value of price elasticity is 11.36 for fresh salmon and that for fresh and frozen taken together is 10.86. Income elasticity of demand for fresh and frozen combined is 4.13. Income elasticities are reasonably high and indicate that Atlantic salmon is a superior commodity. Since cross price flexibilities are not significantly different from zero, we refrained from computing the cross elasticities. The results compare well with similar studies on Atlantic and Pacific salmon for the United States and Canada (Bell 1978; DeVoretz 1980).

The results indicate a strong domestic market for Atlantic salmon. The average income elasticity of demand for fresh/frozen salmon of 3.8 suggests an expanding market over time. If one assumes that real per capita disposable income grows at the same rate as the 1983-86 average of 1.1% a year, demand for Atlantic salmon would grow at 4.2% annually. In addition, an increased preference for fish (for health reasons) will reinforce the income effect.

Per capita consumption of Atlantic salmon in Canada is approximately one-quarter that of western Europe, per capita consumpton of all salmon approximately one-sixth that of Japan (Irish Sea Fisheries Board 1986). A shift in consumer preferences towards the European/Japanese norm would have a dramatic upward impact on salmon prices and farm incomes. The average price elasticity for fresh/frozen salmon of -9.7 suggests that domestic demand would increase by approximately 10% if prices fell by 1%. Revenues of salmon farmers would increase by almost 9%. The high price elasticity indicates that even with sharply expanded Canadian and international output of salmon, farm incomes should increase.

Exports

Canada exports approximately one-quarter of its total landings of Atlantic salmon, ranging from 600 t in 1980 to 92 t in 1984. A growing share of the export market is of fresh rather than frozen salmon. In 1986, Canada exported 143 t of fresh and 116 t of frozen Atlantic salmon for a total value of $2.1 million Canadian. The export prices of both the fresh and frozen varieties fluctuated considerably during the sample period (Table 1). The fluctuations originate mainly from two sources: the price of Atlantic salmon in the international market and the value of the Canadian dollar. Since Atlantic salmon is a luxury food item, its price has been influenced significantly by fluctuations in per capita real income in the consuming countries. During 1980-82, real export prices (export price indices deflated by the consumer price index) declined consistently and a major reason for this was the depressed state of economic activity experienced by the United States.

The volume of frozen salmon exports shrunk to a fourth of its 1973 level, and this is reflected in the value; frozen salmon earned less in 1983 than in 1973. The nominal price has increased by 46.7% during the sample period, but the real price has declined by about 40%, suggesting that demand has fallen. The situation for fresh salmon is more positive. Quantity, value and nominal price have increased (intermittently) over time, with the real price rising to 1979 before declining. The United States typically absorbs more than 90% of the Canada's export of fresh Atlantic salmon but it imports only a small portion of Canadian frozen Atlantic salmon (typically less than 30%). West Germany, the United Kingdom and France have been major purchasers of frozen Atlantic salmon from Canada and in 1983, their combined imports were more than three times those of the United States. However, Canada has increasingly concentrated on exporting fresh rather than frozen Atlantic salmon. The volume, value and share of fresh salmon exports have increased; the opposite has occurred with frozen salmon. Between 1973 and 1983, fresh Atlantic salmon exports almost doubled in volume and more than doubled in real value (nominal value increased more than five times); as a share of total volume of salmon exports, fresh salmon rose from 1% to 65%.

The foreign exchange benefit can be considerable. Over 10 yr, with one-third of its output exported, a 45-t sea-cage operation could earn almost one million U.S. dollars in net foreign exchange. A higher proportion exported would, of course, earn more. Norway exports more than 80% of its production.

Marketing

With Canadian and world supply of Atlantic salmon expanding, marketing the finished product is critical. Norway's success is illustrative. Between 1982 and 1986, Norwegian exports of fresh salmon tripled in volume and value. Exports to the United States alone increased ninefold, and were more than 9000 t by 1986, the United States replacing France as Norway's principal export market for fresh salmon. Norwegian success has been based on quality control. In 1978, the Norwegians established their Fish Farmers Sales Organization, responsible for promoting Norwegian salmon exports. Sales from farms to exporters are transacted through this Organization. By emphasizing quality and a superior product, the Norwegians can differentiate their product and demand a premium price. In March 1986, the f.o.b. price in Seattle of 2-3 kg Norwegian farmed salmon was $11.86 per kilogram, more than a dollar higher than farmed salmon from Washington State.

The Norwegian success has been copied by New Brunswick salmon farmers who have established a marketing co-operative, Atlantic Silver Ltd. In contrast with Norway, membership in the organization is voluntary. At present, 23 of the salmon farmers have joined. An administrative fee of 3% on sales is charged; any surplus is returned to the members. To ensure product freshness, harvesting does not occur until an order has been placed; then the fish are slaughtered and processed, with delivery within 24 h anywhere in North America.

The principal export market for Atlantic salmon from Atlantic Canada is clearly the United States. Western Europe markets are dominated by Norway and would be difficult to penetrate. A study has forecast that the U.S. market for farmed salmon could reach 30,000 t by 1990, and that Canada could obtain one-tenth of that market (Woods-Gordon 1983). Moreover, there is not yet an adequate year-round production from the Bay of Fundy industry.

Canada's principal competitor in the U.S. market is Norway, which acounts for almost three-quarters of all fresh salmon imported. Canada's competitive advantage lies in its proximity to the United States. Air freighting fresh salmon from Europe to the eastern U.S. adds an additional 10% to the price; to the West Coast this is an additional 15%. Thus New York and Boston are the principal ports of entry of Norwegian, British and Irish fresh salmon. However, Los Angeles accounts for a quarter of Irish fresh salmon, surpassing New York. In addition to transport costs, exchange rates may favor Canadian exports. Part of Norwegian success has been attributed to its depreciating currency vis a vis the U.S. dollar. Over the last year, this has been reversed and, between April 1986 and April 1987, its currency has appreciated more than that of Canada, increasing the competitiveness of Canadian compared with Norwegian exports. If Canadian and Norwegian farmed salmon are qualitatively comparable, lower transport costs and higher exchange rates would favor Canadian exports.

CONCLUSION

The report has examined certain economic aspects of Atlantic salmon farming in Canada. Using Canadian data where available and substituting Norwegian data where necessary, market supply and demand have been analyzed. The supply of Atlantic salmon is projected to increase sharply, not only in Canada but also among competitors. Actual profits in Norway and Scotland, and potential profits elsewhere, have attracted investment in spite of biological and technical risks. A major handicap facing owner-operators is an inevitable cash-flow shortage in the early years of operation; in New Brunswick, initial cash grants and later loan guarantees have eased this difficulty. Such assistance to an infant industry appears justifiable given the potential for job creation and income generation in a disadvantaged region. The prospect that increased Canadian and world supply may cause the collapse of prices was examined by estimating elasticities. Both price and income elasticity of demand for Atlantic salmon within Canada suggest that the market should grow. Estimates of cross-elasticity with Pacific salmon indicate little substitutability. Export demand to the U.S. also has potential. The key, as has often been stated, is to provide a quality product. The success of the marketing co-operative, Atlantic Silver, augers well for the future of Atlantic salmon farming in eastern Canada.

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