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LONG-TERM MANAGEMENT PLAN FOR THE  
DIADROMOUS FISHERIES OF THE ST. CROIX RIVER

Anon.<sup>1</sup>

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PREAMBLE

The development of this plan was a cooperative effort by the Maine Atlantic Sea Run Salmon Commission, Maine Department of Marine Resources, Maine Department of Inland Fisheries & Wildlife and the Department of Fisheries & Oceans, Canada. The Saint Croix River Steering Committee was first formed at a meeting of various American and Canadian Departmental representatives on August 31, 1983, in Saint Andrews, New Brunswick. Since that time, annual meetings were convened to discuss ways and means to restore and manage the diadromous fisheries in the boundary waters of the river system.

The Committee consisted of the following members:

Glen Jefferson, Chairman (Department of Fisheries & Oceans, Canada);  
Neil MacEachern (Department of Fisheries & Oceans, Canada);  
Charles (Chuck) Thompson (Department of Fisheries & Oceans); replaced in  
September, 1984, by Jack Davis;  
Ed Baum (Maine Atlantic Sea Run Salmon Commission);  
Lewis Flagg (Department of Marine Resources, Maine, USA); and  
Robert Foye (Department of Inland Fisheries & Wildlife, Maine, USA); replaced  
in October, 1984, by Kendall Warner.

The Committee endorsed this Saint Croix River Diadromous Fisheries Management Plan in April, 1986, and encourages implementation by the fishery management agencies involved. It is recognized that this plan can only be successfully implemented through cooperation and joint management of the fisheries in these boundary waters.

### ABSTRACT

Anon., 1988. Long-term management plan for the diadromous fisheries of the St. Croix River. Can. MS Rep. Fish. Aquat. Sci. No. 1969. vii + 68 p.

The St. Croix River, a US/Canada international river bordering the State of Maine and the Province of New Brunswick, drains southwesterly into Passamaquoddy Bay of the Bay of Fundy. Approximately 1,619 km<sup>2</sup> (625 mi<sup>2</sup>) of the river's drainage basin is in New Brunswick and 2,616 km<sup>2</sup> (1,010 mi<sup>2</sup>) is in Maine. The St. Croix River has undergone dramatic changes over the years as the result of development of industry related activities; mainly pulp mill and power generation activities. Atlantic salmon (Salmo salar) and other anadromous fish species decreased dramatically as the industrial development expanded throughout the system. Fisheries management to rehabilitate these species became a matter of international concern and to deal with this a joint US/Canada St. Croix River Steering Committee was established for the purpose of seeking mutual agreement on a course of action to rebuild the depleted stocks and to develop a long-term river specific management strategy. This report is a result of the Steering Committee and its subcommittee's deliberations and recommends the appropriate steps to be followed to manage the anadromous fish resources of the St. Croix during the 1980's and 1990's.

Keywords: St. Croix River, New Brunswick, Maine, diadromous fish, management

### RÉSUMÉ

Anon., 1988. Long-term management plan for the diadromous fisheries of the St. Croix River. Can. MS Rep. Fish. Aquat. Sci. No. 1969. viii.

La rivière St. Croix, rivière canado-américaine se trouvant à la frontière du Maine et du Nouveau-Brunswick s'écoule vers le sud-ouest et se jette dans la baie Passamaquoddy, elle-même située dans la baie de Fundy. Son bassin versant s'étend sur une superficie d'environ 1 619 km<sup>2</sup> (625 mi<sup>2</sup>) au Nouveau-Brunswick et 2 616 km<sup>2</sup> (1 010 mi<sup>2</sup>) dans l'état du Maine. L'accroissement de l'activité industrielle, principalement dans le secteur de la pâte à papier et de la production d'énergie, a eu des effets désastreux sur la rivière. Le nombre de saumons de l'Atlantique (Salmo salar) et de poissons d'autres espèces anadromes a chuté au rythme de l'expansion industrielle le long du cours de la rivière. La reconstitution des stocks de poisson, par la gestion, est devenue une préoccupation commune aux deux pays frontaliers. Le comité canado-américain de direction de la rivière St. Croix a été créé dans le but de trouver des moyens d'action communs pour rétablir les stocks décimés et concevoir une stratégie de gestion de la rivière à long terme. Le présent rapport est le fruit des délibérations du comité directeur et de ses sous-comités. Il recommande des étapes à suivre pour gérer les stocks de poissons anadromes de la rivière St. Croix durant la décennie 1980 et 1990.

## **1.0 Introduction**

The sixty-two miles of the St. Croix River (Figure 1) from Vanceboro to tidewater at Passamaquoddy Bay form the international boundary between Canada and the United States. By virtue of its boundary water status, the fish resources in this portion of the river are under the joint jurisdiction of fisheries agencies in both countries. Much work has been done to free the river system of harmful pollutants and to establish a suitable water flow regime. The task now is to work towards the restoration of fish stocks and the continuing development and regulation of the fisheries. To achieve the rebuilding and protection of fish stocks will require close coordination and mutual agreements between the fisheries management agencies of both countries.

### **1.1. St. Croix River Steering Committee**

The St. Croix River Steering Committee was established for the purpose of seeking mutual agreement on a course of action to rebuild the depleted fish stocks and for management strategies as the fisheries develop. The terms of reference for the Committee are outlined as follows:

- coordinate the effort and obtain cooperation and support of the managing agencies in developing management objectives and measures for fish stocks of common concern;
- coordinate the management and enhancement plans undertaken by the various agencies represented on the Committee;
- provide liaison and obtain input and support from other government agencies and an informed public during the development and implementation of management plans;
- direct assignments to, and be supported by, three main Subcommittees, namely: Biological, Enforcement and Fish Health;
- the Steering Committee and Subcommittees shall be represented by six members each, and include three American and three Canadian representatives designated by the managing agencies.

### **1.2 Management Objectives**

The St. Croix River has undergone dramatic changes over the years as the result of cultural development in the form of industry related activities. Pulp mill and power generating facilities now dominate the main stem of the river, and it is overly optimistic to believe that the fisheries can be developed to the levels experienced in the previous natural state of the river. At the outset, it must be realized that fish production and levels of abundance will be limited by the many constraints associated with the current industrialization. With the knowledge of the problems associated with fish

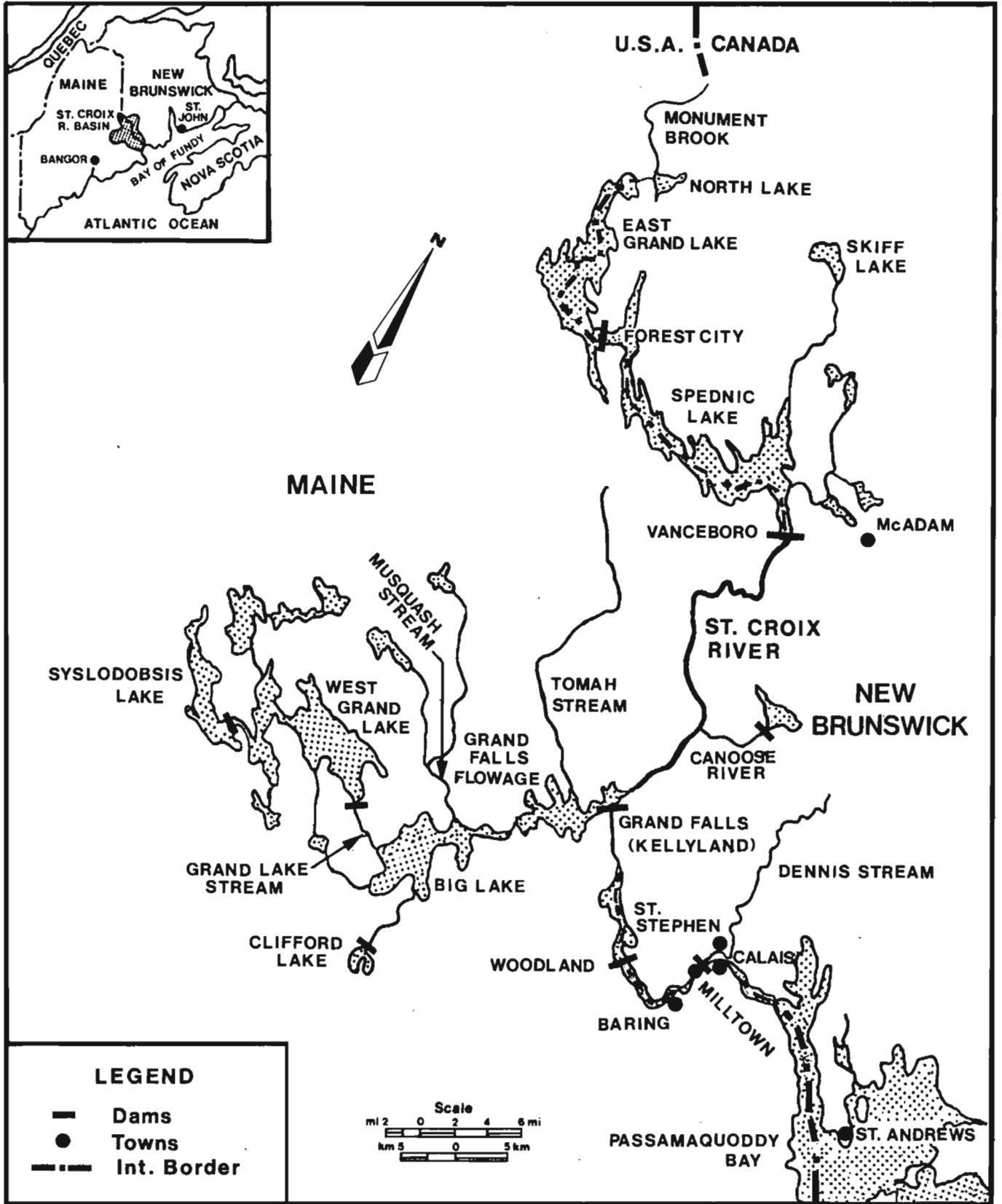


FIGURE I: Map of St. Croix River System, New Brunswick/Maine

passage through the various dams and with the production and return rates for the anadromous species, the following objectives are outlined for the river system:

- to restore, improve and maintain the fish populations of the St. Croix River System in cooperation with managing agencies;
- to develop a long-term plan and annual fishing plans, which outlines a flexible management system for the protection, development and utilization of the fish resources of the river system;
- optimize net benefits to the public from both the existing resources and enhancement opportunities;
- ensure distribution of the benefits among authorized users of the fish resources in accordance with social and economic values.

### **1.3 Management Strategy**

Fisheries management in the Saint Croix River is a matter of international concern. Cooperation will be sought from the various government agencies involved in the development and regulation of the fisheries and the sharing of available harvests. It is also recognized that effective policy implementation requires input and support of an informed public, and every reasonable effort will be made to obtain broad public input during the decision-making process. It will be necessary to endorse a joint management system to involve the managing authorities from both countries to manage the fish stocks and share the harvests.

In regard to the harvesting of Atlantic salmon, American shad, smelt and striped bass species, precedence will be given to sport fishing. Future allocation of these species for commercial harvest will be warranted only on wild, self-sustaining stocks not needed in the sports fishery. For the harvesting of alewives and American eel, precedence will be given to the commercial fishery.

### **1.4 Fishery Managing Agencies**

#### **1.4.1 Maine Atlantic Sea-Run Salmon Commission**

The Atlantic Sea-Run Salmon Commission was established by the Maine legislature in 1947 to manage and conserve Atlantic salmon (*Salmo salar*) in all waters of the State of Maine and to restore the Atlantic salmon to the rivers of the State. The Commission is authorized to purchase or lease lands, dams, and other structures within the State; to acquire flowage rights, mill privileges and rights-of-way; and to build dams and other structures for the purpose of conservation of Atlantic sea-run salmon. The Commission has sole authority to adopt

regulations regarding the taking of Atlantic sea-run salmon, but its authority is limited to regulation of the time, method, number, weight, and length of salmon and the locations from which they may be taken.

The Commission also may investigate, or cause to be investigated, conditions affecting the salmon in any waters of the State and may, on its own initiative, make or amend such regulations as it deems necessary to conserve Atlantic salmon or promote their propagation.

The Commission is composed of the following three members: Commissioner of Inland Fisheries and Wildlife, Commissioner of Marine Resources, and a public member appointed by the Governor for a term of four years. The Commissioner of Inland Fisheries and Wildlife acts as permanent Chairman of the Commission and has sole authority over administrative and financial matters.

The rules and regulations of the Commission, governing the taking of Atlantic salmon within the State of Maine, are enforced by the Warden Service of the Department of Inland Fisheries and Wildlife in inland waters and by the Marine Patrol of the Department of Marine Resources in tidal waters.

#### **1.4.2 Maine Department of Inland Fisheries and Wildlife**

The goals of the Department are:

- to maintain optimum population levels of freshwater fishes and associated aquatic species;
- maintain optimum quality, quantity and diversity of habitat; and
- provide for optimum and diverse uses of freshwater fishes for sportfishing, aesthetic, economic, ecologic, scientific and educational purposes.

The Department's statutory mandates are derived from the Revised Status of 1964, Title 12, Chapters 301 to 337, and related subject matters, as amended by the public Laws of 1965, 1967, 1969, 1971, 1973, 1975, and 1977. Historically, the responsibilities of the Department have focused on the administration and enforcement of the inland fisheries and wildlife laws. These responsibilities have been significantly expanded in the past decade as the legislature has passed to the Commissioner more and more of the responsibilities of the establishment of rules and regulations governing the taking of inland fish and wildlife. In carrying out its legislated fish and wildlife management mandates, the Department has established a goal to ensure that all species of wildlife are maintained and perpetuated for their intrinsic and ecological values, for their economic contributions to the State, and for their recreational, scientific, and educational use by the people of the State.

### **1.4.3 Maine Department of Marine Resources**

This agency is established to conserve and develop marine and estuarine resources; to conduct and sponsor scientific research; to promote and develop the Maine coastal fishing industries; to conserve, develop, and restore anadromous fish resources; and implement, administer and enforce laws and regulations necessary for these enumerated purposes.

The Commissioner of Marine Resources is empowered to regulate the taking of living marine organisms from the coastal waters. Regulations may only limit the taking of marine organisms by one or more of the following: Time, Method, Number, Weight, Length, or Location.

All living marine resources within the coastal waters of the State of Maine are under the jurisdiction of the Department of Marine Resources. Coastal waters are defined as all waters of the State within the rise and fall of the tide and within the marine limits of the jurisdiction of the state, but do not include areas above any fishway or dam when the fishway or dam is the dividing line between tidewater and fresh waters.

### **1.4.4 Federal Department of Fisheries and Oceans**

By authority of Section 91(12) of the BNA Act, respecting "sea coast and inland fisheries", the federal government has been vested with responsibility for the regulation and administration of the fisheries in Canada. Certain provinces have been delegated responsibility for administering salmon fisheries; for example, Quebec has been delegated this responsibility in Atlantic Canada.

The Department of Fisheries and Oceans Act, (1979) established the Department of Fisheries and Oceans and sets out the Minister's responsibility for the management and direction of the Department. The Minister's duties, powers and functions extend to and include sea coast and inland fisheries, fishing and recreational harbours, hydrography and marine sciences, as well as the coordination of the policies and programs of the government respecting oceans.

Under the authority of the Fisheries Act, regulations may be made by the Governor in Council relating to the conservation and protection of fish; the catching, loading, landing, handling, transportation, possession and disposal of fish; the operation of fishing vessels; the use of fishing gear and equipment; the issue, suspension and cancellation of licences and leases; the terms and conditions under which a lease or licence may be issued; the conservation and protection of spawning grounds; the export of fish or any part thereof from one province of Canada to any other province; the powers and duties of persons engaged or employed in the administration or enforcement of

this Act and provisions for the carrying out of those duties and powers; and the varying of any close time or fishing quota that had been fixed by the regulations.

#### **1.4.5 International Joint Commission**

The Boundary Waters Treaty of 1909 is unique in relations between two independent States. The drafters of the Treaty developed an organization to solve problems between two countries through the unitary deliberations of a permanent body composed equally of Canadians and Americans, rather than the usual bilateral negotiations. The institution, the International Joint Commission, has operated since 1912 in this spirit of trust and cooperation.

The International Joint Commission (IJC) is composed of six members: three from the United States and three from Canada. The United States members are appointed by the President with the advice and consent of the Senate. The Canadian members are appointed by the Governor in Council of Canada. The Commission is directed by U.S. and Canadian co-chairmen who serve in their positions on a full-time basis, while the other Commissioners serve part-time. The Commissioners conduct their business as a single body, not as separate national delegations representing their respective governments, but effectively seeking common impartial solutions in the mutual interest of both countries.

The Commission has three principal functions:

- Regulatory - Approves or disapproves applications from government, companies or individuals for obstructions, uses or diversions of water which affect the natural level or flow of boundary water on the other side of the international boundary or raise the level of transboundary rivers at the boundary.
- Investigative - Investigates questions or matters of difference along the common frontier. These investigations and studies, which are referred to the Commission by the two governments, are called "References".
- Surveillance/Coordination - Monitors compliance with the terms and conditions set forth in "Orders of Approval" it has issued. When requested by the two governments, the IJC monitors and coordinates actions or programs that result from governmental acceptance of recommendations made by the Commission.

Under the parent organization, the IJC, are two IJC Boards specifically focussed on the international consequences in the St. Croix River of water pollution. These are the St. Croix River Pollution Advisory Board, mandated to achieve water pollution control commensurate with restoration of Atlantic salmon, and the St. Croix River Board of

Control, mandated with providing adequate river flow for maintenance of Atlantic salmon stocks.

## 2.0 Description of the St. Croix River Basin

The St. Croix River (Figure 1) is international, draining parts of the Province of New Brunswick and the State of Maine. The drainage area, including some tidal estuary, is 4,235 km<sup>2</sup> (1,635 mi<sup>2</sup>) of which 1,619 km<sup>2</sup> (625 mi<sup>2</sup>) is in New Brunswick and 2,616 km<sup>2</sup> (1,010 mi<sup>2</sup>) is in Maine (Int. St. Croix River Eng. Bd., 1957). The main stem and the East Branch (84 km, 52 mi long), the Chiputneticook Lakes 66 km, 41 mi long), and Monument Brook (19 km, 12 mi long) determine the international boundary south of latitude N 45°58'25", a total distance of about 169 km (105 mi).

The East Branch drains an area of 1,668 km<sup>2</sup> (644 mi<sup>2</sup>) of southwestern portions of York and Charlotte counties, New Brunswick, parts of northeastern Washington County and a small portion of Aroostook County in Maine. This Branch has two very large lakes and several smaller lakes and its main course is mixed gradient river environment. The Branch drops at an average gradient about 1.06 m/km (5.7 ft/mi) from Vanceboro to Grand Falls.

The West Branch, however, principally comprised of large lakes separated by short thoroughfares or short streams, lies wholly in Maine and drains an area of 1,728 km<sup>2</sup> (667 mi<sup>2</sup>) of Washington, Penobscot and Hancock counties. Gradient is confined in large measure to the lake tributaries.

The East and West Branches join at Grand Falls Flowage to form the main stem of the St. Croix which flows 31 km (19 mi) to tidewater at Calais/St. Stephen. This section, plus that draining into the 23 km (14 mi) estuarial portion of the river, collects runoff from a further 839 km<sup>2</sup> (324 mi<sup>2</sup>). The mean tidal amplitude at Calais/St. Stephen is 6.25 m (20.5 ft).

The most outstanding feature of the St. Croix River waterways is the abundance of lakes and ponds (lotic environments). These waters cover an area of about 445 km<sup>2</sup> (172 mi<sup>2</sup>), or about 9.5 percent of the basin area. Adding an area for streams and brooks (lentic environments) brings the total St. Croix water surface area to an impressive amount of fish-bearing habitat.

A large portion of the St. Croix River Basin is a near-wilderness area. Forests of second-growth hardwoods and conifers cover over 80 percent of the drainage. The basin is sparsely settled, containing about 21,500 people of which about three-fourth live between Calais and Baileyville, in Maine, and in St. Stephen, New Brunswick. Less than ten percent of the basin area is devoted to agriculture, principally dairying, poultry farming, and blueberry growing. Almost all of the recreational

development in the drainage is in the form of privately owned summer cottages or commercially operated fishing camps. Major industrial development is confined to a major forest products processing complex in Baileyville, below the junction of the East and West Branches.

Water quality, except for the main stem below the confluence of the two branches, has not changed significantly in the last hundred years. Some minor deterioration has taken place in upstream areas as a result of sedimentation, log deposition, and silting from logging and road construction, and some additional minor pollution occurs from the small towns and summer cottages. These waters, however, retain a substantial fish-rearing potential.

The St. Croix River Basin has a long history of dams. These structures have been of many sizes, and in some cases, were built, rebuilt or modified as time went on. About 30 dams are now in existence, and their uses are mainly power generation, water storage, lake level regulation, or waterfowl management. Table 1 contains information about the major dams in the St. Croix River drainage. The listed structures are all equipped with fishways.

### **3.0 Potential Biological Production of Diadromous Fishes**

Three anadromous fish species and one catadromous species could become important in the St. Croix River. The Atlantic salmon, alewife, and American shad are marine species that spawn and spend their juvenile lives in fresh water. The American eel, however, is a marine spawner that spends much of its growing life in fresh or brackish waters. These species are those which will likely benefit most from the current restoration program for the St. Croix River.

#### **3.1 Atlantic Salmon**

The Atlantic salmon is the most prized of the anadromous species proposed for restoration. Moreover, this species is also the most demanding in its river environmental requirements, because adults spend 2-10 months in the river and juveniles are resident for 2½-3½ years. Not only must the river provide adequate resting, spawning, and growing conditions for juvenile and adults, but must also provide free access to spawning areas for migrating adults.

A major determinant for estimating the capacity of a drainage for Atlantic salmon production is the extent of nursery and rearing area suitable for the young fish during freshwater residence. Stream surveys for determination of the potential rearing areas were completed for the St. Croix in 1956. Havey (1963) presents a somewhat refined estimate of

**TABLE 1****Major water control dams in the St. Croix River basin**

Structure and Location	Ownership	Distance From Sea	Height	Operating Head	Fishway Type	Remarks
Cotton Mill Dam Milltown, N.B.	New Brunswick Electric Power Commission	1 km (½ mi)	7.3 m (24 ft)	6.7 m (22 ft)	Pool and weir	Rebuilt in 1980
Woodland Mill Dam Baileyville	Georgia-Pacific Corporation	14.5 km (9 mi)	14.3 m (47 ft)	14.9 m (49 ft)	Denil	745' long, built 1964-65
Kellyland Dam Baileyville	Georgia-Pacific Corporation	30.6 km (19 mi)	app. 11.6 m (app. 38 ft)	15.5 m (51 ft)	Denil	600' long, built 1964-65
Indian Flowage Dam Canoose River	Georgia-Pacific Corporation	58.4 km (34 mi)	5.2 m (17 ft)	4.6 m (15 ft)	Pool and weir	Needs upgrading
Spednik Lake Dam Vanceboro	Georgia-Pacific Corporation	83.7 km (52 mi)	app. 6.1 m (app. 20 ft)	4.3 m (14.2 ft)	Vertical slot	
East Grand Lake Forest City	Georgia Pacific Corporation	62.8 km (39 mi)	2.7 m (9 ft)	2.4 m (8 ft)	Vertical slot	
West Grand Lake Grand Lake Stream	Georgia-Pacific Corporations	124 km (77 mi)	2.4 m (8 ft)	2.4 m (8 ft)	Vertical slot	

spawning and rearing area of 3,890,000 m<sup>2</sup> (4,649,000 yd<sup>2</sup>).

Maine fishery scientists, among others, are concerned about the continued viability of the St. Croix River landlocked salmon populations if Atlantic salmon are introduced to the same waters. For this reason especially, it seems prudent to reestablish Atlantic salmon only in those waters with no substantial utilization by landlocked salmon.

Therefore, Havey's estimate of total Atlantic salmon rearing area has been reduced (Table 2), assuming Atlantic Salmon are not encouraged to develop standing populations above St. Croix (Vanceboro) on the East Branch or on the West Branch.

In effect this restriction would confine the Atlantic salmon mainly to that part of the St. Croix River Basin in Maine, lying south of New Brunswick Highway 4-Maine Route 6 and east of U.S. Route 1 from Calais to Topsfield, and to the contiguous New Brunswick portion. Salmon production will take place mainly above the Grand Falls flowage on the East Branch of the main river and its tributaries. However, it is unrealistic to equate the main stem rearing area below Woodland to that in upstream areas not exposed to the pulp and paper mill's waste disposal, so a reduced smolt production is expected from that area.

An average smolt production of 2.5 fish per 100 m<sup>2</sup> (119.6 yd<sup>2</sup>) for the 30,786 rearing units would result in about 77,000 smolts. The smolts will be subject to some predation losses and turbine mortalities during their migration to the sea; combined loss is estimated at 15 percent. Survival of smolts at sea to the adult stage is expected to be about 11 percent, of which about 35% will be harvested in marine waters distant from the home river. This information, summarized in Table 3, suggests about 4,600 fish will return on average to the home estuary.

Many of these fish will be required for spawning. Spawning requirements can be calculated on the basis of 240 eggs/100 m<sup>2</sup>, male:female ratio of 1:1, 7,200 eggs/female to obtain the required 7.389 million eggs. This calculation identifies the female spawner component as 1,020 fish, or a male and female spawning run of 2,040 fish. Some additional fish should be added to adjust for any ineffectiveness of fish passage facilities and uneven distribution of spawners. Thus, the target spawners requirement is rounded off at 2,200 fish, leaving up to 2,400 of the 4,600 arriving at the estuary as available for harvest in fisheries. The major angling harvest will take place in the main stem between Grand Falls powerhouse and the tidewater. Although the fishways are expected to be quite effective, some slow-down of salmon movement is likely. This stretch of river has sites suitable for salmon angling, but they will have to be identified by trial and error. Information on the "old salmon holes" may be relatively worthless, because of river changes over the last decades and because former salmon anglers have passed away taking angling information with them. Furthermore, Rathburn and Wakeham (1897) report very little fishing was ever done above Salmon Falls, site of the present

TABLE 2

Potential rearing area for Atlantic salmon  
in a selected portion of the St. Croix River basin

Water	Rearing Area	
	m <sup>2</sup>	yd <sup>2</sup>
<b><u>East Branch</u></b>		
Vanceboro to Little Falls	877,925	1,050,000
Little Falls to Loon Bay	978,260	1,170,000
Scott's Brook	73,580	88,000
Loon Bay to Grand Falls	244,985	293,000
Canoose River	67,725	81,000
Tomah Stream		178,000
<b><u>Main Stem</u></b>		
Grand Falls to Woodland	242,475	290,000
Woodland to Calais	530,100	634,000
Wapsaconhagen Stream	49,330	59,000
Magurrewock Stream	14,215	17,000
	3,078,595	3,860,000

TABLE 3

**Estimated production potential and homewater return of  
Atlantic salmon reared in the St. Croix River**

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**SMOLT PRODUCTION**

Rearing area potential (2.5 smolts/100 m <sup>2</sup> ; 2.1/100 yd <sup>2</sup> produces	:	77,000 smolts
Reduced by 15% loss to predation and to main stem dam losses leaves	:	65,450 smolts to the sea

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**ADULT PRODUCTION**

Smolt survival to adult (11%) results in	:	7,200 adults
Reduced by 35% commercial harvest (2,520) in waters away from the home estuary leaves	:	4,680 adults

So, the return to the home estuary is about 4,600 adults.

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stabilization of an angling rate, but the latter may be expected to reach 30-35 percent of the river run if the run enters when temperatures are suitable for angling.

Perley (1852) reports that records over about a 30 year period, beginning 1853 from Wilson's weir near Devil's Head, show that salmon came later in the spring to the St. Croix than in other western rivers of the Bay of Fundy. Fifty-two percent of the catch was obtained later than the month of June. This information might indicate a somewhat delayed migration into the St. Croix River, or else the catches may have been the result of inability of salmon to pass the old dams except at low flows, thereby exposing the fish to multiple chances for saltwater exploitation while awaiting in the tidal waters for suitable migrating conditions.

Water quality data, taken during the last decade, indicate that the average weekly water temperature in most years will rise to 20°C (68°F) during the last week of June. During July, August, and the first week of September, the average weekly temperature will hold in the 20-22°C (68-71.6°F) range with the daily maximum frequently at least 2-3°C (3.5-5.4°F) higher. Salmon migrating at these temperatures are often reluctant to strike at an artificial fly, so angling success will be decreased during the warmwater period. Fish migrating before the last week of June will be accompanied by many alewives. Since salmon are reluctant to use fishways choked with alewives, the time interval available for salmon entry to the river while water temperatures are below 20°C (68°F) may be limited in June. This pattern may prevail if the traditional spring-run salmon are re-introduced. Consideration might be extended to the establishment of a fall run of salmon, i.e., a stock which enters in September, or during October, when the weekly water temperature falls below 20°C (68°F). A fall run would not be unduly withheld from entering due to low river discharges, since the storage capacity of the basin will ensure sufficient water for main stem migration at most times. Fishway capacity at that time would be available for exclusive use, but entrance to smaller tributary streams would be retarded pending fall rains. The biggest angling disadvantages to initiating a fall run are the lowered flesh quality, the less vigorous sporting quality of the fish as spawning season approaches and a reduced angling season.

### 3.2 Alewife (gaspereau)

The alewife (*Alosa pseudoharengus*), a member of the herring family, spawns mainly in lakes and ponds where the young spend some weeks before migrating to sea for further feeding. The spawning run tends to enter fresh water in May and June barely before the Atlantic salmon runs begin. The dense schools of young start emigrating to sea about mid-July, and all are out of fresh water by November. The blueback herring (*Alosa aestivalis*), a very closely related species, also uses many of the same streams as the alewife though slightly later in run timing. For all

intents and purposes, the two species are often managed together as alewives. The relative importance of the blueback herring in the St. Croix River is unknown.

The production of alewives is determined in large measure by the area of suitable spawning and nursery water accessible to the spawners. Havey (1968) measured the freshwater production of alewife juveniles at just less than 4.8 kg/ha (4.3 lb/acre). These juveniles go to sea where their average weight changes from 353 fish per kg (160 fish/lb) to an average weight in the spawning run (mixed ages 3-9) of 0.26 kg (9 oz).

Maine scientists have determined that adult alewife production on a unit-freshwater-area basis varies from about 168 kg/ha (150 lb/acre) to as much as 784 kg/ha (700 lb/acre), depending on the trophic nature of the freshwaters, on the distance from the sea, and on the adequacy of previous spawning escapements (L. Flagg, pers. comm.). Because many of the St. Croix alewife production areas are eutrophic and mortalities during downstream migration can be minimized by installing downstream passage facilities, a conservative estimate of the St. Croix River alewife production, after a stock is fully established, is an average 225 kg/ha (200 lb/acre). Reduced alewife production in inaccessible lake areas or in extreme headwater lakes will be compensated to a significant degree by production from dead water or slow-moving sections of rivers and streams located closer to the sea.

Successful alewife fisheries are maintained with spawning escapements of 15 percent. The St. Croix River Basin should receive a minimum 15 percent level of alewife escapement until experience indicates a lower level will not reduce production. On this basis, the St. Croix River Basin, if all lakes were accessible, would produce about 10,000 metric tons (11,000 tons) of alewives in total. Not all the St. Croix River drainage will be immediately accessible to alewives, however. Maine fisheries officials would prefer, at the present time, to exclude the alewife from the West Branch drainage above West Grand Lake, and a migration barrier is now in place. Once a fully developed alewife resource in the main stem and East Branch becomes fully utilized by a commercial fishery, consideration will be given to development of the alewife potential of the West Branch above West Grand Lake. Restricting the alewife to below West Grand Lake, would reduce the potential annual production to about 5,140 metric tons (5,665 tons). Such a basin production, with a 15 percent spawning escapement, would make 4,370 metric tons (4,815 tons) available for annual harvest. This harvest is attainable with existing fishway capacity based on exclusion of the West Branch production potential.

The total St. Croix River Basin potential for the production of alewives (gaspereau and blueback herring) cannot be attained with present fish passage facilities. If the West Branch is utilized for alewife production in the future, the fishways will be inadequate to pass the required number of spawners (5,775,000 fish).

Estimates of the alewife production permitted by present fishway capacity are about 20 million fish, weighing 5,140 tonnes (5,665 tons). This production should be approached about eight to twelve years commencing at the time of the Milltown fishway reconstruction. At that time, an 85 percent exploitation rate for the commercial fishery will provide (at a 20-million fish total run) about a 4,370-ton harvest (about 9.6 million lb.).

The best method of harvesting the alewives is to take them below the Milltown Dam structure by dipping or brailing. It does not make particular sense to remove the catch from the upper fishway area because you are, in effect, wasting fishway capacity by doing so. The location and details for harvesting alewives will have to be worked out and developed.

### 3.3 American Shad

The shad, the largest member of the herring family in the Bay of Fundy, is another freshwater spawner that migrates to sea for growth. The eggs, which are deposited over clean bottom in deep, slow-moving rivers, are semi-buoyant and drift along during incubation, as opposed to those of the alewife which are adhesive and which incubate at the spawning site. Adult shad return to the sea promptly after spawning, which would peak in the St. Croix River in June. Young shad move to sea in the fall after a summer's growth in fresh waters.

Prior to installation of dams on the main stem, annual catches of shad were allegedly sufficient for filling ships each year. Shad populations suffered badly from the inadequacy of fish passage facilities, and only a small number has been intermittently captured in the St. Croix river for a century.

Data collected at other fish passage facilities now show that shad are capable of using fishways, including the pool-and-weir, Denil or vertical slot types. However, there is strong, though fragmentary, evidence that shad will not enter a fishway, in numbers, when it is being concurrently utilized by alewives. There is apparently a density or behavioural factor which prevents shared usage of fishways by these two species. Since the alewife begins its spawning run earlier and is present in far greater numbers than the shad, a new shad run will be held up at all main stem dams, thereby interfering with most-effective shad reproduction. For this reason, there is no expectation that any appreciable shad stock will develop in the St. Croix River as long as joint usage of present fish passage designs is a requirement.

### 3.4 American Eel

The eel is catadromous, meaning it is a sea-spawner which spends much of its growing time in brackish or fresh waters. Traditional commercial fisheries utilize the nocturnal behaviour of the eels to capture them in baited traps or in nets and weirs during their local or spawning migrations. It has generally been found that fishing for so-called "yellow", resident eels usually results in a short-lived fishery because these slow-growing animals are easily over-exploited. When the eels are ready for the seaward spawning migration, physiological changes take place, including development of silvery appearance. The "silver" eels bring the best price on the market. Harvesting silver eels during the seaward migration is most logical, since the price is better and the freshwater production is otherwise lost to the sea for reproductive purposes.

Smith and Saunders (1955) report that small lakes in southwestern New Brunswick have eel populations ranging 0.78 kg/ha (0-70 lb/acre) with many ponds in the 2.24-8.97 kg/ha (2.3-9 kg/ha; 2-8 lb/acre) range. The standing crop is apparently related to proximity to the sea and to water quality, where warm shallow lakes have greatest eel populations. Smith (1966) describes the eel migration from one lake over a 15-year period as averaging 2.24 kg/ha/yr (2 lb/acre/yr).

Surveys of Maine lakes in the St. Croix River Basin have confirmed that eels are widespread in the drainage. This information suggests that recruitment of eelers to those waters is not completely prevented by the main stem dams. It is reasonable to expect adequate eel recruitment, when adequate fish passage facilities are maintained in the main stem dams, although it is not known if reduced recruitment is presently limiting the size of the freshwater eel populations.

At first, approximation of potential eel production for the St. Croix Basin can be derived using Smith's production figure and the lake area in the Basin. This estimate is about 100,000 kg (220,000 lb) per year. Of course, headwaters will likely be understocked, thereby reducing production from Smith's level. On the other hand, no production areas for rivers and streams are included in this estimate, and it is certain that production from these riverine areas would compensate for some understocking of headwater lakes.

The eel population will probably continue to increase slowly for a few years after installation of efficient main stem fish passage devices. Annual yield of silver eels may tend to stabilize after about ten years at about the 22,700 kg (50,000 lb) level. In order to optimize harvest of silver eels, the harvest should take place above the hydro-electric generating facilities.

### 3.5 Rainbow Smelt

The anadromous rainbow smelt supports significant recreational and commercial fisheries in Maine and eastern maritime Canada. In Maine, a fall and winter hook and line fishery in bays and estuaries is followed by an intensive spring dip net fishery on the freshwater spawning grounds.

Smelt ascend to freshwater spawning areas of streams and rivers as the ice goes out and the water temperatures increase. There is a wide range of variation in the timing of runs and the types of spawning areas used. Some smelts spawn immediately after ice-out in the deeper waters of the main rivers, while others spawn in tributary brooks and streams (Flagg, 1972). McKenzie (1964) found that smelt in the Miramichi River arrived at head of tide in the main branches and larger tributaries as temperatures reached 4-5°C, whereas they did not enter the smaller streams and

tributaries until temperatures reached 6-7°C. Flagg (1972) has observed spawning to occur in Maine streams at temperatures ranging from 0.6°C to 11°C with peak spawning at temperatures of 4°C to 9°C. It is unlikely that the time of spawning is controlled by one factor such as temperature; but is probably the cumulative effect of a number of both intrinsic and extrinsic factors.

Spawning occurs in a variety of habitats ranging from swift water to dead water pools and on a variety of substrates from silt to gravel to rock ledge (Bigelow and Schroeder, 1953). Percentage hatch is probably dependent on a number of variables such as substrate, temperature, stream flow, and density of egg depositions. McKenzie (1964) found that the percentage hatch decreased with increasing densities. Hatching success was 3.6% at 487 eggs per 1 foot<sup>2</sup>. Concentrations as high as 180,200 eggs per 1 foot<sup>2</sup> are commonly found below obstructions. Hulbert (1974 M.S.) found that eggs incubated on substrates with flat surfaces, such as sand, may experience more severe fungal infection than eggs on substrates with large interstitial spaces such as gravel.

Hatching usually occurs in 15 to 30 days depending on water temperatures. McKenzie (1964) found that hatching in the Miramichi River took 29 days at 6-7°C, 25 days at 7-8°C and 19 days at 9-10°C. The majority of adults mature at two and three years of age and comprise the bulk of the spawning run.

As smelts are unable to negotiate a vertical drop of more than 6 to 8 inches, spawning habitat in the St. Croix River is restricted to the area below the Milltown Dam. Since the Milltown Dam is located in an area of relatively steep gradient, it is likely that sea run smelts did not historically ascend above this point in the river. The current status of the smelt resource and fishery in the St. Croix is unknown. Prior to severe water pollution problems in the lower river, active smelt dip net fisheries did occur and were regulated through private and special laws of the State of Maine. With recently improved water quality in the lower

river, an estuarial smelt fishery could be redeveloped. Commercial smelt harvests in the Pleasant River in western Washington County range from 5,000 to 20,000 pounds per year. Although the smelt production potential of the St. Croix is unknown, it is reasonable to assume that the rainbow smelt harvest could range from 10,000 to 40,000 pounds annually. This harvest could be allocated to be a fall/winter hook and line/gill net fishery and a spring dip net fishery by joint regulation by the participating fishery management agencies.

### **3.6 Striped Bass**

The striped bass, a member of the Percichthyidae or temperate bass family, is a riverine spawning anadromous fish. This highly prized commercial and

recreational fish species ascends rivers in the spring and spawns in early summer, depending on water temperature. Spawning occurs at water temperatures ranging from 50 to 75°F, but the optimum temperature for egg incubation and larval development is 65°F. Incubation time is dependent on water temperatures with eggs hatching in 30 hours at 72°F and 74 hours at 58°F. Spawning habitat varies from the upper to middle reaches of major unobstructed river systems to the low salinity confines of large estuaries. Spawning areas range from head of tide in Chesapeake Bay to small tidal rivers 10 to 12 miles long to several hundred miles above tidewater in rivers of the southeast Atlantic states. Live striped bass eggs are not normally found in areas where salinity exceeds three (3) parts per thousand. At a salinity of 25 parts per thousand, 100% mortality of newly hatched larvae occurs.

The historical status of striped bass in the St. Croix is unknown. Spawning anadromous striped bass are not known to reproduce successfully above dams, and it is unlikely that a spawning run could be established below Milltown because of the very limited freshwater spawning habitat available. Migratory striped bass from the mid-Atlantic States sustain valuable seasonal sport fisheries along the coast of Maine from May through October. A striped bass fishery does occur in the lower St. Croix River. This fishery is probably sustained by migratory fish from the mid-Atlantic States or from the St. John River in Canada which supports a native population. Future fisheries in the St. Croix will be dependent on year class strength and migratory habitats of stocks from these producing areas. Management of this species in the boundary waters of the St. Croix should be based on uniform regulations that are mutually acceptable to fishery managers in Canada and the United States.

## 4.0 Problems for Fisheries Restoration and Management

### 4.1 Water Quality

One important element for fish restoration is the chemical suitability of the water through which the fish migrants must pass to and from the sea. The quality of the lower main stream waters was allowed to deteriorate badly in the 1950's and 1960's to the point of virtual exclusion of fish life from some of those waters, at least on a seasonal basis. The summer and early fall seasons of fish migration unfortunately coincide with the times when water quality conditions have been poorest.

The installation of an effluent treatment system for the Georgia-Pacific Mill at Woodland has resulted in a dramatic improvement in water quality since 1981. Oxygen levels above six (6) mg/litre have been maintained with some consistency, and this level of oxygen is usually considered adequate for the survival of adult migrating salmon. When actively migrating, the salmon's oxygen requirements are high, and this has been a common biological standard by which the success of pollution abatement programs is measured. Salmon mortalities on two occasions suggest, however, that the water quality problems have not yet been completely resolved. Even with the new treatment facilities, the existing summer water quality may be inadequate at times. Unfortunately, the chemical monitoring station was clogged with debris and inoperable at the time, so no concomitant chemical data are available. A disease check showed no sign of pathogens.

The monitoring of salmon conditions, travel times, and success rates in traversing the St. Croix River from Milltown to Woodland and Grand Falls during the upstream fish passage studies in 1984-86, and correlating this with data from the chemical monitor, will provide direct evidence of the adequacy of the present water quality conditions to sustain a run of anadromous Atlantic salmon. Provision for more reliable operational conditions in the chemical monitor would be desirable at this time.

There is an additional facet to the pollution problem that has not been resolved by the abatement facility at the Woodland Mill. The additional complication is the waste depositions on the river bottom. Grand Falls flowage exhibits reduced oxygen levels in waters below five (5) meters depth in summer, apparently as a result of the inundated vegetation and the pulpwood and logs sunken during past river driving operations. The mill owners had practiced wood driving and river storage between the Grand Falls and Woodland dams prior to 1976. Consequently, the river bottom in the Woodland headpond is liberally coated with pulpwood, bark, and wood fragments. This material is creating a biochemical oxygen demand which reduces the dissolved oxygen available for consumption by the industrial effluent poured into the river below Woodland dam.

The effect of the river bottom deposits between Woodland dam and tidal

water is less well understood. The deposit in the river section between Woodland and Baring is more compact than that in the lower river sections. It is too soon to predict what fishes can take up residence in this portion of the river. However, because of the sensitivity of the semi-planktonic shad embryo to water quality at the sediment/water interface, there is reason to suspect that this portion of what was historically shad habitat will not be utilizable for the foreseeable future. A survey of benthic invertebrates, especially oligochaetes, would provide a good indication of the actual extent of biologically effective water quality improvement in this section of the St. Croix River.

In summary, there is still some uncertainty about forecasting the adequacy of short term water quality conditions in the river section from Milltown dam to tidal water. Conditions do appear favourable for passage of migratory fishes safely through these waters, but biological evidence suggests that short term deficiencies brought on by high seasonal water temperatures and/or intermittent failure of the waste treatment facilities could bring about fish kills in this portion of the river.

## **4.2 Fish Passage**

Freedom of movement to the spawning and rearing areas and safe migration to the sea are attributes that rivers must provide for anadromous fishes. The adults must reach the spawning grounds in favorable numbers, in good health and at the proper time for successful reproduction. Also important is the safe return to the sea of the survivors of the spawning. The juveniles must not be delayed unnecessarily in their downstream migration and must be in good physiological condition for successful osmoregulation when entering sea water.

Upstream and downstream fish passage at the three mainstem dams is absolutely essential to an anadromous fisheries restoration program. Part of these requirements is filled by present structures, although additional facilities and modifications would probably be required for a concerted restoration effort.

### **4.2.1 Upstream Passage**

Through the 1950's and 1960's the polluted state of the lower St. Croix River voided any real requirement for fish passage. Nevertheless, a pool-and-weir fishway was installed inside the Milltown powerhouse in 1960, and Denil fishways were constructed at the Grand Falls and Woodland dams in 1964-65.

The previous Milltown fishway was a make-shift facility which never performed satisfactorily. In 1980, a new, much larger fishway was constructed outside the Milltown power plant by excavating a channel through the rock. The new fishway is a ramped, pool-and-weir design

with adequate freeboard and larger pools, including resting pools. This fishway has performed effectively for alewives and there are, as yet, no observed deficiencies for salmon passage. The entrance is quite well situated for attraction during low water conditions, and there is a provision for doubling the water discharge at the entrance to further enhance attraction.

The Denil fishway at the Woodland Dam is one of the longest of its type in the world. The 227-meter length was required because the elevation in mid-length had to be carried horizontally in order that the upper part of the fishway permitted the proper safety clearance under high-voltage transmission lines spanning the river. The fishway is located on the east side of the powerhouse-grinder room with entrance and exit situated close to the building in both the tailwater and headpond, respectively. Fish attraction to the entrance could be improved by installation of a fish-collection facility on the face of the grinder room adjacent to the fishway entrance.

The Grand Falls Dam and powerhouse are separated by a distance of about 800 meters. Water from the headpond is drawn via a power canal. The Denil fishway is installed at the powerhouse. The entrance is effectively located on the north side of the powerhouse, and fishway appears to be efficient for passing large numbers of fishes.

Other major fishways which will be important to restoration of alewives are those at Spednic and East Grand Lakes. These fishways are the vertical-slot type and are effective over a wide range of water level fluctuations. These structures are built of concrete and should remain serviceable for many years. Fish passage at additional sites, e.g. Canoose River, Bolton Lake and Little Digdeguash River, must be assured if the full alewife potential of the East Branch is to be attained. The mainstem dams have another complication for upstream migrating fishes. The Woodland and Grand Fall dams have spillways which are separated from the powerhouses. At times when water is being spilled, upstream migrating fish may be drawn into the spillway channels only to face obstruction to further movement. They would then have to drop downstream out of the spillway channel to gain access to the discharge from the powerhouse for access to the fishway entrances there.

Because of its lowermost river position and small turbine capacity, spillage at Milltown continues, on average, later into the summer and recommences earlier in the autumn. The hydraulic capacities of the Woodland and Grand Falls dams are similar (3,000 c.f.s.), and both are higher than that of the Milltown dam located downstream. Because of the highly regulated nature of the watershed, spillage at the Woodland and Grand Falls dams is an irregular occurrence during upstream and downstream migration periods. Spillage at Woodland and Grand Falls may occur at any time during the spring and summer, following heavy rains. During periods of spillage, attraction to spillage discharge may result in stranding of upstream migrating fish. If stranding of salmon, shad

and/or alewives becomes a problem, one of several measures may have to be undertaken including:

1. Installing a fishway at the spillway dams.
2. Construction of a barrier to prevent entry of fish into the spillway channels.

If salmon enter the spillway channels, they might be encouraged to drop out if a small amount of water can be spilled to provide a transportation flow. In the absence of this possibility, there will likely be a requirement for salvage of the trapped fish.

#### **4.2.2 Downstream passage**

Anadromous fish stocks must be able to migrate downstream to the sea in a safe manner. Restoration in the St. Croix River basin requires this freedom for adults of salmon, shad, alewives, and eels and for the juveniles of salmon, shad, and alewives.

The earliest downstream migrants each year will be spent salmon, followed by smolts, and most will be out of the river by June 10. Adult alewives will commence a return to sea even while passing upstream members of the spawning run, and fall stragglers in very poor physical condition are not unusual. These latter fish apparently have been trapped in small pools when summer low flows occurred before spawning is completed. Juvenile alewives start moving downstream about mid-July and continue until late fall. Juvenile shad move down to the sea in the fall, usually after the water temperature falls below 15°C for several consecutive days.

The annual interval used by downstream migrants is from April to November. During April, May and early June there will likely be spillage of surplus water at all mainstream dams. At these times, downstream migrants will have an opportunity to pass down over the spillways. There will be risk of some mortality at the spillways depending on fish size, amount of water spilling, and the physical conditions at the site.

When no spillage of surplus water is occurring, the fish must pass down the fishways or pass through the turbines. Fishways are often not significant as pathways for downstream migrants because the location is usually chosen for maximum upstream migration utility and the fishway flow is usually small compared to the powerhouse intake flows. On the St. Croix River, however, it is expected that especially the Grand Falls fishway will be utilized by modest numbers of downstream moving fishes because the location here is conducive for use by downstream migrants, and some modest modifications around that fishway exit would promote even greater usage. The Milltown site is less likely to be troubled by downstream fish passage mortalities because it has the

lowest turbine capacity and highest discharge, thus necessitating more frequent spillage than at the upstream sites. The fishway exit is also moderately well located for downstream fish passage.

Downstream movements are effected not only by the obstructions on the river, but also by the existence of headponds. The Woodland and Milltown headponds are run-of-the-river type, and the water current there will not result in significant time delay of the migrations. The Grand Falls flowage, however, is a different matter for a measureable slow down of salmon smolt movement can be predicted. Rates of smolt movement in rivers usually average about five (5) km per day. Smolt movement through lakes and impoundments averages about 0.8 km per day. Smolts entering the Grand Falls flowage from the East Branch will have an impoundment migration path of five (5) km. This distance will result in an average net delay of five days for east branch smolts during passage through the Grand Falls flowage. Such delays can reduce the survival of Atlantic salmon smolts. This delay will also increase the exposure of smolts to predation by the chain pickerel population in the flowage.

Over a significant portion of the fish migration period, downstream migrants, especially juvenile alewives and shad, will be faced with passage through or around the three main river powerhouses. The circumstance which requires all migrants to pass through powerhouse turbines is ominous for all diadromous fish. The close spacing of the trash rack bars at Woodland and Grand Falls prevents entrainment of significant numbers of smolts and post-spawner adult alewives into the turbines and migration delays and mortalities often occur due to impingement of the fish on these trash racks.

No studies of fish turbine mortalities have been conducted on the St. Croix River. Although many factors affect these mortality rates, thereby making each installation and individual case, there are methods for estimating the order-of-magnitude mortality rates to be expected. Other studies in other areas indicate mortalities could be as high as 40 percent for 20 cm fish. Priority is now being given to preparation of direct estimates of mortality (by releases of tagged salmon smolts and monitoring of returns) to confirm the need for guidance systems and/or installation of by-passes.

An additional problem is the increased delays in migration which is believed caused by the spacing of the existing trashracks at Woodland and Grand Falls.

### **4.3 Predators and Competition**

Predation and competition are important in the ecology of the fishes' environment and will figure dominantly during restoration of anadromous fishes to the St. Croix River Basin. The St. Croix River list of fish

species resident in the basin has at least two species that have been introduced by Man, the chain pickerel, Esox niger, and the smallmouth bass, Micropterus dolomieu. These two were probably introduced in the American portion of the river basin.

Accurate information about the timing of the introductions of these three species to the St. Croix Basin is not available. The chain pickerel was reportedly released into Little Musquash Lake in the mid-1850's. (McCabe, 1976, quoting First Rept. Comm. Fish. of Maine, 1867-68). Smallmouth bass were stocked in 1877 into Meddybemps Lake, a water with outlets to both the St. Croix and Dennys Rivers (Eleventh Rept. Comm., Fish. of Maine, 1877). Since the bass was providing a sport fishery in Big Lake by 1900, it seems likely that the species was also introduced further upstream at about the same time.

The chain pickerel is the species which will have greatest negative impact on a salmon restoration effort. The pickerel is piscivorous and, over a size of 7.6 cm (3 in.), is a serious predator on other fishes. It normally inhabits ponds and lakes, although dead waters and back waters of rivers are also occupied. The habitat of the pickerel and the juvenile salmon will not normally overlap. However, when the salmon smolts migrate to sea, they will pass through pickerel environment, where considerable predation by the pickerel is certain to occur.

Pickerel in this area of North America are spring spawners which occupy shallow weedy areas for that activity. Spawning normally takes place at about 8.3-11.1°C (47-52°F) for 7-10 days in April or May. This temperature coincides with the 7.2°C (45°F) mean daily water temperature at which most smolt migrations are initiated. However, because the very shallow lake waters warm faster in the spring and can be at least ten degrees warmer than nearby surface waters, the pickerel spawning activity often precedes the smolt migration. This sequence means that the pickerel may be recovering from spawning and feeding vigorously just when the smolts begin to move through the pickerel territory.

Predation by pickerel can, at times, be appreciable. Pike, Esox lucius, a close relative of the pickerel, have been shown in Scotland to consume salmon smolts in April and May to 20 percent of their diet (Webster, 1961). Barr (1962) reports that 21 percent of the pickerel over about 25.4 cm (10 in.) contained salmon smolts during the 1961 smolt run of several hundred fish through a lake in Maine. Also of importance, Barr noted pickerel predation during winter on those pre-smolt salmon which moved into the lake during the fall prior to the seaward migration. Finding 1-4 smolts in chain pickerel stomachs during the smolt migration is not uncommon.

Regulations for open water and for ice fishing, particularly in Grand Falls flowage, should be liberalized as much as possible to encourage pickerel harvest. Likewise, public access to flowage waters should be promoted, by such methods as provision of boat-launching ramps and plowing of roads in winter.

The smallmouth bass is more of a stream resident than the chain pickerel, so habitats are more overlapping with those of juvenile salmon. Larger bass, however, which are the most voracious predators, are more common in lakes than in rivers. This species doesn't begin to feed in the spring until the water temperature reaches about 8.5°C (47.3°F). The smolt run will be underway by that time in most years. With rapidly rising water temperature, the bass, which is a spring spawner, soon becomes engaged in spawning activities. Nest building begins at about 14.5°C (58°F) and spawning activity peaks near 17.8°C (64°F). Males are engaged full-time with nest construction, courtship, and guarding of the fry in areas free of most current. The smallmouth bass is not expected to be a significant predator on juvenile salmon, although on occasion there will be competition for food in the rivers.

Two other species, the fallfish, Semotilus corporalis, and the burbot, Lota lota, are also potential predators. Although the impact is expected to be very minor, no data are yet available on possible predator-prey relationships with the Atlantic salmon juveniles.

The strongest competitor of Atlantic salmon is the landlocked salmon. If the sea-run form is introduced, the landlocked form is expected to decline, unless reproductive and rearing isolation can be attained. Few documented examples show the existence of landlocked and sea-run salmon together in a watershed unless separated by a barrier. It appears that the length of Spednik Lake may be sufficient to discourage interference by sea-run salmon with the landlocked salmon in East Grand Lake, but use of the East Branch below Spednik Lake by landlocked salmon is expected to decline. The landlocked salmon populations on the West Branch, particularly in Grand Lake Stream and Musquash Stream, could be deleteriously affected.

Restoration of an appreciable alewife resource could have side-effects. In particular, the availability of additional forage fish in the form of juvenile alewives over a several-month period will be beneficial to some resident fish species. The chain pickerel and smallmouth bass may achieve better growth rates if the juvenile alewives are more suitable forage than that presently available during the summer-fall then be ever more important as seasonal predators on the juvenile salmon. There is some concern that heavy grazing by juvenile alewives will be competitive with the juvenile rainbow smelt, and with juvenile smallmouth bass in Spednic Lake (a species which is a major forage for landlocked salmon) and with juvenile smallmouth bass in Spedaic Lake. Unless the alewives can substitute for the smelt, speculation is that there may be some reduction in the landlocked salmon growth rate.

#### **4.4 International Sharing of Fish Harvests**

The fishery resources of the boundary waters and tributary streams will be managed in accordance with sound biological principles to attain optimum

sustainable utilization. As a guideline for respective management agencies, a flexible management system will be endorsed for the protection, development and utilization of the fish populations. The system must have capability to react quickly to annual fluctuations in production and levels of abundance of single species populations. The same principle of flexibility will be applied to access the harvestable surpluses and control the level of harvest on both sides of the border.

The St. Croix watershed is sparsely populated and almost all of the recreational development in the area is in the form of privately owned summer cottages or commercially operated fishing camps. The present level of recreational fishing effort is not a major concern; however, the growing interest in sport fishing, especially for Atlantic salmon, will require immediate attention to measures which guard against excessive fishing effort and deterioration of the quality of fishing. Cooperation with managing agencies will be sought in establishing and maintaining compatible licensing systems and measures which may include, but not limited to, controlling participation in the fisheries and allocation of allowable harvest by individual fishermen.

#### **4.5 Selection of Donor Fish Stocks**

The reestablishment of anadromous and catadromous stocks in the St. Croix River Basin will require a stock nucleus for each fish resource. The bases for the alewife and eel stocks are already present in the basin, and no significant further stock development work is required. Experience may show that alewives are not migrating into selected sub-drainages or tributaries and, if so, some transfer of spawners into those barren (of alewives) areas may be required to initiate usage of those production areas.

Small numbers of shad are present in the St. Croix estuary, and these may be the most suitable source of that stock. The need for the shad stock nucleus is not urgent because fish passage problems must be overcome and the reliable operation of the main stem pollution abatement facilities must be proved. It seems likely that the shad population may naturally increase about as fast as the technical problems of fish passage and water clean-up are resolved. If the resident stock is insufficient to accelerate the population expansion at the desired rate, then a decision to move stock from the Saint John River or other donor location where the spawning migration was similarly lengthy could be considered. Difficulties with successful transfer of spawners or with adequate survival of transferred eggs, however, are additional obstacles to be overcome.

Atlantic salmon stock must be introduced in significant amount if the restoration is to be achieved within a decade. Some stocks have been introduced, beginning in 1897, but the pace has increased since 1966 (Table 4). Many of the hatchery-reared lots planted since 1975 were

**TABLE 4**

**Recorded releases of Atlantic salmon  
into the St. Croix River since 1897**

Year	# of Fish	Size	Stock Origin
1897	150,000		
1989	137,500		
1926	106,000		
1927	150,000		
1940	5,000	2.8g	
1949	101,000	No.3 fingerlings	Miramichi
1966	51,700	44 g	Miramichi
	94,100	15-36g	Maine (Machias & Narraguagus Rivers)
1967	55,300	49 g	Miramichi
	9,000	20 g	Miramichi
1968	17,100	28-48g	Miramichi
	25,000	22 g	Maine (Machias River)
1975	47,500	eggs	Mixed North American Research Centre
	3,300	fry	Mixed North American Research Centre
1976	45,800	eggs	Magaguadavic
1978	20	adults	Waweig
1979	60,000	fry	Waweig
1980	444	118-1SW& 326-MSW	Saint John
1981	19,700	131 g (2 <sup>+</sup> )	Maine (Penobscot & Union Rivers)
1982	20,000	45 g (1 <sup>+</sup> )	Maine (Penobscot River)
	500	fry	Waweig
	101,000	fry	Maine (Penobscot River)
	50,000	10.3g	Maine (Penobscot River)
	20,000	fry (0 <sup>+</sup> )	Maine
1983	20,000	66 g (1+) smolt	Maine (Union River)
	25,500	19 g (1+) parr	Maine
1984	95,500	61 g (1+) smolt	Maine
	13,800	21 g (1+) parr	Maine
	52,500	fry (0 <sup>+</sup> )	Maine
1985	59,600	61 g (1+) smolt	Maine
	12,900	23 g (1+) parr	Maine
	46,400	8.6 g (0 <sup>+</sup> ) parr	Maine
	177,500	fry (0 <sup>+</sup> )	Maine

experimental for the purpose of evaluating river habitat or assessing the mortality of smolts at main stem powerdams.

Donor stocks should be selected with care. Studies have shown that the closer geographically the donor river is located, the better the chance for successful introductions. Certainly the area of selection should be limited to the northerly Gulf of Maine or the westerly Bay of Fundy rivers.

The closer the introduced stock is to the smolt stage, the quicker will be the build-up of the salmon run, and the sooner the salmon potential in the basin can be used to reach an optimal population level. Table 5 shows estimates of salmon of different stages required to stock the St. Croix River Basin if only that one stage is used for the restoration effort over a five-year program.

The cost of brood fish varies considerably depending on the type of product used for the restoration program. This variation results because of more effective use of the reproductive potential if that potential is utilized in an artificial fish culture system. That use, however, comes at appreciable dollar cost including high distribution expense. On the surface, broodstock requirements for an adult transfer are far more extensive than for those tactics using fish culture techniques. Among the latter, the brood fish requirement for the smolt stocking technique is most economical in fish.

#### **4.6 Fish Disease**

Any plan for introduction of salmon stocks must operate under a fish disease policy that provides adequate protection for the wild stocks in the basin. The policy will prohibit the introduction of fish stocks which are positive for a prescribed list of fish disease or which come from a facility having any history of the prescribed diseases. The impact of the policy now is to permit suitable stocks only from the Green Lake National Fish Hatchery in Maine, or wild broodstock which have not been held on surface water supplies. This restrictive policy is of particular importance since the St. Croix watershed has major sport fisheries and important fish culture facilities operated for salmonid output to other basins. Periodic review or revision of the fish disease policy may be warranted by future findings with reference to fish diseases in the St. Croix Basin. The Fish Health Management Plan is outlined in Appendix 4 of this report.

#### **4.7 Factors External to the River Basin**

Anadromous fish restoration in the St. Croix River can be affected by developments or conditions not within the confines of the basin or estuary. In particular, economic conditions which influence the cost of energy can impact on the resources of the drainage.

TABLE 5

Estimates of salmon of different stages  
required to stock the St. Croix River

Stage (age)	Number required* annually	Female salmon broodstock requirement**
Egg (contained in 2,200 males and females transferred per year)	7,390,000	1,026
Fed fry (0)	1,110,000	195
Fall fingerlings (0+)	740,000	145
Yearling (1+)	555,000	140
Smolt (1+ or 2+)	148,000	50

\* Calculated as follows:

Number per 100 m<sup>2</sup>: eggs, 240; fed fry, 36;  
fall fingerlings, 24; yearlings, 18; and smolts, 4.8.

\*\* Calculated as follows:

Survival rates of egg input to hatcheries: fed fry, 80%;  
fall fingerlings, 70%; yearlings, 55%; and smolts, 40%.

Passamaquoddy Bay has long been under consideration as a site for a tidal hydroelectric project. If this project should materialize, it seems quite certain that anadromous fish runs to streams entering the project impoundments will be affected or the potential for those stocks will disappear. During the last period of intense interest in the tidal power project about two decades ago, the suggested design had a two-pool feature. Fish leaving the rivers would pass out through the power house while adult fish entering the rivers would have no way of homing into the upper pool without passing over two tidal dams. The fish passage problems would appear to be insurmountable in this case.

The three main river dams are hydroelectric facilities, mainly run-of-the-river with little storage capacity. Major storage occurs in lakes on the East and West Branches. Any major shifts in economic costs of alternate sources of energy, such as nuclear, gas, or oil, could influence the presence of the hydroelectric structures. If alternate energy costs rise, further hydroelectric redevelopment could take place. Alternatively a substantial decrease in energy costs might discourage the maintenance of the present structures. Changes to the structures can have positive or negative effects on the continuing fish passage problems of the St. Croix River.

Another external factor that could impact on the anadromous fish restoration plans is aquaculture in the Bay of Fundy, particularly Passamaquoddy Bay. In attempts to supply appropriate salmon stocks to the St. Croix there is a potential problem with Atlantic salmon escapees from fish farms. Their presence in the St. Croix could have an influence on the gene pool of "new" St. Croix stock at a very critical time in the restoration plan. There is also the potential for introducing disease with these escapees. One could have some control over this situation if stocks entering the river were closely monitored at Milltown during initial years of restoration activities.

## **5.0 Required Action to Overcome Problems**

### **5.1 Ensure Adequate and Reliable Water Quality**

The IJC Pollution Advisory Board and State/Provincial biologists working under the auspices of the St. Croix River Steering Committee should work together to monitor and maintain adequate water quality in the St. Croix River. Reliable collection of chemical data will probably require the manual collection of daily water samples, and a program to do so should be implemented during the period of upstream fish passage assessment for Atlantic salmon in for the critical low flow and high water temperature months of June through September. Water samples can be collected daily by the crews tending each fishway, and simple chemistry (oxygen, pH, temperature and colour) can be performed on the spot. More complex

analysis, such as BOD, would require laboratory participation.

In addition, the condition of the salmon as they reach each successive fishway, as well as percent survival through the reach from Milltown to Woodland, and the timing of their passage through various sections of the river, will contribute to assessment of the present water quality adequacy.

A new survey of benthic invertebrates, especially oligochaetes, should also be undertaken before 1987. By comparison with previous data sets from 1972 to 1978, this would provide a good indication of the extent of biologically effective water quality improvement.

A two or three day workshop on water quality in the St. Croix River should be held to bring together all concerned parties. The workshop should decide on the water quality standards required for a sustainable Atlantic salmon resource; whether they have been achieved or are achievable on the St. Croix; and how best to ensure reliable water quality conditions during the periods when migratory species are present in the lower reaches of the river. The question of satisfactory water quality standards for fish species reproduction should also be addressed at the same time.

## **5.2 Document and Institute Solutions for Fish Passage Problem**

The St. Croix River was stocked by adult transfers (from the St. John River in 1980) and juvenile salmon stocking (from Green Lake hatchery in 1981-85) so that a sufficient number of returning adult salmon would be present for assessing the efficiency of the fishways for upstream and downstream passage. An outline for all salmon stocking activities during the years 1980-85 is presented in Table 6.

A computer simulation model (Appendix 2) has been constructed and approved by the Biological Subcommittee to predict the salmon returns that can be anticipated from the stocking effort and to serve as a tool for identifying and quantifying potential salmon management problems. The model projections for salmon returns to the Milltown fishway are given in Table 7. The actual 1984 returns were 172 grilse and 72 salmon; which is a good fit to the "pessimistic" version of the model. This implies that juvenile survival, downstream survival, and sea survival were all unusually low for 1983 smolts. It does not necessarily imply that these low survival values will persist for future salmon returns. The returns for 1985 up to the end of September are following closer to the pessimistic version with recorded count at the Milltown fishway of 268 salmon and 31 grilse. If problems can be resolved, salmon returns to the river can be changed by improving the efficiency of both upstream and downstream fish passage. Also, selecting a stock more suitable to the river could improve returns.

TABLE 6

St. Croix River stocking information complete to October 1985

Year	Eggs from SJR Adult Transfers	Green Lake Tagged Smolts (fish passage)	GL Smolts Above G.F.	GL Smolts at Milltown	GL Parr	GL Fall Fingerlings	GL Fry
1980	1,550,000						
1981		19,700					
1982		20,000			50,000	20,000	101,000
1983		20,000			25,500		
1984			46,600	48,900	13,800		52,500
1985				59,600	12,900	46,400	177,500

**TABLE 7**

**Returns predicted by the pessimistic St. Croix model**

<b>Year</b>	<b>Grilse</b>	<b>Salmon</b>	<b>Salmon and Grilse</b>
1984	185	68	253
1985	112	297	409
1986	32	796	828
1987	42	105	147
1988	30	107	137
1989	35	36	71
1990	26	70	96
1991	24	132	156
1992	24	54	78
1993	24	43	67
1994	27	27	54
1995	25	30	55
1996	24	37	61
1997	24	28	52
1998	24	25	49
1999	25	22	47

**Returns Predicted by the Optimistic St. Croix Model**

<b>Year</b>	<b>Grilse</b>	<b>Salmon</b>	<b>Salmon and Grilse</b>
1984	625	68	693
1985	160	805	965
1986	52	1,106	1,158
1987	92	186	278
1988	84	199	283
1989	296	112	408
1990	56	629	685
1991	27	767	794
1992	26	299	325
1993	36	224	260
1994	241	151	392
1995	62	505	567
1996	36	561	597
1997	27	319	346
1998	30	226	256
1999	175	173	348

### 5.2.1 Upstream Problems

The new Milltown fishway was evaluated for upstream passage of alewives in 1981. Internally, the fishway appears to function equally well throughout; the average time required to pass each pool was about 0.5 hours regardless of whether the fish were released near the fishway entrance or exit. The percent downstream fallback ranged from 8.3 percent to 17 percent as compared with 33.6 percent to 39.8 percent in the previous fishway constructed through the powerhouse. The efficiency of the new fishway in successfully passing alewives from the estuary was estimated to be 65 ( $\pm$  33) percent. The high error stems from high mortalities in the controls.

During the summer of 1984, 24 grilse taken from the Milltown fishway trap were tagged, and 22 were released again approximately one kilometer downriver (two fish died shortly after tagging, both at 24° C water temperature). Fifteen of these were recovered again at the fishway trap, giving an uncorrected recovery rate of 68%. Allowing for an estimated 10% tagging mortality after release yields a fish passage efficiency of 76  $\pm$  9% for salmon from the St. Croix estuary. The other 24% would represent natural estuarial mortalities, exploitation, and straying. Many of the fish entering the Milltown fishway in 1984 had net scars, and one had what appeared to be a gunshot or spear wound.

Additional studies are planned to refine all fish passage efficiency estimates at Milltown, Woodland and Grand Falls.

Significantly enhanced salmon runs should occur over the three year period, 1985-87, and upstream fish passage studies should be carried out within this time frame. During these years, salmon traps should be monitored daily at Milltown, Woodland and Grand Falls. All salmon captured at Milltown should be tagged, scale samples collected, and other vital statistics recorded including time of release. These fish should then be monitored through Woodland and Grand Falls fishways. In addition, about 20 of the fish captured at Milltown should be tagged and released back in the estuary in 1986, so that an estimate of efficiency can also be derived for salmon entering the Milltown fishway.

From these data, and from detailed observations of fish behaviour at the three fishway sites (speed of passage through the fishways, etc.), a list of required modifications will be drawn up to enhance attraction at low efficiency sites and redress any other perceived deficiencies in the upstream passage system. Because the fish must pass through three fishways before reaching their spawning grounds, it is vitally important that all three fishways function at the highest possible efficiency.

### 5.2.2 Downstream Problems

Considerable priority has been given to assessing downstream mortality of salmon smolts at the three mainstem power stations. Tag returns up to the end of the 1985 season from salmon fisheries, and returns of tagged adults to the Milltown fishway trap have provided mortality estimates relative to Milltown for each of the upstream sites.

During 1984, a planned release of marked smolts (left and right ventral fin clips) above and below Milltown went awry when a failure of the aeration system led to an unscheduled jettisoning of one load at the wrong release site. Releases of marked smolts above and below Milltown in 1986 to provide an estimate of absolute mortality at Milltown and also of the upstream sites will be conducted.

These data will allow us to identify specific downstream problems and to prepare remedies. Additional studies may be required to estimate the mortalities due to predation, etc., involved in smolt passage through the Grand Falls flowage.

Downstream mortality mitigation at Milltown, if required, may be achieved by a special downstream bypass channel, which could be constructed at relatively modest cost by utilizing the old fishway site inside the powerhouse. Entrances to the fish paths would be located on both sides of the central pier between the two banks of turbines.

A downstream bypass channel, at modest cost, is also feasible for the Grand Falls site by modifications to the existing log flume. Special measures could be taken to modify the intake structure and flume entrance, and the use of floating guidance devices might be considered as an additional technique.

The Woodland Dam site would be the most difficult and expensive of all the provisions of an effective downstream bypass system. Unfortunately, this is also the most likely site on the river to exhibit a high downstream mortality problem because of the physical configuration of the water intake structures which would tend to attract surface swimming fish and because of the high turbine capacity which precludes frequent spillage.

### 5.3 Regulatory Measures

To ensure that the management plan is implemented effectively, uniform regulations must be developed for both sides of the border. Regulations promulgated under the Acts and Statutes of both jurisdictions may include, but are not limited to seasons, size limits, daily and seasonal bag limits, type and method of fishing, allowable harvest among users, limitations on effort and the establishment of restricted areas. Management of the fish stocks in the sea coast approaches and inland areas

of the St. Croix River System is of international interest; therefore, it is essential to institute compatible regulatory measures for these fish stocks of common concern.

The development and implementation of regulatory controls, based on a sound understanding of the fish stocks, requires the collection of accurate harvesting and utilization statistics, as well as continuing update on assessment and inventory data. To ensure that the conservation requirements are being met, the various enforcement agencies on both sides of the border will meet annually to review the effectiveness of regulatory controls and recommend amendments as necessary.

#### **5.4 Stocking Plans**

The success of stocking programs for Atlantic salmon and American shad have already been described as contingent upon the solution of problems related to water quality and fish passage. The initial effort will be to ensure suitable conditions for the salmon restoration.

Information on the water quality of the main stem is accumulating following the improvement of municipal treatment facilities and the installation of extensive treatment for the waste at the Woodland Mills. Additional confirmation of the accuracy of the data, of the effectiveness of the treatment facilities, and particularly of the spring-summer-fall reliability of all the waste treatment facilities is required. It appears feasible to assess, plan, design and install current or new equipment so that reliable maintenance of water quality standards can be attained for 1991.

Assessment of downstream fish passage problems has begun with stocking of tagged lots of hatchery-reared smolts in 1981-83. Last returns from these experimental lots were due back to the river in 1985. The intent of these stockings was to relate the relative smolt losses at the three mainstem dams to each other. In 1984 and 1985, two of three planned annual releases of smolts were made which will provide information on the losses at the Milltown power facility, thus providing a baseline for relating the losses at the Woodland and Grand Falls power facilities. Returns from these latter smolt plantings will not be complete until 1988. The early returns from the smolt stockings indicate the need for downstream bypass facilities at least at Grand Falls and Woodland. It appears feasible to begin the negotiations, design, and financial planning that will culminate in installations in the 1986-89 period, in time for a substantial smolt run in 1990, and these facilities will also benefit other anadromous fish species. Any introductions of stock, which will result in smolt runs prior to 1990, will be expected to run the risk of reduced survival before reaching the sea.

In the prior Section 4.6 of Selection of Donor Fish Stocks, it was pointed out that the only fish culture facilities which are acceptable under present disease policy are from Green Lake National Fish Hatcheries in

Maine. Canadian sources of stock could be adult fish from the Magaguadavic or Saint John Rivers, and these sources, in all likelihood, could not provide the full requirements for adult fish in one year unless unexpected dramatic changes in stock levels should occur in those donor rivers. Another option to provide salmon stocks from a Canadian source is to have the Saint John fish culture station meet the requirements of the Fish Health Management Plan outlined in a previous section of this report.

Changes in this concerted stocking schedule will occur depending on future possible occurrences, including change in disease policy that permits fish culture stock from more facilities, availability of more adult fish for transfer, or acceleration of the attainment of reliable water quality and adequate downstream bypasses. Some flexibility in the salmon stocking schedule will always have to be anticipated.

Stocking of American shad will necessarily be slow, pending identification of suitable donor stocks. Successful passage of shad spawners in the remnant run through the Milltown fishway might, in time, obviate the need for the introduction of any additional shad stock.

### **5.5 Fish Disease Control Policy**

The reintroduction of anadromous stocks in the St. Croix River system will undoubtedly impact the fish health of established fish populations within the drainage. It is important to safeguard against the introduction of diseases or pathogens which will defeat the efforts of the stock restoration program. The following policy will be implemented by the managing agencies in regard to stock introductions to the river system:

- establish a Fish Health Review Committee of recognized fish health officials to review annually the fish health status of all wild stocks of fish to be transplanted from other watersheds and all fish cultural facilities.
  - (a) within the watershed,
  - (b) stocking directly into the watershed, or
  - (c) transferring fish, eggs, or sperm into fish culture facilities within the watershed; and
  - (d) wild brood stocks supplying eggs or sperm to fish culture facilities within the watershed;
- make available copies of all fish health inspection reports of the above stocks to the Fish Health Review Committee;
- prevent the introduction or release of fish with emergency and certifiable pathogens in the St. Croix River watershed;
- refer all proposed non-salmonid fish introductions to the Fish Health

Review Committee for prior approval of fish health status;

- report all diseases or pathogens detected in fish health examinations related to the St. Croix River;
- develop legislative authority and regulations as required to control and eradicate fish disease;
- take prompt and effective action to eradicate emergency pathogens.

Note: The Fish Health Subcommittee has developed a management plan which is outlined in Appendix 4.

## **6.0 Timetable for Fisheries Restoration**

### **6.1 Sequence of Events**

Table 8 is a diagrammatic representation of the proposed timetable up to the year 1995 for activities related to the restoration of anadromous fisheries (salmon, alewives, and shad) in the St. Croix River.

The items described within the timetable for the years 1980-84 are accomplished. The years 1985-90 contain a sequence of studies and mitigative activities leading to a full-scale Atlantic salmon restocking effort during the late 1980's and subsequent monitoring of adult returns during the early 1990's.

Studies relating to shad restoration will commence after the salmon problems have been resolved, in 1991.

Responsibility for coordination of the overall restoration plan rests with the St. Croix River Steering Committee. This group will ensure that regulations are in place at the proper times to protect returning salmon during the fish passage study and restocking phases. The Steering Committee will ensure that fishery regulations on both sides of the St. Croix River are compatible.

### **6.2 Key Turning Points**

The timetable has been laid out sequentially so that significant milestones and critical event sequences are readily apparent (Table 8). The stocking efforts during 1980-85 were undertaken to assess the rearing potential of the St. Croix River habitat, to assess smolt losses at the mainstem dams and to provide a sufficient number of returning adult salmon for an assessment of the adequacy of present upstream fish passage conditions. The enhanced adult returns will occur in 1984-87. The upstream fish passage studies for the three fishways and for the river system, as a whole, will be completed within this time window. Continuing

**TABLE 8**

**Timetable for restoration of the anadromous fisheries of the St. Croix River (Maine-New Brunswick)**

Time Scale:            1980   1981   1982   1983   1984   1985   1986   1987   1988   1989   1990   1991   1992   1993   1994   1995

Program Components:

1980-95. Continued monitoring of water quality (including biological indicators) by U.S. and Can. Agencies.

Water Quality  
Requirements and  
Control

1984-86. Salmon  
and other  
biological mon-  
itoring may in-  
dicate deficiencies  
FRD, DOF and DEP.

1987. W.Q. Rev.  
U.S. and  
Can.

1988-90. Correct  
water inadequacies  
by upgrading,  
dredging, etc.  
U.S. and Can. Agencies.

1991-95. Revised W.Q.  
requirements to be reliably  
reliably maintained.

Fish Passage  
(common)

1981-95. Monitoring Milltown fishway for 7 months each year to count and record alewife, shad and salmon returns, record salmon tags, collect and read salmon scales, and provide vital statistics data on alewives, salmon and shad. FRB.

Downstream Fish  
Passage

1981-83. Release  
of tagged smolts  
above mainstem dams  
for mortality  
estimate. ASRSC.

1984-86. Release  
of marked smolts  
above and below  
Milltown for mor-  
tality estimate.  
ASRSC.

1986-90. Install downstream  
guidance systems at high mor-  
tality sites. ASRSC and FRB\*.

1991-93. Release  
tagged smolts to  
assess new guidance  
systems. ASRSC and  
FRB.

TABLE 8 CONT'D

Time Scale:            1980   1981   1982   1983   1984   1985   1986   1987   1988   1989   1990   1991   1992   1993   1994   1995

Program Components:

Upstream Fish Passage	1980 Adult salmon transfer to provide returns for f.p. study. FRB.	1981 Mill-town evaluation for alewives FRB.	1982-84. Juvenile salmon give returns for fish passage evaluation. ASRSC.	1985-87. Monitor and evaluate all 3 mainstem fishways as a system for upstream salmon and alewife passage. FRB and ASRSC.	1987-90. Alter or upgrade fishways as required for upstream salmon passage. ASRSC and FRB*.	1991-94. Adult shad transfers to study restoration potential and to furnish returns for fishway evaluations. FRB and DMR.
Atlantic Salmon Research/Restoration				1986 and onwards. Stocking of Atlantic salmon coincident with the resolution of fish passage problems. Stocking for purpose of researching downstream problems will continue.		
Alewife Restoration		1981-83. Count all alewives passing Milltown and collect vital statistics data FRB.	1984-95. Do sample counts at all three mainstem fishways and continue to collect vital statistics as the population builds up. Monitor fishway capacities and potential for interference with other anadromous species. FRB and DNR.			
Shad Restoration			1983-95. St. Croix River Biological Party to coordinate biological investigations on fish passage studies and fish introductions. ASRSC, DNR, DIF&W, FRB.			1991-95. Commence investigation for shad restoration.



salmon stocking beyond 1985 will allow ongoing fishway assessment beyond 1987.

Counting of the entire alewife run at the Milltown fishway during 1981-83 caused some delay to the run, and this in turn, could hold up the early salmon. The first substantially enhanced salmon run returned in 1984, and at the time, the collection of baseline population data on the alewives was reduced to periodic sampling for vital statistics and hourly timed counts of the rate of fish passage. It is anticipated that the upper limits to the alewife population will be set by fishway efficiency and capacity rather than available habitat, and that fishway crowding by the alewives will likely interfere with the potential shad and early salmon runs.

Observation of upstream salmon passage during the fishway evaluations (1984-87) will provide information relating to the adequacy of present water quality conditions for sustaining an anadromous salmon resource on the river. Chemical studies and biological indicator organism surveys should also be conducted concurrently so that a final consensus on water quality requirements for anadromous salmon restoration can be reached by 1987.

During 1981-83, a number of tagged smolts were released for assessment of downstream mortality problems at Grand Falls and Woodland dams. Return rate of adults from these tagged smolts was extremely low, but they did indicate that a progressively more serious downstream mortality problem from the Milltown headpond released to the Grand Fall headpond of tagged smolts. More releases of marked smolts were conducted during 1984 and 1985 to estimate downstream mortality at Milltown.

The sequence of goals laid out in the timetable for the years 1984-90 will have to be accomplished before an Atlantic salmon restoration program can proceed with any reasonable assurance of success. On the assumption that this program proceeds smoothly, the final stages have been allowed to overlap, with the start-up of full-scale stocking for salmon restoration, which could begin (with adult transfers) as early as 1986. This rather optimistic scheduling assumes that the following goals will have been accomplished:

- (a) Water quality has been evaluated and judged suitable for salmon.
- (b) Downstream mortalities have been judged insignificant, or downstream guidance systems are being installed at problem sites and will be operational before the first enhanced smolt run.
- (c) Upstream fish passage adequacy has been evaluated for each of the three fishways individually and for the river as a whole (tidal up to spawning area), and either judged adequate or deficiencies are being made good and will be in place before the first enhanced spawning run.

acceptable to the managing agencies. Restoration stocking will be timed to provide the first full-scale smolt run after all significant water quality and fish passage problems are resolved.

Since a large proportion of the historic shad habitat is in the lower portion of the river, directed investigations into the habitat potential and fish passage requirements for shad will not commence until after satisfactory resolution of all water quality and fish passage problems for salmon. The target date for start-up of shad studies is 1991. Shad investigations could be advanced to 1988 if the 1987 review fails to identify any significant water quality problems.

Stocking has already taken place to provide adequate salmon returns for evaluation studies in 1984-87. Significant local exploitation of returning adult stocks would seriously disrupt and probably invalidate the evaluation of fish passage facilities.

## **7.0 Recommendations**

To ensure the orderly development of the diadromous fish stocks in the St. Croix River, care must be exercised in the selection of donor stocks, the evaluation of upstream and downstream fish passage facilities in concert with stocking programs, improve fish passage efficiency as deemed necessary and ensure that the water quality standards and water flow regimes are maintained.

Each phase of the restoration program must be carefully planned and the annual activities evaluated to determine the degree of progress being made and identify problems which need to be resolved before major commitments are made. The following recommendations provide general guidelines for follow-on activities:

- stocking programs should be carried out in conjunction with the evaluation of the efficiency of the upstream fish passage facilities;
- evaluate downstream salmon smolt and alewives mortality problems at the three main river dams, and if the problems are judged significant, negotiate with the owners to carry out improvements;
- continue monitoring of water quality and coordinate a survey of benthic invertebrates during 1987. These activities should be coordinated with the Water Pollution Board of the International Joint Commission;
- select disease-free fish stocks from suitable donor populations for restoration of Atlantic salmon and limit initial stocking to a level that provides sufficient adult returns for fish passage evaluation (monitoring for disease could be carried out by sampling salmon returning to Milltown fishway.

- develop uniform regulations for conservation of the developing fish stocks and control of allowable harvest for the anadromous and freshwater fish species;
- the St. Croix River Steering Committee and its Subcommittees should continue the role of coordinating the activities of the managing agencies in regard to all aspects of the restoration and management of the various fisheries in close cooperation with the IJC St. Croix River Pollution Advisory Board and the Board of Control.

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**Description of the St. Croix River Basin**

The St. Croix River is international, draining parts of the Province of New Brunswick and the State of Maine. The drainage area, including some tidal estuary, is 4,235 km<sup>2</sup> (1,635 mi<sup>2</sup>) of which 1,619 km<sup>2</sup> (625 mi<sup>2</sup>) is in New Brunswick and 2,616 km<sup>2</sup> (1,010 mi<sup>2</sup>) is in Maine (Table 1) (Int. St. Croix River Eng. Bd., 1957). The main stem and the East Branch (84 km, 52 mi long), the Chiputneticook Lakes (66 km, 41 mi long), and Monument Brook (19 km, 12 mi long) determine the international boundary south of latitude N 45°58'25", a total distance of about 169 km (105 mi).

The St. Croix River system (Fig. 1) has generally the form of the letter "Y", with the stem draining southeasterly into Passamaquoddy Bay of the Bay of Fundy. The basin is, in general, a dissected lowland with topography that has been considerably modified by glacial and marine invasion. The lowlands of the basin, characterized by the extensive lake systems and many flat or gently rolling plains, are below elevation 150 m (500 ft). Low hills rise above the lakes and swampy plains, and a few hilltops reach elevations over 300 m (1,000 ft). The highest point in the basin, Musquash Mountain, rises to an elevation of 377 m (1,238 ft) msl.

The East Branch drains an area of 1,668 km<sup>2</sup> (644 mi<sup>2</sup>) of southwestern portions of York and Charlotte counties, New Brunswick, parts of northeastern Washington County and a small portion of Aroostook County in Maine. This Branch has two very large lakes and several smaller lakes and its main course is mixed gradient river environment. The Branch drops from about elevation 374 at Vanceboro to about elevation 203 at Grand Falls flowage, at an average gradient about 1.06 m/km (5.7 ft/mi).

The West Branch, however, principally comprised of large lakes separated by short thoroughfares or short streams, lies wholly in Maine and drains an area of 1,728 km<sup>2</sup> (667 mi<sup>2</sup>) of Washington, Penobscot and Hancock counties. Gradient is confined in large measure to the lake tributaries.

The East and West Branches join at Grand Falls Flowage to form the main stem of the St. Croix which flows 31 km (19 mi) to tidewater at Calais/St. Stephen. This section, plus that draining into the 23 km (14 mi) estuarial portion of the river, collects runoff from a further 839 km<sup>2</sup> (324 mi<sup>2</sup>). The mean tidal amplitude at Calais/St. Stephen is 6.25 m (20.5 ft).

The most outstanding feature of the St. Croix River waterways is the abundance of lakes and ponds (lotic environments). These waters cover an area of about 445 km<sup>2</sup> (172 mi<sup>2</sup>), or about 9.5 percent of the basin area (Table 2). Adding an area for streams and brooks (lentic environments) brings the total St. Croix water surface area to an impressive amount of fish-bearing habitat.

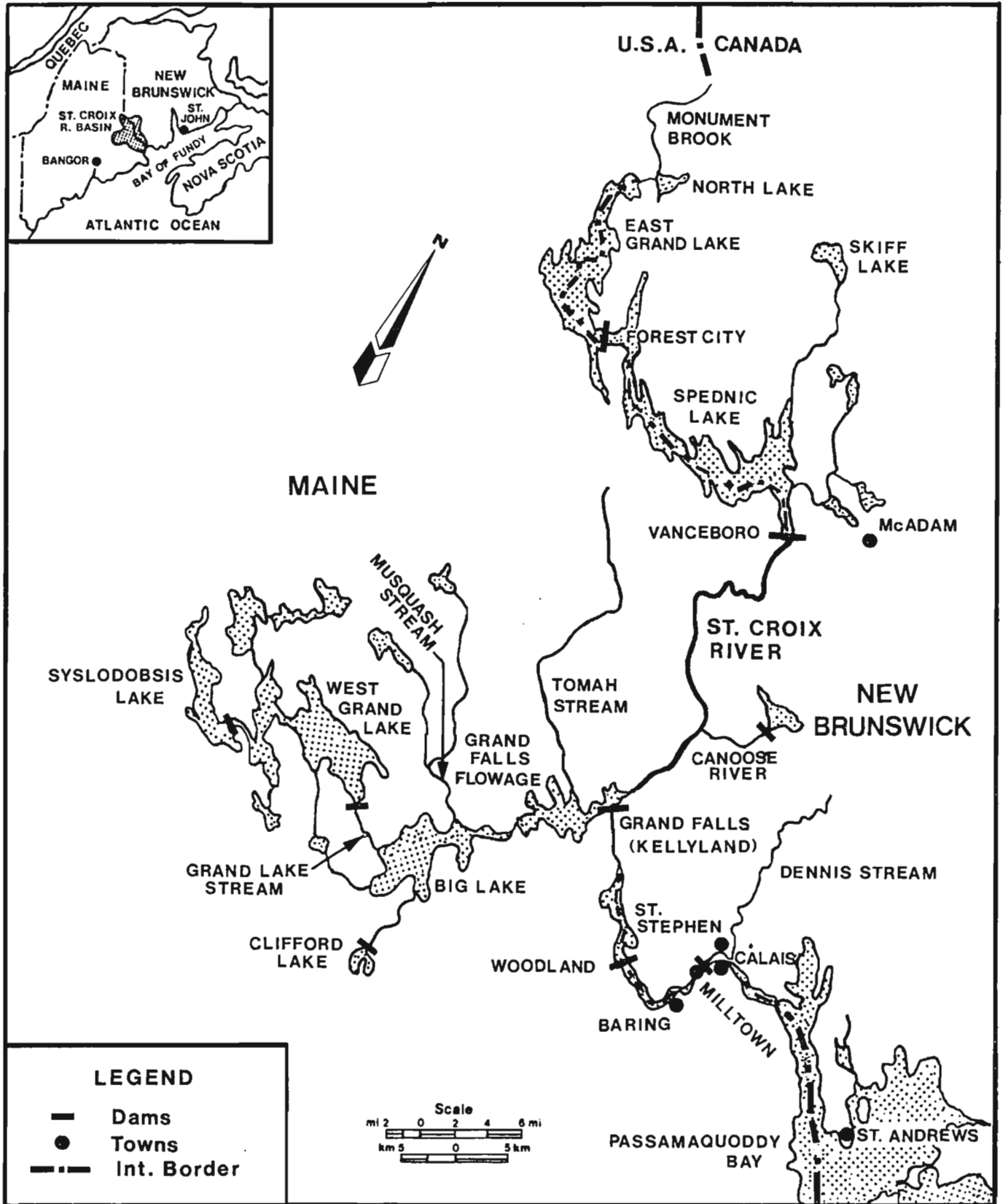


FIGURE 1: Map of St. Croix River System, New Brunswick/Maine

TABLE 1

AREAS OF SUB-DRAINAGES IN THE ST. CROIX RIVER BASIN

Measuring point or sub-drainage	Area drained	
	km <sup>2</sup>	mi <sup>2</sup>
St. Croix River (Lewis Cove, North Perry, Maine, to Navy Island, St. Andrews, New Brunswick)		
New Brunswick	1,619	625
Maine	2,616	1,010
TOTAL	<u>4,235</u>	<u>1,635</u>
Milltown Dam	3,781	1,460
Baring Gauging Station	3,600	1,390
Woodland Dam	3,497	1,350
Baileyville Gauging Station (Grand Falls Dam)	3,419	1,320
West Branch	1,728	667
West Branch Gauging Station	1,318	509
Tomah Stream	399	154
Grand Lake Stream Gauging Station	580	224
East Branch	1,668	644
Vanceboro (Spednik Lake at St. Croix Gauging Station)	1,080	417
East Grand Lake Gauging Station		
New Brunswick	153	59
Maine	205	79
TOTAL	<u>358</u>	<u>138</u>

TABLE 2

SUMMARY OF AREAS OF LAKES IN SELECTED PORTIONS OF THE ST. CROIX RIVER BASIN

	Cumulated Area of Lakes			
	ha	km <sup>2</sup>	acres	mi <sup>2</sup>
<u>By sub-drainage</u>				
Estuary	744	7.4	1,838	2.87
Main stem and East Branch	1,373	13.7	3,394	5.30
West Branch	24,318	243.2	60,090	93.90
Spednic Lake	<u>18,100</u>	<u>181.0</u>	<u>44,725</u>	<u>69.88</u>
Basin Totals	44,535	445.3	110,047	171.95
<u>By political jurisdiction</u>				
New Brunswick	4,585	45.8	11,330	17.70
Maine	23,260	232.6	57,477	89.81
Joint waters (incl. Grand Falls Flowage)	<u>16,690</u>	<u>166.9</u>	<u>41,240</u>	<u>64.44</u>
Basin Totals	44,535	445.3	110,047	171.95
<u>Basin exclusive of the West Branch above the Princeton Bridge on U.S. Route 1</u>				
	22,925	229.3	56,648	88.51

The mean annual precipitation for the basin is about 1 m (40 in). Annual snowfall is about 178 cm (70 in) in the southern portion of the basin, while the more inland parts receive about 254 cm (100 in). This precipitation provides an average annual run-off for the basin of 58 cm (22.8 in) ( $18.4/s/km^2$ , 1.68 cfs/mi) of which about one-third occurs in the months of March, April and May. Monthly variations in run-off are not great because of the extensive natural and developed storage. The maximum recorded discharge of  $660 m^3/s$  (23,300 cfs) occurred on May 1, 1923, but normal spring freshets usually cause only inconsequential flooding. The mean river discharge at Baileyville, 1920-1979, was  $66.3 m^3$  (2,340 cu ft). The useable water storage capacity in the St. Croix River reservoir system, available at the power station in Baileyville, is approximately  $737.7 \times 10^6 m^3$  (26 billion cubic feet).

The bedrock of the St. Croix River Basin consists of Ordovician and Silurian sediments and volcanics and extensive areas of Devonian granitic and associated igneous rocks. Bedrocks have been closely folded into beds that dip steeply with the axes of the folds, trending northeast-southwest. The shales, sandstones, and volcanics have been altered to quartzite, and locally to schist and gneiss. These metamorphic rocks underlie the upper part of the basin from the northern limit to the Chiputneticook Lakes, where a large granitic mass borders the lakes and extends toward the southwest. From the outlet of the lakes the river flows across the trend of the sediments to the granitic rocks between Woodland and Calais. Most of the marine estuary of the St. Croix is cut in granites. The end of the long peninsula, occupied by the town of St. Andrews, New Brunswick, and a matching area on the United States side at the mouth of the river are underlaid by red sandstone and conglomerate, which are believed to be upper Devonian in age.

Soils of the upper St. Croix River are of the Marlow-Peru-Lyman group. Marlow soils are deep, well-drained soils, often with hardspan substratum. Above the hardspan, permeability is moderate. Peru soils are seasonally wet sand soils in firm glacial till. They are moderately well-drained and cover bedrock by at least four feet. Lyman soils cover the bedrock by only 9-20 inches and have a rapid permeability.

In the townships of Dyer (T1 R2) and Fowler (T1 R1) in upper Washington County, Maine, soils of the Ridgebury-Peru-Histosols group are found along a 10-mile section of the St. Croix River. Ridgebury soils are deep, level, poorly drained wetland soils formed in firm, stony glacial till. Peru soils are seasonally wet, as described above. The Histosols are wetland soils associated with peat bogs and swamps. These soils are composed of organic materials over sand, clay, or loamy materials.

Below Spednik Lake, soils of the Perham-Daigle group occur along about eight miles of the river. Perham soils tend to be silty, but well-drained deep soils developed in firm glacial till. Generally they are composed of two feet of silt loam over less than two feet of a firm gravelly-clay-loam subsoil below which is bedrock. Daigle soils are seasonally wet, low permeability, silty soils formed from shale and slate glacial till. The upper foot of soil is dark and silty, with about two feet of gravelly clay loam beneath. Both of

these layers are over a clayey-glacial till with a high gravel content. The lower St. Croix drainage, from Baileyville to Robbinston along the American shore, has soils that are of the Marlow-Peru-Lyman group described above for the upper St. Croix drainage.

A large portion of the St. Croix River Basin is a near-wilderness area. Forests of second-growth hardwoods and conifers cover over 80 percent of the drainage. The basin is sparsely settled, containing about 21,500 people of which about three-fourths live between Calais and Baileyville, in Maine, and in St. Stephen, New Brunswick. Less than ten percent of the basin area is devoted to agriculture, principally dairying, poultry farming, and blueberry growing. Almost all of the recreational development in the drainage is in the form of privately owned summer cottages or commercially operated fishing camps. Major industrial development is confined to a major forest products processing complex in Baileyville, below the junction of the East and West branches.

The St. Croix River watershed contains one Indian reservation. Indian Township on the St. Croix is the locale of two settlements, the Strip and Peter Dana Point, having a combined population of 561 persons.

Water quality, except for the main stem below the confluence of the two branches, has not changed significantly in the last hundred years. Some minor deterioration has taken place in upstream areas as a result of sedimentation, log deposition, and silting from logging and road construction, and some additional minor pollution occurs from the small towns and summer cottages. These waters, however, retain a substantial fish-rearing potential.

The St. Croix drainage is relatively free of harmful pollutants. It is a Class B1 river, as classified by the State of Maine Revised Statutes. Tidewater section of the river at Calais is classified as SB2. The city of Calais and town of Baileyville have activated sludge secondary treatment sewage plants in operation. As the two largest Maine communities on the river, the operation of these facilities decreases the domestic wastes entering the river. However, municipal wastes are negligible when compared with the industrial wastes from the Woodland pulp and paper mill complex of the Georgia-Pacific Corporation. The Corporation has installed primary and secondary pollution control systems including primary treatment clarifiers that remove most settleable solids. The effluent is then pumped to a 40.5 ha (100-acre) secondary treatment lagoon, divided by earthen dikes into three ponds which retain up to 1.89 million m<sup>3</sup> (half billion gallons) of effluent. After ten hours in the settling lagoon, the effluent passes into two aeration sections where the oxygen level is restored by propellers functioning like high eggbeaters. The re-oxygenated effluent is then piped to a defoaming lagoon before discharge to the river.

A legacy of the old forest-harvesting industries still remains in the form of waste deposits on the river bottom. Roundwood clutters the dead water portions, particularly in Grand Falls flowage between the East Branch inlet and the Grand Falls Dam and behind the Woodland Dam. Wood fiber, bark, and

coal ashes were present on the main stem below Woodland in very large quantities. As long ago as 1910, the U.S. government enacted legislation to dredge the estuary to permit vessels to reach Calais. A 1967 survey of the river bottom from Woodland to tidewater indicated the presence of about 1,835,000 m<sup>3</sup> (2.4 million yd<sup>3</sup>) of waste materials. That amount would make a streambank pile 100 m (328 ft) wide, 3 m (9.8 ft) high, and 6,115 m (3.8 mi) long. Less than ten percent of this amount was found in that stretch from Woodland Dam down to the point where the river turns north just upstream from Baring. These materials have tended to be flushed away somewhat, now there is no constant replacement by further wastes.

The St. Croix River Basin has a long history of dams. These structures have been of many sizes, and in some cases, were built, rebuilt or modified as time went on. About 30 dams are now in existence and their uses are mainly power generation, water storage, lake level regulation, or waterfowl management.

Even in the absence of anadromous fish stocks, the existing fish resources of the basin are substantial. Sport fishing for coldwater and warmwater inland fishes rates well compared to other areas in eastern North America. The smallmouth bass, introduced into the St. Croix River Basin on the 19th century, has established so well that the angling is now widely renowned.

Landlocked salmon populations are maintained by natural reproduction and by stocking by the State of Maine in at least six of the major lakes. Lake trout provides angling in five lakes. The eastern brook trout populations are managed in the Maine portion of the basin in several of the smaller waters, but this species is widely distributed seasonally when water temperatures are suitable. The white perch and chain pickerel provide substantial sport, both summer and winter, while yellow perch, brown bullhead, and whitefish provide minor fisheries.

Freshwater populations of smelt are an important component of inland fisheries resources of the St. Croix drainage.

The principal role of the smelt is as a forage fish for both warmwater and coldwater sport fish. Smelt are particularly important in lakes managed for landlocked salmon and lake trout. There are a few lakes supporting thriving salmon populations without smelt. Smelt also support hook and line fisheries and are a choice commercial baitfish.

There are 28 surveyed lakes (99,581 acres) in the St. Croix drainage known to contain smelts.

## APPENDIX II

### A DESCRIPTION OF THE ST. CROIX RIVER SIMULATION MODEL (Last Update on January 16, 1985)

A predictive model, tailored to the St. Croix River, is designed to operate on an HP-150 micro-computer with VisiCalc. It predicts adult returns of Atlantic salmon to the Milltown fishway trap; hence the efficiency of the Milltown fishway is inherent in the model. This is so because all relevant salmon returns data available for use in model calibration are of returns to the fishway trap. The predicted returns are computed from known stockings, from wild returns, and from computed progeny. In terms of absolute numbers of returning salmon, the predictions are only likely to be accurate for two or three years into the future. Beyond three years the most useful aspect of the projection is in the long term trend (upward or downward) of future returns.

The model contains a number of parameters involving stock survival, which have been tentatively estimated based on experience with the donor stocks in other rivers. Estimates for these parameters have been expressed in two-level ranges because of the uncertainty over comparability with the St. Croix River environment. These parameters are:

1. egg-to-smolt survival;
2. survival (of stocked fry, of fall fingerlings, and of parr) to the smolt stage;
3. smolt mortality during downstream migration;
4. survival at sea; and
5. upstream fish passage efficiency.

The model presently exists in both "pessimistic" and "optimistic" versions. A review of the 1981-84 returns has made apparent that the best fit to the current data set is provided by use of the pessimistic estimates for parameters one to four. The data do not yet permit an evaluation of parameter five.

Earliest versions of this model had contained three levels (pessimistic, median, and optimistic), but results to date suggest that in the St. Croix situation the earlier optimistic level (which was based on Pollet River results) is unrealistic. This upper level of the model has been deleted, and the earlier "median" version is the one now referred to as "optimistic".

#### A. For adult transfers from Saint John River:

1. 90% of eggs produce 2-year smolts with 0.96-1.44% survival to smolts (Elson, 1962).  
10% of eggs produce 3-year smolts with 0.38-0.58% survival to smolts (idem.).

2. Downstream migration survival is 40-70%. (Downstream survival of tagged smolts in 1981 was 38% in passing Grand Falls and Woodland, as estimated from tag returns in 1982-84.)
3. Sea survival is 5-8% as returns to the Milltown fishway trap.
4. The grilse/salmon ratio in returns is 50/50 for each smolt-class.
5. Grilse are 7.4% female and salmon are 82.9% female.
6. Fecundity is as for Mactaquac hatchery fish in 1980:  
 Grilse - 3,850 eggs/female  
 Salmon - 7,450 eggs/female

B. For Green Lake Hatchery Stock

1. 0.70-1.39% average sea survival for Green Lake smolts (Baum, 1983; pers comm 9 November, 1984).
2. 40-70% downstream migration survival, thus yielding the following survival table (adapted from Elson, 1962, with additional 20% stocking mortality):

Juvenile Stage	% Returns to River when stocked above Grand Falls			
	"pessimistic"	"optimistic"	at Milltown "pes"	"opt"
Fry	0.04%	0.14%		
Fall Fingerlings	0.07%	0.24%		
Parr	0.11%	0.39%		
Smolts	0.28%	0.98%	0.70%	1.39%

The 20,000 severely stressed smolts stocked at Milltown in 1984 are assumed to have a survival potential of 0.35% (25% of usual).

3. Grilse/salmon ratio is 10/90 in returns to Milltown.

C. Tagged Green Lake smolts stocked for evaluation of downstream mortalities are assumed to return to Milltown with a survival rate of 0.13% (average return rate from the 1981 and 1982 releases).

D. "Wild" returns to Milltown fishway 1981-83 - 0.03605 fork length (cm)

1. Eggs/female = 430.19 e  
This equation was derived from Saint John River data.
2. Average lengths and sex ratios are from 1982 vital statistics:

	% female	Length of female	Calculated eggs/female
Grilse	35%	57.6 cm	3,430 eggs
Salmon	60%	73.5 cm	6,130 eggs

3. Survival rates are assumed to be the same as for the Saint John River fish described in Section 'A' above.
4. Upstream fish passage efficiency through Woodland and Grand Falls is 30-64% (assumes average fishway efficiencies of 55 and 80%).

E. "Wild" returns to Milltown after 1983

Saint John River stock characteristics (based on unpublished F.R.B. data from Mactaquac and on Fletcher and Meister, 1982):

1. 90% of eggs produce 2-year smolts with 0.96%-1.44% survival to smolts (Elson, 1962).  
10% of eggs produce 3-year smolts with 0.38%-0.58% survival to smolts (idem.).
2. Downstream migration survival is 40%-70%.
3. Sea survival is 5%-8%.
4. The grilse/salmon ratio in returns is 50/50 for each smolt class.
5. Grilse are 7.4% female and salmon are 82.9% female.
6. Fecundity is as for Mactaquac hatchery fish in 1980:  
Grilse - 3,850 eggs/female  
Salmon - 7,450 eggs/female
7. Egg deposition is taken to be saturated for the East Branch St. Croix at nine million. Smolt production is proportional to egg deposition up to six million eggs, above six million there is a gradual reduction in survival, and above nine million eggs increasing the deposition the deposition does not increase smolt production.

8. 10.7% of the salmon are previous spawners (5% consecutive and 5.7% alternate).
9. Upstream fish passage efficiency (from above Milltown to above Grand Falls) is 30%-64%.
10. Angling exploitation above Milltown is 33%

Narraguagus River stock characteristics (based on Meister and Cutting, 1967 and Baum and Meister, 1971):

1. 83% of eggs produce 2-year smolts with 0.96%-1.44% survival to smolts.  
17% of eggs produce 3-year smolts with 0.38%-0.58% survival to smolts.
2. Downstream migration survival is 40%-70%.
3. Sea survival is 3%-5%. The estimated survivals are lower than for Saint John stock because distant exploitation is higher (50% as opposed to 20%).
4. "Virgin" salmon are 59% female. 88% of these are two-sea-year producing 7,200 eggs/female. 1.7% are three-sea-year producing 9,300 eggs/female (fecundity estimates are calculated from Baum and Meister, 1971).
5. 9.0% of the returns are previous spawners which are 73% female and product 9,300 eggs/female.
6. The optimum egg deposition curve is as described above (section E-7, for Saint John fish).
7. Upstream fish passage efficiency from above Milltown to above Grand Falls is 30-64% for smolts stocked above Grand Falls; and half these values for smolts stocked below Milltown. This correction is based on migratory behaviour data, 1976-83, for Mactaquac hatchery vs wild salmon in the Saint John River.
8. Angling exploitation above Milltown is 33%.

To calculate a projection of future returns over several generations of salmon, the vital statistics parameters (% 2-yr. smolts, % sea survival, grilse/salmon ratio, and sex ratios) for the population of "wild" St. Croix River returns that result from the mixing of the two donor stocks is calculated in linear proportion to genetic representation (based on numbers of fish) of the original stocks in the principal spawning populations (4 and 5 years) previous).

W.D. Watt & R.E. Cutting

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APPENDIX 3

REPORT TO ST. CROIX RIVER STEERING COMMITTEE ON  
SALMON RETURN PROJECTIONS WITH THE SIMULATION MODEL

January 16, 1985

Requests received from the Steering Committee were:

- 1) Operate the "pessimistic" version of the model with a new and higher "optimistic" value for upstream fish passage efficiency.
- 2) Run both the "pessimistic" and "optimistic" versions of the model to project the returns to be anticipated from annual stocking of 75,000 Green Lake Hatchery smolts into the St. Croix River at alternate sites below Woodland, below Grand Falls, and above Grand Falls flowage.

Fish Passage Efficiency

All previous runs of the "pessimistic" version have used the "optimistic" assumption of an average 70% efficiency for fish passage from the Milltown fishway exit to the Woodland fishway exit, and a further 70% from Woodland to the Grand Falls fishway exit. The earlier three level version of the St. Croix simulation model employed 55%, 70% and 80%. In general, where fish passage efficiency has been evaluated with tagged Atlantic salmon studies and modern fishways, the efficiency estimates have been within the range of 55-80%. The higher efficiencies, as at Mactaquac, appear to be associated with special attraction devices and absence of downstream impoundments. There is also a noticeable seasonal element, with early run fish showing higher migration efficiencies (Watt, in prep).

The Biological Working Group, in considering the St. Croix fishways, concluded tentatively that the Milltown, Woodland and Grand Falls fishways were all likely to be near the upper end of the efficiency range, and the average for all three would probably be near 70%. The Steering Committee's suggested change from 70 to 80% may be a better guess, and this change has been incorporated into the model.

It is apparent that there is a requirement for an evaluation of fish passage efficiencies on the St. Croix. This work will have to be done, and any detected deficiencies rectified, before Atlantic salmon restoration can be contemplated with any reasonable assurance of success.

### Smolt Stocking Alternatives

The stocking of smolts above Grand Falls Flowage would encourage adult returns to this section of the river for spawning. Unfortunately, it also results in their being subject to downstream mortalities from predation and turbines. Smolts stocked in the lower section of the river would escape the downstream mortality problem, but the adult returns could not be expected to show the same level of migratory behavior up to spawning areas above the stocking site. On the Saint John River the fish passage efficiency from Mactaquac to Beechwood for adult returns from smolts released at Mactaquac is only half that observed for wild smolts (34.1% and 63.2% respectively, averaged over 1976-1983 but not corrected for angling which is about 10%). For this report the simulation model's fish passage efficiency has been set at 80% at the Woodland and Grand Falls fishways for smolts stocked above Grand Falls, and at 40% for smolts stocked below Woodland.

Smolt stocking between Woodland and Grand Falls is not considered a useful option. Smolts stocked here would be subject to turbines and impingement at Woodland, which present data suggest would yield about 40% mortality, and there is little angling or spawning and rearing habitat between Woodland and Grand Falls that would make it useful to have the returning adults migrate back up to this area.

The six tables accompanying this report show the results predicted by the simulation model using the optimistic upstream fish passage rate in all cases. The "pessimistic" and "optimistic" versions each were run with three options:

1. No further stocking;
2. 75,000 Green Lake Hatchery smolts stocked annually (from 1985 on) above Grand Falls; and
3. 75,000 Green Lake Hatchery smolts stocked annually (from 1985 on) below Woodland.

The two tables (PES 1 and OPT 2) showing the results without further stocking are included because of minor changes made to the model since the last report. Data supplied by Baum (pers comm; 1984) have made it feasible to establish a range for the sea survival parameter of Green Lake Hatchery fish. Also, the 1984 data have been altered to show the observed return. See attached "DESCRIPTION..." for detail.

In the "pessimistic" version the estimated average returns of stocked fish are 188 salmon plus 20 grilse annually from stocking above Grand Falls (Table PES 2), and 472 salmon plus 52 grilse annually if stocking occurs below Woodland (Table PES 3). Tables PES 2 and PES 3 indicate that under these pessimistic assumptions, returns to Milltown (hence, salmon available for angling) would be maximized by stocking below Woodland.

With the "optimistic" version a higher return rate is expected from the fish stocked below Woodland (938 salmon plus 104 grilse) than from those released above Grand Falls (661 plus 73). However, Tables OPT 2 and OPT 3 indicate that under these assumptions the total returns to Milltown would be maximized by stocking above Grand Falls because of the enhanced reproductive success of the adult returns.

These results imply that, if "pessimistic" rates prevail, more fish will be made available for harvest if stocking takes place below Woodland. This option, however, virtually writes off the natural production capability and makes the St. Croix run heavily dependent on the fish culture program. On the other hand, if "optimistic" rates prevail or can be made to prevail, greater numbers of salmon will be available for harvest with stocking above Grand Falls Flowage because the natural production capability supplements the fish culture program.

W.D. Watt & R.E. Cutting

Table PES 1

Returns to Milltown predicted by the pessimistic St. Croix model  
(with optimistic upstream fish passage rate)  
With no further stocking

	YEAR	GRILSE	SALMON	TOTAL
(Observed Return)	1984	186	54	240
	1985	70	245	315
	1986	30	414	444
	1987	40	67	107
	1988	37	68	105
	1989	51	35	86
	1990	29	76	105
	1991	37	67	104
	1992	36	43	79
	1993	29	38	67
	1994	30	27	57
	1995	28	36	64
	1996	31	34	65
	1997	30	29	59
	1998	27	28	55
	1999	27	24	51

Table PES 2

Returns to Milltown predicted by the pessimistic St. Croix model  
(with optimistic upstream fish passage rate)  
With 75,000 G.L. smolts/yr stocked above Grand Falls

	YEAR	GRILSE	SALMON	TOTAL
(Observed Return)	1984	186	54	240
	1985	70	245	315
	1986	50	414	464
	1987	60	255	315
	1988	57	267	324
	1989	71	243	314
	1990	49	284	333
	1991	54	275	329
	1992	55	290	345
	1993	53	293	346
	1994	52	288	340
	1995	48	294	342
	1996	48	291	339
	1997	48	294	342
	1998	48	294	342
	1999	47	293	340

Table PES 3

**Returns to Milltown predicted by the pessimistic St. Croix model**  
(with optimistic upstream fish passage rate)  
With 75,000 G.L. smolts/yr stocked below Woodland

	YEAR	GRILSE	SALMON	TOTAL
(Observed Return)	1984	186	54	240
	1985	70	245	315
	1986	82	414	496
	1987	92	539	631
	1988	89	567	656
	1989	103	557	660
	1990	81	598	679
	1991	78	589	667
	1992	79	569	648
	1993	79	573	652
	1994	79	573	652
	1995	77	579	656
	1996	77	576	653
	1997	76	571	647
	1998	76	570	646
	1999	76	570	646

Table OPT 1

Returns to Milltown predicted by the optimistic St. Croix model  
With no further stocking

	YEAR	GRILSE	SALMON	TOTAL
(Observed Return)	1984	186	54	240
	1985	160	803	963
	1986	52	1,105	1,157
	1987	92	186	278
	1988	77	199	276
	1989	432	96	528
	1990	92	809	901
	1991	170	718	888
	1992	153	352	505
	1993	101	289	390
	1994	390	180	570
	1995	164	826	990
	1996	243	783	1,026
	1997	194	517	711
	1998	137	397	534
	1999	357	283	640

Table OPT 2

**Returns to Milltown predicted by the optimistic St. Croix model  
With 75,000 G.L. smolts/yr stocked above Grand Falls**

	YEAR	GRILSE	SALMON	TOTAL
(Observed Return)	1984	186	54	240
	1985	160	803	963
	1986	125	1,105	1,230
	1987	165	847	1,012
	1988	150	898	1,048
	1989	505	828	1,333
	1990	163	1,541	1,704
	1991	208	1,456	1,664
	1992	221	1,662	1,883
	1993	282	1,717	1,999
	1994	451	1,730	2,181
	1995	215	2,342	2,557
	1996	241	2,245	2,486
	1997	251	2,472	2,723
	1998	326	2,547	2,873
	1999	432	2,642	3,074

Table OPT 3

Returns to Milltown predicted by the optimistic St. Croix model  
With 75,000 G.L. smolts/yr stocked below Woodland

	YEAR	GRILSE	SALMON	TOTAL
(Observed Return)	1984	186	54	240
	1985	160	803	963
	1986	156	1,105	1,261
	1987	196	1,124	1,320
	1988	181	1,191	1,372
	1989	536	1,134	1,670
	1990	192	1,848	2,040
	1991	158	1,752	1,910
	1992	167	1,441	1,608
	1993	193	1,452	1,645
	1994	327	1,466	1,793
	1995	192	2,077	2,269
	1996	162	1,963	2,125
	1997	155	1,735	1,890
	1998	171	1,686	1,857
	1999	237	1,713	1,950

**Report to the St. Croix River Biological Working Group  
on Statistical Analysis of St. Croix River tag return  
Data for Information on Downstream Migration Mortality of  
Atlantic salmon smolts**

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In 1981, 1982 and 1983, approximately 7,000 smolts from Green Lake Hatchery were fitted with small Carlin tags and released above each of the three mainstem dams on the St. Croix River. The object was to evaluate downstream mortality at the Woodland and Grand Falls dams. The Milltown dam has lower installed power generation capacity than the upstream sites, thus it spills a higher proportion of the spring flow and so is expected to cause lower smolt mortality than the upstream sites (a separate study to evaluate the Milltown site is now underway).

Smolt mortality at the upriver dams can be estimated by tag returns from the angling and commercial fisheries and from the Milltown fishway trap. Total tag returns to date are 111 from 59,719 tagged smolts (0.19%). Details of release sites and year of stocking are given in the accompanying table. Further details on tag returns from the commercial fishery (there were no angling returns) and estimates of effect of tag loss have been presented in the annual reports of the Milltown trap returns presented to the St. Croix River Biological Working Group.

**Smolt Releases and Tag Returns by Year of Release**

SITE	1981		1982		1983		TOTALS	
	Releases	Returns	Releases	Returns	Releases	Returns	Releases	Returns
Grand Falls	6,932	14	7,000	0	7,038	13	20,970	27
Woodland	6,535	20	6,598	2	6,600	11	19,733	33
Milltown	6,236	39	6,380	3	6,400	9	19,016	51
<b>TOTALS</b>	<b>19,703</b>	<b>73</b>	<b>19,978</b>	<b>5</b>	<b>20,038</b>	<b>33</b>	<b>59,719</b>	<b>111</b>

Using chi-square analysis, and summing over years, indicates highly significant differences in tag returns by site (p less than 0.005), but summing over sites indicates that there were also highly significant differences (p less than 0.001) from year to year. This raises the likelihood that the data are heterogeneous

and it may not be valid to calculate variance estimates from the site totals. Year-by-year chi-square analyses indicate highly significant differences (p less than 0.001) in tag returns from the three release sites for 1981, but no significant differences for 1982 and 1983 releases. The lack of significant site differences in the 1982 and 1983 releases may be largely due to the much lower tag returns for these years. This variation in significance of the release site effect from year to year is a strong indication of heterogeneity.

To examine the site total for significance relative to the heterogeneity component, the nine tag return percentages were converted with the angular transformation, and a variance analysis calculated using the year-site interaction as an error variance. With this approach, the year-to-year variation in percent tag returns is still a significant (p less than 0.025), but site of release is not significant.

For 1981, the release site tag return rates with their standard errors are:

<u>Release Site</u>	<u>Tag Return Rate</u>
Grand Falls	0.13% (0.06%-0.22%)
Woodland	0.17% (0.09%-0.27%)
Milltown	0.27% (0.17%-0.39%)

These data indicate downstream migrating smolt mortality rates in 1981 of 34% between the Falls and Woodland release sites and 51% between Woodland and Milltown. Overall downstream mortality from above Grand Falls to above Milltown was 68% in 1981 (i.e., 32% survival).

The site tag return rates with standard error limits (from variance analysis) for the combined data from all three years of tagged smolt releases are:

<u>Release Site</u>	<u>Tag Return Rate</u>
Grand Falls	0.13% (0.06%-0.22%)
Woodland	0.17% (0.09%-0.27%)
Milltown	0.27% (0.17%-0.39%)

The corresponding "average" mortality rate estimates for the combined data are 23% mortality between Grand Falls and Woodland release sites, and 38% mortality between Woodland and Milltown. Overall mortality from Grand Falls to Milltown is estimated at 52%. Although these mortality rate estimates from the combined data are not based on significantly different tag return rates relative to the heterogeneity component of the variance, for fisheries management purposes they are still the best estimators of average smolt mortality rates.

**APPENDIX 4**

**Fish Health Management Plan**

Fish health management in the St. Croix River is the responsibility of the fisheries agencies managing the resources in the watershed. The following plan will serve as a guide to these agencies in order to meet the requirements of the above fish disease control policy.

A committee of recognized fish health officials shall be established to review annually the fish health status of all fish cultural facilities:

- (a) within the watershed,
- (b) stocking directly into the watershed, or
- (c) transferring fish, eggs, or sperm into fish culture facilities within the watershed and
- (d) wild brood stocks supplying eggs or sperm to fish culture facilities within the watershed.

The Department of Fisheries and Oceans of Canada, the United States Fish and Wildlife Service and the Maine Department of Inland Fisheries and Wildlife currently have qualified fish health personnel suitable for this review committee. Representatives of other agencies may be included on the Fish Health Review Committee as they acquire qualified personnel.

Copies of all fish health inspection reports of the above fish culture facilities or wild brood stocks shall be made available to the Fish Health Committee on a timely basis. The committee shall be notified immediately of the finding of either an emergency or certifiable pathogen in any of the above sources. The committee will promptly make their expertise available upon the finding of an emergency or certifiable pathogen. In the case of an emergency pathogen, an effective eradication plan will be developed and implemented promptly. In the case of the finding of a certifiable pathogen, the committee will recommend eradication or control as the situation dictates.

All proposals to introduce non-salmonid fish into the watershed shall be submitted to the Fish Health Review Committee well in advance so that the health status of the source may be investigated and the risks of introducing new fish pathogens can be thoroughly assessed.

The Fish Health Review Committee shall review the Fish Disease Control Policy and the Fish Health Management Plan annually and recommend changes, where appropriate, including addition or deletion of named diseases.

All fish cultural facilities (a) within the watershed, (b) stocking directly into the watershed, or (c) transferring fish or eggs into fish culture facilities within the watershed and wild brood stocks supplying eggs to fish

cultural facilities within the watershed, shall be inspected by an approved fish health inspector at least once a year at a time or times most conducive for the detection of pathogens with regard to age and size of fish and environmental conditions. The inspections shall be done in accordance with the "Procedures for the Detection and Identification of Certain Fish Pathogens" developed by the Fish Health Section of the American Fisheries Society and/or the Fish Health Protection Regulations Manual of Compliance of the Canadian Department of Fisheries and Oceans.

Fish disease inspection reports shall be completed promptly following an annual inspection of all lots of fish utilizing a format that includes the following information:

1. Name and location of source.
2. Type of water supply and treatment in any.
3. Inspection dates including previous inspections.
4. Fish species examined.
5. Lot(s).
6. Fish age.
7. Number of fish in lot.
8. Sample sizes.
9. Pathogens inspected for.
10. Methods utilized.
11. Results.

If at any time a fish health inspector finds, suspects, or becomes aware of the presence of any emergency or certifiable fish pathogen at a fish cultural facility subsequent to an annual fish health inspection that did not reveal that pathogen, the inspector shall promptly notify the appropriate fish health officials.

All fish imported into fish cultural facilities within the watershed shall come only from sources that have been inspected within one year and reveal no evidence of emergency and certifiable fish pathogens. Any introductions made to an approved source subsequent to an annual inspection from other uninspected

or positive sources shall negate the transfer of fish or eggs into the watershed.

All eggs and sperm imported into fish cultural facilities within the watershed shall come only from sources that have been inspected within one year and reveal no evidence of the following vertically transmitted pathogens:

- Viral Hemorrhagic Septicemia virus (VHS)
- Infectious Hematopoietic Necrosis virus (IHN)
- Infectious Pancreatic Necrosis virus (IPN)
- Any other filterable replicating agent capable of causing cytopathic effect (CPE) in appropriate fish cell lines
- Clinical Bacterial Kidney Disease (BKD) - Renibacterium salmoninarum

Importations of "green" eggs into fish cultural facilities within the watershed from uninspected brood stocks shall be held in isolation pending the outcome of a satisfactory fish health inspection for the above pathogens. If the inspection of the "green" egg source reveals one of the above vertically transmitted pathogens the eggs held in isolation will have to either be removed from the watershed or destroyed.

All egg importations shall be properly disinfected with PVP organic iodine at 100 ppm active ingredients for 10 minutes prior to introduction to fish cultural facilities.

No fish shall be released anywhere within the St. Croix River watershed unless they come from sources that have been inspected within one year and reveal no evidence of emergency and certifiable fish pathogens as outlined as follows:

A. Emergency Pathogens

1. Myxosoma cerebralis, causative agent of Whirling Disease.
2. Ceratomyxa shasta, causative agent of Ceratomyxosis.
3. Viral Hemorrhagic Septicemia Virus (VHSV).
4. Infectious hematopoietic Necrosis Virus (IHNV).
5. Any other serious fish pathogen not known to occur in the north eastern United States and the Canadian Maritimes (e.g. the causative agent of Proliferative Kidney Disease).

B. Certifiable Pathogens

1. Infectious Pancreatic Necrosis Virus (IPNV).

2. Yersinia ruckeri, causative agent of Enteric Redmouth (ERM).
3. Aeromonas salmonicida, causative agent of Furunculosis.
4. Renibacterium salmoninarum, causative agent of Bacterial Kidney Disease (BKD), in clinical disease form confirmed by Gram Stain.

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