Chapter 2
Two Centuries of Change in Human and Marine Species Populations

Heike Lotze

"[E]*very human activity which is related to animate nature* […] *can, therefore, only be understood as an interaction of two different populations; on the one hand the human population of hunters and fishermen, on the other the stock or 'population' of living organisms, the annual renewal of which will always fluctuate* […] *depending both on events in Nature and on human activity*." (Hjort 1938 in Smith 1994)

2.1. Human population change

2.1.1. Archaeological sites and prehistoric settlements

The first known human settlement in the Maritimes by Paleo-Indians occurred about 11000 B.P., when humans for the first time moved into the area from the south and west after retreat of the glaciers (Spiess et al. 1990). At that time, sea level was about 50 meters lower than today, so coastal sites from that era are submerged. Early and Middle Archaic populations at around 10000-6000 B.P. were only scantily present in the Maritimes, but many sites were occupied by Late Archaic populations around 5000 B.P.

Evidence of prehistoric populations in the Quoddy Region and the greater St. Croix River basin is mostly from the Late Archaic, Early and Middle Woodland age (Table 2.1.1). During the dominant Late Archaic Susqueshanna Tradition, people had a terrestrially-oriented subsistence economy, and their remains show a general lack of shellfish utilization (Black 2000).

In the later Maritime Woodland period however, people depended on marine resources for parts or most of the year. Compared to shell middens found along the coast of Maine and in other Maritime areas, people in the Quoddy Region showed a much stronger orientation towards the marine environment than has usually been attributed to Woodland period coastal foragers (Black 2000). The intense use of marine resources in cold and warm seasons, as well as the great diversity of mollusc remains led archaeologists to define a distinct lifestyle, the "Quoddy Tradition" from 2200-350 B.P. (Black 1986, Sanger 1986). At some sites, 80-90 per cent of bone remains were from fish (mainly large cod, pollock, herring); others consisted mainly of mammal remains (particularly beaver, harbour seal, grey seal, white-tailed dear, moose) (Table 2.1.2, Bishop & Black 1988). While fishing was mainly a summer activity, seal hunting, trapping and hunting for deer and moose provided food in winter (Black & Turnbull 1986, Black 2000).

Prior to European arrival in the region, the entire St. Croix valley was inhabited by the Passamaquoddy people. Their tribe belongs to the northeastern Abanaki group of the widespread Algonkian tribe (Gatschet 1897). Passamaquoddy Bay and the St. Croix River are the center and heart of their territory. The word "Passamaquoddy" denotes a bay full of pollock and "fishers of pollock" in the Algonkian language.

Table 2.1.1. *Prehistoric settlements in the Quoddy Region. Data from Black 1986, 2000, Black & Turnbull 1986, Sanger 1986, Bishop & Black 1988, Spiess et al. 1990.*

Time (B.P.)	People / Period	Area / Sites	Food remains (marine)
11000	Paleao-Indians	coastal sites submerged, sea level was 50m lower than today	--
10000-6000	Early – Middle Archaic period	scantily present in the region, coastal sites submerged, one site off Grand Manan	--
6000-3000	Late Archaic period		
4200-3800	Moorehead Phase	St. Croix River system	alewife
3900-3100	Susqueshanna Tradition	St. Croix River (Mud Lake Stream), Quoddy islands (e.g. Minister's Is., Moose Is.)	large cod, general lack of shellfish remains, more terrestrially oriented subsistence
3000-500	Woodland / Ceramic period		
=> 2200-350	"Quoddy Tradition" or "Maritime" Woodland period		
3000-2000	Early Woodland	Ministers I., Partridge I.	mainly large cod, also pollock, herring, soft-shelled clam, seal
2000-1000	Middle Woodland	around Passamaquoddy Bay (mainland and islands)	shellfish (clam, mussel, whelk, barnacle), sea urchin, fish (cod, pollock, haddock, herring), mammals (harbor seal, grey seal), seabirds and waterfowl (ducks, loons, auks)
1000-500	Late Woodland	Bliss I., Campobello I.	

Table 2.1.2. *Faunal remains from archaeological sites (4000-1000 B.P.) in the Quoddy region, some of the species are extinct today. Data from Bishop & Black 1988, Black & Turnbull 1986, Murphy & Black 1996, Spiess et al. 1990, Black 2000).*

Mammals	Fish	Invertebrates	Birds
common:			
White-tailed deer	Cod (large)	Soft-shelled clam	Common loon
Beaver	Pollock	Barnacle (large, 2.5cm)	Wood duck
Moose	Herring	Blue mussel	Brant
Dog (domesticated)	Longhorn sculpin	Common northern whelk	Goldeneye
Porcupine	Haddock	Sea urchin	Eider duck
			Great auk (extinct)
more rare:		more rare:	Common murre
Grey seal		Atlantic dogwinkle	Thick-billed murre
Harbour seal		Eastern mud whelk	Greater shearwater
Muskrat		Atlantic plate limpet	Passenger pigeon (extinct)
Sea mink (Extinct)		Horse mussel	Eagle
Terrestrial mink		Hairy colus	Osprey
Snowshoe hare		Periwinkle	
Marten		Northern cardita	
Red fox			
Black bear			

The Passamaquoddy people moved among permanent settlements and traditional camping, hunting and fishing grounds in pursuit of fish, game, fruits, berries, and other resources such as building materials. They fished notably for pollock, salmon, herring and striped bass, gathered lobster and clams, hunted waterfowls, and collected seabird eggs. The aboriginal population was estimated between 1000-10,000 people. Today, 3200 Passamaquoddy people are living mainly in Maine (SCEP 1997). A recent census of Passamaquoddies in Canada puts the number at approximately 250.

2..1.2. Arrival of Europeans – Historic Settlements

European explorers are believed to have visited the ara in the early 1600s without settling here. The first permanent settlement was attempted by the French in the St. Croix estuary on St. Croix Island in 1604, but was abandoned the next year and moved to Port Royal in Nova Scotia. In the late 1700s, Europeans started to settle permanently in the area in some number. Some 1500 United Empire Loyalist refugees arrived from New England in or around 1783, fleeing the aftermath of the American Revolution (Table 2.1.3). Within a matter of years, these settlers transformed the region culturally, economically and environmentally (SCEP 1997). Native people were forced to abandon traditional settlements and hunting territories.

Table 2.1.3. *Historic European settlements in the Quoddy Region. Data from Gatschet 1897, Boardman 1903, Fletcher & Meister 1982, Anonymous 1988, SCEP 1997.*

Time (A.D.)	
1604-1605	Champlain de Monts expedition – first attempt of European settlement, overwintering on St. Croix island, but abandoned in spring
ca. 1650	Seasonal summer settlements for cod-fishery were established
late 1700s	Permanent European settlement and arrival of 1500 Loyalists from New England after American Revolution. Fishery, forestry, shipbuilding, shipping enterprises are cornerstones of the colonial industry until early 1900's
1776-1779	St. Stephen was settled
1780	Southern part of Calais was settled
	Native Passamaquoddy people moved their major settlement from St. Andrews to Indian Island, thence to Pleasant Point, Maine
1783	Establishment of St. Andrews
1891	Estimated population in St. Stephen 2,400
1842	Establishment of the U.S. – Canada border
1899	Canada's first and portable Marine Biological Station opened in St. Andrews
1908	The permanent Atlantic Biological Station opened in St. Andrews
1911	Estimated population in St. Andrews 1,000, in St. Stephen 2,900
1991	Estimated year-round population in St. Andrews 1,650, in St. Stephen 5,000
1993	Estimated year-round population in St. Croix watershed 23,000

During the next 200 years, the European-descended population increased 15-fold within the St. Croix watershed to 23,000 in 1993 (Table 2.1.3, SCEP 1997). However, while 10 percent of the overall New Brunswick population inhabited Charlotte County in 1851, this percentage steadily declined to about four percent in 1961 and remained stable until 1991 (SCEP 1997). Between the late 18th and the early 20th centuries, fisheries, forestry, shipbuilding and shipping enterprises were the cornerstones of the colonial economy (SCEP 1997, Chapter 4). Major timber harvesting began in the late 1700s, and numerous sawmills sprang up along the Charlotte County shoreline. Between 1840 and 1870, more lumber was shipped from St. Croix River ports than any other port in North America (Rees 1995, SCEP 1997). St. Andrews was regarded as one of the real fishing centers of eastern Canada, which led to the establishment of Canada's first Marine Biological Station in 1899 and the Atlantic Biological Station in 1908 to perform research engaged in solving problems associated with the fishing industry (Penhallow 1912).

2.2. Changes in diadromous fish and their river habitat

"The two great branches of the St. Croix, with their numerous tributaries, and the large lakes at the head of each branch, present every variety of river, lake, and stream, adapted to the breeding and feeding of fish." (Perley 1852)

" About thirty years since, salmon, shad, and gaspereau, were exceedingly abundant in the St. Croix; the average catch at the Salmon Falls was 200 salmon per day, for three months in each season. The gaspereau came in such quantities, that it was supposed they never could be destroyed; and the numbers of shad were almost incredible." (Perley 1852)

"… but in that year [1825] *the Union Dam, (the lowermost), was built without a fishway, and the fisheries instantly fell off, continuing to diminish ever since, and now they can scarcely be said to exist*." (Perley 1852)

"By 1909, the cumulative effects of declining water quality, increasing numbers of obstructions and reduced plantings of salmon fry resulted in the near extinction of the salmon." (Marshall 1976)

2.2.1. General description and species characteristics

The two main rivers draining into Passamaquoddy Bay (and the Quoddy Region in general) are the St. Croix and Magaguadavic River. Several diadromous fish species originally inhabited these rivers and were found frequently in Passamaquoddy Bay on their way to or from their native spawning grounds. Diadromous species spend part of their life in marine and in freshwater habitats respectively. Anadromous species live in the ocean, but their spawning and often their early nursery habitats are in rivers and adjoining brooks, ponds and lakes. Catadromous species live in freshwater habitat, but migrate to the ocean to their marine spawning grounds. Thus, these species depend on marine, estuarine and freshwater habitat, and have specific needs regarding spawning, nursery and adult feeding grounds.

The highest profile anadromous fish in this region is the **Atlantic salmon** (*Salmo salar*). Salmon enter the rivers in spring or fall to spawn in rapid gravelly runs in October to November. Adult survivors return to sea in the same fall or following spring, spending altogether 2-10 months in the river. Young salmon (parr) may retain in streams for 2-4 years before going to sea as smolts. Smolts in turn remain at sea for one winter (1SW, grilse) or several winters (MSW salmon) before returning to their native river to spawn. In its marine life, salmon is a pelagic fish feeding on smaller fish, shrimps and squid. Salmon is highly valued for human food consumption and for angling and was extensively exploited over time (Caddy & Chandler 1976, Fletcher & Meister 1982, Anonymous 1988).

Fairly abundant around Passamaquoddy Bay are **gaspereau** or "river herring", which are members of the herring family. These consist of two closely similar species, the common alewife (*Alosa pseudoharengus*) and the less abundant blueback herring (*A. aestivalis*). They are common in inshore waters in spring, ascending rivers in April-May, and spawning in May-June in quiet reaches or connecting lakes. The eggs are adhesive to the bottom. The young spend some weeks at the spawning site before migrating to the sea for further feeding in late September. The adults return to sea after spawning and live pelagic, feeding on shrimps and small fish. Gaspereau have a low commercial value, but have been heavily exploited and used as bait in the lobster and crab fishery, as well as for pet food and fish meal production (Caddy & Chandler 1976, Fletcher & Meister 1982, Anonymous 1988).

American shad (*Alosa sapidissima*) is an anadromous species ascending rivers to spawn in May and June. The eggs are deposited over clean bottoms in deep, slow-moving rivers; they are semi-buoyant and drift along during incubation. The adults return to sea promptly after spawning; the larvae enter brackish water by late September after one summer's growth in freshwater. Shads are planktivores that feed on copepods and mysid shrimps, and only occasionally on small fish. They are valued as human food, but their numbers declined rapidly in earlier times due to habitat degradation, river damming and overfishing (Caddy & Chandler 1976, Fletcher & Meister 1982, Anonymous 1988).

Anadromous **Rainbow smelts** (*Osmerus mordax)* are common along the Atlantic coast and highly valued as food. The small fish usually enter river estuaries in fall and winter where they congregate until moving upstream in March. They spawn in brooks and streams above the head of the tide or in the estuaries themselves from April to May. The fry are carried down to the estuary soon after hatching. This species stays inshore feeding on crustaceans (Caddy & Chandler 1976, Fletcher & Meister 1982, Anonymous 1988).

The historical status of anadromous **Striped bass** (*Roccus saxatilis*) in the rivers draining into Passamaquoddy Bay is uncertain, but none are believed to have supported spawning runs because of their unsuitable geophysical nature. Although some Striped bass are occasionally caught in the St. Croix estuary, they are most likely feeding migrants from elsewhere. This species usually migrates upriver in early June. Spawning habitat varies from upper to middle reaches of major unobstructed river systems. The young remain close to the estuary for the first few years. Adults are seldom found more than a few miles from shore (Caddy & Chandler 1976, Fletcher & Meister 1982, Anonymous 1988, B. Jessop, *pers. comm*).

The **American eel** (*Anguilla rostrata*) is a catadromous species living in lakes, rivers and estuaries. After from five-to-10 years in freshwater, they migrate to sea where they spawn and then die. Spawning areas are located in deep-sea waters of the Sargasso Sea east of Florida and the Bahamas. After about one year at sea, in March and April young eels enter estuaries as elvers, ascending into their fresh water river habitats in May-June (Caddy & Chandler 1976, Fletcher & Meister 1982, Anonymous 1988, B. Jessop, *pers. comm*).

Most diadromous species are strongly affected by humans. The degradation of river habitats due to pollution, construction, and water flow control dams severely diminished the quality and quantity of spawning and nursery grounds in the Passamaquoddy watershed. Dams block or hamper up- and down-river migration and alter and reduce river habitat. Many species are taken as by-catch in the pelagic fishery at sea. Introduction of the freshwater Smallmouth bass and Chain pickerel, valued for sports fishing, altered species composition and interactions in river systems. A directed fishery exists for species on their upriver migration as they accumulate in estuaries and rivers before reaching their spawning grounds. For the catadromous eel, mature eels migrating towards their spawning grounds at sea are harvested commercially.

2.2.2. St. Croix River and its history of human impacts

The St. Croix River forms much of the international boundary between New Brunswick, Canada and the State of Maine, USA. Approximately 1619 km^2 of the river's drainage basin is in New Brunswick and 2616 km^2 is in Maine (Fig. 2.1, Anonymous 1988). The most outstanding feature of the St. Croix watershed is the abundance of lakes and ponds covering an area of about 445 km^2 or 9.5 percent of the basin area. Including the area of streams and brooks, the total St. Croix water surface area provides an impressive extent of critical fish habitat (Anonymous 1988).

The major anadromous fish in the St. Croix River are Atlantic salmon, gaspereau (Alewife and Blueback herring), and American shad. Rainbow smelt, Atlantic tomcod, Striped bass and the catadromous American eel occur in minor numbers. Important freshwater fish are Smallmouth bass, land-locked salmon and the Chain pickerel (Anonymous 1988).

Over the last 200 years, the St. Croix has undergone dramatic changes as the result of European settlement, municipal and industrial development, damming and water pollution. Atlantic salmon and other anadromous fish decreased drastically with expanding industrial activity. Fisheries management and restoration efforts in the St. Croix started early in the 20th century. Not until the 1980s, however, was waste water treatment upgraded and fish passages provided on most of the 30 dams (Marshall 1976, Anonymous 1988). Reestablishment of anadromous fish in the St. Croix then became possible.

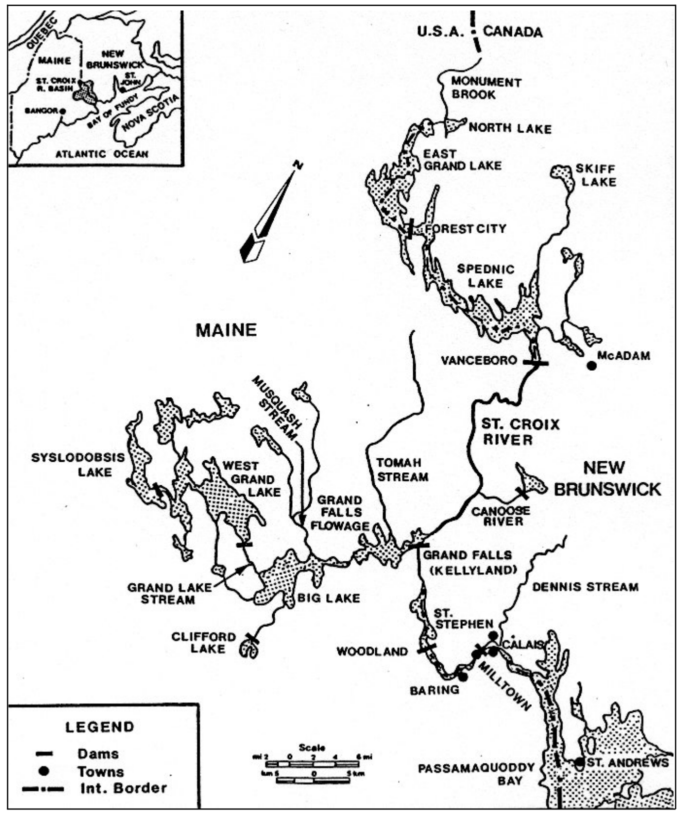

Fig. 2.2.1. *Map of the St. Croix watershed with major dams and towns (from Anonymous 1988).*

In the meantime, new threats have developed for salmon and gaspereau. In the case of Atlantic salmon, restoration success has been confounded by overall decreasing numbers of wild salmon returns to North American rivers (Anderson et al. 2000). Other threats to wild salmon are interactions with aquaculture-raised salmon, disease, and pollutants that act as endocrine disrupters (Anderson et al. 2000). Gaspereau, which re-established successfully once fish passage was improved, are now assumed to interfere with other anadromous and freshwater fish valued by the sport fishing industry, especially the introduced Smallmouth bass (Anonymous 2000). Fig. 2.2.2 illustrates these multiple human influences on diadromous fish.

The first dams on St. Croix River were built with the establishment of sawmills in the 1790s. These dams were provided with effective fishways, and thus had no major effect on anadromous fish passage (Marshall 1976). However, in 1825, the lowermost Union Dam (which no longer exists) was constructed without a fishway, thereby inhibiting upstream migration of most anadromous fish (Perley 1852). A few salmon worked their way over the dam to reach their spawning grounds, enabling the stock to barely survive. It was not until 1869 that the dam was provided with a fishway. In the meantime, the river habitat had become heavily degraded (Marshall 1976).

The construction, establishment and maintenance of effective fish passages were a problem throughout the history of efforts to reestablish anadromous fish and fishery in the St. Croix (Table 4.2.1). Besides the early Union Dam, there are still three major barrier systems in the lower river at Milltown, Woodland and Grand Falls, and several dams in the upper river tributaries, for a total of 30 dams on the entire system (Fig. 2.2.1, Wilson 1956, Fletcher & Meister 1982, Anonymous 1988). The dams not only diminished fish passage, they also altered the habitat. High rapids, which may have served as natural barriers to migrating fish, were partly destroyed for the establishment of dams. Areas of low water flow were created and may have increased nursery areas (Wilson 1956, Fletcher & Meister 1982). On the other hand, there has been a significant loss of once extensive, high-quality spawning habitat, and deterioration of potential nursery areas due to siltation, compaction of substrates, and pollution (Fletcher & Meister 1982, Chapter 4).

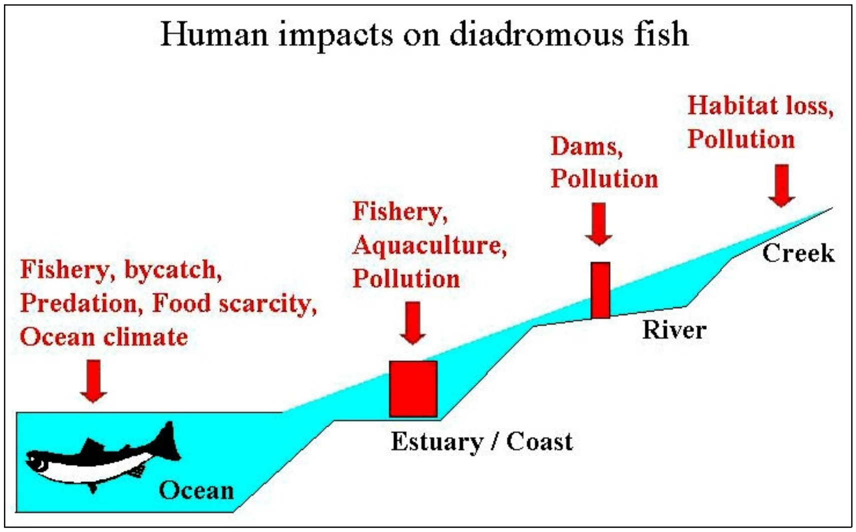

Fig. 2.2.2. *Illustration of multiple human and some natural impacts on diadromous fish in their river and marine habitats.*

Wastes from the saw and pulp mills were discharged directly into the river, accumulating and causing fouling conditions (Table 2.2.1, Wilson 1956, Marshall 1976). Low oxygen levels, low pH (acid conditions) and rising temperatures all contributed to reduced survival and recruitment of salmonids (Wilson 1956, Marshall 1976). A variety of chemical, biological, and toxic contaminants was discharged from tanneries, textile and paper mills (Table 2.2.1, Marshall 1976).

Deteriorating water quality and river habitat, together with the frequent blocking of fish passage, diminished the success of intensive hatchery and stocking efforts which first started in the 1880s (Marshall 1976). By 1909, the cumulative effects of declining water quality, increasing numbers of obstructions and reduced plantings of salmon fry resulted in the near-extirpation of salmon in the watershed (Marshall 1976).

In 1909, the International Joint Commission (IJC) was established by the US and Canada under the auspices of the Boundary Waters Treaty, to oversee resource issues and resolve disputes on boundary waters. Although the IJC recommended the construction of fishways, it did not have the authority to order their construction. For several decades following, governments, commissions, agencies, scientists, engineers and citizens held meetings, supported investigations and wrote recommendations for the re-establishment of the anadromous fish and fishery in the St. Croix. Government agencies involved were the St. Croix River Pollution Advisory Board and the St. Croix River Board of Control, both under the auspices of the IJC, Fisheries and Oceans Canada and its predecessors, the Maine Atlantic Sea-run Salmon Commission (since 1947), the Maine Department of Inland Fisheries and Wildlife, and the Maine Department of Marine Resources (Anonymous 1988). Many people took part in a back-and-forth struggle between conservation and economic interests, and agencies argued over who should take the lead role in restoration efforts. Almost no concrete action was taken until the 1970-80s, when initial pollution controls for municipal and industrial wastes were implemented and upstream fishways were installed.

Downstream passage, however, was and still is a problem. High water levels enable fish passage over spillways, but at lower water levels in summer, many fish move through the turbines. This causes mortality rates of up to 40 percent for fish of 20 cm length during their downstream passage (Anonymous 1988).

Furthermore, predatory and competitive freshwater fish hampered recovery of anadromous fish in the St. Croix River (Wilson 1956). The piscivore Chain pickerel (*Esox niger*, introduced in 1800s) and the Smallmouth bass (*Micropterus dolomieui*, introduced in 1870s) probably represent major predators on juvenile gaspereau and salmon (Anonymous 1988). Heavy grazing by juvenile gaspereau could compete with juvenile Smallmouth bass, and landlocked salmon would be a major competitor for sea-run salmon habitat (Anonymous 1988). Predatory birds were not considered to be an important threat (Anonymous 1988, 2000). A major threat to American shad is the fact that this species will not use fishways when they are utilized by gaspereau, which are usually found in much larger numbers (Anonymous 1988).

In the 1980s, new stocking efforts were made and a small number of wild and hatched salmon returned to the St. Croix River (Fig. 2.2.3). Water quality improved to the degree that salmon survival and recruitment were possible (Anonymous 1988). Gaspereau also returned in increasing numbers to the St. Croix (Fig. 2.2.4).

Since then, however, new threats evolved for these two species. Returns of wild Atlantic salmon to North American rivers have undergone a steep decline in the last 30 years, apparently caused by increased mortality at sea (Anderson et al. 2000). Relatively new threats to the salmon are the depletion of major offshore food species such as capelin by commercial fisheries; exposure of juveniles to the endocrine disrupting chemical nonylphenol leading to mortality in the later marine phase, and interactions with farm-escaped salmon such as interbreeding, competition, and transmission of diseases, which can lead to reduced fitness in wild salmon populations (Whoriskey et al. 1998, Anderson et al. 2000). Other factors such as large-scale oceanographic perturbations due to temperature shifts, disease, or increased predation are also considered possible, but as yet untested reasons for the salmon decline (Anderson et al. 2000). In 2000, Atlantic salmon runs in certain downeast Maine rivers were listed under the Endangered Species Act in the U.S.

When gaspereau runs greatly increased after construction of the new fishway in Milltown Dam in 1980, concern was raised by the sports fishing industry that large numbers of gaspereau would have negative impacts on introduced Smallmouth bass, angling for which is an important economic activity in eastern Maine (Anonymous 2000). In 1987, the State government in Maine responded unilaterally by blocking the fishway at the Vanceboro Dam to restrict gaspereau access to Spednic Lakes. The fishway at the Grand Falls Dam was blocked in 1991 and the Woodland Dam was blocked in 1995 (Anonymous 2000). These blockages greatly diminished gaspereau runs in the St. Croix (Fig.2.2.4). Canada has protested these blockages.

The suspected negative interactions between bass and gaspereau have never been demonstrated. In fact, sports fishers in Nova Scotia are concerned about low numbers of returning gaspereau because they assume overall positive effects of gaspereau on bass (Meade 2000). Yet, after 100 years of struggling to reestablish anadromous fish in the St. Croix, and although the official goal of the Maine Department of Marine Resources is to restore anadromous fish species to their historical habitat in the State of Maine (Anonymous 2000), introduced Smallmouth bass were favoured over the native gaspereau in these decisions.

In May 2001, the Maine legislature defeated a Bill to repeal the law enacting the 1995 closure of the Woodland and Grand Falls fishways to the passage of gaspereau, but the Senate voted to pass the Bill. It was returned to the Legislature which again defeated it. In opposition to the decision to retain the dams, in spring 2001Fisheries and Oceans Canada captured and trucked about 4,000 gaspereau around the Milltown dam (about 75 percent of that run) and released them in the Woodland flowage (L. Marshall, pers. comm).

In the past, for conservation and management purposes, several calculations have been done to estimate the potential production or carrying capacity of the river habitat for anadromous fish. Such calculations include estimates of potential spawning and nursery habitat, the potential production of smolts per area, and the potential survival of smolts towards the adult stage (see below). Required egg deposition to utilize available habitat, as well as the required spawner abundance to meet the egg deposition were also calculated. Results indicate a potential adult production of Atlantic salmon in the St. Croix River ranging from 7,000 to 18,000 adults, with the most recent estimates of 7,200 to 9,847 (Fig. 2.2.3, Fletcher & Meister 1982, Anonymous 1988).

For gaspereau, potential abundance estimates range from 14 million to 38 million adults (see below). Only rough estimates are available for potential production of 50,000 adult shad (Wilson 1956, Harvey 1963), 100,000 kg of eels, and 4,500-18,000 kg of smelts (Anonymous 1988). No estimate is available for Striped bass (Anonymous 1988).

Table 2.2.1. *Historical human impacts on the St. Croix River and its fish. Data from Perley 1852, Boardman 1903, Wilson 1956, Marshall 1976, Fletcher & Meister 1982, Anonymous 1988, 2000, SCEP 1997.*

Time (A.D.)	Activity	Impact
1790	Timber harvest begun	
1790s	Numerous saw mills on St. Croix River (first in Milltown, 1790)	pollution with logs, sawdust, edgings, slabs, shavings, bark
1793	First dams built on the lower St. Croix with fishways	
1800s	Introduction of Chain pickerel	introduced species
1825	Union Dam built on lower St. Croix without fishway	blocking fish migration towards spawning habitat, species plummeted
1850-60s	Effluents from tanneries located upriver	pollution with salt liquids, lime and tan liquor, skin scrapings, tan bark
1857-1873	Zenith of timber industry	
1860s	Public interest revived in nearly lost anadromous fisheries	
1865	Investigation of tanneries by a British Royal Commission	
1869	All dams including Union Dam equipped with fishways	St. Croix reopened to fish after 40 yrs
1870s	Introduction of Smallmouth bass	introduced species
1871	Discharge of all but sawdust prohibited by law (ignored until 1883)	
1880s	Salmon hatchery opened; during 1881-1892 over 1.4 million Atlantic salmon stocked in the St. Croix, but only few returned	salmon stocking
1881	Cotton Mill (Milltown) Dam constructed, textile mill discharged significant chemical and biological wastes	fish blockage lower river pollution with chemicals
1883	Milltown Dam provided with fishway	fish passage
1906	Woodland Dam (power dam) built with a fishway	
	Associated Paper Company a major polluter	major pollution
1909	Near extirpation of salmon	
1909	International Joint Commission (IJC) established	
1915	Grand Falls Dam used by St. Croix Paper Company approved without fishway by IJC	blockage of upper river
1923	Order by IJC of reconstruction of fishways at Union and Milltown Dam	fish passage lower river
1929	Approval by IJC of abandonment of Woodland fishway because of upriver blockage at Grand Falls	fish blockage lower river

Table 2.2.1 cont'd.

Time (A.D.)	Activity	Impact
1934	Union Dam destroyed by freshets, leaving only 3 dams on lower river	
1930-1960	Repeated efforts made to get agencies to provide fish passage and reduce pollution, but no action taken	
1947	Maine Atlantic Sea-Run Salmon Commission established	
1960	Milltown fishway constructed but remained ineffective	
1960	Pollution survey indicated lethal conditions for juvenile salmon	toxic water conditions
1962	Pollution survey indicated severe bacterial pollution by domestic sewage and industrial discharges	heavy sewage pollution chemical pollution (sulphide waste) physical pollution (coal ash, wood wastes)
1963	Fish kills reported	low oxygen, toxics (sulphide)
1964-65	Fishway constructed at Woodland and Grand Falls Dam	fish passage in mid and upper river
1965	New stockings of gaspereau and salmon revealed very high mortality due to low dissolved oxygen levels and high sulphide pollution	low dissolved oxygen levels
1966	Large shellfish area in St. Croix estuary polluted	shellfish closure
1967	River survey indicated sludge deposits 7 ft deep (coal ash, sawdust, wood chips, bark, sunken logs)	oxygen depletion in river water and sediments due to deomposition
1968	Caged fish test showed continued lethal effects on salmon of pulp mill effluents at Milltown and Woodland	lethal water conditions
1969	A few adult salmon seen below Milltown Dam; a dozen or more found dead at Calais	toxic water conditions low oxygen levels
1972	Municipal effluents received some form of treatment	some sewage treatment
1972	Fundy commercial salmon fishery closed	
1979	Water pollution control program implemented on the St. Croix by the IJC after 20 years of struggling	water pollution reduced, recovery of fish and benthic invertebrates
1979	Salmon aquaculture started in Quoddy Region	
1980	Milltown Dam provided with new fish passage	fish passage lower river, increase in gaspereau runs
	400 adult salmon released and spawned successfully	salmon stocking
1981	Effluent treatment system established at Woodland pulp mill 20000 tagged, hatched smolts released (U.S. and Canada) New fish passage for Woodland Dam was designed	improvement of water quality
1982	All main dams have fishways (Cotton Mill, Woodland, Grand Falls, Vanceboro, Forest City)	fish passage throughout main River
1987	Vanceboro Dam closed to restrict gaspereau access to Spednic Lake	gaspereau decline
1990s	Salmon aquaculture production expands throughout Quoddy	farm-raised salmon escapees interact with wild fish, enter river
1991	Gaspereau blocked at Grand Falls Dam	gaspereau decline
1995	Woodland fishway closed to gaspereau	gaspereau decline
2000	Downeast Atlantic salmon runs listed under US Endangered Species Act	

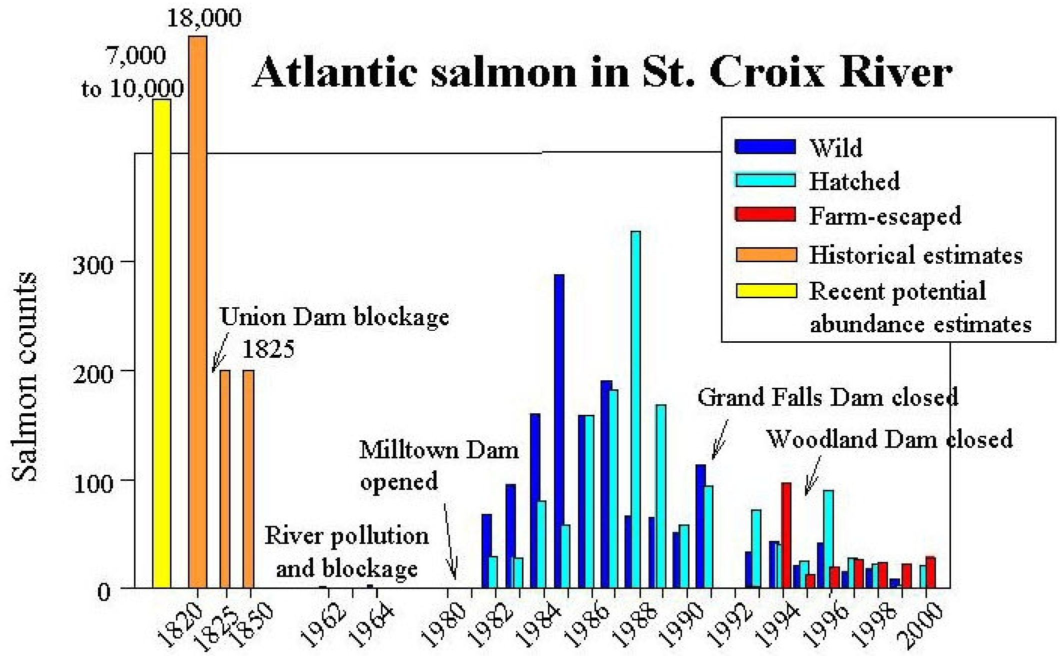

Fig. 2.2.3. *Potential abundance and annual fish counts of returning Atlantic salmon to St. Croix River. Data sources: counts of wild, hatched and farm-escaped salmon from Chaput & Prevost 1998, Marshall et al.1999; historical estimates from Perley 1852; potential abundance estimates from Fletcher & Meister 1982, Anonymous 1988.*

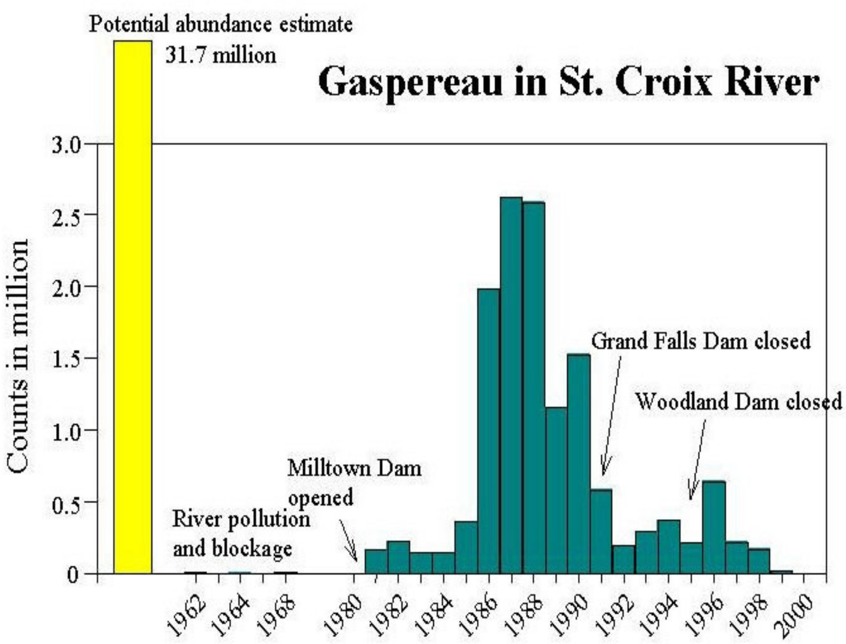

Fig. 2.2.4. *Potential abundance and annual counts of retuning gaspereau to the St. Croix River. Data sources: counts from Anonymous 1971, L. Marshall (DFO); potential abundance estimate from Anonymous 1993*

2.2.3. Magaguadavic River and its history of human impacts

The Magaguadavic River drains an area of 1812 km^2 and enters Passamaquoddy Bay at St. George (Fig. 2.5, Carr et al. 1997). One hydroelectric dam is located on the lower river. This dam is equipped with a fishway suitable for salmon and gaspereau (Marshall et al. 1999). More than 103 tributaries and 55 lakes are part of the drainage system. The main diadromous species found in the Magaguadavic River are Atlantic salmon, gaspereau and American eel. The main freshwater fish are land-locked salmon, Brook trout, and Smallmouth bass (Martin 1984).

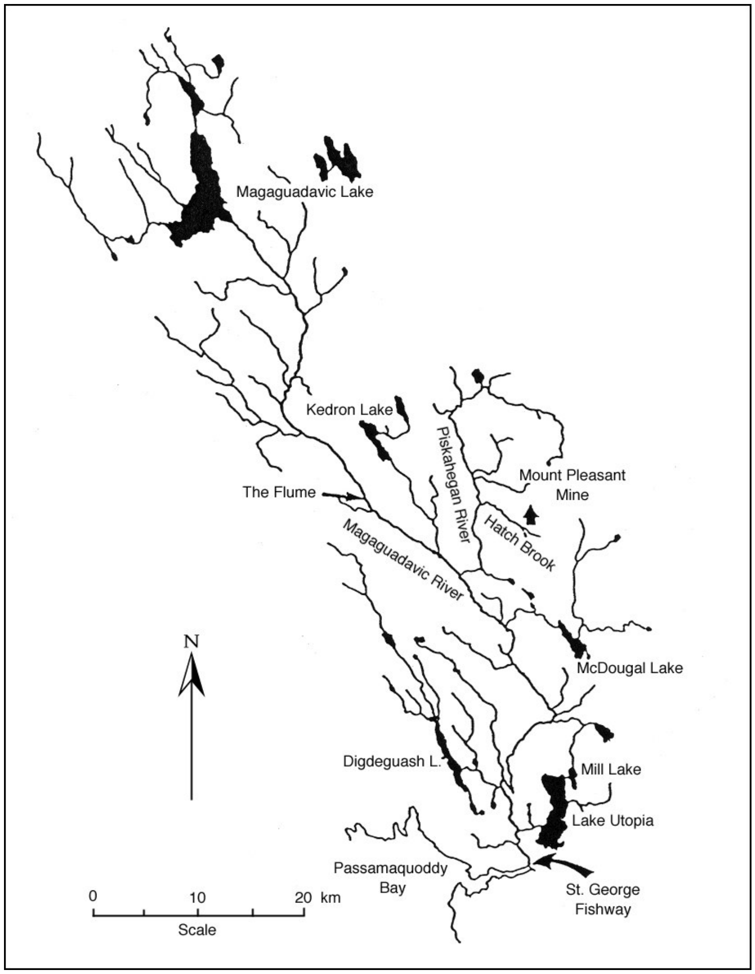

Fig. 2.2.5. *The Magaguadavic River watershed (from Martin 1984).*

The historical impact of human activity on the Magaguadavic watershed is poorly documented compared to that of the St. Croix. It is assumed, however, that the lower river was never completely blocked to migrating anadromous fish, thus native stocks were able to maintain themselves (Carr et al. 1997). In the past, major polluters on the river have been the St. George Pulp and Paper Mill and the community itself (Table 2.2.2). Further concerns related to the Mount Pleasant mine, located near some upper tributaries of the Magaguadavic (Martin 1984). This mine was redeveloped in the 1980s from a tin to a tungsten mine.

Impacts of these human activities on the river resources have not been investigated in a systematic way. This has changed somewhat in recent years due to concerns about the potential impacts of salmon aquaculture. Because of its close proximity to the center of the New Brunswick salmon aquaculture industry, the Magaguadavic has attracted more salmon escapees than any other monitored river in eastern North America (Marshall et al. 1999). Besides competing and possibly interbreeding with wild populations, escapees can carry culture-originated or exacerbated diseases. In 1996, the Infectious Salmon Anemia (ISA) virus was detected on salmon farms in the Quoddy region and in 1999, it was detected for the first time in wild salmon taken from the Magaguadavic (Carr & Whoriskey 1999). The general trend of decreasing wild returns of Atlantic salmon to North American rivers (see above, Anderson et al. 2000) is also visible in the Magaguadavic (Fig. 2.6). While returning wild salmon almost achieved the conservation requirements for egg deposition in 1992 (80 percent), this level dropped to 35 percent in 1994, 12 percent in 1997, 2.3 percent in 1998, and only 0.2 percent in 1999 (Whoriskey et al. 1998, Carr & Whoriskey 1999).

For the Magaguadavic River, estimated potential production of adult salmon ranges from 1400 (based on calculations from St. Croix River, see below) and 3000 (Martin 1984). No numbers are known for other anadromous species in the Magaguadavic, but in 1983, ‘some’ 10,000 gaspereau and ‘some’

1,000 American eels were counted at the St. George fishway (Martin 1984). Commercial catch statistics indicate that about 1 tonne of eels is caught annually in the Magaguadavic River, indicating a much larger base population (B. Jessop, *pers. comm*).

Table 2.2.2. *Historical human impacts on the Magaguadavic River. Data from Carr et al. 1997, Carr & Whoriskey 1999, Marshall et al. 1999*

Time (A.D.)	Activity	Impact
1903	St. George Pulp and Paper Mill Dam constructed, but a natural fishway occurred	water pollution
1928	Fishway constructed in St. George Dam	fish passage
1930-40s	Introduction of Smallmouth bass	introduced species
1967	Pulp mill closed, dam kept for hydroelectric power station	
	Additional water storage dams present at entrances to four lakes (Mill, Digdeguash, McDougall, Magaguadavic)	
	Flume Ridge Dam removed	access to 30% more habitat
1980	Redevelopment of Mount Pleasant tin mine to a tungsten mine near some upper river tributaries	possibly pollution through run-off
1980-90s	Salmon aquaculture started in Passamaquoddy Bay, over 70% of farms located within 10 km of river mouth	farmed salmon escape
	3 commercial salmon hatcheries located on the river producing smolts	farmed smolt escape, water pollution
1980s	Stocking of anadromous and land-locked salmon	
1990	Stocking of Arctic char	
1996	Infectious Salmon Anemia (ISA) virus detected on salmon farms in the Quoddy region	
1999	ISA virus was detected for the first time in wild Atlantic salmon	disease transfer to wild salmon, taken from the Magaguadavic. required destruction of breeding females.

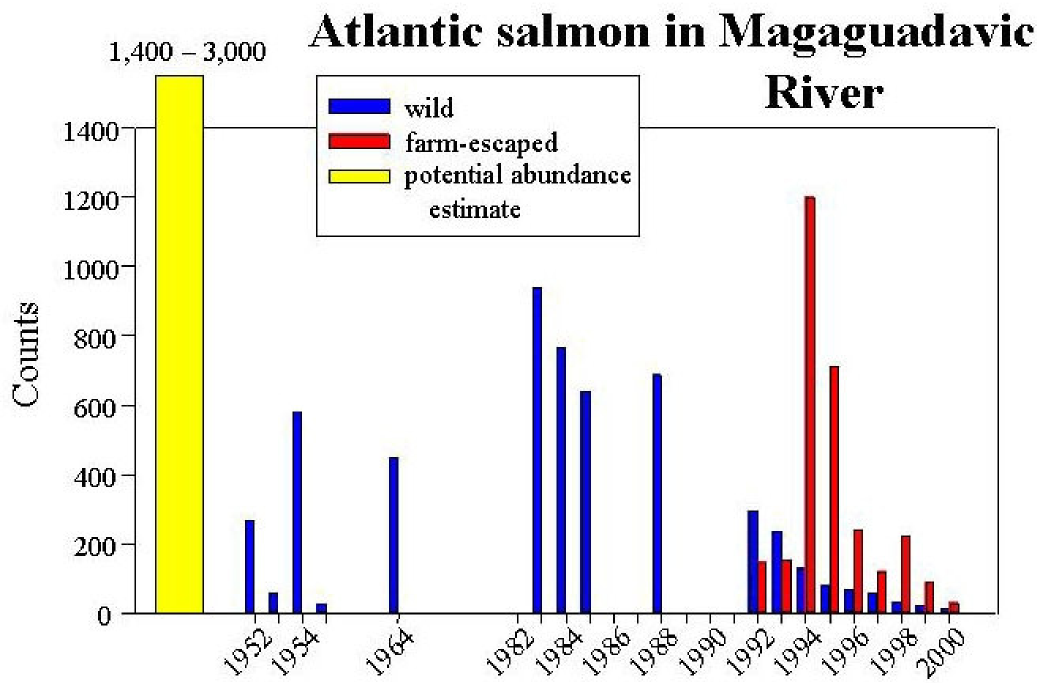

Fig. 2.2.6. *Potential abundance and annual fish counts of returning Atlantic salmon to Magaguadavic River. Data sources: counts of wild and farm- escaped salmon from Whoriskey et al. 1998; potential abundance estimates from Martin 1984 and own estimate (refer to text).*

2.2.4. Detailed reconstruction of carrying capacity of Atlantic salmon and gaspereau in St. Croix and Magaguadavic River

Atlantic salmon – St. Croix River:

Estimated total potential spawning and nursery area

1) 3,293,004 m^2 (329 ha) (Fletcher & Meister 1982)
2) 2,973,652 m^2 nursery and 522,249 m^2 spawning area (Wilson 1956)
3) 3,078,695 m^2 (Anonymous 1988)

Potential production of smolts

1) 196,950 smolts (assumed 4 smolts per 100 sq. yd., Fletcher & Meister 1982)
2) 77,000 smolts (assumed 2.5 smolts per 100 m^2 or 2.1 per 100 sq. yd., Anonymous 1988)

Potential production of adult salmon (based on a 5-10 percent survival rate of smolts)

1) 9,847 adult salmon (Fletcher & Meister 1982)
2) 7,000 - 14,000 adult salmon (Wilson 1956)
3) 9,000 - 18,000 adult salmon (Kerswill 1960)
4) 8,400 adult salmon (revised figures from Kerswill by DFO 1977)
5) 7,200 adult salmon (Anonymous 1988)

Required egg deposition to utilize habitat

1) 8.7 million eggs (Fletcher & Meister 1982)
2) 7.4 million eggs (Anonymous 1988)

3) 7.4 million eggs (Marshall et al. 1999)

Required spawners to meet egg deposition

1) 1,155 females (a 7,500 eggs) plus same amount males = 2,300 adult salmons (Fletcher & Meister 1982)

2) 1,020 females = 2,040 adults (Anonymous 1988)

3) 1,710 MSW (multi sea-winter) and 680 1SW (1 sea-winter) salmon (Marshall et al. 1999)

Required total adult spawning escapements (assumed distant, at sea exploitation rate of 50 percent plus angling catch of returns 20 percent)

1) 5,800 adults (Fletcher & Meister 1982)

Gaspereau – St. Croix River:

Potential adult production

1) 1,517.6 – 3,035.1 metric tons (Wilson 1956). 352 km^2 lake area could support up to 3,682.89 metric tons, but fishway efficiency and capacity are considered to be limiting factors => 14.16 million fish (assumed mean adult weight 0.26 kg, Anonymous 1993)

2) 225 kg / ha = 10,000 metric tons total (Anonymous 1988) => 38.46 million fish (assumed mean adult weight of 0.26 kg, Anonymous 1993). Without West Branch above West Grand Lake (Maine restricts accessibility on purpose) only 5,140 metric tons => 20 million fish

3) St. Croix total accessible area = 36,598 ha, 225 kg/ha, 0.26 kg mean adult weight, => total 31,7 million (Anonymous 1993)

Atlantic salmon – Magaguadavic River

Estimated spawning and nursery area

1) accessible habitat = 9.33 km^2, suitable juvenile rearing habitat = 0.563 km^2 (Whoriskey et al. 1998)

Estimated conservation requirements (2.4 eggs / m^2)

1) 1.35 million eggs (Whoriskey et al. 1998)

Required spawners to meet egg deposition

1) 230 MSW and 140 1SW (Whoriskey et al. 1998)

Estimated potential production of adult salmon

1) 3000 (Martin 1984)

2) 1400 (own estimate assuming same relationship between egg deposition and adult production as for St. Croix River)