Salmonid Rearing Trials at Deer Island, New Brunswick, with Some Projections on Economic Viability

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Fisheries and Aquatic Sciences 1011

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SALMONID REARING TRIALS AT DEER ISLAND, NEW BRUNSWICK, WITH SOME PROJECTIONS ON ECONOMIC VIABILITY

by

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This is the one hundred and thirty-fourth Technical Report from the Biological Station, St. Andrews, N.B.

PREFACE

The Fundy Salmonid Aquaculture Project in this report was a cooperative research and development venture undertaken by:

The Department of Fisheries and Oceans
Biological Station
St. Andrews, N.B.

The Research and Development Branch of
The New Brunswick Department of Fisheries
Fredericton, N.B.

Marine Research Associates
Deer Island, N.B.

Mr. Nelson Adams
Fredericton, N.B.

A letter of understanding was drawn up among the participating agencies and parties to outline areas of responsibility in terms of cost sharing and services to be provided. We feel that because of the inherent flexibility of this agreement, we were able to accomplish our objectives more effectively than had the venture been undertaken by a single private or government concern.

This project was conducted from June 1978-December 1979 with the responsibility for the operations gradually being transferred to the private sector. The work was continued during 1979-80 through a contract between DFO and MRA to examine the biological and economic feasibility of rearing Atlantic and pink salmon at the Deer Island site. It is anticipated that future results of the ongoing rearing trials will be made available in technical report form.

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ABSTRACT

Sutterlin, A. M., E. B. Henderson, Susan P. Merrill, R. L. Saunders, and A. A. MacKay. 1981. Salmonid rearing trials at Deer Island, New Brunswick, with some projections on economic viability. Can. Tech. Rep. Fish. Aquat. Sci. 1011, iv + 28 p.

Experimental salmonid rearing trials (1978-79) were undertaken as a joint venture between Federal and Provincial Fisheries Departments and the private sector. Atlantic salmon, pink salmon, and rainbow trout were placed in 4- and 12-m diameter ocean pens near Deer Island, N.B., and their growth was followed for 4-18 mo. Pink salmon weighing 10 g were placed in ocean pens at the beginning of June, reached a size of 248 g in 6.5 mo, and survived the winter. Under the same rearing conditions, 120-g rainbow trout reached a weight of 461 g in 4 mo. Atlantic salmon smolts, stocked in pens on May 12, 1978, at a weight of 60-80 g, were harvested 18 mo later at a weight of 3.3 kg. Small differences were observed in the growth rates of 1+ and 2+ Atlantic salmon smolts during the second summer in the sea. Pink salmon brood stock held in indoor tanks matured later in the season than expected but yielded viable products with eggs hatching normally. Two kilograms (dry weight) of a homemade moist pellet were required to produce 1 kg wet weight of Atlantic salmon or rainbow trout. Instantaneous growth rates of 450-g salmon during their first summer were double the instantaneous growth rate of 2300-g salmon during the second summer. The magnitude of salmon growth in fish pens closely resembled the growth of fish with comparable sea age on ocean feeding grounds. However, the incidence of maturation as grilse in the caged fish was less than 1% compared to 50% for hatchery returns of sea-ranched smolts of the same strain and hatchery rearing history. It is suggested that low winter temperatures and/or reduced feed intake may alter maturation rates. Despite winter sea temperatures as low as 0.9°C, it is possible to feed and overwinter Atlantic salmon with few mortalities. A marine farm, operated by two people with an annual production of between 50 and 60 tons of salmon, appears to be the minimum-sized unit necessary for economic viability. Special problem areas concerning disease, biofouling, predation, and overwintering are also considered.

Key words: Aquaculture, mariculture, salmonid farming, Atlantic salmon, pink salmon, rainbow trout, maturation, temperature

RÉSUMÉ

Sutterlin, A. M., E. B. Henderson, Susan P. Merrill, R. L. Saunders, and A. A. MacKay. 1981. Salmonid rearing trials at Deer Island, New Brunswick, with some projections on economic viability. Can. Tech. Rep. Fish. Aquat. Sci. 1011, iv + 28 p.

Des expériences d'élevage de salmonidés ont été menées conjointement en 1978 et 1979 par les ministères fédéral et provincial des Pêches et le secteur privé. Du saumon de l'Atlantique, du saumon rose et des truites arc-en-ciel ont été placés dans des enclos de mer de 4 et 12 mètres de diamètre à proximité de l'île Deer (N.-B.) et on a suivi leur croissance pendant 4 à 18 mois. Des saumons roses pesant 10 g placés dans les enclos au début de juin, ont atteint un poids de 248 g en 6,5 mois et ont survécu à l'hiver. Dans les mêmes conditions d'élevage, des truites arc-en-ciel de 120 g ont atteint 461 g en quatre mois. Des saumoneaux de l'Atlantique placés en enclos le 12 mai 1978 et pesant alors de 60 à 80 grammes ont atteint un poids de 3,3 kg en 18 mois. De petites différences ont été observées pour les taux de croissance des saumoneaux de l'Atlantique de plus d'un an et de plus de deux ans pendant le deuxième été en mer. Les saumons roses reproducteurs élevés dans des cuves à l'intérieur sont parvenus à maturité plus tard dans la saison que prévu, mais leurs oeufs étaient viables et ont éclos normalement. Deux kilogrammes (poids sec) de comprimés humides fabriqués sur place étaient nécessaires pour produire un kilogramme de poids frais de saumon de l'Atlantique ou de truite arc-en-ciel. Le taux de croissance instantanée du saumon de 450 g pendant le premier été était le double du taux de croissance instantané du saumon de 2 300 g pendant le deuxième été. Le taux de croissance du saumon élevé en enclos de mer était voisin de celui du poisson sauvage d'un âge comparable. Toutefois, le nombre de poissons en enclos parvenus à maturité au stade de madeleineaux était inférieur à 1% contre 50% pour les saumoneaux d'élevage de la même souche relâchés en mer et revenus au point de départ. On pense que les basses températures d'hiver ou une alimentation réduite peuvent modifier les taux de maturation. Malgré une température d'eau de mer descendant jusqu'à 0,9°C en hiver, il est possible de nourrir le saumon de l'Atlantique et de lui faire passer l'hiver avec une mortalité réduite. Il semble qu'une installation d'élevage en mer dirigée par deux personnes et produisant chaque année entre 50 et 60 tonnes de saumon soit l'unité de production minimale nécessaire à une rentabilité économique. Les problèmes spéciaux relatifs à la maladie, à l'encrassement des filets par des matières biologiques, à la prédation et à la survie en hiver sont également examinés.

INTRODUCTION

During the last 10 yr salmonid mariculture research and development in eastern Canada has focused predominantly on those species of salmonids that are suspected as being most appropriate for marine culture during a single growing season. Nearly all federal and provincial fisheries agencies in the Maritime Provinces and Newfoundland have experimented with rainbow trout (Salmo gairdneri) and, to a lesser extent, with brook trout (Salvelinus fontinalis). Larger sized rainbow trout are routinely produced by overwintering fish beneath ice-covered brackish areas of Cape Breton, Nova Scotia (R. Drinnan, pers. comm.). The results of such pilot-rearing endeavors have been applied and refined by private marine trout growers in Nova Scotia, Prince Edward Island, and Newfoundland. As a result, some marine rainbow trout farms appear to be approaching a stage of economic viability.

With the exception of the earlier efforts by MacDonald and Baker (Baker 1975), the possibilities of year-round mariculture of Atlantic salmon (Salmo salar) have received less attention. Baker describes the successful overwintering of Atlantic salmon in ocean pens situated on the eastern coast of Nova Scotia, with good growth rates considering the low ocean temperature experienced by the salmon. Smolts (74 g) stocked in ocean pens in June reached a weight of 3.3 kg after two summers and one winter in the sea. Unpublished reports by Joan Caulder also describe the successful overwintering of Atlantic salmon in Nova Scotia (R. Drinnan, pers. comm.).

Atlantic salmon rearing trials by Saunders et al. (1975) revealed that the lower lethal temperature for Atlantic salmon, brook trout, and rainbow trout in sea water was -0.7°C as expected from blood osmolarity. As with all salmonids studied to date, protection by blood antifreeze systems appears to be lacking. With sea surface temperatures approaching -2°C prior to freeze-up in many Atlantic oceanic environments (S.W. Gulf of St. Lawrence, N.W. Newfoundland, and Labrador Sea) in conjunction with problems of surface ice development in all low salinity fjord, estuarine, and barachois environments in eastern Canada, the prospects of a broad-based, year-round, Atlantic salmon mariculture industry did not appear promising.

Upon reconsideration of prevailing temperature conditions prior to the onset of the rearing trials described in this report, it was concluded that the opportunities for salmon mariculture in certain areas of eastern Canada had not been completely assessed. Firstly, several successful Norwegian salmon farms located at latitudes of 70-80°N experience sea surface winter temperatures of 2°C (Sutterlin and Merrill 1978). The summer temperatures experienced by these Norwegian farms are often lower than those found in most coastal areas south of the northern peninsula of Newfoundland. Also, for those Canadian coastal areas having a yearly range of sea surface temperatures between 1-15°C, the number of degree days, presumably conducive to growth, is greater in parts of eastern Canada than at farms in northern Norway. Secondly, subsurface and deep oceanic temperatures experienced by eastern Canadian stocks in feeding and presumed overwintering areas (Bay of Fundy, N.W. Newfoundland and W. Greenland) lie between 1 and 3°C. Thirdly, it is commonly observed during the hatchery propagation of salmon that, under natural stream temperature conditions, the provision of maximum rations can markedly enhance growth rates of cultured fish compared to their wild counterparts. It was therefore concluded that temperature conditions along a portion of the Maritime Provinces and perhaps southern Newfoundland could permit the survival of cultivated salmon during the winter, and it appeared likely that the growth rates could equal those of wild salmon.

The comparative performance of two other species (pink salmon (Oncorhynchus gorbuscha) and rainbow trout) was also included in the rearing trials. The high growth rates exhibited by pink salmon (Brett 1974; Gjedrem and Gunnes 1978), coupled with their high salinity tolerance at an early age, suggested that they could be reared to the pan size (300-350 g) within 1 yr.

SITE SELECTION AND PREPARATION

During the winter (1977-78), prior to the rearing trials, various locations on Deer Island were surveyed and temperatures were periodically recorded; this information, along with an analysis of past records of the nearest oceanographic stations (Fig. 1, 2), suggested that the archipelagic areas involving the Deer-Campobello Islands complex should afford sufficient protection from wind and waves and receive warmer oceanic waters during the winter than areas within Passamaquoddy Bay. During the winter of 1977-78, the minimum daily surface seawater temperature recorded at the Biological Station within the bay was -0.6°C, while the minimum observed at Deer Island was 1.4°C. Mean monthly records of subsurface temperatures for a period of 6 yr at the offshore station, the Wolves (Fig. 1), revealed a minimum of 1.2°C. A comparison of temperature at the three sites during the rearing trials (1978-79) again confirmed that, while temperature at the Biological Station dropped to -1.2°C, the minimum temperature experienced at the Deer Island marine site remained safe for salmon at 0.9°C (Fig. 2). Periodic discrepancies which indicate higher winter water temperatures at Deer Island than at the Wolves could be explained by periods of upwelling along the eastern shores and between the islands.

The minimum temperature of -1.2°C recorded at the Biological Station during February 1979 has only been exceeded four times in the last 15 yr, with the lowest recorded temperature during that period of -1.7°C. Assuming a winter temperature differential between the two sites of about 2°C, historical records suggest that the Deer Island site should only infrequently, if ever, experience temperatures lethal to salmon.

The lack of major river systems in the area of the islands, coupled with the large tides (6 m) and tremendous upwelling of deeper water, prevent the establishment of major stratifications in temperature and salinity. It was felt that this area of thorough mixing would be less likely to experience surface ice formation or drift ice, and would not be subjected to rapid fluctuations in salinity.

Once ocean temperatures around the islands were found to be acceptable, 20 possible sites were evaluated by using the following additional criteria: protection from wind and waves, sufficient flushing and current velocity, ample water depth,

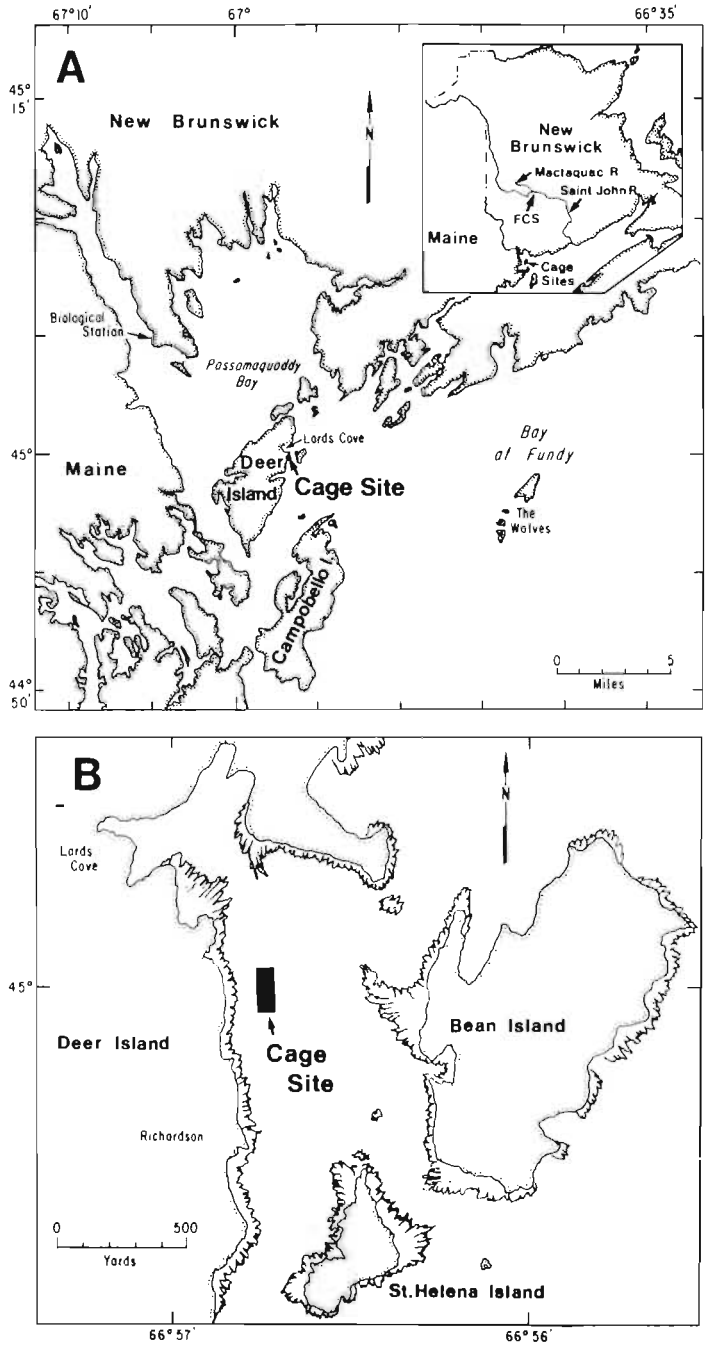

Fig. 1. Passamaquoddy Bay and island complex indicating location of marine farm and temperature monitoring stations.

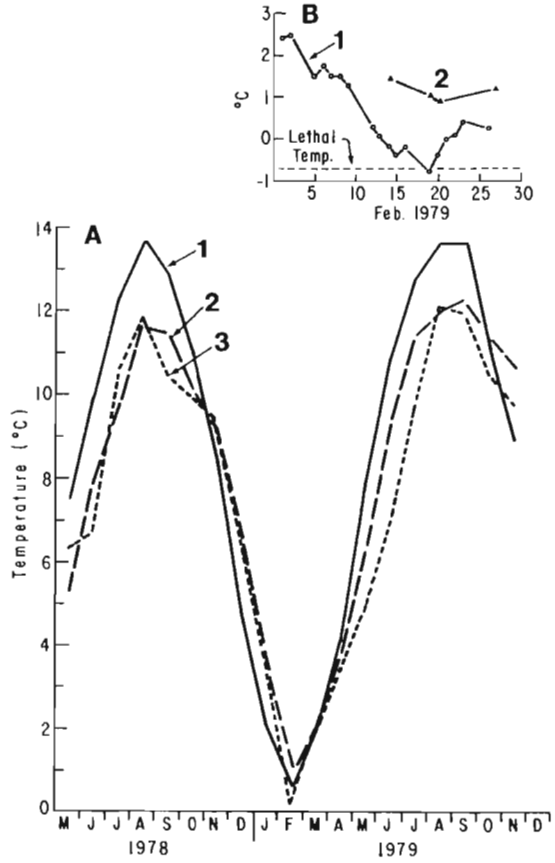

Fig. 2. A. Mean monthly surface temperatures: 1. Biological Station; 2. Deer Island; 3. The Wolves. B. Surface temperatures for February 1979: 1. Biological Station; 2. Deer Island.

non-interference from pollution sources, access to and availablility of shore facilities, required assets for security and surveillance, potential conflicts with navigation and the fisheries, and bottom suitability for moorings. Detailed information of this site evaluation study can be found in a report at the Biological Station, St. Andrews, N.B. (Merrill, unpubl. rep.). In summary, the area between Bean Island and Deer Island satisfied most criteria and was chosen as the site for the rearing trials (Fig. 1). A mooring permit issued by the Department of Transport as required under the Navigable Waters Protection Act and a Commercial Fish Farm Permit (#NB20) issued by Fisheries and Oceans were applied for and received (see Appendix 1).

The cage site was located approximately 500 m from a former fish plant owned by Marine Research Associates which was used as a place to moor the service boat, store gear and fish food, and which could eventually house the food-making equipment and necessary freezer facilities. It was expected that a series of islands to the east of the cage site would provide protection from severe winter storms with southeasterly winds coming off the ocean, and the headlands of Deer Island would provide some protection from the cold northwest winds associated with passing of high pressure, cold fronts during the winter. Current velocities at the site ranged from 5-19 cm/s at extreme tidal amplitudes. The bottom appeared to be of a well compacted mud suitable for driving piles or holding anchors.

Two 12-m diameter, Norwegian-type, octagonal fish frames were constructed to hold the rainbow trout and Atlantic salmon (for details of construction, see Sutterlin and Merrill 1978). The netting extended to a depth of 4 m and was weighted with concrete blocks attached to a lead line. The pink salmon were placed in a 4 x 4 x 4 m rectangular fish pen supported by a wooden frame enclosing styrofoam flotation. The initial nylon netting (210/15, 2.86 cm stretched mesh) was changed to a heavier type (210/27, 2.86 cm stretched mesh) for overwintering.

Past experience at the Biological Station, St. Andrews, suggested that pilings driven 3 m into the bottom could be used successfully to moor fish pens and avoid displacement problems (slack line) encountered in an anchored system due to the 6-m tidal amplitude in the area (Sutterlin et al. 1976). Eight 17- to 20-m spruce logs were obtained from a local saw mill; the butt ends were sharpened, weighted with sand bags and driven into the mud by a pile driver. Flotation-filled truck tires were placed over the pilings. The tires moved up and down with the tide, and ropes attached to the tires secured the fish pens in place.

It was soon apparent that, because of the buoyancy of such large pilings and hard bottom, this was not a good choice for a mooring system for the Deer Island site. Many of the pilings lifted during the first summer and Danforth anchors (100-150 kg) were employed to moor the fish pens.

FOOD PREPARATION AND FEEDING

Food-making equipment was set up at the St. Andrews Biological Station and food was transported several times a week and stored in chest freezers at the fish plant at Deer Island. A 15-HP Hobart Grinder and an 8-HP, 300-lb capacity cake mixer were used. A moist pellet was prepared by first grinding scrap fish and combining this in the mixer with fish oil, fish meal, shrimp meal, and vitamins. The resulting moist crumble was extruded by the grinder in the form of noodles that were collected in plastic trays and frozen in 14-kg lots. Prior to feeding, the frozen blocks of noodles were dumped from the trays and struck several times with a shovel to break the noodles apart.

Although alternate ingredients were occasionally substituted, the formulation most often adhered to is described in Table 1. Soybean meal was initially substituted for 30% of the fish meal, but the cost per protein unit of soya meal obtained from a local supplier was not competitive with local fish meal and its use was discontinued (see Appendix 2). Although a fat level of nearly 20% is much higher than that usually encountered in dry commercial pellets, such levels are commonly used in culturing Atlantic salmon in Norway. The high ash content in the diet is to some extent due to the high bone content of herring meal made from packing plant trimmings and from shrimp meal used to impart color to the salmon.

The legality (under the Food and Drug Act) of using carophyll red, a synthetic canthaxanthin

Table 1. Moist pellet formulation and costs in 1978.

	A	B	C	
	% weight	cost/kg ingredients	% cost of ingredients	AxB ¢/kg
Gaspereau and trash fish	48	$ 0.18	21.5	8.6
Herring meal	32	0.49	39.3	15.7
Shrimp meal	13.4	0.53	17.7	7.1
Herring oil	5.7	0.51	7.3	2.9
Vitamin premix	0.8	5.34	10.7	4.3
Ascorbic acid	0.1	13.47	3.5	1.4
				40.0

Cost of ingredients wet weight - 40.0¢/kg (33.9% moisture)[a]

Cost of ingredients dry weight - 60.5¢/kg

Approximate analysis of dry matter (%):

Protein	56.0
Lipid	19.4
Ash	16.6

[a]Current prices of ingredients to formulate the moist pellet are 55.0¢/kg.

normally used to color the flesh of salmonids, was in question in 1978 and other means of pigmentation were used. The addition of 13.4% shrimp meal to the diet provided adequate pigmentation but, as stated above, also increased the ash content. Irritation of the digestive tract of pink salmon might have been due to the high ash content of the diet (Dr. S. Lall, pers. comm.). Although it is now legally permissible to use carophyll red in fish diets, inexpensive sources of frozen shrimp wastes and shrimp meal could be cost-competitive with synthetic pigments because of their added protein component.

GROWTH AND FOOD CONVERSION

ATLANTIC SALMON

The Atlantic salmon used in this study consisted of 800 1+ yr smolts reared at the St. Andrews Biological Station, and 3000 2+ yr smolts from the Mactaquac Fish Culture Station. Both groups were from Saint John River stock maintained during three to four generations of hatching, rearing, and release to the sea from Mactaquac Fish Culture Station. The 2+ yr smolts were marked by removal of the adipose fin to permit comparison of growth and maturation performance of both groups. The 1+ yr smolts were acclimated to salt water before transfer by tank truck from the Biological Station. No facility was available for acclimating the 2+ yr smolts and they were transferred directly from fresh to salt water. Much of the recorded and some of the unrecorded mortality (Table 2) occurring in the first summer (May-December) is believed to have occurred soon after transfer as a result of transport and osmoregulatory stress. The salt water was colder than the hatchery water, adding additional stress. The fish were fed to satiation three times a day from May-October, twice a day during November and December, and once daily from January-March. Feeding was discontinued on stormy, winter days when it was not safe to visit the cages.

Samples of salmon were measured in August, October, and November of 1978 and January, March, July, and October 1979. The January and March samples were small (N=15 and 6) and may not truly represent the whole group. Gonads were removed and weighed from July and October 1979 samples, and additional data were collected on sexual maturation between Oct. 31 and Dec. 13, 1979, during harvest.

Mean length, weight, and condition factors are shown in Table 3, and growth comparisons with the other species in Fig. 3. When harvesting began on Oct. 31, 1979, the salmon had reached a mean size of 64.7 cm and 3.3 kg and had a mean condition factor of 1.2 ($CF = 100 \times wt\ (g)/l^{-3}\ (cm)$). Little change in length and weight occurred beyond this date due to falling water temperatures and disturbance to the fish during harvest. The salmon were also deliberately starved for several days before harvesting so that they would be void of food when processed. Mean fish weight, together with monthly food consumption, are shown in Fig. 4. During the summer months when water temperatures were high, growth and food consumption were high (Fig. 5). During the winter months of low water temperatures, food consumption fell dramatically, and growth in weight was slightly negative for part of this period. Instantaneous growth rates were calculated for the growth intervals using the formula: $100(\ln W_2 - \ln W_1/T_2-T_1)$, where ln is the natural logarithm, W is mean weight at times T_1 and T_2 (in days), T_2 being later than T_1. The instantaneous growth thus calculated represents the average daily weight gain as a percent of the salmon's body weight. Instantaneous growth rates were highest during the first summer, fell to near or below zero during the winter, and rose to intermediate levels in the second summer (Fig. 5). Table 4 shows comparative size and instantaneous growth rates of 1+ vs 2+ yr smolts from July-November 1979. It is not possible to make earlier comparisons as growth data on the separate groups were not collected prior to this time. On the three dates when information was collected, the 2+ yr smolts were consistently longer

Table 2. Survival of Atlantic salmon, pink salmon and rainbow trout.

Species	Stocking date	Number stocked	Survival to	No. survived	Survival to	No. survived	% loss Unrecorded	% loss Recorded	% loss Total
Atlantic salmon	May 12/78	3719	Dec./78	2163	Dec./79	2045[a]	30	15	45
Pink salmon	May 31/78	1796	Dec. 15/78	782			42	14	56
Rainbow trout	May 24/78	1345	Oct. 5/78	923			24	7	31

[a]Note only 5% mortality occurred after the first summer.

Table 3. Growth of Atlantic salmon (1- and 2-yr smolts combined).

Date	Number measured	Mean length (cm)	SE	Number measured	Mean weight (kg)	SE	Condition[a] factor	SE
1978								
May 12		21.0[b]	-		0.085[c]	-	-	-
Aug. 5	100	28.2	-	100	0.232	-	1.034	-
Oct. 16	52	39.9	-	52	0.702	-	1.105	-
Nov. 31	100	43.1	-	100	1.006	-	1.256	-
1979								
Jan. 23	15	45.8	0.59	15	0.965	0.037	1.000	0.014
Mar. 22	6	48.1	1.21	6	1.101	0.095	0.990	0.034
July 19	109	54.0	0.38	109	1.561	0.031	0.991	0.008
Oct. 16	60	63.2	0.63	60	3.023	0.075	1.197	0.012
Oct. 31-Nov. 1	167	64.7	0.36	167	3.316	0.054	1.224	0.007
Nov. 7, 8	81	65.0	0.52	81	3.316	0.078	1.207	0.001
Nov. 14	212	65.5	0.31	212	3.360	0.047	1.196	0.006
Nov. 19-21	548	65.0	0.25	548	3.361	0.037	1.224	0.005
Nov. 28, 29	152	65.1	0.35	329	3.216	0.051	1.166	0.007
Dec. 5-7	20	67.2	1.45	56	3.201	0.175	1.055	0.037
Dec. 10-13	-	-	-	269	2.638	-	-	-

[a]Condition factor = $\frac{\text{Weight(g)} \times 100}{\text{Length(cm)}^3}$

[b]Mean size of 2-yr smolts; 1-yr smolts not measured.

[c]Fish weighed in groups; unable to calculate standard errors.

Table 4. Comparative size and instantaneous growth rates of 1+ and 2+ yr smolts.

Date	1+ yr smolts N	1+ yr smolts Mean length (cm)	1+ yr smolts Mean weight (kg)	1+ yr smolts Condition factor	2 + yr smolts N	2 + yr smolts Mean length (cm)	2 + yr smolts Mean weight (kg)	2 + yr smolts Condition factor	Longer (%)	Heavier (%)
July 19/79	20	47.9	1.287	1.173	89	55.4	1.623	0.954	15.7	28.1
Oct. 16/79	11	60.4	2.782	1.264	49	63.9	3.078	1.182	5.8	10.6
Oct. 31/79	169	62.1	3.004	1.254	812	65.8	3.424	1.202	6.0	14.0
Instantaneous Growth rates										
July 19-Oct. 16		0.26	0.87			0.16	0.72			
Oct. 16-Oct. 31		0.17	0.48			0.18	0.66			
July 19-Oct. 31		0.28	0.81			0.16	0.71			

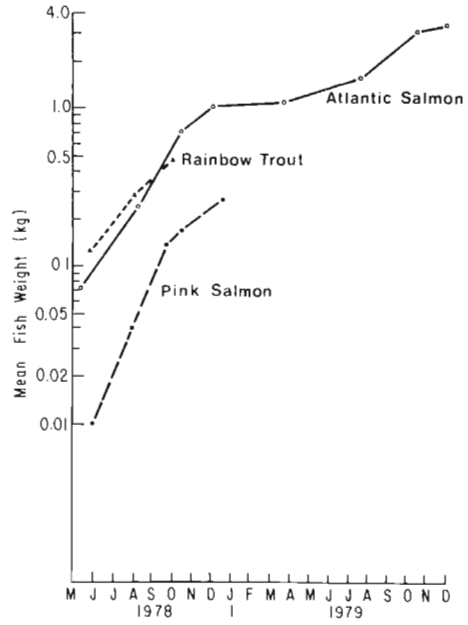

Fig. 3. Comparative growth of three species of salmonids at Deer Island.

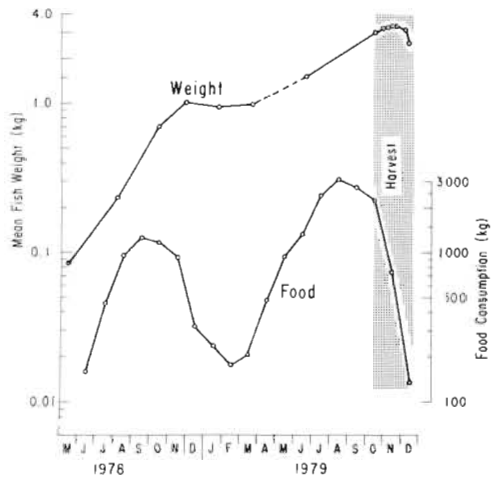

Fig. 4. Mean weight of Atlantic salmon and monthly food consumption.

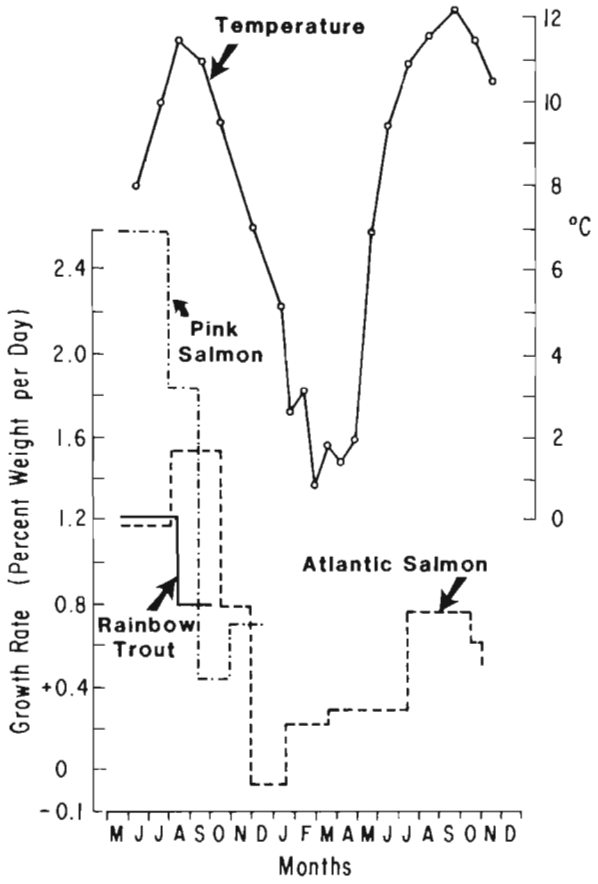

Fig. 5. Sea temperatures and instantaneous growth rates (% wt day^{-1}) of three salmonid species at Deer Island. T, temperature; P, pink salmon; R, rainbow trout; A, Atlantic salmon.

and heavier than 1+ smolts (Table 4). The 1+ yr smolts always had higher condition factors. Although the instantaneous growth rate of 1+ smolts was always greater than for 2+ smolts, it was never sufficient to enable them to reach a comparable size. It is impossible to determine whether the seasonal differences in growth rates of the two groups of smolts are size or age dependent. Although we observed a greater instantaneous growth rate by 1+ smolts compared to 2+ smolts during the second summer, Naevdal et al. (1979) describe slower growth by 1+ smolts during the first summer.

The size attained by Atlantic salmon in sea cages at Deer Island in 1978-79 is extremely encouraging. While temperatures are not as high in summer and are much lower in winter at Deer Island than on fish farms located in the southern fjords along the west coast of Norway, the size attained by Atlantic salmon at Deer Island was generally greater than those reported from Norwegian fish farms. The size of 3.3 kg attained by the Deer Island salmon after 537 d in the sea is equalled by only one farm in six described by Møller et al. (1976). Starting with 18-cm, 2+ smolts, only one strain out of the 16 studied obtained a length of 65 cm after 1.5 yr in Norwegian sea pens (Naevdal et al. 1979). At Deer Island 2+ smolts (21 cm) reached 66 cm after 1.5 yr, despite 4 mo of nearly zero winter growth.

The differences in final weight obtained at Deer Island and at some Norwegian farms can be accounted for by considering the initial smolt size. Norwegian smolts are stocked at a weight of 20-30 g (Gjedrem and Gunnes 1978) and the Deer Island smolts were twice as large. In order to produce 3.5-kg salmon in 18 mo, a larger smolt might have to be used to compensate for the reduced winter growth under Canadian conditions.

A comparison of growth in the sea cages can be made with growth of Atlantic salmon on ocean feeding grounds. Sea growth taken from Allen et al. (1972) is reproduced with the mean lengths of the salmon from the present study also plotted (Fig. 6). For this comparison, mean fork lengths were adjusted by using the formula given by Allen et al. (1972) to correspond to total length. Recent data (Reddin 1980) give 3.6 kg as the mean weights of North American Atlantic salmon caught in the West Greenland fishery in October.

A more relevant comparison can be made by using the same stock and year-class of 2+ yr smolts reared at the same hatchery, but having spent the first sea-year under different conditions. The mean length of 252 grilse that returned to Mactaquac Fish Culture Station in June and July 1979 was 56.4 cm (J. Ritter, pers. comm.) and compares with 55.4 cm for the same stock of caged-reared fish measured in July 1979. Departures in growth rates of fish destined to mature in different years have been shown to occur in July for salmon held in ocean pens in Norway. The findings of Allen et al. (1972) also show a divergence in growth rates during the second sea summer between salmon maturing as grilse and non-maturing fish.

Based on growth rates obtained in this study, it would appear unlikely that a size of 3.5 kg could be reached in 18 mo starting with a 30-g smolt. Under prevailing temperatures in the Bay of Fundy, it seems possible to obtain a 3.5-kg salmon from an 85-g smolt in 18 mo, and it seems likely that a 50-g smolt could attain a weight of 3.5 kg in 19 mo. However, other factors affecting such marine production strategies must be considered:

a) A future market advantage could develop for different-sized fish;

b) There may be an advantage in extending the marketing of fresh fish over several months;

c) Problems could develop in flesh texture, palatability, and fat content of salmon held in fish pens later than Dec. 31;

d) Assuming maturation rates remain independent of smolt age in future cage-rearing ventures, the advantage of 1+ over 2+ smolts will depend on their relative production costs.

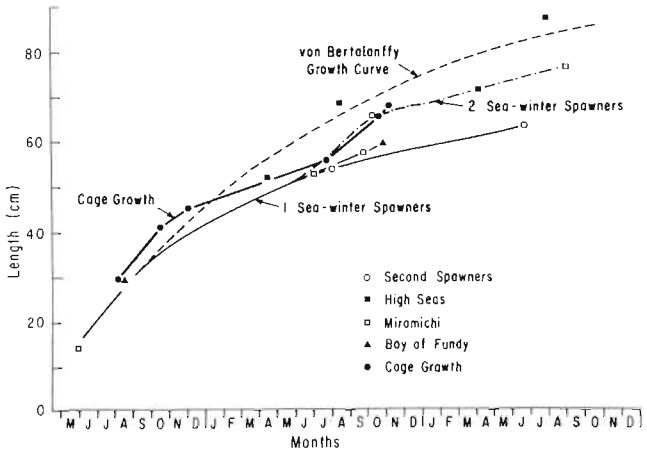

Fig. 6. Comparative growth rates of wild and cultured Atlantic salmon (data for wild salmon reproduced from Allen et al. 1972).

The availability of suitable, natural, freshwater resources, the adaptability of industrial sources of waste heat, and the use of recirculation technology for accelerated smolt production can be expected to influence future smolt production schedules.

Food consumption by Atlantic salmon is shown in Table 5. Data are not available prior to December 1978 because high mortalities in the early summer left us unsure of the number of fish in the cage. An actual count of the fish on Dec. 1, 1978, and low mortality thereafter allow fairly accurate determinations of food consumption during monthly intervals between Dec. 1978 and Oct. 1979 when marketing began. Despite the limited time elapsed between certain sampling dates and the inclusion of small sample sizes, the calculations of food conversion are believed to be useful for practical purposes. Food conversions (food/gain) were determined for the period July 19–Oct. 16, 1979, and for the total period May 12, 1978–Dec. 16, 1979 (Table 6). Conversions of 3.22:1 and 2.70:1 are in reasonable agreement and we suggest that the figure for the second summer be considered more reliable. If the average figure of 3:1 is used in calculating the pounds of moist food required to produce a pound of fish, intolerable errors should not be encountered. This conversion corresponds to 2.05:1 (dry weight food:wet weight fish) and is considered quite acceptable for the total saltwater growth period. It also compares well with that obtained with moist food at Norwegian fish farms (Sutterlin and Merrill 1978). The performance of the diet can probably be attributed to the high protein and fat levels in the formulation (Table 1).

RAINBOW TROUT

Approximately 1900 rainbow trout (120 g), reared from the fry stage at the St. Andrews Biological Station, were acclimated to seawater and transported by tank truck to the marine farm on May 24, 1978, and harvested Sept. 29, 1978. The growth rate of rainbow trout during the summer averaged 1.2%/d and was similar to Atlantic salmon (Fig. 3, 5). During the fall the growth rate of the trout fell to 0.8%/d, almost half of that measured for Atlantic salmon of comparable size. Differences in adaptiveness to cooler, saline water between trout and salmon could explain the departure in growth rates during the fall. Food conversion for the rainbow trout was nearly identical to Atlantic salmon (3:1) for the wet food and 2:1 based on dry weight of food. The rainbow trout used at Deer Island were progeny from fall spawning stock. This rapid decline in growth rate can be partly accounted for by the onset of sexual maturation; developed gonads were observed at harvest in a number of fish.

The relatively poor growth rates, the high incidence of sexual maturity, the limited market value for pan-sized rainbow trout, and the greater degree of competition from North American and international producers of rainbow trout suggest that this species is less economically suitable for culture than Atlantic salmon in the cold, highly saline water of the Bay of Fundy. Possibly, the development of a late-maturing rainbow trout, capable of overwintering and obtaining a marketable weight of 2 kg, could be competitive with Atlantic salmon if the cost of rainbow smolts was below that of salmon smolts. However, Norwegian results with rainbow trout cultured in cold ocean water at latitudes

Table 5. Monthly food consumption by Atlantic salmon.

Date	Fish wt (kg)	Food consumed (kg - wet wt)	Food consumption percent of fish wt/d
1978			
June		158.1	
July		459.3	
August		974.6	
September		1252.1	
October		1175.6	
November		914.5	
December	2153.1	313.7	0.47
	Total 1978	5247.9	
1979			
January	2122.0	236.7	0.36
February	2197.0	178.4	0.29
March	2162.3	207.8	0.31
April	2688.9	484.0	0.60
May	2876.3	963.0	1.08
June	3094.4	1327.5	1.43
July	3406.5	2407.7	2.28
August	4303.1	3161.5	2.37
September	5292.9	2747.0	1.73
October	6139.9	2265.0	1.19
November		740.0	
December		135.0	
	Total 1979	14853.6	
	Total 1978/79	20101.5	

Table 6. Food conversion by Atlantic salmon.

Weight gained (kg)	Food consumed (kg)	Conversion ratio[b]
	May 12, 1978-Dec. 16, 1979	
6240[a]	20101.6	3.22:1
	July 19, 1979-Oct. 16, 1979	
2937.1	7936.5	2.70:1
		Mean = 3.06:1

[a]Based on the assumption that the average number of fish for the entire period was 2000 and that the initial weight was 0.08 x 2000 = 160 kg.

[b]Wet weight food (33% moisture) : wet weight of fish.

greater than 60°N have not been especially promising (Sutterlin and Merrill 1978).

PINK SALMON

A special permit was issued by the Department of Fisheries and Oceans (DFO) for the use of pink salmon in the experimental rearing trials, with the provisions that the trials be supervised by staff from the St. Andrews Biological Station and that special security precautions be taken. A second permit from DFO ensured that pink salmon brood stock, from which the imported eggs were derived, was disease-free as specified under the Fish Health Protection Regulations. Eyed pink salmon eggs were obtained from Quinsam Hatchery, Vancouver Island, B.C. The eggs were hatched and fry reared at the St. Andrews Biological Station. At a length of 6-7 cm the fish were gradually acclimated to seawater and transported to the marine farm by a boat equipped with pumped salt water.

Pink salmon stocked in ocean pens in June at 10 g exhibited growth rates of 2.6%/d during the summer, falling to 0.6%/d by November (Fig. 5). The fish had reached a size of 250 g by the beginning of December (Fig. 3). With better disease control, it would appear possible to produce a pan-sized, 300-g pink salmon in 7 mo from a 10- to 15-g smolt stocked in June. Although information concerning food conversion by pink salmon is lacking, it is interesting to note that food intake by 250-g pinks in January at sea temperatures of 5.0-2.1°C was 0.75%/d compared to 0.36%/d by 1000-g Atlantic salmon during the same period. The growth rates exhibited by the pink salmon at Deer Island exceeded those at the Pacific Biological Station Fish Farm where temperatures averaged 3°C higher (Kennedy et al. 1976).

Several members of a taste panel judged the texture and taste of the pan-sized pink salmon to be inferior to rainbow trout of comparable size reared at the same site. Although both species were fed the same food, the pink salmon flesh was not as pigmented as the trout flesh.

SEXUAL MATURATION

The propensity of Atlantic salmon to mature sexually as grilse is undesirable in cage culture operations. This phenomenon is not completely understood and hence not always controllable. A number of authors (Peterson 1971, 1973; Gray 1973; Ritter 1972, 1975; Ritter and Newbould 1977; Chadwick et al. 1978; Bailey et al. 1980) show a relationship between smolt size and age, and age at first maturity. Simpson and Thorpe (1976) discuss this relationship. Occasionally, but of less consequence, a small percentage of cultured Atlantic salmon has been found to mature as postsmolts during their first summer (Saunders and Henderson 1965; Sutterlin et al. 1978). The Deer Island results are particularly interesting in respect to sexual maturation. Ratios of gonad weight to body weight calculated from measurements done on July 19, 1979, and Oct. 16, 1979, indicated only one fish out of 168 sampled (a male from the 2+ yr smolt group) that was likely to mature in 1979 (Table 7). The gonad weight-body weight ratio has been shown to be a useful index of sexual maturation (Ishida and Miyaguchi 1958; Godfrey 1961; Gunstrom 1968; Saunders and Henderson 1976). Only three mature males and one mature female were observed in 548 salmon gutted during harvest in November. All four fish were also from the 2+ yr smolt group in which the sexually mature fish amounted to less than 1% of the sample.

Since both groups of salmon reared at Deer Island were from Saint John River stock, comparison can be made with hatchery returns to Mactaquac Fish Culture Station described by Ritter (1975), where 6% of the 1-yr smolts and 44% of the 2-yr smolts returned as grilse.

More recent information regarding survival to the grilse and larger salmon stages from 2-yr smolts released at Mactaquac Fish Culture Station suggests that the ratio is close to 1:1. A number of assumptions including tag loss and tag-related mortality,

Table 7. Gonad development of Atlantic salmon (gonad weight as a percent of body weight) and number of salmon sexually mature at harvest time.

Date		1+ yr smolts Male	1+ yr smolts Female	2+ yr smolts Male	2+ yr smolts Female
July 19/79 (sample)	N	12	8	55	33
	Mean	0.08	0.19	0.11	0.22
	Range	0.05-0.13	0.16-0.33	0.05-0.23[a]	0.16-0.38
Oct. 16/79 (sample)	N	5	6	30	19
	Mean	0.07	0.17	0.10	0.22
	Range	0.06-0.10	0.07-0.24	0.06-0.13	0.15-0.17
Nov./79 (harvest)		No. examined		No. examined	
		46	48	235	219
		No. mature		No. mature	
		0	0	3	1
Ratio male to female in above samples		1.02:1		1.18:1	

[a]One fish at 0.78

natural mortality, nonreporting of tags, noncatch mortality, poaching, and fishway efficiency were made in calculating these ratios for sea-ranched fish (Ritter, pers. comm.). This ratio is, nevertheless, in sharp contrast with that for cage-reared fish.

Naevdal et al. (1979) observed a greater incidence of maturation as grilse in 1+ than in 2+ smolts when both were reared in Norwegian fish pens, these results being opposite to those of Ritter and Newbould (1977) who studied fish returning from the ocean. The average incidence of maturation as grilse among 16 sib groups studied by Naevdal was 15 and 20% for 2+ and 1+ smolts, respectively, compared to less than 1% in the Deer Island fish.

Because of the initial large size of the smolts and their high growth rates during the first summer in the cages, they were of comparable length to wild one-sea-winter spawners (Fig. 6) and to their hatchery counterparts returning as grilse the following summer. It is therefore doubtful that size alone could account for the low incidence of sexual maturity of the cage-reared salmon (see Alm 1959).

Two factors possibly worth considering are low temperature and/or reduced food consumption during the winter. Low temperature might have inhibited some critical step necessary in the maturation process or could have resulted in such a reduced food intake that the condition of fish prevented them from diverting available energy into reproductive effort. Food intake and growth during the winter indicate that the salmon were at maintenance levels or slightly below (Fig. 5). Part of the reduced food intake is no doubt voluntary, due to temperature, but some might be attributed to low food availability during certain periods because feeders could not reach the fish pens because of stormy weather.

In this area, winter temperatures in the sea cages are probably lower than those to which salmon are exposed on ocean feeding grounds. This suggestion is supported by the fact that growth in the cages was actually slightly negative for weight (Table 3), whereas growth on the ocean feeding grounds, while depressed during the winter, continues at a reduced rate (Allen et al. 1972). Although fat content was not measured in our salmon in the spring after overwintering, it is probably reasonable to assume that it was at a low level. The low condition factors of the salmon recorded on July 19, 1979, particularly for the 2+ yr smolt group, support this assumption (Table 3). In an excellent review of factors affecting timing of sexual maturation in Atlantic salmon, Thurow (1966) states that salmon having a fat content of at least 12% in the spring will probably spawn in the fall of the same year, and that fish with a fat content of 6.5% or less in the spring will not spawn in that year. Scott (1962) was able to reduce the incidence of sexual maturation in rainbow trout by restricting rations during periods of ovarian maturation.

An interesting observation when comparing the 1+ and 2+ yr smolt groups is that the 1+ yr smolts always had higher condition factors. According to Simpson and Thorpe (1976), this is indicative of salmon that will mature as grilse. However, none of the 1+ yr smolts matured as grilse in this study.

It is interesting to note that the Norwegian coast experienced unseasonably low sea temperatures during the winter of 1978, and a marked reduction in the incidence of sexual maturation as grilse was observed at some fish farms (T. Gjedrem, pers. comm.).

While a genetic influence determining the age at first maturity among different river populations of Atlantic salmon has been demonstrated (Gardner 1976; Naevdal et al. 1978), we suggest that environmental factors encountered during the marine phase can also alter maturation rates and perhaps be an important component of the reproductive strategy of Atlantic salmon.

The sex ratios of 2+ smolts produced at Mactaquac Fish Culture Station during 1976 and 1977 were 1.18:1 and 1.08:1 (male:female) and are assumed to be similar for Mactaquac smolts stocked at Deer Island in 1978 (J. Ritter, pers. comm.). The sex ratio of 1.18:1 (male:female) of Mactaquac 2+ smolts after 18 mo in sea cages (Table 7) does not indicate a sex dependent mortality in the cages. The incidence of sexual maturity in rainbow trout harvested in the fall of 1978 was not recorded but numerous mature fish were observed.

A sample of pink salmon held in tanks during the winter at intermediate salinity all matured in the fall of 1979 as expected and produced viable products that hatched normally.

HARVESTING, MARKETING, AND ECONOMICS

DEER ISLAND EXPERIMENT

In the Fundy Island area, the economic prospects of culturing Atlantic salmon appear more favorable than those for the culture of rainbow trout and pink salmon. The following discussion will therefore be restricted to the marketing and economics of Atlantic salmon.

Approximately 7 tons of 3.3-kg salmon (round weight) were harvested during the early winter of 1979. The fish were removed from the pens once markets had been previously secured. The netting was pursed up, fish were seined together, removed with dip nets, and killed by a blow on the head. Some fish were marketed whole; the remainder were beheaded and gutted. The weight losses resulting from gutting, and gutting plus heading averaged 11 and 19%, respectively (Table 8).

Salmon were marketed in several cities in New Brunswick and some were sent to brokers in Montreal. Based upon this limited market survey, it is anticipated that a combined domestic and export market readily exists for up to 500 tons/yr of salmon during late fall and early winter. Prices obtained (FOB plant) varied from $2.75/lb round to 4.00/lb dressed. The quality of the fish (flesh color, texture, palatability) appeared acceptable although the product was not compared with wild salmon.

THE ECONOMICS OF A THEORETICAL SALMON FARM

Based on the experience gained at Deer Island, attempts have been made to determine costs and to draw up a pro forma cash flow analysis and income statement for a theoretical salmon farm operated by two people with a production capacity of 56 tons/yr (Table 9, 10). The following assumptions are used:

1. Production cycle of 18 mo is necessary for 70-g smolts to reach a market weight of 3.5 kg.
2. Four fish pens are required the first year for smolts with the addition of nine more in year 2 (eight pens for older fish and one for brood stock).
3. Seven tons (approximately 1800 fish) are harvested from each of the eight 12-m fish pens yielding 16 kg/m^3 (1 lb/ft^3).
4. Twenty thousand smolts are required each year with 73% surviving and 3% being retained for brood stock which should yield over 1 million eggs. Total fish marketed equals 70% of original stock. Losses occur

Table 8. Weight loss of Atlantic salmon from gutting and heading.

Date 1979	Number sampled	Mean wt round (kg)	Mean wt gutted (kg)	Percent loss	Mean wt gutted and head off	Percent loss
Oct. 16	60	3.023	2.654	12.22	2.350	22.27
" 31	4	3.274			2.679	18.18
" 31	60	3.407	3.067	9.99		
Nov. 1	103	3.265	2.943	9.87	2.680	17.94
" 7	70	3.280	2.959	9.80	2.696	17.81
" 7	6	3.605	3.274	9.17	2.981	17.30
" 8	4	3.785	3.423	9.55	3.118	17.60
" 14	105	3.393	2.973	12.38		
" 14	107	3.328			2.714	18.46
" 28	70	3.264	2.875	11.91		
Dec. 7	20	3.384			2.801	17.25
Means				10.99[a]		18.87[b]

[a] n = 374
[b] n = 478

Table 9. Costs and depreciations for a theoretical salmon farm ($000).

Capital Expenditures	Year 1	2	3	4	5	6	7	8	9	10
Land	10.4									
Fish pens										
Net frames	2.4	5.3				4.0	9.0			
Netting	2.4	5.3	3.0	6.6	3.6	8.1	4.5	10.0	5.5	12.3
Anchors	4.0					6.2				
Ropes	1.0			1.3			1.7			2.2
Fish food boxes	.6			.8			1.1			1.8
1/2-ton truck	8.0					12.3				
Outboard motor	1.3			1.7			2.2			2.8
Boat	4.0					6.2				
Building	25.0									
Freezer	10.0									
Furnace	2.0									
Total Capital Expenditures	70.7	10.6	3.0	10.4	3.6	36.8	18.5	10.0	5.5	19.1

Depreciation		1	2	3	4	5	6	7	8	9	10
Fish pens											
Net frames	(20%)	.5	1.5	1.5	1.5	1.5	2.0	2.6	2.6	2.6	2.6
Netting	(20%)	.5	1.5	2.1	4.1	4.2	5.3	5.2	6.6	6.3	8.1
Anchors	(20%)	.8	.8	.8	.8	.8	1.2	1.2	1.2	1.2	1.2
Ropes	(20%)	.2	.2	.2	.5	.5	.3	.6	.4	.3	.8
Fish food boxes	(20%)	.1	.1	.1	.3	.3	.3	.4	.2	.2	.6
1/2-ton truck	(30%)	2.4	2.4	2.4	.8		3.7	3.7	1.2		
Outboard motor	(30%)	.4	.4	.4	.6	.5	.5	.9	.7	.7	.9
Boat	(15%)	.6	.6	.6	.6	.6	1.5	1.3	.9	.9	.9
Building	(5%)	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Freezer	(20%)	2.0	2.0	2.0	2.0	2.0					
Furnace	(20%)	.4	.4	.4	.4	.4					
Total Depreciation		9.2	11.2	11.8	12.9	12.1	16.1	17.2	14.7	14.7	15.4

Costs of Production	1	2	3	4	5	6	7	8	9	10
Fish food	32.4	110.4	120.3	131.2	143.0	155.8	169.9	185.2	201.8	220.0
Smolts	40.0	43.6	47.5	51.8	56.5	61.5	67.1	73.1	79.7	86.9
Gasoline	2.0	2.2	2.5	2.7	3.0	3.4	3.7	4.2	4.6	5.1
Electricity	3.6	4.0	4.4	4.9	5.5	6.1	6.7	7.5	8.3	9.2
Heating oil	1.2	1.3	1.5	1.6	1.8	2.0	2.2	2.5	2.8	3.1
Water	.1	.1	.1	.1	.1	.2	.2	.2	.2	.2
Labor										
Workman (1/2 time)	12.5	13.9	15.4	17.1	19.0	21.1	23.4	26.0	28.8	32.0
Workman	16.0	17.8	19.7	21.9	24.3	27.0	29.9	33.2	36.9	40.9
Maintenance	.7	.8	.9	.9	1.0	1.1	1.2	1.3	1.4	1.5
Total Production Costs	108.5	194.1	213.1	232.2	254.2	278.2	304.3	333.2	364.2	398.9

Administration and Selling	1	2	3	4	5	6	7	8	9	10
Telephone	1.2	1.3	1.4	1.6	1.7	1.9	2.0	2.2	2.4	2.6
Insurance	.8	.9	1.0	1.0	1.1	1.2	1.3	1.5	1.6	1.7
Office supplies	.3	.3	.4	.4	.4	.5	.5	.6	.6	.7
Labor										
Manager (1/2 time)	12.5	13.9	15.4	17.1	19.0	21.1	23.4	26.0	28.8	32.0
Acct/Sec.	10.0	11.1	12.3	13.7	15.2	16.9	18.7	20.8	23.1	25.6
Total Admin and Selling Exp.	24.8	27.5	30.5	33.8	37.4	41.6	45.9	51.1	56.5	62.6

Table 10. Ten-year pro forma income and cash flow statements.

	Income ($000) Year									
	1	2	3	4	5	6	7	8	9	10
Revenue	-	352.5	384.2	418.8	456.5	497.6	542.4	591.2	644.4	702.4
Expenses										
Production costs	108.5	194.1	213.1	232.2	254.2	278.2	304.3	333.2	364.4	398.9
Admin & selling	24.8	27.5	30.5	33.8	37.4	41.6	45.9	51.1	56.5	62.6
Depreciation	9.2	11.2	11.8	12.9	12.1	16.1	17.2	17.6	14.7	15.4
Total expenses	142.5	232.8	255.4	278.9	303.7	335.9	367.4	401.9	435.6	476.9
Earning before I. & T.	(142.5)	119.7	123.8	139.9	152.8	161.7	175.0	189.3	208.8	225.5
Interest										
5-yr loan (200,000)	32.0	27.3	21.9	15.6	8.4					
10-yr loan (100,000)	16.0	15.3	14.4	13.4	12.2	10.8	9.3	7.4	5.3	2.9
Total interest	48.0	42.6	36.3	29.0	20.6	10.8	9.3	7.4	5.3	2.9
Earnings before taxes	(190.5)	77.1	87.5	110.9	132.2	150.9	165.7	181.9	203.5	222.6
Income tax	(57.2)	23.1	26.3	33.3	39.7	45.3	49.7	54.6	61.1	66.8
Tax loss adjustment		(23.1)	(26.3)	(7.8)						
Net income	-	77.1	87.5	85.4	92.5	105.6	116.0	127.3	142.5	156.8

	Cash flow analysis ($000) Year									
	1	2	3	4	5	6	7	8	9	10
Earnings before taxes	(190.5)	77.1	87.5	110.9	132.2	150.9	165.7	181.9	203.5	222.6
Depreciation	9.2	11.2	11.8	12.9	12.1	16.1	17.2	17.6	14.7	15.4
Loans	300.0									
Total inflows	118.7	88.3	99.3	123.8	144.3	167.0	182.9	199.5	218.2	238.0
Capital expense	70.7	10.6	3.0	10.4	3.6	36.8	18.5	10.0	5.5	19.1
Repayment of principal										
5-yr loan	29.1	33.7	39.1	45.4	52.7					
10-yr loan	4.7	5.5	6.3	7.3	8.5	9.9	11.4	13.3	15.4	17.7
Income tax	-	-	-	25.5	39.7	45.3	49.7	54.6	61.1	66.8
Total outflows	104.5	49.8	48.4	88.6	104.5	91.0	79.6	77.9	82.0	103.6
Net cash flow	14.2	38.5	50.9	35.2	39.8	76.0	103.3	121.6	136.2	134.4

predominantly in the first summer, permitting annual harvest of 54 tons in the winter of year 2.

5. None of the fish mature as grilse.

6. Smolts are purchased for $2.00 each.

7. Moist pelleted food is purchased for $0.60/kg wet weight, and food cost for all three year-classes of fish are considered, using a conversion factor of 3:1 (see footnote in Table 1).

8. Land must be obtained and a shoreside building with freezer facilities for short-term storage must be constructed.

9. A boat, outboard motor, and truck must be purchased.

10. Two workmen are required, one acting as part-time manager; also part-time accounting and secretarial services are enlisted.

11. Initial capital of $300,000 is borrowed from a commercial institution in two parts: a medium-term loan for $200,000 over a period of 5 yr and a long-term loan for $100,000 over a period of 10 yr, at 16% interest on both loans.

12. Fish are sold in the round to a processing plant at a price of $3.27/lb in the winter of year 2.

13. The costs of acclimation and vaccination, if necessary, would be included in the smolt costs.

14. Revenue from the possible sale of excess eggs after year 3 is not considered.

The basis for the pro forma statements is as follows: The inflation factor for most items was taken to be 9% per year which is the average change in Consumer Price Index (CPI) over the last 10 yr. The price of salmon also escalates at 9% per year. Petroleum-related items such as gas, oil, electricity, and netting were given an inflation rate of 11%. This is the average of the inflation factors since the dramatic increase in 1973-74. Wages have also appeared to be increasing more rapidly than the CPI, with an inflation factor of 11%. Finally, wood products were found to have the highest inflation rate of 13%.

The interest rate was set as high as is probable which would tend to underestimate profits. This rate could be 2½-3% above the prime since it would be an unsecured loan and, at present, prime is around 13%. If the interest rates fell, then this would have a favorable effect on the income statements. Also, if part of the loan is secured against property, this would lower the rate.

Although the existing minimum tax rate is 25%, to allow for the possibility that all of the reductions might not be applicable, the tax rate was set at 30%.

In most estimates we believe that the above values have been weighed pessimistically and the actual returns should be better than those shown here.

It should be noted that, although there is a net cash flow of $38,530 in the second year, an additional short-term loan will be required for the first half of the year until the salmon are harvested. This loan should be taken out in the second year and should not be for more than 6 mo.

It should be realized that, while these growth projections, food requirements, and incidences of sexual maturity are based on the results obtained in the pilot rearing studies, the reproducibility of these results during subsequent years has not been examined. The use of 73% survival rate in the following analysis may be questioned as only 55% was observed in the pilot trials. However, it is anticipated that markedly improved survival rates can be realized immediately by using better acclimation procedures, more effective predator controls, and improved vaccines. A source from which to obtain large numbers of smolts at $2.00 each does not exist at present, and this cost variable should be carefully examined. The costs and replacement rates are apparent in Table 9 and have been assigned to capital items based on costs and durability of construction material used during this pilot study, and manufacturers' estimates have been used for large capital items. Allowable depreciation rates for capital items follow income tax guidelines.

Many of the necessary capital assets such as shoreside building, boat, truck, freezing and processing facilities are already available to fishermen and fish companies, which would reduce their initial capital investment considerably should they become involved. The manpower requirements were obtained by scaling up the requirements observed during the pilot studies and appear consistent with Norwegian farms of such size (Sutterlin and Merrill 1978). Construction of frames and netting and much of the routine maintenance are performed by the workman during the slack winter period.

It is assumed that the moist pellet will be obtained from a central food plant supplying a number of such farms; therefore, the additional 50% has been added to the cost of ingredients to cover equipment and labor at the food plant. Based on the preparation costs for commercial agricultural feeds, this markup should be sufficient.

No provisions have been included for aquaculture insurance to mitigate against losses of fish. Any attempt to assign an equitable insurance rate at this stage of development would be of limited value.

A 1980 landed price of $3.00/lb round is chosen somewhat arbitrarily but does not seem inconsistent with the 1979 price received for the fish marketed from the pilot study nor with the price of $2.46/lb (FOB Plant) received for wild salmon of mixed size (2-5 kg). The advantage of having uniform-sized salmon available at convenient processing and marketing times is expected to improve the value of the product markedly.

Government assistance by means of cost sharing or low interest loans are common in agriculture and fishing (Farm Development Grants and Fisheries Loan Board) and similar assistance for fish farmers could develop in the future.

Taking into account the magnitude of profits after taxes and the fact that we have not performed any sensitivity analysis of the most important

variables such as growth rates, product price, smolt costs, food costs, and survival rates, it appears that the theoretical salmon farm thus described is approaching the minimum size necessary for economic viability. Despite the limitations in this theoretical analysis, it is hoped that the exercise will at least reveal the types and magnitude of investments that are required to initiate marine salmon farming without financial assistance from the government.

SUPPLY SITUATION OF ATLANTIC SALMON

The eventual growth of an Atlantic salmon cage culture industry and the price obtained by the fish farmer will depend on the supply and demand situation for this product.

Canadian landings of Atlantic salmon from 1968-77 (Appendix 3) indicate that a relatively stable supply existed. However, overfishing on the high seas, industrial pollution, poaching, etc. are suspected of contributing to the marked decline in supply in the last few years. The Federal Government is developing an East Coast enhancement program in the hope that wild stocks can be regenerated. If the program is implemented and proves successful, commercial salmon landings could conceivably double over the next two decades.

Current Canadian supplies of Atlantic salmon come mostly from the Newfoundland fishery which operates from June-September. The landed price rose slowly from $0.50/lb in 1968 to $0.89/lb in 1976. With the recent supply shortages, the price has increased to $1.55 in 1979. The landed price of salmon varies with location of catch and size of the fish. An exact price is not possible to obtain because of the manner in which data are reported by the government. As a result, averages have been used.

MARKET DEMAND FOR ATLANTIC SALMON IN CANADA AND THE UNITED STATES

The Canadian demand for Atlantic salmon in recent years has been generally limited to a small affluent segment of the population. Appendix 4 outlines the decline in domestic consumption in the face of lower supplies, higher prices, and increasing percentage of exports. While some decline in domestic consumption may be a result of higher prices, it may also reflect the ease of marketing larger volumes of fresh and frozen Atlantic salmon in U.S. east coast markets as opposed to local distribution.

Ten marine farms, each containing 12 fish pens, would require a total of 200 000 smolts per year. Their resulting production could contribute 500 tons of salmon and represent a 24% increase based on the 1978 Canadian production of fresh and frozen Atlantic salmon (Appendix 5). Whether or not the Canadian market could immediately absorb such quantities of Atlantic salmon and sustain the recent rate of price increases are matters of some concern (Appendix 6, 7). Historically, domestic consumption has absorbed the majority of our Atlantic salmon production during periods when landings were much higher in spite of the fact that Canada ranks low in the consumption of fish (kilograms per capita) as indicated by the following 1978 figures from LeMessurier (1979): Japan 36.4; Russia 17.0; Britain 9.0; Canada 7.2; United States 5.8.

More important, perhaps, is the changing pattern in fish consumption by Canadians, which has increased by 30.9% over the previous 5 yr. As a result of greater mobility and urbanization of the Canadian populace, the growth in retail fish outlets can be anticipated. It would, therefore, seem reasonable to assume that the demand for Atlantic salmon will continue even in the face of steadily increasing prices and supplies. Product familiarity, population density and proximity suggest that the major markets for Atlantic salmon in Canada are likely to be Halifax, Montreal, and Toronto.

Natural production of Atlantic salmon in the U.S. at the present time is inconsequential, although there is a resurgence of interest in restocking traditional salmon rivers in the New England states. The possibility of Atlantic salmon culture in the northern coastal areas of the state of Maine is very real, especially in light of recent developments in New Brunswick.

While U.S. statistics do not distinguish types of salmon imported, some measure of the importance of Canadian exports of Atlantic salmon can be gained from Statistics Canada (Appendix 8, 9). Although total exports of Canadian Atlantic salmon have decreased in recent years, they parallel declining Canadian landings. It is also apparent that the U.S., like Canada, has experienced rapidly increasing prices over the past decade. Appendix 9 indicates the importance of the U.S. market for Canadian Atlantic salmon. In 1978, 98.5% of Canadian salmon exported fresh went to the U.S. This represented 14.6% of total Canadian production of fresh salmon. The U.S. also took 32% of all frozen salmon produced in Canada. Traditionally, the U.S. market has absorbed the vast majority of fresh salmon exported and, in the past 5 yr has ranked next to West Germany in the purchase of the frozen product.

In summary, the markets for Atlantic salmon in the U.S. and Canada are similar (an urban populace in higher income brackets). The U.S. would seem to be an excellent market for Atlantic salmon. As in Canada, the demand has traditionally been strong, even at import levels far in excess of present supplies. Commercial distribution of Atlantic salmon is at present confined to the Atlantic seaboard from Maine to Maryland. It is therefore suggested that if considerably larger quantities of salmon were available, the U.S. market could easily absorb volumes exceeding the requirements of the Canadian market.

PRODUCT FORM

Atlantic salmon is generally sold in North America by the processor, gutted, head off, fresh or frozen. It is distributed by wholesalers and fish brokers to supermarkets, restaurants, hotels, and fish stores, and sold in the form of steaks, fillets, chunks, or whole. Smaller quantities are pickled and canned. Large salmon (3.5 kg) command the highest prices, and are preferred by the restaurant and hotel trade and are also used for smoking. Small salmon (less than 3.5 kg) are sold mostly by the retail trade.

Cultured salmon of 3.5 kg are of marginal size for cold smoking of fillets because of water loss and shrinkage. However, contained in the same fish

pens as many as 20% of the salmon would range in weight from 4.5-5.5 kg and would be suitable for smoking. Prime quality smoked salmon such as lox demands a price as high as $15-20/lb in city retail delicatessens. Much of this market has traditionally belonged to Atlantic salmon but smoked Pacific salmon is now commonly accepted. The quality requirements are stringent; salt levels and degree and type of smoke are critical. Also, the remaining rib bones must be pulled out of the unskinned fillet by hand before marketing. A common Scandanavian method of serving Atlantic salmon is in the form of a sugar and dill marinade called "gravlaks," which requires a salmon fillet.

Fresh salmon has traditionally been the most important product (Appendix 5). Fresh salmon, properly packed in ice and transported by air or in refrigerated trucks, will keep for 8-10 d before deterioration. However, in recent years, frozen salmon has been gaining a share of the market. The quality of frozen salmon (texture and palatability) depends on the following factors: rate of freezing, holding temperature, water loss, and fat content. Even under the best conditions, the high lipid content of salmon and the subsequent oxidation of fats result in off-flavors after more than 3 mo storage. It is customary for Atlantic salmon in Newfoundland to be gutted and wrapped in plastic prior to freezing. Norwegian salmon are frozen in the round and glazed with several layers of ice to prevent freezer burn or dehydration.

Compared to the traditional harvest of wild salmon, the marketing advantage of a production schedule of a marine farm is obvious. Prior inventory could guarantee a constant supply of fresh fish of specified size. It could also provide a "fresh frozen" product from February to May when the quality of frozen commercial fish would have deteriorated. Salmon derived from the Newfoundland commercial fisheries would best be marketed fresh during the summer.

PRICE OF ATLANTIC SALMON

Price is primarily a function of supply and demand. Supplies have been decreasing drastically in the last few years, coincident with the value of the salmon (FOB processor), regardless of its processed form, increasing rapidly in recent years. An important consideration in attempting to derive future prices for Atlantic salmon is the product's price elasticity. Would, for example, a proportionately large increase in Atlantic salmon production cause a proportionately equal decrease in price? On the basis of historical evidence, it is very unlikely that this would happen. Traditionally, demand has been considerably larger than at present and Atlantic salmon, being the only salmon species found in Atlantic Canada, has long had an appeal as a gourmet item. It is strongly suspected that, within quite broad limits, the demand for Atlantic salmon is price elastic.

The actual price that the producer will receive from his broker/wholesaler will depend on a number of variables such as volume, size of marketable fish, quality, and regularity of supply. Usually, small volumes would suffer from price penalties and large-size salmon would generally command a premium price. The price would also be affected by the substitution of other species for fresh Atlantic salmon or by other sources of Atlantic salmon. It is nearly impossible to predict how traditional Atlantic salmon consumers might react when faced with a choice between Atlantic and Pacific varieties of salmon or marine-grown rainbow trout. More aggressive advertising might be necessary to maintain the price differential.

There is some concern that the success of European Atlantic salmon aquaculture may, in the long run, lead to infiltration into North American markets. However, the relative weakness of the Canadian dollar in relation to the American and most European currencies, along with Canada's geographical proximity to the U.S., would appear to give the Canadian Maritimes a competitive advantage for N. American markets as well as for European markets.

The prices (FOB processor) for fresh Atlantic salmon are rising steeply as indicated in Appendix 7. Fresh salmon, dressed out at less than 8 lb, was selling for $3.50/lb in Montreal during the summer of 1980. The use of a median figure of $3.50 is considered reasonable as the price index for salmon has shown considerably more growth since 1971 than consumer price, wage, or construction indices.

MARKET DISTRIBUTION

Most Atlantic salmon is trucked fresh or frozen, gutted, head off to wholesalers, brokers or, in some cases, retailers in Canadian and U.S. markets. Some salmon is shipped frozen by container boat to Halifax and Europe.

In 1978 the landed cost per pound for fresh Atlantic salmon was $1.45. The processor's price F.O.B. to wholesalers was $2.46 for fresh and $2.91 for frozen. Retailers were charging up to $5.00/lb. Appendix 10 reveals how costs are distributed in marketing fresh Atlantic salmon. There are a number of factors which contribute to the high retail price. About 20% of the fish weight is lost in gutting and heading (Table 8). The cost of this weight loss plus labor, equipment, etc. must be borne by the processor. Other costs are incurred in packaging, refrigeration, and transportation. Some processing also takes place at the retail level in reducing the fish to the consumer package. A further margin can be added for the perishability of the fresh fish in some instances.

While it may prove more profitable for a large-scale aquaculture operation to set up its own processing and distribution system, it would probably be more convenient, at least initially, to use existing facilities. When a producer can guarantee a large, constant supply of Atlantic salmon in a market subject to supply shortages, it is anticipated that he should have little difficulty in gaining a favorable deal with processors and middlemen.

SPECIAL PROBLEMS ENCOUNTERED

PREDATION

A large percentage of unrecorded losses of the pink and Atlantic salmon is suspected to have been inflicted by birds during the early part of the summer. Gulls (*Larus argentatus* and *L. marinus*) facilitated fishing by weighing down the bird net until it touched the water. The top net was subsequently supported by a center pole. Great blue herons, *Ardea horodias*, were observed standing on the frame and were certain to have speared fish

through the side netting as evidenced by the presence of fish scales on the cage frames where the birds presumably attempted to pull the fish through the net. Cuts and lesions were observed in the dorsal surface of numerous young salmon and were believed to have been caused by birds. It is also possible that subsurface predation by diving cormorants (Phalacrocorax auritus), occasionally seen in the vicinity, could also have contributed to such wounds. Although a few seals were observed in the vicinity of the farm, they never, to our knowledge, approached the fish pens.

DISEASES

With the possible exception of bird predation, it is suspected that Vibriosis might have accounted for a high percentage of mortalities in all three species during the first summer (Table 2). This was only confirmed, however, for the pinks. Although half the pink salmon were vaccinated by injection (I.P.) prior to stocking in sea cages in June and July 1978, Vibrio was isolated from both groups in September of the same summer (J. Cornick, pers. comm.). Serological tests confirmed that the strain of Vibrio anguillarum isolated from the pink salmon was different from the west coast strain used in the vaccine. Vibrio was not isolated from the Atlantic salmon, but this is probably because they were not examined in August and September, the months of high Vibrio activity. Losses of Atlantic salmon amounted to only 5% in the second summer in sea cages, compared to 40% for the first summer. Following counting and transferring of the Atlantic salmon to a new cage during December, the fish developed lesions on their snouts, sides, and fins. These were diagnosed as comprising Pseudomonas sp. and Aeromonas sp. infections.

PARASITES

Numerous sea lice, Lepeotheirus salmonis, were observed on the Atlantic salmon during their first summer in the sea. These disappeared by December of the first winter and unexpectedly did not reappear in significant number the next summer. Lice infestations were never heavy enough to cause large lesions.

FISH PEN DESIGN AND PERMANENCY OF MOORING SYSTEM

The 12-m fish pens and bottom anchors performed acceptably and withstood winter storms with waves of 1-m amplitude. A great deal of stress was apparently exerted on the ends of the 5.1 x 15.1 cm timber frame where the conveyor belt was attached by bolts, as some of these timbers split. It is recommended that the ends of these timbers be reinforced with larger washers, steel plates, or steel caps.

In contemplating a larger farm of 10 or more fish pens, it is tempting to consolidate the pens adjacent to each other to simplify the procedure of feeding. However, one should consider the potential collision damage such moving structures can have on each other, and could exert collectively as a point source on mooring structures. Farmers located at even the most amenable sites in the area of the Fundy Islands might have to contend with individually moored and serviced fish pens, certainly not an uncommon configuration for many Norwegian farms (Sutterlin and Merrill 1978).

During the first summer, it was soon apparent that several of the pilings had not been driven to sufficient depth to hold the fish pens. One piling lifted and impaled the netting of one of the fish pens. Steel anchors (90 kg) were used to replace the missing pilings. Those pilings that had been driven into the mud to a depth of about 2 m have remained in place and are still in use as mooring points. The reliability of using longer, thinner, hardwood pilings driven to sufficient depth requires further examination; in the meantime, concrete or steel anchors are recommended.

FLOATING DEBRIS

The collection of rockweed (Fucus or Ascophylum), flotsam, and jetsam against the nets and frames of the fish pens was a continual nuisance, especially during the summer months. Rockweed accumulations on the netting provided increased resistance to flow, resulting in considerable distortions of the netting and adding strain on the mooring system. Discarded and dislodged weir stakes, along with trees eroded from the shoreline, posed a continual threat. One pen of pink salmon was eventually lost when a floating tree or piling tore the netting. Problems of floating debris were especially serious during the periods of extreme tides as much of the material deposited in the upper tidal zone was refloated. The prevailing unidirectional tidal flow through the farm, while beneficial in eliminating null periods of flow, contributed to the accumulation of debris on the upstream side of the netting. Although surface ropes and buoys might be effective in diverting some of the flotsam projecting above the water, no simple system of diverting rockweed and submerged debris can be envisioned. A boom, constructed of used tires, functioning as a breakwater, might be effective in diverting floating trees and logs (Shaw and Ross 1977).

MORTALITIES AND INVENTORY

The turbidity of the seawater during the summer months prevented detection of diseased or dead fish that had fallen to the bottom of the fish pen. Hauling up the net in order to detect and remove dead fish was often impossible and would probably be stressful to the fish. Because the mortality rate appears to be much greater for smaller salmon during their first summer in the cages than subsequently for the larger salmon, it is recommended that more frequent inspections by divers be used during the first summer.

BIOFOULING AND ANTIFOULING TESTS

Within 3 wk of being placed in the water, untreated nets became heavily fouled and impossible to purse up, compared with lightly fouled nets treated with the antifoulant Ren Not 750 B. Treated nets remained relatively free of biofouling for 2 mo and did not accumulate as much fouling as untreated nets. Summer fouling consisted mostly of hydroids and recently set mussel spat (Table 11). Filamentous brown algae accumulated during the winter on clean netting set out the previous fall. The fouled netting provided resistance to water flow and resulted in considerable distortion of the geometry of the pen. The rigorous conditions encountered during the winter dictate that stronger netting be substituted in December; the fouling accumulated during the summer can also be eliminated at this time.

On July 13, 1978, seven 2.5 x 0.5 m panels of 2.86-cm stretched, creosote-treated nylon netting,

attached to rolled steel frames, were treated with different antifouling substances and placed in the water at the marine farm. One additional panel was used as a control. The treatments were creosote, Ren Not 750 B, tri-n-butyl tin fluoride (a boat paint), zinc naphthanate and copper naphthanate (wood preservatives), cutch (a tannin compound used as a preservative), and copper chrome arsenate (a rope and sail preservative).

The panels were taken from the water on Oct. 19, 14 wk later. Although all treatments were significantly better than the control, two substances, Ren Not 750 B and tri-n-butyl tin fluoride, were the most effective (Table 11). The relative abundance (Table 12) of the different fouling organisms may also be significant in choosing an antifoulant as predominant fouling organisms may differ from site to site, even over short distances (Knudson 1977). The fouling communities encountered at this site differ considerably from the predominant organisms encountered in the more estuarine site several kilometers away at the Biological Station at St. Andrews (Sutterlin et al. 1976). Blue mussels were less abundant on the panel treated with zinc naphthanate although the net was heavily fouled by other organisms. In areas where the blue mussel is the chief foulant, zinc naphthanate might be useful.

Although effective, the Norwegian antifoulant, Ren Not 750 B, specifically formulated for netting, is expensive at $4.00/L in 1978. In addition, the duty and freight approximately double the cost. Thirty-forty litres of antifoulant mixed with an equal amount of varsol were used to treat one cage. Further studies are required to evaluate the cost-effectiveness of this antifouling agent in the Fundy area.

LONGEVITY OF NETTING USED IN FISH PENS

The 210/15, 2.86-cm stretched-mesh nylon twine used as netting was of questionable worth after only 7 mo in the sea. Although a 210/27, 2.86-cm stretched-mesh nylon netting was substituted for overwintering, a heavier twine, if available, would have been preferred. It is recommended that 210/27, 2.86-cm mesh be used during the first summer and fall and that black 3-mm diameter, 5-cm stretched-mesh polypropylene or nylon netting be considered for overwintering and for the subsequent rearing of larger salmon. The upper limit of mesh size of such netting might be dictated by the size of the harbor pollock (Pollachius virens) that could enter the enclosure during the second summer and compete for food and space.

NET CHANGING AND HARVESTING

Because of the great weight of the fouled netting, it was difficult to purse nets up for changing or to harvest fish. To change nets the first summer, it is recommended that a large-scale operation consider using the winch on a pile driver to lift the fouled nets from the frames after the clean net is positioned beneath. A central loop with several radiating bridles secured into the bottom of the pen and connected to the lead lines could be used to support the netting as it is winched on board the scow or set on shore for cleaning. If only a portion of fish is to be harvested at a time, the center of the pen could be lifted in similar fashion to crowd the fish toward the edge of the pen for dipnetting. A second alternative for harvesting all the fish in the pen would involve towing the pen to the wharf of the processing building at high tide and allowing the net to gradually bottom out as the tide falls. A third possible method would also involve towing the pen to the wharf at high tide, attaching a fixed line to the center bridle of the net and allowing the net to be lifted as the tide recedes. A scow or barge could be used as a work platform for removing the fish and a winch and boom attached to a brailing basket could be used to lift the fish directly to the killing tank situated on the wharf.

OVERWINTERING

Although we were optimistic of the prospects that the salmon would not freeze to death during the winter, we were concerned about icing of the gear, drift ice, and winter storms. During several cold spells in January and February 1979, frozen wash and spray collected on the walkway, jump netting, and bird netting. The added weight caused the vertical support poles to bend inward, adding considerable stress to the frame. In exposed areas where icing is prevalent, the problem might be resolved by lowering much of the exposed superstructure of the pens into the water during the winter. A smaller mesh bird netting could be floated on the surface and supported by a central buoy.

The 12-m pens withstood several storms with a minimum of damage and, although some drift ice was observed floating in nearby coves, it did not enter the area of the fish farm. High winds and waves prevented the feeding boat from reaching the fish pens, often for several days at a time; the effect this had on winter growth rates is uncertain. Maintaining outboard motors and cleaning ice and snow from the service boat was continually a nuisance. No simple and inexpensive solution, other than perseverance, is immediately apparent.

CONCLUSIONS AND RECOMMENDATIONS FOR THE FUNDY ISLES AREA

The growth rates observed in pink salmon and Atlantic salmon are considered excellent. Although pan-sized rainbow trout were successfully reared during this project, biological and economic factors such as growth rates, size at maturity, tolerance to overwintering and competitive market forces, suggest that the culture of Atlantic salmon is more feasible than rainbow trout in the cold, oceanic waters of the Bay of Fundy. Constraints other than growth rates, e.g., lethal winter sea temperatures and early maturity, could still retard the development of Atlantic salmon farming in selected areas in southern New Brunswick. The availability of salmon smolts is expected to limit the amount of research and development that can be achieved in the near future. Although there are several hatcheries rearing Atlantic salmon in eastern Canada, nearly all the production is allocated for restoration and rehabilitation programs. Based upon the results of the Deer Island rearing trials, an allocation of 200 000 smolts, the production of the largest federal salmon hatchery in New Brunswick, could conceivably result in a yearly production of between 400 and 500 tons of salmon from ten farms, each containing twelve, 12-m fish pens. It is therefore recommended that a greater number of salmon smolts be made available at a reasonable cost over the next few years to private growers and researchers. This will

Table 11. Relative abundance of fouling organisms on net panels treated with different antifoulants. A+ - very abundant; A - abundant; C - common; R - rare; VR - very rare.

	Control		Creosote		Ren Not 750B		Tri-n-butyl tin fluoride		Zinc naphtha-nate		Copper naphtha-nate		Cutch		Copper chrome arsenate	
	Top	Bot	Top	Bot	Top	Bot	Top	Bot	Top	Bot[a]	Top	Bot	Top	Bot	Top	Bot
Algae																
Chaetomorpha sp. (fine green)	A	C	A	R	A+	A+	C	C	A		A+	A+	A	A	A+	C
Ulva lactuca (green lettuce)	C	R	-	R	VR	R	VR	VR	VR		VR	R	-	R	VR	-
Porphyra sp. (green lettuce)	R	-	-	-	-	-	-	-	-		-	-	-	-	-	-
Ceramium (strictum?) (small red)	-	R	-	-	-	-	-	-	-		-	-	-	VR	-	-
Spermothamnion sp. (small red)	-	-	-	-	-	-	-	-	-		-	VR	-	-	-	-
Ascophyllum nodosum (rockweed)	R	-	R	-	VR	-	-	-	C		R	-	R	-	R	-
Hydroids																
Tubularia (larynx?)	A	C	A	A	-	-	-	-	C		A	C	A+	A	A	A
Eudendrium sp.	-	A	A	A	-	-	-	-	-		-	C	-	R	R	A
Gastropods																
Lacuna vincta	R	R	R	R	R	R	-	-	-		R	R	R	R	-	-
Nudibranchs																
Coryphella rufibranchialis	C	R	C	-	C	-	-	-	C		C	R	R	R	A	A
Dendronotus sp.	-	-	-	-	-	-	-	-	-		-	-	-	-	R	-
Bivalves																
Mytilus edulis	A+	A	A	R	VR	-	-	-	VR		C	R	A	C	A	C
Hiatella arctica	R	-	R	-	-	-	-	-	-		-	R	-	R	-	-
Polychaetes																
Autolytus cornutus	R	-	-	R	-	-	-	-	-		-	R	-	-	-	-
Flabelligera sp.	-	-	-	-	-	-	-	-	-		-	-	-	R	-	-
Amphipods																
Dexamine thea	A	C	A	C	C	R	R	R	C		A	C	A	A	A	A
Corophium bonelli	R	-	-	-	-	-	-	-	-		-	-	-	-	-	-
Metopa alderi	R	-	-	-	-	-	-	-	R		-	-	-	-	-	-
Pontogeneia inermis	C	C	C	C	R	C	R	C	C		A	C	R	C	R	A
Calliopius laevinsculus	C	C	C	R	A	C	C	-	R		R	C	-	-	R	R
Ischyrocerus anguipes	A	A	C	A	A	A	C	C	C		A	A	C	A	C	C
Caprellids																
Caprella septentrionalis	-	-	-	-	-	-	-	-	-		-	-	-	-	-	R
Insects																
Halocladius variabilis	C	C	C	C	C	C	R	R	R		C	C	R	C	R	C

[a]panel lost.

Table 12. Weight changes due to biofouling of netting treated with antifoulants.

	% increase wet drained fouled weight/clean dry weight	% increase dry fouled weight/clean dry weight
A. Control	2070	435
B. Creosote	1230	260
C. Ren Not 750 B	730	125
D. Tri-n-butyl tin fluoride	600	105
E. Zinc naphthanate	1100	235
F. Copper naphthanate	1470	205
G. "Cutch"	1130	225
H. Copper chrome arsenate	1700	245

be necessary only until private hatcheries can supply the required smolts.

The sharing of a common fish food production facility and salmon processing plant among several marine farms should be considered to reduce the initial, but largely redundant, capital outlay.

A number of technical and engineering problems need to be solved; these are discussed in detail, particularly in the section Special Problems Encountered. Methods of automating food production, mooring fish pens, changing nets, and transferring and counting fish require additional attention. Prevention of biofouling, diversion of floating debris, and the prevention of winter icing on walkways and netting should be considered. Fish farms operating during the winter must either be located in very protected areas or some method must be found to provide walkways or floating breakwaters so that the pens can be serviced safely. Techniques should be examined to utilize the great tidal amplitude as an asset in vertically transporting netting, food, fish and equipment.

Further biological studies should focus on aspects of nutrition and disease. Although we are satisfied with the performance of the moist pellet used in this study, sources of less expensive ingredients and bulk purchases of ingredients should be considered. Monitoring the quality of batches of ingredients should be performed, (ash, fat, protein content, and rancidity). It is not, however, recommended that the basic formulation used in this study be altered until properly conducted nutritional studies on large salmon in fish pens demonstrate that modifications are warranted. The perfection of "custom" formulations that take into account differences in species, age and season will require a great deal of additional work. Disease-susceptible species such as pink salmon and rainbow trout will require an effective and inexpensive vaccine before they can be cultured routinely. It remains to be seen whether or not Atlantic salmon reared at sea temperatures below 13°C will also require prior immunization.

It will be important in the future to develop a reliable source of brood fish to supply eggs to ensure the continuity of marine farming. The low incidence of sexual maturity after 18 mo in the sea requires further study to ascertain its cause and to provide predictive capability for continuing this favorable situation. The incidence of sexual maturation of salmon after two sea-years, and the viability of the eggs produced will require attention.

A survey of existing marketing information suggests that the present demand for Atlantic salmon exceeds the supply, and that this favorable condition should, at least in the short term, encourage salmon mariculture endeavors. The economic projections described in this report should be viewed with caution in light of their preliminary and site-specific nature. Should public funding be forthcoming to assist salmon farmers, a more detailed, economic evaluation should be undertaken. Some regulatory measures relating to the size of farms might be considered to ensure that any social and economic benefits arising from such an industry would be distributed equitably with traditional user-groups in mind.

With the increasing interest in Atlantic salmon mariculture in southern New Brunswick, southwestern Nova Scotia and southern Newfoundland, production of an Atlantic salmon culture manual, applicable to Maritime conditions, should be undertaken in the near future.

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REFERENCES

Alm, G. 1959. Relationship between maturity, size and age in fishes. Inst. Freshw. Res. Drottningholm 40: 4-145.

Allen, K. R., R. L. Saunders, and P. F. Elson. 1972. Marine growth of Atlantic salmon (Salmo salar) in the Northwest Atlantic. J. Fish. Res. Board Can. 29: 1373-1380.

Bailey, J. K., R. L. Saunders, and M. I. Buzeta. 1980. Influence of parental smolt age and sea age on growth and smolting of hatchery-reared Atlantic salmon (Salmo salar). Can. J. Fish. Aquat. Sci. 37: 1379-1386.

Baker, S. R. 1975. Cage rearing of salmonids in coastal areas of Nova Scotia. Internat. Counc. Explor. Sea (ICES), Fisheries Improvement Committee, M:25.

Brett, J. R. 1974. Tank experiments on the culture of pan sized sockeye (Oncorhynchus nerka) and pink salmon (O. gorbuscha) using environmental control. Aquaculture 4: 311-352.

Chadwick, E. M. P., T. R. Porter, and P. Downton. 1978. Analysis of growth of Atlantic salmon (Salmo salar) in a small Newfoundland river. J. Fish. Res. Board Can. 35: 60-68.

Gardner, M. 1976. A review of factors which influence the sea-age and maturation of Atlantic salmon (Salmo salar). J. Fish Biol. 9: 289-327.

Gray, R. W. 1973. Preliminary assessment of the contribution of hatchery-reared smolts (Salmo salar L.) released in 1970-71 in the Saint John River, New Brunswick, to various fisheries and the spawning escapement. Internat. Counc. Explor. Sea C.M.1973/M:25, 20 p.

Gjedrem, T., and K. Gunnes. 1978. Comparison of growth rates of Atlantic salmon, pink salmon, arctic char, sea trout and rainbow trout under Norwegian farming conditions. Aquaculture 13: 135-142.

Godfrey, H. 1961. Method used to distinguish between immature and maturing sockeye and chum salmon taken by Canadian exploratory fishing vessels in the Gulf of Alaska. Bull. Int. North Pac. Fish. Comm. 5: 17-25.

Gunström, G. K. 1968. Gonad weight/body weight ratio of chinook salmon males as a measure of gonad size. Prog. Fish-Cult. 30: 23-25.

Ishida, T., and K. Miyaguchi. 1958. On the maturity of Pacific salmon (Oncorhynchus nerka and O. gorbuscha) in offshore waters with reference to the seasonal variation in gonad weight. Bull. Hokkaido Reg. Fish. Res. Lab. 18: 11-12.

Kennedy, W. A., C. T. Shoop, W. Griffioen, and A. Solmie. 1976. The 1974 crop of salmon reared on the Pacific Biological Station experimental fish farm. Fish. Mar. Serv. Res. Dev. Tech. Rep. 612, 19 p.

Knudson, S. 1977. Testing of antifoulant agents on nets. Norsk. Fiskeoppdrett 2(1): 4-6 (in Norwegian).

LeMessurier, C. 1979. The fishery of Newfoundland and Labrador. Memorial University of Newfoundland Extension Service, St. John's, Nfld.

Møller, D., Ø. Bjerk, and M. Holm. 1976. Comparative growth studies. II. Intern. Counc. Explor. Sea C.M.1976/E:36.

Naevdal, G., Ø. Bjerk, M. Holm, R. Lerøy, and D. Møller. 1979. Growth rate and age at sexual maturity of Atlantic salmon smoltifying aged one and two years. Fisk. Dir. Stir. Ser. HavUnders 17: 11-17.

Naevdal, G., M. Holm, C. Ingebrigsten, and D. Møller. 1978. Variation in age of spawning of Atlantic salmon (Salmo salar). J. Fish. Res. Board Can. 35: 145-147.

Peterson, H. H. 1971. Smolt rearing methods equipment and techniques used successfully in Sweden. Int. Atl. Salmon Found., Spec. Publ. Ser. 2: 32-62.

1973. Adult returns to date from hatchery-reared one-year-old smolts. Int. Atl. Salmon Found., Spec. Publ. Ser. 4: 219-235.

Reddin, D. G. 1980. Changes in weight of Atlantic salmon at West Greenland and its relationship to numbers of fish caught per tonne. Canadian Atlantic Fisheries Scientific Advisory Committee (CAFSAC) Res. Doc. 80/9.

Ritter, J. A. 1972. Preliminary observations on the influence of smolt size on tag return rate and age at first maturity of Atlantic salmon (Salmo salar). Internat. Counc. Explor. Sea C.M.1972/M:14.

1975. Relationship of smolt size and age with age at first maturity. Atl. Salmon Tech. Rep. Ser. MAR/T-75-5.

Ritter, J. A., and M. Newbould. 1977. Relationship of parentage and smolt age to age of first maturity of Atlantic salmon (Salmo salar). Internat. Counc. Explor. Sea C.M.1977/M:32.

Saunders, R. L., and E. B. Henderson. 1965. Precocious sexual development in male post-smolt Atlantic salmon reared in the laboratory. J. Fish. Res. Board Can. 22: 1567-1570.

1976. The attainment of sexual maturity in Atlantic salmon reared at different salinities. Internat. Counc. Explor. Sea C.M.1976/M:17.

Saunders, R. L., B. C. Muise, and E. B. Henderson. 1975. Mortality of salmonids cultured at low temperature in seawater. Aquaculture 5: 243-252.

Scott, D. P. 1962. Effect of food quantity on fecundity of rainbow trout Salmo gairdneri. J. Fish. Res. Board Can. 19: 715-731.

Shaw, G., and N. Ross. 1977. How to build a floating tire breakwater. Information Bull. #1, Univ. Maine/Univ. New Hampshire Cooperative Institutional Sea Grant Program.

Simpson, T. H., and J. E. Thorpe. 1976. Growth bimodality in the Atlantic salmon. Internat. Counc. Explor. Sea C.M.1976/M:22.

Sutterlin, A. M., P. R. Harmon, and H. Barchard. 1976. The culture of brook trout in salt water. Fish. Mar. Serv. Res. Dev. Tech. Rep. 636, 21 p.

Sutterlin, A. M., P. R. Harmon, and B. Young. 1978. Precocious sexual maturation in Atlantic salmon (Salmo salar) postsmolts reared in a seawater impoundment. J. Fish. Res. Board Can. 35: 1269-1272.

Sutterlin, A. M., and S. P. Merrill. 1978. Norwegian salmonid farming. Fish. Mar. Serv. Tech. Rep. 779, 47 p.

Thurow, F. 1966. Beitrage zur biologie und bestandskunde des Atlantischen laches (Salmo salar L.) in der Ostsee. Ber. Dtsch. Wiss. Komm. Meeresforsch. 18: 223-379. (Fish. Res. Board Can. Transl. Ser. No. 1211.)

Wagner, H. H. 1967. A summary of investigations of the use of hatchery-reared steelhead in the management of a sport fishery. Research Division, Oregon State Game Commission, Fish. Rep. No. 5.

Appendix 1. Sources of advice and information on selected aspects of salmonid aquaculture in the Maritime region.

Aquaculture Permits and General Inquiries

Mr. Roy E. Drinnan (902) 426-7744
Aquaculture Coordinator
Fisheries & Environmental Sciences Div.
Resource Branch
Department of Fisheries & Oceans
P.O. Box 550
Halifax, N.S. B3J 2S7

Fish Nutrition

Dr. Santosh P. Lall (902) 426-6272
Dr. John Castell
Fisheries & Environmental Sciences Div.
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P.O. Box 550
Halifax, N.S. B3J 2S7

Importation, Certification and Fish Health

Dr. Robin MacKelvie (902) 426-6270
Mr. J. W. Cornick
Fish Health Unit
Fisheries & Environmental Sciences Div.
Resource Branch
Department of Fisheries & Oceans
P.O. Box 550
Halifax, N.S. B3J 2S7

Freshwater culture of salmonids in Hatcheries

Mr. George Robbins
Freshwater and Anadromous Division
Department of Fisheries & Oceans
P.O. Box 550
Halifax, N.S. B3J 2S7

Provincial Officials Involved in Aquaculture in N.B.

Mr. Russel Henry (506) 453-2253
Kerry Wilson and
Nihat Ozerdem
Research and Development Branch
N.B. Dept. Fisheries
King's Place, P.O. Box 6000
Fredericton, N.B. E3B 5H1

Mr. Bill Groom
Regional Coordinator
Fundy District
N.B. Dept. of Fisheries
P.O. Box 5001
St. Stephen, N.B.

Mooring Permits in Navigable waters

Mr. Bill Beck (506) 658-4726
in the office of the
District Manager
Canadian Coast Guard
P.O. Box 6730
Station A
Saint John, N.B. E2L 4B6

Mr. B. Williams (902) 426-2726
Aids and Waterways Division
Transport Canada
Canadian Coast Guard
P.O. Box 1013
Dartmouth, N.S. B2Y 3Z7

Appendix 2. Ingredients, prices, and sources of commercial dry fish pellets.

Possible moist diet formulations and cost of ingredients based on 1979 prices. Preparation and freezing costs not included.

	Sutterlin et al. (1976)	Mariculture project 1978-79	Alternate formulations #1	#2	#3	#4
Fish (gaspereau)	44.30%	29.0	43.2			
Fish (waste)		19.0		50.0	50.0	50.0
Herring meal	35.80%	32.0	20.0	20.0	11.4	11.4
Wheat middlings	10.20%				10.0	10.0
Whey powder	2.14%					
Soya meal			10.0	10.0		
Shrimp meal		13.4	20.0	13.2	10.0	20.0
Feather meal					10.0	
Herring oil	5.55%	5.7	5.7	5.7	7.5	7.5
Vitamin premix	1.14%	0.8	1.0	1.0	1.0	1.0
Ascorbic acid	0.09%	0.1	0.1	0.1	0.1	0.1
Choline chloride	0.47%					
Price/kg wet weight	$ 0.393	$ 0.40	$ 0.393	$ 0.336	$ 0.300	$ 0.327
Percent moisture	27	34	30	30	30	30
Price/kg dry weight	$ 0.541	$ 0.605	$ 0.561	$ 0.480	$ 0.429	$ 0.467

Prices of ingredients (1979). Transport and freezing costs not included

Ingredients	$/kg
Herring meal	0.53
Fish meal	0.55
Shrimp meal	0.55
Soya meal	0.36
Tuna meal	0.34
Feather meal	0.38
Wheat middlings	0.18
Whey powder	0.39
Herring oil	0.55
Vitamin premix	1.00
Ascorbic acid	14.81
Trash fish from local fishery	0.18
Fish waste	0.09
Gaspereau	0.13
Herring	0.12

Companies distributing dry fish feeds to eastern Canada

Astra Ewos Chemical Limited
Canadian Representative
Rundell Feeds Limited
Palmerston, Ont. and
Chambley, P.Q.

Martin Feed Mills Limited
Elmira, Ont.

Ralston Purina Limited
Montreal, P.Q.
Sales Rep., Way-Bar Feeds
Sussex, N.B.

Sterling H. Nelson & Sons, Inc.
Murray Elevator Division
Murray, Utah

Co-op Atlantic Limited
Moncton, N.B.

Appendix 3. Canadian landings of Atlantic salmon 1968-79.

Year	Quantity 000 (lb)[a]	Value $000	Landed price value per lb ($)
1968	4634	2330	.50
1969	4291	2285	.53
1970	4615	2727	.59
1971	4048	2267	.56
1972	3355	2130	.63
1973	4796	3471	.72
1974	4883	3657	.75
1975	4876	3617	.74
1976	4815	4270	.89
1977	4693	5489	1.17
1978	3080	4459	1.45
1979	2361	3668	1.55

[a]Landed weight
Canadian Fisheries - Primary Sector Fisheries and Oceans
Source: Fisheries Statistics Canada
Statistics Canada: Catalogue No. 24-201

Appendix 4. Consumption of fresh and frozen Atlantic salmon in Canada 1968-78.

	(000 lb)		
Year	Production	Exports	Domestic consumption
1968	5247	2052	3195
1969	2903	1636	1267
1970	3725	1252	2473
1971	3524	1542	1982
1972	2577	1346	1231
1973	4586	1729	2857
1974	3582	1028	2554
1975	4087	1354	2733
1976	3188	1612	1576
1977	2717	1599	1118
1978	2119	1097	1022

Source: Statistics Canada
Catalogue No. 24-201; 65-202.

Appendix 5. Canadian production of Atlantic salmon by product from 1968-78.

	(000 lb)				
Year	Fresh	Frozen	Pickled	Canned	Total
1968	4046	1201	90	88	5425
1969	1897	1006	189	29	3121
1970	2518	1207	28	44	3797
1971	2101	1423	28	17	3569
1972	1514	1063	96	10	2683
1973	2761	1825	248	*	4834
1974	2129	1453	53	317	3952
1975	2630	1457	154	*	4241
1976	1722	1466	154	64	3406
1977	1346	1371	*	*	2717
1978	1375	744	*	*	2119

*Not available

Source: Fisheries Statistics of Canada
Statistics Canada: Catalogue No. 24-201 1968-76.

Annual Statistical Review of Canadian Fisheries
1978 Department of Fisheries and Oceans 1977-78

Appendix 6. Total value of Canadian production of Atlantic salmon by product from 1968-78.

Year	($000) Fresh	Frozen	Pickled	Canned	Total
1968	3677	1232	59	101	$5097
1969	1870	1140	134	33	3216
1970	2925	1573	24	56	4624
1971	2445	1946	20	23	4474
1972	2098	1588	17	14	3717
1973	3887	2842	45	*	6774
1974	3182	2211	16	35	5444
1975	4414	2468	46	*	6928
1976	3158	2719	42	8	5927
1977	3144	3307	*	*	6451
1978	3382	2165	*	*	5547

*Not available

Source: Fisheries Statistics of Canada
Statistics Canada: Catalogue No. 24-201.

Appendix 7. Price per pound of Canadian production of Atlantic salmon by product from (FOB plant) 1968-78.

Year	Fresh	Frozen	Pickled	Canned
1968	.91	1.03	.66	1.15
1969	.99	1.13	.71	1.14
1970	1.16	1.30	.86	1.27
1971	1.16	1.37	.71	1.35
1972	1.39	1.49	.94	1.40
1973	1.40	1.56	*	*
1974	1.49	1.52	*	*
1975	1.68	1.69	*	*
1976	1.83	1.85	*	*
1977	2.34	2.41	*	*
1978	2.46	2.91	*	*

*Not available.

Source: Fisheries Statistics Canada
Statistics Canada: Catalogue No. 24-201.

Appendix 8. U.S. imports of Atlantic salmon from Canada 1968-78.

Year	Quantity (000 lb)			Value ($000)			Price/lb ($)	
	Fresh	Frozen	Total	Fresh	Frozen	Total	Fresh	Frozen
1968	449	469	918	377	447	824	.84	.95
1969	331	294	625	287	378	665	.87	1.29
1970	461	313	774	491	463	954	1.07	1.48
1971	202	169	371	210	213	423	1.04	1.26
1972	224	203	427	261	266	527	1.17	1.31
1973	184	425	609	248	610	858	1.35	1.44
1974	305	266	571	416	360	776	1.36	1.35
1975	202	267	469	338	397	735	1.67	1.49
1976	140	270	410	294	764	1058	2.10	2.83
1977	181	172	353	437	371	808	2.41	2.16
1978	201	238	439	490	680	1170	2.44	2.86

Source: Exports, Merchandise Trade
Statistics Canada Catalogue No. 65-202.

Appendix 9. Atlantic salmon exported to U.S. expressed as percentage of total exports/total catch 1968-78.

Year	Fresh		Frozen	
	Percent of salmon exported	Percent of total Canadian fresh production	Percent of salmon exported	Percent of total Canadian frozen production
1968	98.9	11.1	29.3	39.1
1969	99.7	17.4	22.5	29.2
1970	94.9	18.3	40.9	25.9
1971	99.5	9.6	12.6	11.9
1972	99.6	14.8	18.1	19.1
1973	93.9	6.6	27.8	23.3
1974	98.7	14.3	37.0	18.3
1975	100.0	5.5	23.1	18.3
1976	98.6	8.1	18.4	18.4
1977	100.0	13.4	12.1	12.5
1978	98.5	14.6	26.7	32.0

Markets for frozen salmon in order of importance 1974-78

1. West Germany
2. United States
3. United Kingdom
4. Denmark
5. Sweden

Source: Fisheries Statistics of Canada
Statistics Canada: Catalogue No. 24-201.

Appendix 10. Example of price structure for fresh Atlantic salmon from supplier to customer 1978 (price/lb).