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A NEW LIFE FOR THE ST. CROIX RIVER

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ABSTRACT

The water quality of the upper 110 kilometres of the St. Croix River is considered to be pristine. A major industrial discharge renders the lower 14 kilometres of the river a water quality limited segment. Prior to 1970 the Georgia-Pacific Pulp and Paper Mill at Woodland, Maine, discharged untreated effluent directly into the river causing dissolved oxygen concentrations to drop well below 5 mg/L, the objective chosen in the interest of restoring endemic fish populations. Since 1972, the Mill has installed primary and secondary treatment, regulated river discharge rate and effluent composition which has greatly improved the summer dissolved oxygen regime. By 1980, dissolved oxygen concentrations were generally above 5.0 mg/L and restocking the river with Atlantic Salmon (Salmo salar) was initiated.

INTRODUCTION

The St. Croix River Basin is located in the southeastern corner of Maine and the southwestern section of New Brunswick and forms part of the International Boundary between the United States and Canada. The upper reach of the river above Woodland, Maine, about 110 km in length, is subject to limited anthropogenic influence and is generally considered to represent background conditions.

The area of water quality concern on the St. Croix River is the 14 kilometre reach between Woodland and Milltown. Historically, the St. Croix Paper Company pulp mill, which was constructed at Woodland in 1903, discharged all wastes directly to the river resulting in low dissolved oxygen levels during the summer months.

In 1950, the International Joint Commission recommended that the "Objectives for Boundary Waters Quality control" be adopted by the Governments of the United States, Canada, Maine and New Brunswick as the criteria to be met in maintaining the boundary waters of the St. Croix River Basin in satisfactory condition as contemplated in Article IV of the Boundary Water Treaty of 1909 (Anonymous, 1963). In general terms, Article IV stipulates that all wastes shall be in such condition when discharged into any stream, that they will not adversely affect the use of those waters for drinking water, fish and wildlife, bathing recreation, etc.

In 1955, the United States and Canada requested the International Joint Commission to undertake studies of the St. Croix River Basin for better use, conservation and regulation of the St. Croix waters (Anonymous, 1985).

This paper traces the 31 years (1956-1987) of degradation and rejuvenation of water quality in the St. Croix River and the processes which led to water quality suitable for fish passage and the subsequent reintroduction of Atlantic Salmon (Salmo salar) to the river.

STUDY AREA

The St. Croix River and its tributary, Monument Brook, have a reach of approximately 124 kilometres and form the international boundary

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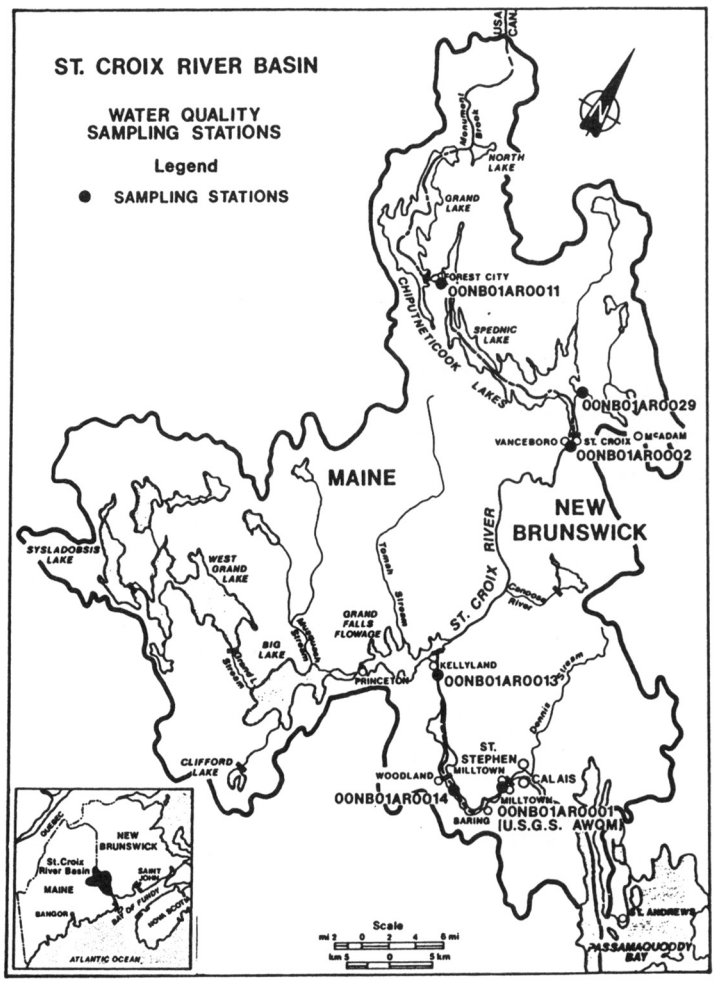
between New Brunswick, Canada and Maine, U.S.A. (Figure 1). The basin covers an area of 4320 km^2 of which 1620 km^2 are located in New Brunswick. Extensive lake systems are a conspicuous feature of the drainage. The system is regulated by a series of dams which are used to provide storage for power generation and to supplement natural flow (Anonymous, 1987).

Land use in the St. Croix River Basin is predominantly forestry related with 80% of the area on both sides of the border devoted to this industry. Agriculture occupies approximately 10% of the basin on the Canadian side and somewhat less on the American side. The remainder of the watershed is occupied by urban associated land uses (Anonymous, 1987).

FIGURE 1



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BACKGROUND

Although early reports do not discuss water quality per se, they do indicate the St. Croix River was considered to be one of the most prolific salmon streams on the Atlantic Coast. Reports tell of daily catches of at least 100 barrels, or that an individual would obtain as many as 50 to 100 or more salmon a day (Anonymous, 1958).

The economic activity of the Basin was primarily concerned with the development of its substantial forestry resources. Numerous sawmills dependent on water power, were constructed in the early to middle 1800's in support of a flourishing shipbuilding trade. The first mill dam on the St. Croix, the Union Mills dam, was built in 1825 without a fishway (Anonymous, 1969). From that time the fishery in the St. Croix River gradually diminished (Anonymous, 1958).

In this century, the pulpwood industry has been dominant in the basin following the construction of the St. Croix Paper Company at Woodland in 1903. The sulphite pulp and paper mill, which began operations in 1906, was producing 300 tonnes of newsprint and 71 tonnes of sulphite pulp daily by August 1956. Hydroelectric dams were constructed at Woodland (1905) and Grand Falls (1915) to supply the mill power requirements (personal communication - G. Pierce). Although fishways were constructed, they were not maintained and soon fell into a state of disrepair.

The river became seriously degraded between Woodland and Milltown due to the discharge of large quantities of solid and liquid wastes (Anonymous, 1969). Above Woodland was also affected, to a lesser degree, due to the practice of log-driving. Deposits of bark, pieces of wood and sunken logs in the waterway, as well as physical degradation caused by logs altering the gravel beds which are the natural spawning grounds for fish contributed to the degradation (Anonymous, 1969).

In 1955, the International St. Croix Engineering Board received terms of reference from the International Joint Commission for an engineering study to consider projects which would improve the use, conservation and regulation of the Basins' waters. Primary issues outstanding in the St. Croix basin at the time were further development of hydro-electric power, fish and game resources and the concept of rehabilitating anadromous species of fish, water pollution and its sources, and lands management (Anonymous, 1985).

The Commission reported the Board's findings in 1956 with recommendations concerning lake levels, pollution abatement and restoration of anadromous fish runs. The recommendations for pollution abatement were approved by both governments in 1961 and included the adoption of specific water quality objectives for the river. They provided for a minimum dissolved oxygen of 5 mg/L, a pH range of 6.7 to 8.5 and a median total coliform of less than 2400 per 100 ml.

In 1962, the Commission established the Advisory Board of Pollution Control for the St. Croix River with a mandate to co-ordinate water quality planning and management efforts in the basin.

METHODS

Since 1956, the data collection in the St. Croix River Basin has been varied in nature.

Early surveys carried out for the International Joint Commission were primarily concerned with dissolved oxygen and biochemical oxygen demand, pH, color, and turbidity. There was usually at least one station above the mill as background and 4 or 5 stations located between Woodland and Calais, Maine.

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Later surveys (1963-1970) which were carried out for the Advisory Board for Pollution Control, were more multi-displinary and multi-agency in nature. Grab and composite samples were collected, from stations from Vanceboro, Maine to the estuary, for chemical and physical analysis with specific emphasis on dissolved oxygen and biochemical oxygen demand. Bioassays using caged salmon and trout and bacteriological parameters were included in most major surveys.

The St. Croix River monitoring has been continuous since 1965 when it became the responsibility of the Water Quality Branch of Environment Canada (formerly part of the Department of Energy, Mines and Resources). The sampling stations have numbered from 3 to 8 with a sampling frequency from 1 to 3 months. All samples have been grab samples, generally analyzed for major ions, nutrients, metals and physical parameters.

An automatic water quality monitor (AWQM) was established at Milltown, Maine by the Environmental Protection Agency in 1966 and has been operated by the United States Geological Survey since 1974. It provides hourly data for specific conductance, pH, temperature and dissolved oxygen. Since June, 1985, the data have been received by Water Quality Branch in Moncton, New Brunswick via satellite retransmission. Monthly summaries of the provisional data are tabulated and distributed to the members of the Advisory Board on Pollution Control on a regular basis.

River flow data have been provided from gauging stations at Kellyland, Grand Falls, and Baring.

RESULTS AND DISCUSSION

The 110 kilometres of the St. Croix River above Woodland, Maine, which are presently relatively free from human influence, are considered pristine and indicative of background water quality conditions. The log drives from Vanceboro, Maine to the mill ceased in 1962. They had been responsible for the deposition of bark and sunken logs in quiescent reaches of the river, introduced biochemical oxygen demand and damaged fish habitats. The logs have now been removed and the bark has gradually disappeared through decomposition and scouring from the river bed during spring freshettes.

Data from present monitoring stations above Woodland indicate that the waters are low in total dissolved solids with specific conductance ranging from 24 to 42 $\mu S/cm$. Dissolved oxygen concentrations range from 90 to 100% saturation and pH values are normally in the 6.5 to 7.0 range at most background stations. The dominant cation is calcium with magnesium or sodium the second most abundant, depending on the season. The anions are dominated by bicarbonate followed by sulphate and chloride (Lockerbie, 1986).

The data from surveys carried out from 1956 to 1970 in the lower 14 km of the river showed a decrease in dissolved oxygen concentrations as illustrated in Figure 2. For the most part, the surveys were conducted in August when river flows were typically low and water temperatures were at their highest.

A four month study by the St. Croix Paper Company and another by the Department of National Health and Welfare formed the basis of the report of International St. Croix Engineering Board to the International Joint Commission in 1956. This report provided an evaluation of river conditions and a basis for comparison for future surveys.

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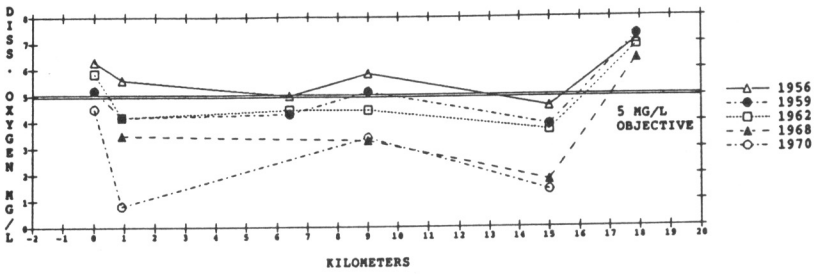
FIGURE 2
COMPARISON OF MEAN DISSOLVED OXYGEN VALUES (MG/L)
IN THE ST. CROIX RIVER DURING SURVEYS FROM 1956 TO 1970
(ANONYMOUS(1968,1970))



0.0 KM - WOODLAND RR BRIDGE
0.9 KM - MILL WASTE
6.4 KM - STONY BROOK
9.0 KM - BARING RR BRIDGE
15.0 KM - MILLTOWN INTERNATIONAL BRIDGE
17.9 KM - ST. STEPHEN INTERNATIONAL BRIDGE

The data from the 1956 survey indicated the BOD input from the St. Croix Paper Company (mean-10.4 mg/L) resulted in lower dissolved oxygen downstream at Stony Creek and Milltown (Figure 2). The BOD values were primarily due to the sulphite waste liquor and physical pollutants such as wood fibre, bark fines, etc. discharged directly to the river. Mininum dissolved oxygen values were often below the water quality objective of 5.0 mg/L (2.9 mg/L on one occasion at Stony Creek) however the authors felt that the waters would support runs of trout and salmon if the artificial barriers (dams at Milltown, Woodland and Grand Falls) were removed. A 1949 study had reported that the waters of the St. Croix River were non-toxic to fish except on the American side just below Woodland (Anonymous, 1956).

The accumulation of wood waste and pulp waste altered the topography of the river bed from Woodland to Milltown. Large areas of the bottom were covered by a slime or mould growth as well as a black grit-like covering of coal ash slag. The effect of those deposits was to blanket the river bottom and thereby smother or at least alter, the natural aquatic life, as well as produce an oxygen demand as the deposits underwent slow organic decay (Anonymous, 1956).

The company carried out an extensive modernization program from 1957 to 1962 which increased production and reduced the suspended solids lost and discharged to the river per ton of paper produced (Anonymous, 1963(a)). However, increases in production at the mill were reflected by higher BOD values as an increased volume of sulphite waste was discharged to the river system. Biochemical oxygen demand at Woodland increased from 10.4 mg/L in 1956 to 15.0 mg/L in 1959 and 33.0 mg/L in 1962.

Dissolved oxygen concentrations were found to be similar in 1959 and 1962. Mean values were in the 4 mg/L range slightly below the 5.0 mg/L water quality objective. The 1963 survey dissolved oxygen data, which are not plotted in Figure 2, continued the downward trend, with mean dissolved oxygen concentration at Milltown of 3.2 mg/L or 36% saturation. The BOD value had dropped slightly to a mean of 29.4 mg/L which represented approximately 42,000 kilograms per day of BOD.

In March 1963, ownership of the St. Croix Paper Company was acquired by the Georgia-Pacific Company. The mill was converted from the sulphite process to Kraft pulp production in 1967. The process change introduced new and toxic elements into the river system,

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primarily from black liquor and the bleach plant. Color and odor problems in the river water increased as a result of the process change. In addition, the biochemical oxygen demand loadings more than doubled from 1967 to 1968 (Anonymous, 1968).

A survey conducted in 1968 indicated that there had been no abatement in the industrial effluents discharged to the river. The dissolved oxygen concentrations were well below the water quality objective from Woodland to Milltown. At Milltown mean dissolved oxygen values fell to a mean of 1.8 mg/L or 20% saturation.

In 1970, Georgia-Pacific finished construction of a water pollution control facility consisting of a main clarifier, a color removal system, and a sanitary waste treatment unit. A 1970 survey (Anonymous, 1971) indicated that the main clarifier removed 85% of the suspended solids but less than 10% of the BOD. The color removal unit was receiving only a third of its design capacity during the survey, however since the unit only received 10% of the total effluent at full capacity, it was unlikely that it would have an impact on the total effluent. During the survey, the treatment facility received less than 70 percent of the mills combined effluent of 155,000,000 Lpd.

The dissolved oxygen levels continued to decline at Milltown from 1968 to 1970, with cross-sectional values ranging from 1.3 to 1.6 mg/L or 15 to 19 percent saturation. Most sites had concentrations similar to 1968 with the exception of the site near the mill outfall which was 0.8 mg/L, or 11% saturation, indicating the strong deoxygenating waste being introduced to the St. Croix River by the Georgia Pacific Mill.

Bioassay tests were conducted along the St.Croix coincident with the physical and chemical monitoring during surveys in 1963, 1965 and 1968. A summary of bio-assay results during these years is presented in Table 1.

In 1963, bio-assay monitoring, using caged salmon fry, indicated that the yearling fish died consistently within twenty four hours in sections of the river where pulp mill effluents have not been diffused or in areas where dissolved oxygen levels did not meet the water quality objective. It should be noted that a physical barrier at the discharge site at Woodland prevents lateral dispersion of the effluent, thereby creating a plume which follows the U.S. bank of the river. The effluent plume remains largely differentiated from the river mass at Baring (Upper Mills) and is mixed into the river by the time it reaches Milltown. Mortality for fish at Baring (U.S. side) and Milltown (U.S. side, middle, Canadian side) occured within 3 hours. The dissolved oxygen concentrations at Milltown ranged from 2.0 to 2.8 mg/L during the period of high mortality (Anonymous, 1963). The data provided in Table 1 for the 1965 bio-assay monitoring are not discussed in the source material. It is assumed that bio-assay techniques were the same as in 1963. The data indicate that the river was extremely toxic to fish.

TABLE 1
SUMMARY OF BIO-ASSAY MONITORING RESULTS
DURING 1963, 1965 AND 1968 ST. CROIX RIVER SURVEYS
(ANONYMOUS, 1968)

YEAR	WOODLAND	UPPER MILLS	MILLTOWN
1963	<24 hours	3 hours	3 hours
1965	2 hours	3 minutes	4.5 minutes
1968	6 hours	96 hours (Can. Side) 29 hours (U.S. Side)	1.75 hours

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The 1968 bio-assay studies were similar to 1963. At Baring (Upper Mills) there was a difference in the rates at which the fish died. This was probably the result of incomplete mixing of the toxic effluent plume across the river. Fish mortalities were most severe at Milltown where the dissolved oxygen levels were always less than 2.0 mg/L, a condition which is itself lethal to salmonid fish (Anonymous, 1968).

In 1970, the in-situ toxicity tests were replaced with a static bioassay procedure to determine the toxicity of the mill's effluent. Fingerling speckled trout were exposed to a range of dilutions of mill effluent. The data were quite variable based on grab and composite samples, from one day to another. For example, the threshold levels for the grab samples ranged between 15 and 50% effluent dilution the for the two days' samples. The discrepancy probably reflected irregularities in mill operation the first day. The results of the bio-assay test did not allow comprehensive assessment of the toxicity characteristics of the effluent, however, there was no doubt that the effluent discharged to the river was detrimental to fisheries resources (Anonymous, 1971).

In addition to the high values of BOD, large quantities of total solids from various mill processes were also discharged to the river. In 1963, it was determined that approximately 187 tonnes (210 tons) of total solids were discharged to the river daily (Anonymous, 1963). By 1968, 2,100,000 cubic metres of bottom sediments consisting of sawdust, wood chips and bark had settled between Woodland and Milltown with 90% of that in the slower-moving 7 kilometre stretch between Baring and Milltown.

As noted previously, the primary clarifier removed approximately 85 percent of the suspended solids during the 1970 survey. As a result, no deposition was observed between Baring and Milltown in 1970.

In the 1970 survey report, the International Joint Commission presented a number of recommendations to improve the water quality in order to meet the IJC objectives and the Maine water quality standards. The major recommendation included the reduction of the waste load to 4500 kg (10,000 pounds) per day of BOD and 2700 kg (6000 pounds) per day of suspended solids. They also recommended expansion of the water pollution control facility to include toxicity and odor reduction, effluent aeration and additonal color removal to name a few. Georgia-Pacific Corp. was to take the necessary steps to meet the recommendation by December, 1972 (Anonymous, 1971).

Data from the automatic water quality monitor located at Milltown, Maine were published by the United States Geological Survey beginning in 1974. Mean dissolved oxygen data for the month of August from 1974 to 1987 are plotted in box and whisker plots as both concentration and percent saturation in Figures 3 and 4.

The data indicate that the primary treatment which had begun in 1970 was not successful in increasing the dissolved oxygen concentrations. From 1974 to 1976 dissolved oxygen concentrations remained well below the water quality objective of 5.0 mg/L, with median values for the month of August in the 2 to 3 mg/L range.

The upgraded waste treatment facility scheduled for 1972 was completed and began operation in April 1977. The secondary treatment consisted of a settling pond and two aeration cells with a retention time of 16 days (personal communication - George Pierce).

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The dissolved oxygen values at Milltown showed a dramatic improvement in 1977 as compared to previous years. The mean dissolved oxygen concentrations increased from 3.5 mg/L in 1976 to 6.0 mg/L in 1977 (Figure 3). The dissolved oxygen concentrations have not approached the water quality objective since an isolated incident in 1980.

FIGURE 3
MEAN DISSOLVED OXYGEN (MG/L) FOR THE ST. CROIX RIVER
AT MILLTOWN FOR AUGUST,1974 TO 1987
(DATA FROM U.S. GEOLOGICAL SURVEY-WATER RESOURCES DATA
FOR MAINE SERIES - 1974 TO 1987

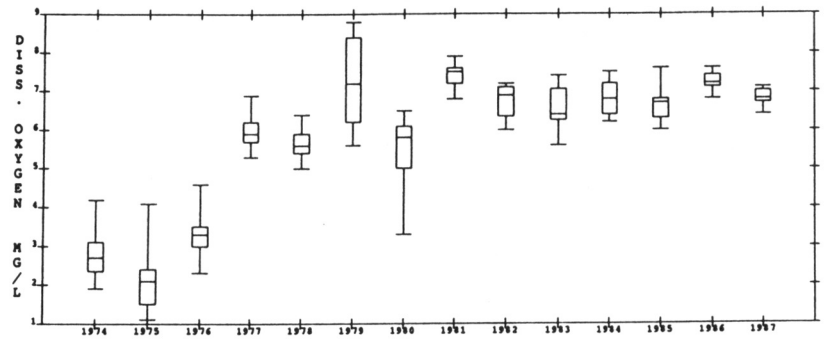
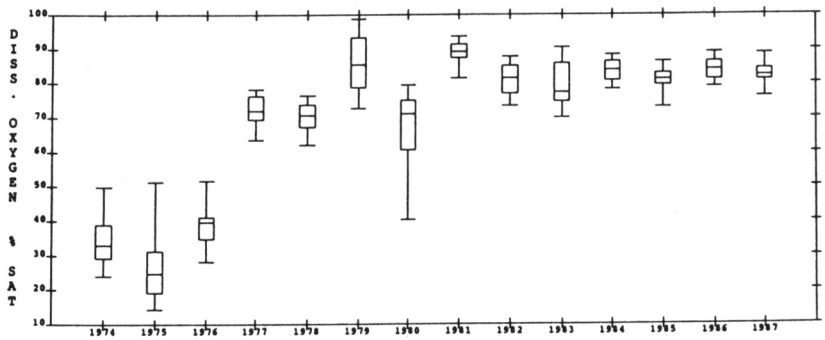


FIGURE 4
MEAN DISSOLVED OXYGEN (% SATURATION) FOR THE ST. CROIX RIVER
AT MILLTOWN FOR AUGUST,1974 TO 1987
(DATA FROM U.S. GEOLOGICAL SURVEY- WATER RESOURCES DATA
FOR MAINE SERIES - 1974 TO 1987)



The improvements in water quality prompted interest in the restoration of the anadromous fishery in the St. Croix River. Slowed by political inaction and required construction and rehabilitation of fishways at Milltown and Woodland respectively, positive steps were taken in 1980 when more than four hundred returning adult Atlantic Salmon were trapped in the Saint John River and transferred to the St. Croix River to spawn. From 1981 to 1985, more than 500,00 fry, parr and smolts were released in the basin. The returns of salmon and alewives for 1981 to 1987 are provided in Table 2.

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TABLE 2:
RETURNS OF SALMON AND ALEWIVES AT THE MILLTOWN COUNTING FENCE FROM 1981 TO 1987 (ANONYMOUS, 1987)

YEAR	SALMON	ALEWIVES
1987	372	2,600,000
1986*	320	2,000,000
1985	342	369,000
1984	244	152,000
1983	124	152,000
1982	98	233,000
1981	79	170,000

- *counting fence did not operate Sept 2 to Oct 10

Although the returns are far from the objective of 7200 salmon, fisheries biologists have been pleased with the increasing returns and other aspects of the salmon restoration program.

Biological indicators monitored in the river above and below the Georgia-Pacific mill indicate the water quality does not affect the health and diversity of benthic macroinvertebrates which constitute a large part of the food source for salmonids. Observations also indicate that a significant number of salmon spawn in the section of river below Woodland (Anonymous, 1987).

A management plan for the diadromous fishery has been prepared and calls for continuing efforts to improve water quality and flow conditions, improvements in upstream and downstream passage, continued stocking and population monitoring as well as habitat assessment.

SUMMARY

During the past 31 years, the St. Croix River has undergone change from a river barely able to sustain fish life in 1956, through a period of excessive pollution loads from 1963 to 1970, to a river capable of supporting endemic fish populations.

Concrete efforts to improve the situation were made in 1970 when Georgia-Pacific constructed the primary treatment system and although it was successful in removing suspended solids, it had little effect on biochemical oxygen demand and dissolved oxygen concentrations which remained below 2 mg/L in the summer months. The completion of the secondary treatment facility with extended aeration in 1977 resulted in dramatic changes in the summer oxygen regime in the first year. Dissolved oxygen concentrations at Milltown increased from a mean of 3.5 mg/L in August, 1976 to 6.0 mg/L in August, 1977.

The water quality and dissolved oxygen levels have remained fairly stable since the installation of secondary treatment. Georgia-pacific has failed on occasion to meet their licensing limit for BOD and suspended solids, which have been lowered periodically, despite large increases in production.

The dramatic improvement in the water quality revived interest in and reintroduction of Atlantic Salmon to the St. Croix River. Fishways were installed or upgraded and vigorous stocking programs have been

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undertaken. The increasing returns of salmon and alewives to the river system have been termed a success.

In retrospect, the situation is quite different from 30 years ago when, during public sessions concerning the recommendations of the International St. Croix Engineering Board in 1956, many briefs suggested abatement measures might result in lack of expansion and/or potential loss of jobs. Many also did not believe that the river could support salmon runs. In 1956, the St. Croix Paper Company produced 300 tonnes of newsprint and 71 tonnes of sulphite pulp daily. Today the Georgia-Pacific Company produces 800 tonnes of bleached Kraft pulp, 570 tonnes of market pulp and 270 tonnes of fine paper daily and salmon and alewives are once again using the river.

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