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by

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ECOLOGICAL DISRUPTION OF ATLANTIC SALMON (Salmo salar) RUNS IN THE SAINT JOHN RIVER, NEW BRUNSWICK, CANADA

by

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SUMMARY

*Deterioration of water quality as a result of the disposal of untreated organic and toxic wastes into the Saint John River Basin began when the river was first settled in 1604, and the amount of waste entering the river has increased substantially over the past two decades. Hydroelectric power developments constructed on the main stem during this recent period have added to the problem by reducing the biological assimilative capacity of the river. The significance of these cultural influences for Atlantic salmon (***Salmo salar****) in the river has been to reduce the quality of its migration route to and from the sea, to eliminate some of its freshwater spawning and rearing areas, and to cause direct mortality of adult and juvenile salmon. As a consequence, the total salmon stock in the Saint John River has declined by approximately 40% over the past two decades. The future prospects for conserving this valuable natural resource in the Saint John River are moderately bright in view of current activities in water pollution abatement, effective regulation of the salmon fisheries, and large-scale artificial propagation.*

As is the case with many other large rivers in Canada, the water resources of the Saint John River Basin are used for varied purposes, some of which are in direct conflict with others. The major uses of water in the river are exerted by waste disposal from industries and municipalities, hydroelectric power, fisheries, wildlife, recreation, and water supply for industries and municipalities. History records that the problem of waste disposal and its conflict with other water users was recognized in the Saint John River Basin as early as 1912. This deterioration has continued and is exacerbated today by increased pollution loads and by a reduction in the biological assimilative capacity of the river as a result of hydroelectric power developments.

The purpose of this paper is to review cultural events up to the present in the Saint John River and to present an assessment of the impact of these events on Atlantic salmon *(Salmo salar)* stocks in the river.

DESCRIPTION OF THE RIVER BASIN AND THE FISHERIES

The Saint John River Basin originates in the State of Maine at an elevation of 482 m.and flows some 676 km. to empty into the Bay of Fundy at the City of Saint John (Fig. 1). The river is international and interprovincial; about 38% of its total drainage area of 54,934 sq.km. lies in the State of Maine, almost 53% in the Province of New Brunswick, and the balance (9%) in the Province of Quebec.

Fig. 1 near here

The first Canadians used the river as a transportation route. In 1604 they began to settle along the fertile valley where the population grew until today it totals about 420,000 people, including 300,000 in New Brunswick, an estimated 100,000 in the State of Maine, and 20,000 in Quebec. The demands that these inhabitants have made on the basin's water resources in recent decades have been mostly detrimental to the 16 economically important species of fish that depend on the river for their existence.

Atlantic salmon are taken by commercial fishermen both in the river estuary, and off the river mouth in the Bay of Fundy. A proportion of the Saint John River salmon stock is also taken in sea fisheries off the coasts of Newfoundland, West Greenland and Nova Scotia. The reputation of the river among salmon anglers has suffered during the past two decades and the sport catch of salmon has declined to less than one-third of the level in the early 1950's.

Alewives *(Alosa pseudoharengus)*, American shad *(Alosa sapidissima)*, and striped bass *(Roccus saxatilis)* are fished by commercial fishermen in the estuary and harbour area. Landings of the first two species have declined in recent years. This reduction is at least partially attributable to decreased market demand. Other commercially fished species of less significant value include Atlantic sturgeon *(Acipenser oxyrhynchus)*, smelt *(Osmerus mordax)*, American eel *(Anguilla rostrata)*, chain pickerel *(Esox niger)*, lake whitefish *(Coregonus clupeaformis)*, and suckers *(Catostomus commersoni* and *C. catostomus)*.

Other species fished for sport in the Saint John River Basin include landlocked Atlantic salmon and lake trout *(Salvelinus namaycush)* in some of the headwater lakes, striped bass in the estuary, and rainbow trout *(Salmo gairdneri)*, brown trout *(Salmo trutta)*, speckled trout *(Salvelinus fontinalis)*, smallmouth bass *(Micropterus dolomieui)*, and chain pickerel in various rivers and lakes throughout the basin. In addition to these economically important species, there are 41 other species of fish reported from the lower basin and the estuary (Meth, MS1971).

ECOLOGICAL DISRUPTION

Pollution

Pollution from untreated municipal and industrial waste disposal is a serious environmental problem in the Saint John River Basin. This can be seen (Table I) by reviewing the 5-day Biological Oxygen Demand (BOD_5) of effluents entering the upper, middle and lower basin (including main river and its tributaries) from industries and municipalities in both Canada and the United States.

TABLE I

The biological oxygen demand of all wastes entering the Saint John River from the United States and Canada[1]

Location		BOD_5 (lb)
Upper Basin	Canada	337,665
	United States	173,090
Middle Basin	Canada	51,715
	United States	146,470
Lower Basin	Canada	234,534[2]

1 Source: H. G. Acres Limited report to the Department of the Environment of Canada, March 1971.

2 Source: Montreal Engineering Company Limited report to the Saint John River Basin Committee, August 1970.

Of the 33 industries located in the basin, only 8 have waste treatment works and some of these provide only partial treatment of the effluent. Similarly in the case of communities, only 19 of the 39 in the basin have provided sewage treatment facilities.

Fig. 2 ar here

Aquatic life in the river has suffered not only because of the magnitude of the pollution load but also because of the location of major sources of pollution. Approximately 48% of the total BOD load in the river emanates 415 km above the river mouth at the pulp mill in Edmundston, New Brunswick and the paper mill directly across the river in Madawaska, Maine. The effects of these wastes are reflected in impaired water quality many miles downstream (Fig. 2). An additional 20% of the total BOD load is released to the middle portion of the main river and three of its tributaries from over one dozen potato processing and starch plants. Two pulp and paper mills in the City of Saint John discharge a further 22% of the total BOD load into the river at its mouth. The remaining proportion of the BOD load (10%) is derived from municipalities and smaller industries scattered throughout the basin.

The impaired water quality of the Saint John River is reflected in the dissolved oxygen profile (Fig. 2) which shows minimum values of less than 5 mg/l at the surface of the three main stem hydroelectric head ponds and also in the flowing water between Grand Falls Dam and Beachwood Headpond. It is not until the river has passed Mactaquac Dam that it has an extended opportunity to recover dissolved oxygen to a level capable of sustaining a healthy aquatic environment.

Other types of pollution include toxic constituents from industrial plant effluents and siltation from agricultural lands together with insecticides, herbicides, fungicides, and nutrient fertilizers in the runoff. In the past, forest spraying with DDT to control the spruce budworm was carried out in the basin over a 16-year period (1953-1968) and the adverse effects on salmon have been documented (Elson, 1967; Elson & Kerswill, 1964).

Hydroelectric Dams

Hydroelectric development in the Saint John River Basin began in 1906 when the Aroostook River in Maine was dammed near its mouth. Passage facilities for anadromous fish were not provided at this site until 1936. When the dam was rebuilt in 1965, no provision was made to pass fish due to the heavy load of organic waste entering the Aroostook River from food processing and starch plants and domestic sources.

The first hydroelectric dam in the Canadian portion of the basin was constructed in 1928 on the main stem at Grand Falls. A natural, impassable waterfall had always existed at this site and, because anadromous fish were never able to pass Grand Falls, no fish passage facilities were installed in the dam. The next power dam was built in 1953 at the mouth of the Tobique River, a major salmon producing tributary. A large pool and weir fishway was incorporated in this structure.

Similarly, provision was made for the passage of anadromous fish in Beechwood Dam built on the main stem in 1957, and at the Mactaquac Dam which was constructed 11 years later at a site on the main river 18 km upstream of Fredericton. A large salmon hatchery was also constructed at Mactaquac Dam to supplement the smolt run that was adversely affected by habitat destruction and turbine mortality (Carey, 1970).

The demands placed on the Saint John River for power and waste disposal have had a severe impact on the aquatic ecology with resultant detrimental effects on salmon stocks. The assimilative capacity of the river for organic wastes has been reduced by the formation of headponds above the three mainstem dams. Several factors are operative in this situation: (1) reaeration coefficients in the ponds have decreased in the order of 12-fold; (2) organic wastes in the river have an opportunity to settle in the ponds, thereby creating a bottom oxygen demand which continues to deplete dissolved oxygen, even if the effluent discharge ceases; and (3) anaerobic conditions are created in parts of the ponds.

Two other problems have been identified in association with the dams: (1) supersaturation of the water below Mactaquac Dam by nitrogen gas; and (2) large daily fluctuations in the river flow below the dams as a result of regulation of the water for hydroelectric power generation.

EFFECTS ON ATLANTIC SALMON

Salmon Abundance

Despite serious encroachment on its habitat and the impairment of the water quality along the migration route, Atlantic salmon still return in large numbers to the Saint John River. This is reflected in estimates (Table II) of the magnitude of catch and spawning escapement during the past two decades.

TABLE II

Average number of salmon in the spawning escapement and taken by commercial fishermen and anglers in the Saint John River from 1949 to 1970.

Time Period	Commercial Fishery[1]	Sport Fishery	Spawning Escapement	Total
1949-53	19,400	3,600	8,000	31,000
1958-62	13,800	2,100	2,800	18,700
1966-70	11,500	1,100	5,500	18,100

[1]Includes the off-harbour and harbour drift net fishery, and the estuary trap net fishery.

These figures indicate that the magnitude of the salmon resource has declined to about 60% of the level that existed two decades ago, before the area was sprayed with DDT, before hydro-power dams at Tobique, Beechwood and Mactaquac were constructed, and before the river became overloaded with pollution from industrial and municipal sources.

The salmon sport fishery has suffered most severely from the changes that have taken place in the river. Over the past two decades the number of salmon taken by anglers has declined by 70%.

The Tobique River sport catch in particular declined from 2206 fish in 1951 to 65 fish in 1957 (Fig. 3). It has never recovered, despite the large runs of 3000-5000 salmon into the river in the years 1963, 1964 and 1965 (Fig. 4). The Tobique River lost its reputation as a salmon angling stream during the 1950's and as a result many guides and sportman's outfitters along the river went out of business. Thus, even when a good run of fish appeared, there were few people left to take advantage of it and, as a result, the the fishing effort was low. Angling success is a complex function of many factors including rod effort, water level and temperature, suitability of holding pools, and the presence of fresh-run fish (Gardner, 1971). The same author (ibid) found no correlation between the fishway trap count at Pitlochry Dam in Scotland and the number of salmon caught in the river below and he concluded that angling catches are not necessarily a reliable index of the number of salmon running up a river. Data from the Tobique River support this conclusion.

Fig. 3 near here

Fig. 4 near here

Total salmon counts through the fishway in Tobique Dam (Fig. 4) present a good example of the effects of a combination of factors on a salmon population. These factors are forest spraying with DDT for six consecutive years (1953-58) and dam construction. Elson & Kerswill (1964) present a strong case attributing most of the damage to salmon stocks in the Tobique River to the persistent spraying over two salmon generations with DDT. On the basis of spray history and assessments of juvenile salmon abundance in the river, these authors correctly predicted that the run would recover in 1963 and continue to increase through 1965.

Salmon angling in the main river below Beechwood Dam appears to have benefited temporarily from construction of the dam in 1957 (Fig. 3); for example, in 1958, 1964 and 1965 the catch was over 2,000 fish and in 1963 it was over 3,000 fish. This can be explained firstly by the large natural increase in the salmon run in the early 1960's (Fig. 4) and secondly by the holdup of fish below the dam due to fluctuating river flows and to the problems salmon encountered in finding and entering the collection facility. Improved angling in this part of the main river was short-lived however because of the construction of Mactaquac Dam in 1968.

Some of the angling pools were flooded by the new headpond, and in addition, water quality had deteriorated to the extent that salmon collected at Mactaquac during the 1968 season were not transported in any numbers to the main river below Beechwood Dam. Since 1967 all salmon not required as brood stock in the hatchery program have been trucked overland from the fish collection facilities at Mactaquac Dam to upriver points, mainly the Tobique River. Other anadromous species have been released into the upper portion of Mactaquac Headpond.

There is evidence (Mills, 1965; Gardner, 1971) from Scotland to the effect that declines in the number of salmon in a river after dam construction may be followed by progressive improvement in the stock size. Gardner (1971) concludes that hydroelectric developments are not responsible for the declines in the spring runs of salmon, the increases in late summer and autumn runs in the River Tummel, or for the decrease in the average weight of salmon in the river. Dams are the only apparent form of ecological disruption in the Scottish rivers under study. One might speculate that, in the case of the Saint John River, which has several dams and a great deal of pollution, reductions in the number of salmon are probably due more to pollution than to hydroelectric developments. However, the presence of large bodies of impounded water behind dams along the mainstem of the river appears to provide an opportunity for much of the organic and toxic wastes to settle and because of the lack of aeration in the impoundments, these areas tend to become heterotrophic (Watt, MS 1972). As such they are not suitable for salmonids or any other species of desirable sport fish.

Loss of salmon smolts due to delay in the headponds and turbine mortality.

Two major concerns of salmon biologists involved in the planning of Mactaquac Dam were the adverse effects on smolt survival of migration delay in hydroelectric power headponds and losses resulting from passage through turbines. Raymond (1969) concluded that in the Columbia River juvenile chinook salmon *(Oncorhynchus tshawytscha)* move only about one-third as fast through impoundments as through free-flowing stretches of river. In Scotland, smolt losses in impoundments have been attributed to delay and predation by birds and fish (Pyefinch, 1966). Results there show losses of 13.4%, 28.7% and 20.7% in successive years and it is suggested that in cases where the downstream migration is delayed, the migratory urge wanes and migration ceases.

Turbine mortality for silver *(Oncorhynchus kisutch)* and chinook salmon and steelhead trout *(Salmo gairdneri)* may range from 9-55% depending upon tailwater levels and turbine operating conditions including: (1) net hydraulic head, (2) water speed, and (3) turbine setting (Cramer & Oligher, 1964). Information from Scotland on Atlantic salmon indicates that about 10-20% of the migrant smolts may be damaged as they pass through turbines (Pyefinch, 1966). If a 25% turbine mortality is assumed at each dam in the Saint

John River, then the accumulative mortality for Tobique River native smolts could reach 58%. For most years, however, it is felt that this estimated mortality may be unrealistically high.

Salmon smolts in the Saint John River leave freshwater for the sea in the spring of each year at a time when water flow is high and water is often spilling over the crest of the dams. Under these conditions, a large number of smolts could pass unharmed over the dams rather than through the turbines. There is evidence in 1971 that there is good survival of smolts from the river basin above Mactaquac Dam; over 90% of the adult salmon returning from the sea to the Mactaquac fish collection facilities had been produced naturally in the middle portion of the basin above the dam. The remainder of these fish were hatchery-reared at Mactaquac Dam Salmon Culture Station.

Recent Fish Kills in the Saint John River.

Fish have been killed below Mactaquac Dam as a result of gas bubble disease caused by exposure to water supersaturated with dissolved nitrogen gas. MacDonald & Hyatt (in preparation) confirmed that nitrogen supersaturation does occur at minimum flow rates through the turbines, particularly on weekends when the demand for electrical power is much reduced. Death by gas bubble disease has been positively identified in two species of fish: Atlantic salmon and American eels.

At Mactaquac Hatchery there have been some fish kills that could not be attributed to low dissolved oxygen or nitrogen super-saturation. A series of laboratory tank bioassays were conducted in 1969 using aerated water from three different depths in Mactaquac Headpond in the vicinity of the hatchery water supply intakes. All tests were for 96 hours and employed salmon parr as test organisms (Table III).

It is tentatively concluded from these data that there were toxic constituents in the river water in April. There are indications that the April mortalities occur at a time when lignosulphonates are at high, but not lethal, concentrations in Mactaquac Headpond. Lignosulphonate is an indicator of the stage of effluent breakdown from the pulp and paper mills upriver. The toxic constituents causing fish mortalities might therefore be associated with the effluent from these mills. This topic needs further study.

The use of pesticides (insecticides, herbicides and fungicides) for agricultural crop treatments has become a significant source of local pollution in the basin. Farmers use small streams as a source of water for their sprayers and overflow from this equipment is allowed frequently to run into the stream. Complete eradication of the fish stock

TABLE III

Percent mortality of Atlantic salmon parr in laboratory bioassays using aerated water from three depths in Mactaquac Headpond in 1969[1].

Depth in Headpond	Date	Per Cent Mortality[2]
12 m	April 11	100
12 m	April 15	No mortality
1 m	April 17	70
12 m	April 17	100
30 m	April 17	90

[1]Source: MacDonald, *et al.* MS 1970.

[2]No mortality occurred at any of the three depths on March 24, 27 and 30; June 3; and July 10.

in a hatchery near Grand Falls Dam in 1961 was traced to the careless use of pesticides and spraying equipment. Thousands of fish were killed at a fish hatchery below Beechwood Dam in 1965 when potato spray was released into the hatchery water supply stream. A fish kill in 1969 involving speckled trout on Portobello Creek below Fredericton was attributed to the careless handling of pesticide sprays. These examples of fish kills resulting from the careless use of agricultural pesticides probably do not give a complete picture of the extent of the damage because many kills occur in remote areas of the basin and therefore do not come to the attention of regulatory agencies.

In the late summer of 1970 a series of bioassays were conducted in the Saint John Harbour area using speckled trout (Table IV). These data show that the fish did not survive in the surface water of the harbour.

TABLE IV

Per cent mortality of juvenile speckled trout held in cages in the Saint John Harbour area in 1970[1].

Location	Date and Length of Test	Per Cent Mortality
1 kilometer above	August 31	
Reversing Falls[2]	5 days	No mortality
	September 9	
	2 days	No mortality
0.5 kilometer below	September 1	
Reversing Falls	8 hours	100
	September 9	
	24 hours	100
	September 14	
	2 1/2 hours	100
1.5 kilometers below	September 9	
Reversing Falls	24 hours	100
	September 14	
	24 hours	100
2.5 kilometers below	September 1	
Reversing Falls	4 days	20
Mispec Bay, outside	September 15	
Harbour (in Bay of Fundy)	36 hours	No mortality

[1]Source: Mr. J. R. MacDonald, personal communication.

[2]Reversing Falls designates the upriver extremity of Saint John Harbour; the harbour is approximately 5 kilometers long.

Data on the depth of capture of salmon in the gill nets of commercial fishermen in Saint John Harbour reveal that fish travel deeper in the harbour water than they do in the Bay of Fundy off the mouth of the Saint John River (Mr. C. E. Wykes, personal communication). In view of this observation and the results contained in Table IV, it is concluded that the surface water quality of Saint John Harbour leaves much to be desired and that delays may occur in the migration of fish into or out of the harbour.

FUTURE OF THE SAINT JOHN RIVER

An example of improved water quality resulting from reduced pollution load in the Saint John River.

In 1971, an opportunity became available to assess the effects on the water quality of the river of a considerable reduction in the flow of pulp mill effluent from the Edmundston operations. On July 9, a strike of workers at the paper mill in Madawaska, Maine, resulted in a decreased demand for pulp from the Edmundston mill. The strike lasted for nine weeks and during this period pulp production was reduced to approximately 10% of the normal output.

In previous years, Grand Falls Headpond has been the most severely affected portion of the river as a result of effluent disposal from the Edmundston pulp mill. Throughout the late 1960's, dissolved oxygen measurements in Grand Falls

Headpond showed a gradual deterioration in water quality through the summer so that by August the oxygen concentration had fallen below 5.0 mg/l. However, in July of 1971 after three weeks of reduced BOD loading, a reversal of the summer decline had occurred (Fig. 6)(Mr. H. A. Hall, personal communication). The dissolved oxygen concentration in the headpond just above Grand Falls Dam increased from 4.3 mg/l on July 12, 1971, to 7.7 mg/l on July 28, 1971, and the situation was similar at other locations between the mill and Grand Falls Dam. The rapid improvement of dissolved oxygen levels in Grand Falls Headpond during the summer of 1971 is an encouraging indication of the benefits to the aquatic environment that may be anticipated following pollution abatement at the Edmundston-Madawaska Mills.

Fig. 6 near here

The Interim Plan for Water Quality Management.

The Saint John River Basin Board was established in 1970 under an agreement between the Federal Government of Canada and the Provincial Government of New Brunswick to provide an inter-jurisdictional cooperative approach to comprehensive planning, development and management of the water resources in the Saint John River Basin. The Board reviewed water quality and the demands for water use in the river in 1970 and concluded that the most urgent problem in the basin results from the disposal of industrial and municipal wastes. The Board felt that the significance of this waste disposal practise is such that the pollutants, many of which have a high organic content, have affected the basic ecosystem of the waters of much of the Saint John Basin, thus limiting many other desirable uses of the water.

The purpose of the 1970 interim plan was to reduce the gross pollution in the river while a refined plan for optimal water use was being developed. The Board recommended that within the period up to June 1973, action to abate pollution be taken that is technically possible, reasonable and attainable for all major waste disposers. Specifically, the Board recommended that the Edmundston pulp mill reduce its present pollution load of BOD by at least 90%; that the food processing plant at Florenceville (located about 16 km below Beechwood Dam) provide secondary treatment for its effluent; that the largest pulp and paper mill in the City of Saint John reduce its present pollution load of BOD by at least 90%; and that discussions commence immediately between Canada and the United States on appropriate steps to reduce waste inputs to the Saint John River Basin from the State of Maine.

To date, officials of the Edmundston pulp mill have agreed to take appropriate action before December, 1975, to reduce their BOD loading by 95% and to produce an effluent that will be non-toxic to salmon at 65% concentration. The largest pulp and paper mill in the City of Saint John has begun to take action to eliminate its flow of effluent into Saint John Harbour by December 1972. Construction has also commenced on a primary treatment system for another pulp and paper mill in the City of Saint John.

When these pollution abatement procedures become operational, the result will be a reduction of approximately 53% in the total BOD load to the river.

The Comprehensive Planning Study.

In their review of recent comprehensive planning studies of water resources undertaken in Canada, Forbes & Hodges (1971) state that the prime function of planning is to provide information for decision making. In 1970, under the aegis of the Saint John River Basin Board, such a planning study began to devise a water management plan for the Canadian portion of the basin. The objective of this project will be to issue a water-management plan aimed at improving the quality of the river's water without worsening the economy of the Province of New Brunswick. In an effort to put the water management problems of the Saint John River into perspective, this project will proceed while government agencies continue to insist that industries and municipalities curb their untreated wastes. Gaps in information concerning the ecological, hydrological and socio-economic effects of long-range planning for the river are currently being filled in.

Particular emphasis is being placed on obtaining a better understanding of the aquatic ecology. A botanist, a zoologist and a fishery biologist are engaged in describing and cataloguing the aquatic flora and fauna in the basin. Primary productivity in the main stem and Tobique tributary headponds is being elucidated and the order of magnitude of secondary and tertiary production is being estimated. The primary aim of these biological investigations is to provide information on how the biological systems in the headponds have adjusted to the present pollution load, and to predict their probable response to change. The extent of eutrophication and heterotrophication in the headponds will be measured, and the biological stability of each system will be estimated along with the potential for biological manipulation. A model will be developed to predict the probable biological consequences of change in input of sewage, industrial wastes and agricultural run-off.

Salmon Management

Because of the increased imposition of adverse conditions on salmon stocks in the Saint John River since the 1950's, together with concommitant expenditures of effort and financial resources by government fishery agencies, the emphasis for these agencies has now shifted from the single role of protecting the environment to a dual activity of environmental protection and scientific fisheries management. This larger, more important role was accelerated in 1968 when the Mactaquac hydroelectric power station was constructed. The location and size of this dam resulted in the individual handling and mechanical transportation of all fish destined for the upper parts of the river.

A portion of the salmon run in the Saint John River Basin is now maintained by artificial means, involving in particular the fish collection facilities at Mactaquac Dam, the overland fish transporting system, and the large smolt-rearing establishment below Mactaquac Dam. Each year, approximately 1,000 salmon from the collection facilities are selected for use as broodstock in the hatchery, and the remainder of the run is transported to the main Saint John River above Mactaquac Headpond and to the Tobique River for the purposes of angling and natural spawning.

Perhaps the most important feature in the approach to management of salmon in the Saint John River is the selective breeding program being persued at Mactaquac smolt rearing station (Carey, 1970). The first step in this important program is to duplicate as nearly as possible the genetic characteristics of the normal population, then to proceed cautiously by crossing fish of different backgrounds and to carefully evaluate the results of these selections. Evaluation criteria will include growth rates, survival, and contribution to various fisheries of all genetic crosses.

Since 1969, the commercial and sport fisheries for Atlantic salmon in the Saint John River have been restricted by specific regulations that were imposed to ensure adequate seeding for the hatchery and for natural reproduction. In 1969 the commercial fisheries were permitted to operate two days weekly until mid-June, three days weekly for the third week in June and for the regular five days thereafter; the sport fishery was not changed. In 1970 and 1971, the closure implemented consisted of a staggered two week period which restricted all commercial fishing in the Bay of Fundy and Saint John Harbour area for the second and third week in June, in the area above Saint John Harbour for the third and fourth week in June, and all angling in the main river and its tributaries above Mactaquac Dam for the fourth week in June and the first week in July.

The prospects for the success of all programs concerned with the management of Atlantic salmon stocks in the Saint John River Basin appear favourable but it must be emphasized that their continued success is contingent upon aggressive pollution abatement and environmental protection.

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Fig. 1 Map of the Saint John River Basin showing: (1) Mactaquac Dam, (2) Beechwood Dam, (3) Tobique Dam, (4) Aroostook River Dam, (5) Grand Falls Dam, and (SCS) Mactaquac Salmon Culture Station.

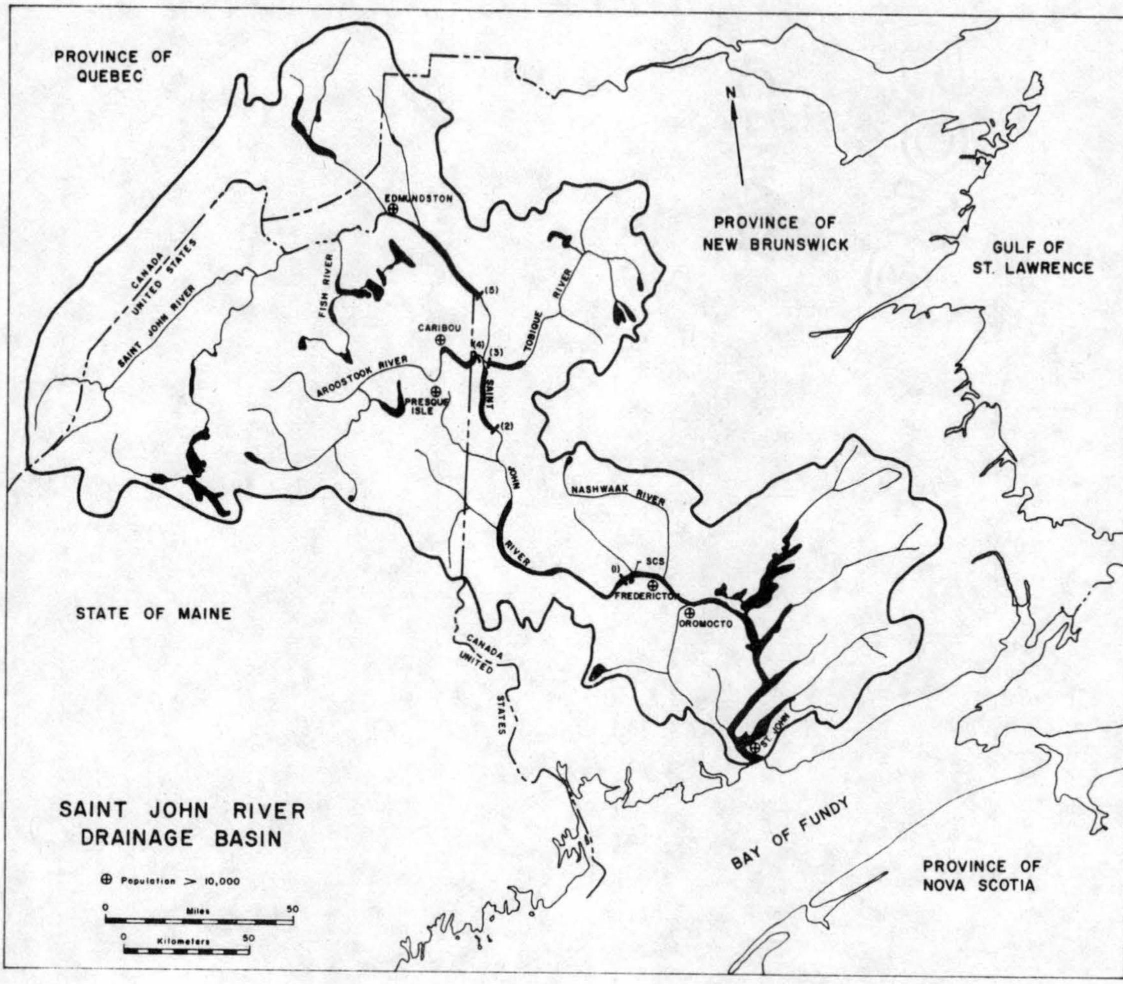

Fig. 2 Profile of dissolved oxygen concentration in the surface water of the Saint John River in 1969. The minimum acceptable level for salmonid fishes (5 mg/l) is indicated.

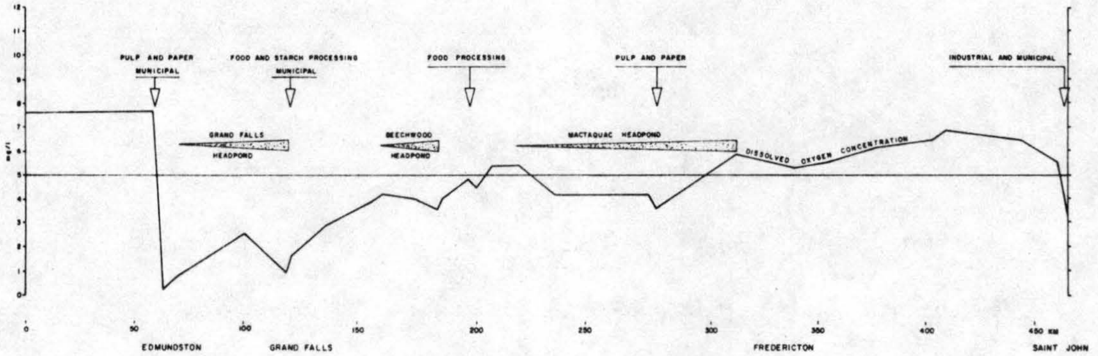

Fig. 3 Atlantic salmon angling catches in the Tobique River and the main Saint John River below Beechwood Dam, 1951-1971.

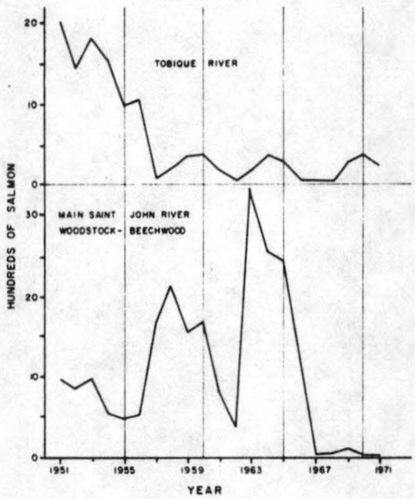

Fig. 4 Counts of Atlantic salmon through the fishway at Tobique Dam, and in the fish collection facilities at Beechwood and Mactaquac Dams for the years indicated.

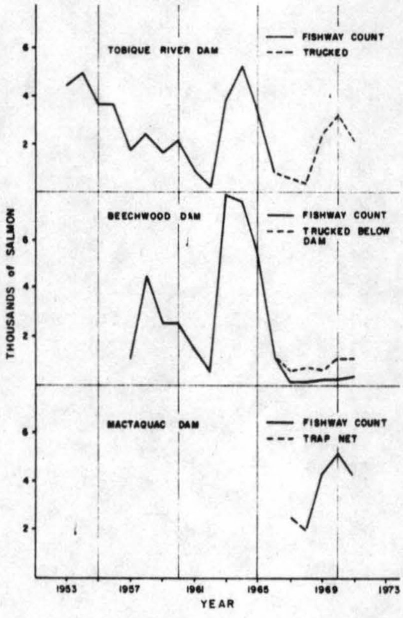

Fig. 5 Improvement in dissolved oxygen concentration in the main Saint John River below Edmundston following a 90% reduction in pulp and paper mill effluent in 1971.