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Understanding the Striped Bass of the Saint John River:

Towards Future Successful Reproduction

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DISCLAIMER

Intended use and technical limitations of the report, "Understanding the Striped Bass of the Saint John River: Towards Future Successful Reproduction". This report describes the current state of understanding regarding the ecology of Striped Bass in the Saint John River, with a discussion of future needs is presented. The CRI doesn't assume liability for any use of the included information and data outside the stated scope.

Executive Summary

The Striped Bass *Morone saxatilis* of the Saint John River, New Brunswick is an enigma, having now existed in a state of uncertain species status for over four decades. Despite a well-established, historic record of adult occurrence in large numbers, the available literature, historic accounts, and status reports contain no evidence for the persistence of a native, reproducing Striped Bass population. In 2012, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) listed the Saint John River Striped Bass as endangered as part of the Bay of Fundy Designatable Unit. This listing lacked current peer-reviewed literature and based its conclusions predominately on restatements of findings and opinions from the 1970s and 80s. After the apparent failure of Striped Bass spawning in the 1975, the decline of native Striped Bass was accredited to many factors ranging from DDT to over-fishing to the installation of a sizeable hydropower facility. Modest attempts to locate eggs and juveniles of the native species have been taken; however, the results have been inconclusive due to ineffective, infrequent and poorly timed sampling. New information will be required to re-discover and effectively describe, manage, and recover (if required) this apparently missing population.

Introduction

Striped Bass *Morone saxatilis* is a large anadromous fish ranging naturally along the Atlantic Seaboard of North America from the St. Johns River, Florida in the south, to the St. Lawrence River, Quebec in the north (Scott and Crossman 1973; Scott and Scott 1988; Rulifson and Dadswell 1995). Striped Bass spawn in fresh or brackish water at or above the head of tide of rivers in the early spring (Setzler et al. 1980; Scott and Scott 1988; Melvin 1991) and often occupy coastal or estuarine environments where they serve as the apex predator of the inshore environment throughout much of their range (Setzler et al. 1980).

Striped Bass have been artificially introduced to numerous fresh water reservoirs in the continental United States and the Pacific coast (Setzler et al. 1980). Canadian origin fish are still confined to their historic range and rivers (Scott and Scott 1988; Rulifson and Dadswell 1995). For management purposes, the species range within Atlantic Canada has been subdivided into three Designatable Units by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) comprising the St. Lawrence River, the Southern Gulf of St. Lawrence and the Bay of Fundy (COSEWIC 2004; 2012).

Most recently, the Bay of Fundy Designatable Unit has come under scrutiny because the region, once supporting three self-sustaining Striped Bass populations, i.e., Shubenacadie River, Annapolis River, and Saint John River (SJR), (Jessop 1990; DFO 1999), may now be reduced to a sole reproducing population in the Shubenacadie River (COSEWIC 2012; DFO 2014; Bradford et al. 2014). This sobering conclusion has resulted in the recent designation of "endangered" for Bay of Fundy Striped Bass by COSEWIC (COSEWIC 2012).

The Striped Bass of the SJR were at one time present as adults, in great abundance supporting both commercial (Dadswell 1976; 1983; Dadswell et al. 1984; Jessop 1990; 1991; Rulifson and Dadswell 1995) and recreational fisheries (Wilson 1958; O'Donnell 1963; Dadswell 1976; 1983; Dadswell et al. 1984; Manderson 1979). Striped Bass in the SJR had been prominently recognized throughout Atlantic Canada and along the New England coast for their size and numbers (O'Donnell 1963) and were harvested commercially throughout the SJR (DMF 1871-1916; DFSC 1918-1951; DFNB 1952-1962; SCNB 1963-1976; Fisheries and Marine Service Halifax (Reid 1978)).

There are many accounts describing the spawning of Striped Bass in the river, (e.g., Adams 1873; O'Donnell 1963; Scott and Crossman 1973; Dadswell 1975; Williamson 1974) suggesting the abundant adults were a native, self-sustaining population during these earlier times. Declining abundance and the apparent lack of recruitment in the mid-1970's resulted in a closure of the commercial fishery in 1930 (Jessop 1991; Rulifson and Dadswell 1995; Dadswell 1975). It has been widely hypothesized that pollution and the construction of the Mactaquac Dam and associated Mactaquac Generating Station (MGS), the largest and lowermost hydro-electric power station on the SJR may have adversely affected important spawning locations and egg viability, (e.g., Meth 1972; Dadswell 1975; Jessop 1990; 1991; 1995; Wirgin et al. 1995; Douglas et al. 2003; COSEWIC 2004; 2012; Robinson and Courtenay 2006; Forsythe 2010; Bradford et al. 2012; 2014; DFO 2011; 2014).

Understanding the enigma surrounding the SJR Striped Bass should be the first step in designating and/or recovering this socio-economically important population. It is particularly important that we quickly improve our understanding of the population given the pending decision to either rebuild or remove the Mactaquac Dam (Hayman et al. 2010; Stantec 2015), which has been described as one of the major threats for this species in the SJR (COSEWIC 2004, 2012). The lack of information and misinterpretations of historic records regarding this population in contemporary literature greatly impedes decision making to protect or recover the species. Here we review the available information from peer-reviewed literature; academic; government; NGO reports; historic fishery catches; landings data; angling; and historic accounts to better understand population trends, potential lack of recruitment and the origin and movements of SJR Striped Bass. We discuss information voids that must be imminently addressed to understand the SJR Striped Bass and assess the potential impacts of the Mactaquac Dam's future (Hayman et al. 2010; Stantec 2015). This information will directly impact the conservation mandate of COSEWIC to assess species at risk and its ability to inform the Canadian Species at Risk Act (SARA) in mandating conservation actions.

Saint John River

The SJR is the largest watershed between the St Lawrence and Mississippi rivers spanning 55,000 km^2 within the provinces of New Brunswick (NB) and Quebec, and the State of Maine (Cunjak et al. 2011; Figure 1). The SJR extends ~670 km from the Little Saint John Lake on the Maine/ Quebec border to the City of Saint John, NB where it empties through a relatively narrow opening (~100 m) known as Reversing Falls, into the Bay of Fundy (Cunjak et al. 2011; Figure 2). The head of tide is ~130km upriver (City of Fredericton) and salt water penetrates the estuary ~70 km upriver (Village of Gagetown), (Carter and Dadswell 1983; Figure 2). The large tidal range of the Bay of Fundy provides expansive saline, estuary habitat for fish throughout the year (Trites 1960; Dadswell 1983).

Due to the narrow river mouth and extreme tidal fluctuation of the Bay of Fundy, tidal filling of the river upstream and subsequent emptying can be delayed by many hours from the occurrence of high and low tide (Hachey 1934). This phenomenon has a large effect on water level and current direction and has also been observed to determine the timing of migratory fish entering and exiting the river (Dadswell et al. 1984). The large tidal range of the Bay of Fundy, combined with heterogeneous mix of interspersed lentic and fluvial habitats, various colonization routes and a history of species introductions have resulted in relatively diverse fish fauna with a community comprising of 54 documented fish species (5 marine, 35 freshwater and 14 diadromous: CRI unpublished data; Mark Gautreau, University of New Brunswick, Fredericton, personal communication)

The SJR has five major dams along its length: three on the main stem and one near the mouth of the Aroostook and Tobique Rivers (Ruggles and Watt 1975, Cunjak et al. 2011). The Mactaquac Generating Station is the largest, most recent (installed in 1968), and the lowermost obstruction to migratory fish on the SJR, and is located ~150km from the river mouth (Figure 2, 3, 4). The operation of the MGS as a run-of-the-river facility and its function as a critical energy producer for NB creates several physical effects; (i.e., altered discharge/velocity regimes, river levels, and sediment fluxes) on the river downstream especially between the Dam and the City of Fredericton (Figure 4; Cunjak et al. 2011; Curry et al. 2015). The next upstream obstruction to the SJR is the Beechwood Generating Station constructed in 1952 (Ruggles and Watt 1975), it lies ~285 km from the river mouth.

Saint John River Striped Bass Meristics, Growth and Sexual Maturation

Williamson (1974) and Melvin (1976) reported similar meristic observations for Striped Bass sampled in the SJR (N=411 and N=57; respectively). Sampled fish had 17-22 caudal fin rays, 30-36 pectoral fin rays, 1 spine and 11-12 soft rays on the second dorsal fin, and < 64 lateral line scales for most fish. These meristics are similar to populations in the Annapolis River, Chesapeake Bay, Albemarle Sound, and St. John River Florida, thus these methods were unable to distinguish a native SJR Striped Bass from other possible migrants to the SJR. Mixing with other rivers could, however, have masked possible differences (Williamson 1974). Lateral line scales for a small number of fish (N=3) did offer some notable deviations (> 64 lateral line scales), (Williamson 1974) from known scale count ranges for Canadian populations typically expressing 58-64 scales (Scott and Crossman 1973).

Striped Bass in the SJR were found to reach sexual maturation at age 3-7 (Williamson 1974). Males can mature at age 3 with 84% being fully mature at age 5 (Williamson 1974). Females have been observed to reach maturity later with most being ready to spawn by age 6 (82%) or 7 (100%); no females of age 3 were found to be mature (Williamson 1974). Female Striped Bass may only spawn every other year in the SJR (Williamson 1974); skipping spawning years is possible and has been observed, for example on the Roanoke River (Lewis 1962).

Growth of Striped Bass in the SJR is comparable to that of more southern populations in the first few years (Dadswell 1976), but slows substantially after age 6 (Williamson 1974; Dadswell 1976). No comprehensive length-weight relationship exists in published literature across a representative range of fish lengths; however, Williamson (1974) described length weight relationship for Striped Bass ranging from 28.0 - 81.9 cm as $\log L = 0.608 + \log_{10} 0.0550W$ where L is length and W is weight. Dadswell (1976) calculated a b value of 0.660 for the $\log_{10}$ length-weight relationship. Striped Bass up to 19 years of age were captured by Melvin (1976), though Striped Bass in the SJR may live 30-40 years (Dadswell 1976). The largest Striped Bass confirmed on the SJR was caught on August 15, 1979; it weighed 28.58 kg and was measured at 133 cm in length, with a girth of 81 cm and was determined to be 21 years of age (M. J. Dadswell, in Manderson 1979).

Population trends inferred from fisheries data

Population monitoring

The Striped Bass population of the SJR has never been fully assessed (Melvin 1976). There is currently no monitoring program that could produce an estimate of the number of the Striped Bass annually emigrating, immigrating or residing within the SJR. The only current population data comes from the Department of Fisheries and Oceans (DFO)'s fish collection gallery at the MGS, which has provided an annual record of Striped Bass captures since its completion in 1968 (Table 1; Ruggles and Watt 1975). This record, however, is solely an enumeration of Striped Bass taken as bycatch while attempting to pass Atlantic Salmon *Salmo salar* and Gaspereau (combination of Alewife *Alosa pseudoharengus* and Blueback Herring *Alosa aestivalis*) above the Mactaquac Dam. Operation of the fish lift is predominantly conducted for the passage of Atlantic salmon (Williamson 1974) for, which it was chiefly designed (Ruggles and Watt 1975).

Although the fish lift was originally intended to "*protect various fish populations using the* (river) *system*" as they were of "*significant value*" (Smith 1979), the remaining species arriving at the fish lift, including Striped Bass are now considered to be "*garbage fish*" (Armstrong 2006). These other species are actively inhibited from passing, and, in the case of the Striped Bass at least, from accessing upstream habitat occupied historically (Figure 5; Table A. 1; Warner 1956; Meth 1974; Smith 1979; Ingram 1981; Jessop 1990). Fish captures incurred at the Beechwood Dam display an abrupt attenuation of Striped Bass observations both during and following the construction of the Mactaquac Dam initiated in 1966 (Figure 5).

Sampling effort; (i.e., the number of times the fish lift is raised and duration the hopper is left to fish) at the MGS is undocumented. The Striped Bass capture records at the MGS are further undermined as "*attraction efficiency of the fish lift for Striped Bass can be manipulated through the alteration of flow, allowing, on occasion for the targeted capture of the species*" (Rob Beaumaster, Fish Lift Operator, Department of Fisheries and Oceans, personal communication). These catches of Striped Bass taken as occasional by-catch, and infrequent targeted captures for research purposes are combined into yearly counts (Table 1). This practice has most probably resulted in

artificial peaks in the number of Striped Bass captured at the fish lift, which was operated to selectively target the species for tagging, e.g., in 1999-2002, (Table. 1; Douglas et al. 2003).

These additional targeted captures and inferred population spike have been used to match the relative strength of adult return to juvenile recruitment peaks of previous years in US rivers, (e.g., Douglas et al. 2003). Depending on the fish lift at MGS as the sole counting facility also inherently assumes that every Striped Bass in the SJR, regardless of origin migrates to this upstream point, an unlikely assumption that has never been proven as fact.

The unreliable selectivity of the fish lift is also visible in weekly Striped Bass captures: Douglas (2003; for 1968-2000) and Williamson (1974; for 1968-1973) who report peak Striped Bass captures (and therefore occurrence at the MGS) occurring from August to September (standard week 31-35). This peak period, coincides with periods of increased fishing (fish lift operations) for migrating Atlantic Salmon (Smith 1979) and not with true Striped Bass seasonal abundance. Striped Bass arrive at the MGS in large numbers in early spring coinciding with the runs of Gaspereau, or for the purpose of spawning and later return in the fall (October) to feed (Kings Clear First Nation anglers, personal communication; S. Andrews unpublished data). It should also be noted that "*dense runs of Gaspereau in the early spring can clog the entrance gallery of the fish lift and often prevent other species from entering at this time*" (Rob Beaumaster, Fish Lift Operator, Department of Fisheries and Oceans, personal communication) possibly inhibiting the capture of Striped Bass in spring, even when present.

Sampling conducted from a single fish lift hopper at a single location far upstream during only part of the year, i.e., "*May 1st – October 31 depending on conditions*" (Leroy Anderson, Department of Fisheries and Oceans, personal communication) cannot represent the complex multi-population dynamics of Striped Bass within the accessible portion of the SJR, which stretches nearly 150km from the sea.

Numerous incongruous fish lift counts also undermine any conclusion regarding the SJR Striped Bass population (Meth 1972; Williamson 1974; Smith 1979; Ingram 1980; 1985; Jessop 1990; Hooper 1991; Douglas et al. 2003) as well as current stock status reporting by DFO (Table 1).

Commercial fishery

The SJR Striped Bass population has been subject to heavy fishing pressure since at least the early 1800s (Rogers 1936; Dadswell 1983; Jessop 1991). Striped Bass were initially taken mainly for sustenance and many accounts describe the fisheries conducted by the native peoples and early settlers of the area (Perley 1852; Adams 1873; Cox 1893; DMF 1871-1916; Rogers 1936), with substantial exports to US markets in later years (DMF 1871-1916). Striped Bass were captured by angling, set line, seine net, bag net, dip nets, bow net and spear, both on the spring spawning grounds and in the winter through the ice (Adams 1873; Rogers 1936; DFO 1992). Concern about Striped Bass abundance had already begun by the late 1800s (Adams 1873; Bayne 1930; DMF 1871-1916).

Initially, the SJR supported no directed commercial fishery for Striped Bass (Table A.1; DMF 1871-1916). However, substantial harvest still occurred from the Saint John Harbour to Carleton County (Figure 3; Table A.1; DMF 1871-1916; Jessop 1991). These landings were predominantly taken as bycatch in other fisheries (Atlantic salmon, Gaspereau, American Shad *Alosa sapidissima*, Rainbow Smelt *Osmerus mordax* and Sturgeon (Atlantic and Shortnose) *Acipenser oxyrinchus* and *Acipenser brevirostrum*), (DMF 1871-1916; Dadswell 1983). Striped Bass taken as bycatch were legally marketable at the time (Reid 1978; Bradford et al. 2014). It was noted by Reid (1978) that not all bycatch was reported and thus the total bycatch is uncertain, i.e., true catches could be much higher than reported (Figure 6). In addition, poaching was most probably occurring according to Fisheries Wardens Reports (Fisheries Warden report, DMF 1876).

The major producer in the area was Kings County (Figure 3; Table A.1) where "*the principal bass fishery was in Belleisle Bay*" (Figure 2; DMF 1889) with catches being taken primarily in winter. Catches were also incurred in the Kennebecasis River, i.e., Queens County (Jessop 1991), and the Saint John harbour, most notably from 1876 to 1879 (Figure 2; Table A.1; DMF 1871-1916).

Early commercial catches were large and peaked between 1888 and 1890 (Jessop 1991), (Figure 5). Steep declines throughout the river forced a closure "*prohibiting fishing for bass, in any manner whatever for the period of three years from May 1st 1892*" (Figure 6; DMF 1892; Jessop 1991). The retention closure remained from May 1st 1892 until it was reopened in the winter of

1895 with catch record being available in 1896 (DMF 1896). Following the closure, fisheries was primarily restricted to Belleisle Bay with only small quantities, possibly taken as bycatch, occasionally being registered from Queens and York Counties (Figure 3; Table A.1).

The fishery once again failed between 1903 and 1906 (Figure 6; DMF 1871-1916; Jessop 1991). Catches peaked in 1913 before dropping to relatively low levels for close to 10 years, and high catches were not seen again before 1926 when over 11,000 kg were landed (Figure 6; Table A.1; Dadswell 1976). Declines in the fishery were of concern to Bayne (1930) who described the destruction of young Striped Bass as bycatch in the Rainbow Smelt fishery, he feared the complete destruction of Striped Bass stock after the forceful opposition by fishermen to every attempt to regulate the fishery at the time.

In 1930, a directed winter Striped Bass fishery was officially opened in Belleisle Bay, Kings County (Figure 3). Fishermen were directed to use 13cm mesh gill nets (Reid 1978; Dadswell 1976 and 1983), which may have removed immature Striped Bass age 4-6 prior to their first spawn (Reid 1978). Nets were set under the ice at depths from 10-30 m using an ice jigger (Dadswell 1983). This directed commercial fishery was conducted between late December and early February (Meth 1971) or March (Meth 1972; 1973), however, newspaper articles of the time and evidence of higher monthly catches reported by Smith (1969) and Reid (1978) suggest the true season extended from December 1st to March 31st. The highest catches were often seen early in the season (Meth 1973), with large quantities being shipped to major cities in the USA, e.g., Boston and New York (New Paper Article (date unknown)). License data for commercial fisherman is available for a small window (1947-1974; Figure 6, 7), where each license holder would have been permitted to fish one net. The fishery in Belleisle Bay remained "*reasonably good*" until ~1970 even though recreational catches at the mouth of the river had declined to almost nothing (Meth 1972).

The general patterns of abundance according to the commercial fishery reports followed a 9-11 year cycle (Dadswell 1983; but see Jessop 1990 who proposed 7-14 year cycles) until steep declines post 1970 (Figure 6, 7; Table A.1; Dadswell 1976, Jessop 1990). Managers at the time feared the disappearance of the native population following a steep drop in catches and apparent lack of recruitment since 1973 (Dadswell et al. 1984), including a spawning failure event observed in 1975 (Dadswell 1976). The directed commercial fishery was finally closed for a 10-

year period in 1978 to allow for stock recovery (Dadswell 1983), it has not re-opened (Figure 6; Table A.1).

After the 1978 closure, Striped Bass was still taken as by-catch in other fisheries and could be retained and sold commercially (Ingram and Burnley (date unknown); Bradford et al. 2012). No catch data exist from this time until present in published records. In 1996, the commercial by-catch fishery of Striped bass was closed completely (Bradford et al. 2012). Since then, licensed commercial fishermen along the SJR have only been allowed to retain one Striped Bass ≥ 68cm total length per day for personal consumption (DFO 1999; Bradford et al. 2012; DFO 2014).

Recreational fishery

The Striped Bass was first described as a game fish in the SJR by Adams (1873). The recreational fishery has mainly been focused in the area of Reversing Falls in the City of Saint John (Figure 2; Jessop 1991). Anecdotal evidence from anglers suggest that the recreational fishery was poor in 1915 (Dadswell 1976) and, increased in popularity (and most likely productivity) from 1950-60 continuing to 1970 (O'Donnell 1963; Mosher 1969; Balance 1969; Moss 1971; Meth 1972; Jessop 1991). Following this short boom "*The angling fishery at reversing falls declined to virtually nothing in 1971"* (Meth 1972). This decline in recreational fishery catches, however, did not mirror catches in the Belleisle Bay winter commercial fishery that *"while experiencing a decline from the previous year, was still reasonably good."* (Figure 6; Meth 1972). This comparison suggested that the two fisheries may be supported by separate populations or groups of Striped Bass in the river (Dadswell 1976), though the Belleisle Bay fishery declined steeply in the following year and crashed soon after (Figure 6; Table A.1).

Little to no regulations for Striped Bass angling or retention were present prior to 1990 (Jessop 1990). A management strategy implemented in 1994 limited angler retention to a single Striped Bass per person per day with the season extending from May 1 to October 15 in inland waters. A minimum retention size of ≥38 cm was imposed in this first year (1994) with the minimum size transitioning to ≥68 cm by 1996 (Bradford et al. 2012). A Striped Bass of this size would be age 6-8 years (Williamson 1974; Dadswell 1976) and would have had at least 2 opportunities to spawn if female and 3-4 spawning opportunities if male (Williamson 1974).

Initally, a season occuring from July 1 - October 30 had been proposed for the SJR in 1992 with catch and release angling of Striped Bass being implemented for the first five years (DFO 1992), but this proposal was never enacted. Retentions are currently open year round in tidal areas including almost all waters of the SJR from Reversing Falls, upstream, to the Hartts Island campground 5km upstream of the City of Fredericton (Figure 2, 4; Bradford et al. 2012), and the minimun retention size is the same as in inland waters (>68 cm).

Overall, the recreational fishery for Striped Bass in the SJR is very poorly understood (Meth 1972; Duston et al. 2009; Duston 2010; Forsythe 2010). In a three-year creel-survey conducted from 2007 - 2009, only one angler reported SJR Striped Bass catch data severely limiting any possible conclusions on the fishery (Duston et al. 2009; Duston 2010; Forsythe 2010). There are currently no management plans for the recreational fishery for Striped Bass beyond the season and minimum size regulations. By definition, Striped Bass is not considered to be a sport fish in New Brunswick or other Canadian maritime provinces.

Early Life History in Saint John River

Spawning

Early documentation suggests the SJR Striped Bass were spawning in the spring in fresh water portions of the river (Perley 1852; Cox 1893; Bayne 1930; Rogers 1936) or at the head of the estuary (Meth 1973). No reports provide specific coordinates, leaving a significant number of possible spawning locations suspect as suggested by Dadswell (1976). Some early accounts provide clues suggesting that areas around the islands near the City of Fredericton (Figure 4) were a "*favorite resort*" (Adams 1873) and "*pools at the head of tide*" (Meth 1972), specifically, the Hartt's Island pool located 5km upstream from the City of Fredericton (Figure 4; O'Donnell 1963; Hooper 1967; Williamson 1974) may have been a spawning location. Unfortunately, no eggs or larvae were, or have ever been collected in the vicinity of these locations and thus, confirmation of successful spawning and reproduction at these locations has not occurred.

Literature regarding presumed spawning in the vicinity of Mactaquac Dam unanimously concludes that all spawning ceased in 1968, coincident with the completion of the MGS (Meth 1972; Jessop 1990; 1991; 1995; Wirgin et al. 1995; Douglas et al. 2003; COSEWIC 2004; 2012;

Robinson and Courtenay 2006; Forsythe 2010; Bradford et al. 2001; 2012; 2014; DFO 2011; 2014). Multiple hypotheses can be derived to try to explain possible effects of the dam, e.g., altered temperature and flows regimes, including potential effects induced by hydropeaking operation of the MGS, (e.g., Setzler et al. 1980; Rulifson and Manooch 1990), but no study has ever addressed the apparent loss of spawning at this location. While the evidence seems to point to the existence of some cause-effect relationship between the construction of the MGS and the disappearance of spawning, it is important to note that spawning seems to have also ceased in other, non-dam affected localities within the SJR in a similar time frame, (e.g., Dadswell 1975). Evidence therefore suggests some other, more widespread phenomenon may have also affected spawning success of Striped Bass in the SJR in the late 60's and early 70's.

It remains probable that the reach downstream of the MGS was used for spawning by Striped Bass, but the only evidence of gravid Striped Bass are incidental reports during spring electrofishing surveys (Curry unpublished data), anecdotal evidence from local anglers, and the recent capture of two ripe males at the MGS fish lift (9 and 23 June, 2016: S. Andrews unpublished data). It may be the case that spawning was and could still be occurring in many smaller tributaries of the SJR (Dadswell 1976) including those of Belleisle Bay and Grand Lake (Figure 2) as suggested by local knowledge (Melvin 1978; Cunjak et al. 2011; DFO 2014; Bradford et al. 2014). Additionally, large gravid Striped Bass have been caught in Washademoak Lake, Belleisle Bay and Kennebecasis Bay (Williamson 1974) as well as Grand Lake where a large egg bearing female was observed (28 May, 2015: S. Andrews unpublished data), (Figure 2). The first documented report of gravid Striped Bass in the SJR came from Belleisle Creek in May 1972 (Dadswell 1976), and two years later, 40 male and 40 female Striped Bass with running milt and eggs were captured in gill nets in May in the same location (Dadswell 1976; Table 2).

Surveys of Eggs and Larvae

In 1975, > 1800 Striped Bass eggs were collected from Belleisle Creek between May 12 and 19 (Figure 2; Table 2; Dadswell 1976). Spawning was initiated when water temperatures reached 11.5 °C with peak egg production (661 eggs / 24hours) occurring at 14.5 °C (May 15th) (Dadswell 1976). This is the only true confirmation of spawning of Striped Bass in the SJR, i.e., release of gametes that drifted freely. A reference to spawning in 1979 as alluded to in various reports (Douglas et al. 2003; COSEWIC 2004; 2012 Cunjak et al. 2011; Wallace 2012; Bradford et

al. 2001; 2012; 2014; DFO 2015) is incorrect. These reports reference a letter (Dadswell 1982) that clearly states "*There also appears to have been a first year-class in many years produced in the Saint John about this time. We captured 1-yr-old bass there in 1979 for the first time since 1968*", but the letter, as confirmed by the author (M. J. Dadswell) makes no reference to the collection of eggs, or larvae, nor does it suggest Belleisle Bay as a possible location for such a collection. The reported juveniles cannot be confirmed as SJR origin as they could be migrants from other rivers (see also DFO 2014).

Since 1975, intermittent surveys for Striped Bass spawning and eggs/larvae have been inconclusive (Table 2; Ingraham and Burnley (date unknown); Jessop 1995). Accordingly, such results have since prompted the status downgrade of the species to "threatened" in the Bay of Fundy Designatable Unit (COSEWIC 2004) and more recently to "endangered" (COSEWIC 2012). It should be noted, however that absence of evidence is not evidence of absence, and the seeming loss of a native SJR Striped Bass population may only stem from the lack of any effective search for the eggs; (i.e., Ingram and Burnley (date unknown); Jessop 1995) or larvae of the species since the late 1970s; (i.e., Dadswell 1976; Dadswell 1982; Jessop 1995). Recent efforts have conducted only sparse sampling over selected locations and have consistently missed critical spawning times; (i.e., Table 2; Ingram and Burnley (date unknown); DFO 2014; Bradford et al. 2014; Jessop 1995).

Juvenile Surveys

Only three accounts exist that document the occurrence of juvenile Striped Bass in the SJR. Hooper (1967) documents a single, age 1 Striped Bass collected in a commercial Gaspereau net (location unknown). Dadswell (1982) mentioned the capture of some number of age 1 Striped Bass in 1979. DFO (2014; 2015) both mention that age 1 and 2 Striped Bass have been "*detected*", which appears to be a reference to COSEWIC (2012) where the capture of "*14 juveniles, 1-2 years of age*" is reported in 2008 possibly referring an unpublished follow up study to Bentzen and Paterson (2008); these juveniles were determined to be of Shubenacadie River origin (Table 3). Dadswell (1976) indicates that commercial fishermen recalled catching age 1-2 Striped Bass regularly until 1969 within the SJR (location unknown).

Numerous other studies have tried and failed to locate juvenile Striped Bass within the SJR (Table. 3; Ingram and Burnley (date unknown); Dadswell 1976; Jessop 1995; DFO 2007; 2009).

All unsuccessful studies employed beach seining methods in various locations and various times (Table 3). A failure to capture juveniles in these haphazard sampling events is not scientific evidence that they are not present in the SJR. Most recently, commercial fishermen operating within the SJR (i.e., Grand Lake and Kennebecasis) have noticed large numbers of juvenile Striped Bass (FL range 12-30 cm) in their nets beginning in 2013.

Adult Life History in the Saint John River

Mark-recapture Studies

While recruitment remains uncertain, adult Striped Bass are still relatively common in the SJR (Douglas et al. 2003). The abundance of adult Striped Bass suggests one or more alternative river stocks are immigrating to the SJR (Dadswell 1976). Mark-recapture studies from 1964-73 (Table 4) identified fish in the SJR travelling or returning to areas throughout the Atlantic seaboard ranging from the Blackstone River, Rhode Island, Maryland, New Jersey, Delaware and Massachusetts (O'Donnell 1967; Williamson 1974; Dadswell 1976; Scott and Scott 1988), the origin of these individuals, however, is unknown. The persistence of a SJR stock was suggested by Striped Bass being both tagged and recaptured within the SJR, predominantly in Belleisle Bay during the winter commercial fishery, i.e., the existence of an overwintering and thus possible resident population (Moss 1971; Williamson 1974; Dadswell 1976).

Collectively these previous mark-recapture studies marked 952 Striped Bass within the river (Table 4). There have been 39 local in-river recaptures and seven fish recaptured from various locations along the Atlantic seaboard of the United States (Table 4). One tagging study conducted by Boone (personal communication. in Rulifson and Dadswell 1995) marked 1,375 Striped Bass in the United States, one of which that was tagged in the Nanticoke River in Maryland was re-captured at Reversing Falls at the mouth of the SJR in 1976 after 1,279 days at large.

Historical re-capture data (pre-1976) suggests that two distinct migratory trends may exist: 1) a native population, overwintering within the river, and 2) a transient contingent that leaves the river in the fall or sometimes overwinters (Dadswell 1976; Dadswell et al. 1984). Striped Bass tagged in the river in summer have been recaptured in Belleisle Bay during the

winter in the commercial fishery (8-19%; Table 4). Furthermore, Striped Bass tagged after capture in the winter commercial fishery have been recaptured near Reversing Falls in the SJR in the summer. These results suggest the presence of a population that spends the warmer months of the year feeding in the estuary and retreating to overwinter in Belleisle Bay or other deep stretches of the river (Dadswell 1976). This tactic would be predicted for a native SJR population.

Recapture data also suggests the presence of United States origin fish within the river (O'Donnell 1967; Moss 1971; Williamson 1974; Dadswell 1976; Dadswell et al. 1984; Rulifson and Dadswell 1995). This movement data suggests that individuals from some southern populations migrate North arriving in the SJR in early spring, most likely following the runs of Gaspereau, and then return to their natal river for overwintering. This also suggests that non-native Striped Bass in the SJR either spawn with native Striped Bass and/or skip reproduction in some years. Rulifson et al (2008) tagged nearly 2,000 Striped Bass in the Cobequid and Minas Basins of the Inner Bay of Fundy, Nova Scotia and none were recovered in the SJR. One recently tagged fish in the SJR did travel to the Minas Basin (S. Andrews unpublished data), though it may have originally been of Shubenacadie River origin. Despite the compilation of recaptures, the marine migration patterns of the true SJR origin Striped Bass remains uncertain including if such a migration actually occurs.

Tracking Studies

The most recent (still ongoing) and the only comprehensive tracking study to date also supports the native and non-native hypotheses (Wallace 2012; AMEC 2011 and 2012; S. Andrews unpublished data). Acoustic tracking data of 40 Striped Bass (27 tagged by Wallace 2012, 13 tagged by S. Andrews unpublished data) observed multiple fish making upstream movements towards the MGS in the spring. Only two fish were confirmed to leave the river during the spawning period, and of these, one was detected in the vicinity of the Shubenacadie River in Nova Scotia before promptly returning to the SJR (S. Andrews unpublished data).

Genetic Population Structuring

Two genetic studies have been conducted on Striped Bass within the SJR (Wirgin et al. 1995; Bentzen and Paterson 2008). Wirgin et al. (1995) examined the genetic structure of 128

Striped Bass caught in the SJR from 1992 to 1993. The majority (N=97) were captured at MGS (N=47 in 1992 and N=50 in 1993) and the remaining samples came from Reversing Falls in 1993 (N=35). It was concluded that 63 % and 97 % of Striped Bass in 1992 and 1993, respectively, were of United States origin while the remainder were most probably from the Shubenacadie River in Nova Scotia; no fish suspected to be native to the SJR were identified (Wirgin et al. 1995).

In a more recent study, Bentzen and Paterson (2008) collected samples from 720 Striped Bass in the vicinity of the MGS (N=447, from the DFO operated fish lift at the MGS in 1999-2006; N=273 collected by Kings Clear First Nation fishers from the tailrace of MGS in 2006). Over all sampling years, 11.9 - 61.0 % of Striped Bass sampled in the SJR were determined to have originated from the US and Shubenacadie populations, respectively. Interestingly, 22.8 % (range 9 % - 85 % over sampling years 1999-2006) of the samples pointed to an "*unknown population*" that did not match any major reference population (Kennebec, Hudson, Chesapeake and Shubenacadie Rivers) and were inferred to be native SJR fish (Bentzen and Paterson 2008). However, this "*unknown population*" had "*genetic characteristic(s) that has not yet been identified from elsewhere*" and therefore may have been a mixture of untested, US origin genotypes (DFO 2011). The unknown group is unlikely from the Gulf of St. Lawrence population, which appears genetically isolated (Robinson and Courtenay 1999). Based on the work of Bentzen and Patterson (2008), it is apparent that three populations intermingle within the river: US origin, Shubenacadie River, and a currently unknown, though possibly native group (DFO 2006).

Subsequent to these studies, another 90 Striped Bass appear to have been genotyped (See DFO 2011; 2015 and Bradford et al. 2012 referencing 810 Striped Bass genotyped from 1999-2008, possibly including juveniles), but these data, in addition to the 720 Striped Bass genotyped by Bentzen and Paterson (2008) are unpublished. This unreported follow up study only further confounds what is known about SJR Striped Bass and their origins, however, this documentation is not alone in its opacity. Cairns (1999) mentions the capture and artificial propagation of adult Striped Bass of presumed SJR origin at the Huntsman Biological Station in Saint Andrews NB, in the mid-1990s. Eggs from this brood stock were said to have been later transferred to the Nova Scotia Agricultural College in 1998, however, no genetic study exists proving the true population affinity of the adult Striped Bass taken for brood stock, or if this lineage is still maintained.

The existing genetic analyses are based on fish sampled either at the MGS or the river mouth at Reversing Falls (Figure 2; Wirgin et al. 1995; Bentzen and Patterson 2008) and both studies reported a mixed Striped Bass population with a very high proportion of migrants. These two chosen sampling locations are most likely bottlenecks for migrating Striped Bass in the river and they do not represent the complete and wide ranging variety of habitats for Striped Bass in the SJR system. Mark-recapture studies and local knowledge suggest that areas like the Hammond River and Grand Lake (Figure 2) could support resident populations (Dadswell 1976; Raney 1952). Therefore, studies of these reaches and sampling of multiple age classes including juveniles accounting for temporal variation in habitat use are warranted (see for example, Dadswell 1976; Dadswell 1983; Douglas et al. 2003).

Effects of Pollution

Several reports have hypothesized that chemicals such as DDT, PCBs, heavy metals, and other industrial pollutants have adversely impacted the SJR Striped Bass (Smith 1969; Dadswell 1975; Dadswell 1976; Jessop 1990). DDT was applied heavily across forests (0.11-0.23 kg/acre over 0.2-5.2 million acres) in NB from 1952-1968 for spruce budworm control (Yule and Tomlin 1971; Miller and Kettela 1975), peak application occurred from 1957-1961 (Miller and Kettela 1975). Striped Bass sampled from Belleisle Bay had average DDT concentrations of 0.44 ppm and 3.6 ppm in muscle and gonads, respectively, with one gonad sample of 8.1 ppm DDT (Dadswell 1975). Methyl Mercury concentrations averaged 2.13 ppm with a maximum 3.16 ppm (Dadswell 1975). DDT was suggested as being linked to spawning failures observed in 1975 when 95.4 % of SJR Striped Bass eggs were observed to have ruptured chorionic membranes (Dadswell 1975; 1976). As a result of these chemical effects on spawning it has been hypothesized that Striped Bass within the SJR could be faced with "*Biochemical Extinction*" (Dadswell 1975).

Higher DDT concentrations have been reported in Striped Bass (9.93 ppm in flesh and 9.72 ppm in ova) without causing reproductive failure (Hunt and Linn 1970). The true impact of DDT on Striped Bass use in the Province of New Brunswick remains unknown.

Conclusion

Knowledge Gaps, Future Research and Management Needs

Collectively, the reports to date (including both tagging and genetic studies) support a hypothesis that three populations of distinct origin make up the SJR Striped Bass Striped Bass assemblage. One group of Striped Bass migrate from the rivers of the United States for feeding, concentrating in areas such as Reversing Falls and below the MGS. These individuals may leave in the fall to return to their natal rivers, or overwinter within the SJR prior to leaving in the spring. A second group migrates to SJR from the Shubenacadie River, Nova Scotia. It is not clear from preliminary reports when these fish arrive or how long they remain in the SJR. A third native resident group once existed; however, their current persistence is now in question.

An extensive Striped Bass acoustic tracking study is currently being undertaken within the SJR (S. Andrews unpublished data); a small number of these tagged individuals reside within the river over the entire year except for the spawning period (late May/early June), when they quickly migrate to the Shubenacadie River, promptly return to the SJR, and they have repeated this migration over several seasons. The vast majority of acoustic tagged fish appear to remain in the river year round over multiple, consecutive years. These individuals never leave the river and move upstream to various areas during the spring spawning period. It remains unknown if these multi-year residents are native in origin or if they are US or Nova Scotia origin fish that have colonized and may now be spawning and/or hybridizing in the river.

It is uncertain if Striped Bass are reproducing successfully in the SJR, although juveniles were captured in 2014 to 2016 (N= 77: S. Andrews unpublished data). Acoustically tagged juveniles have so far remained within the river during the first year of tracking, suggesting that areas within the SJR serve as nursery areas for Striped Bass.

Despite a long, though inconsistent record of studies, the Striped Bass of the SJR remains poorly understood. The increasing collection of studies starting in the 1970s began with directed observation that improved our understanding of this complex population, but recent studies and technical reports are principally recitations of old documents, often reporting exaggerated and inaccurate information. Curiously, this lack of understanding is not reflected in the COSEWIC reports that have, in actuality, been assessing the SJR Striped Bass population of the mid 1980s

due to a lack of recent original studies (see COSEWIC 2004; 2012). There are reasons to consider a special status for the population, e.g., poor understanding of the ecology, uncertain reproductive success and no comprehensive studies in over three decades, but no indication of this need is given anywhere in published COSEWIC reports, nor does this lack of information seem to be a concern, at any point, in these documents.

Future Steps

Ten key areas must be urgently addressed:

1) Population Size and Structure: The most pressing need is a determination of the population size, abundance, and structure, e.g., mixed/uniform stock, size, age, and sex.
2) Juvenile Ecology: There is no information on juvenile Striped Bass in the SJR, especially in their first 2 years (Melvin 1991). Where these juveniles occur, seasonality, feeding, nursery areas, abundance, origin, movements, overwintering areas, and survival all remains unknown.
3) Recreational Fisheries: There is no information on the number of Striped Bass harvested by recreational anglers within the SJR, or what sizes or age classes of fish are most often taken. In addition, there are no records of commercial bycatch or catches by Aboriginal fisheries or how a combination of these fisheries, is currently affecting the population (which is of unknown size).
4) Reproductive Success: The last confirmed spawning event (although unsuccessful) was reported in Belleisle Creek in 1975. Even though several studies have since attempted to confirm reproduction of Striped Bass within the SJR, these surveys occurred long after the Striped Bass spawning period and cannot be considered evidence of a lack, or failure of spawning. Current spawning by Striped Bass must be carefully assessed.
5) Habitats: There is no information of critical habitat for any SJR Striped Bass life stage, even though impact to habitat is often invoked as the overarching issue facing SJR Striped Bass. We have yet to determine if all, some, or what mixture of Striped Bass (both juvenile and adult) use various habitats. In particular, winter residence is documented historically but habitats including movements and overwintering locations have not been studied.
6) Marine Movements: The direction, timing and magnitude of marine movements of SJR Striped Bass are mostly unknown. Such information will help distinguish between

contingents, varying life history strategies, and possibly reveal density-dependent tends associated with migration patterns. (8)

7) Genetic Structure: The existing studies of the genetic structure of the SJR Striped Bass population remain highly equivocal (Wirgin et al. 1995; Bentzen and Paterson 2008). This is in part due to the restricted sampling of Striped Bass in these studies, and therefore, broader and more conclusive sampling of age class structure throughout the river at various locations and times of the year is required. Pre-migratory juveniles/larvae would provide the most credible genetic baseline, however, it remains possible that current spawners may include emigrants from elsewhere.
8) Feeding and Species Interaction: No information is available on the diet or seasonal feeding habits of Striped Bass within the SJR. Nothing is known about how Striped Bass may be impacting other fish species or how the SJR's various commercial fisheries; (i.e., American Shad, Gaspereau) may be impacting Striped Bass.
9) Other Potential Stressors: The effect of pollutants (DDT, heavy metals, PCBs, mercury) on Striped Bass egg and larvae survival as well as information on bioaccumulation in adults must be updated (Dadswell 1975, Jessop 1990).
10) Mactaquac Dam: Much speculation exists surrounding the impact that the construction of the Mactaquac Dam had on Striped Bass spawning after its completion in 1968. It is unknown how these impacts would change or if they could be reversed if the Mactaquac Dam is reconstructed or removed. It is also unknown if the Mactaquac Head pond could support a landlocked population of Striped Bass should the Mactaquac Dam be left in place.

Until more rigorous studies establish the true population status, origins, movements, threats and concrete recovery strategies for Striped Bass in the SJR, fisheries managers will continue blindly into the future of a species whose ecology and population dynamics, both past and present, they barely understand.

Striped Bass Fisheries of Reservoirs

Introduction

The existence of localized Striped Bass populations introduced to reservoirs has been documented over time in many different areas throughout central United States.. This is primarily due the ability of the Striped Bass to complete its entire life cycle in freshwater (Scruggs, 1957). Striped Bass populations can thrive in freshwater reservoirs; however, there are very few reservoirs that can sustain naturally reproducing populations (Baker, Boxrucker, & Kuklinski, 2009). There are numerous benefits, concerns, and considerations that have been identified by the stakeholders and members of the public, which have been further researched over time. Examples include the economic gain of a successful Striped Bass fishery on the local and regional economy, the effect on local/native species of fish in a reservoir after it becomes stocked with Striped Bass, and whether or not bass populations can remain stable in reservoirs over time.

Maintaining and Managing Striped Bass in Reservoirs

Striped bass are able to thrive in reservoirs for numerous reasons, including their aforementioned ability to live their lives entirely in fresh water, as well as their occupation of potentially empty niches. When living in reservoirs, Striped Bass are pelagic predators and open water inhabitants, and tend to prey largely upon clupeids, e.g., the Gizzard Shad (*Dorosoma cepedianum*). Striped Bass are typically very selective regarding prey and often only prey on the shad species with reports that Striped Bass populations will starve to death after depleting the shad populations even though other potential forage is persists(Van Horn, 2012).

The main challenge in maintaining populations of Striped Bass in reservoirs over time relates to their spawning habits. Striped bass require extended stretches of free flowing rivers for spawning and because of this, it is highly unlikely they can reproduce in reservoirs without connecting rivers. Consequently, it is uncommon for Striped Bass populations to be maintained in reservoirs without the assistance of stocking (Baker et al. 2009). Numerous management

strategies exist in North America that focus on stocking Striped Bass in reservoirs, which have found that stocking adults does not tend to work, while stocking many fingerlings does (Van Horn, 2012). It is noteworthy that, while the need for human interference may cost money and be inconvenient, it does give a large degree of control over the Striped Bass population (Raborn, Miranda, & Driscoll, 2002). If Striped Bass populations in reservoirs need stocking to be maintained, it is unlikely that the population would grow out of control.

Striped Bass Fisheries

Reservoirs that have seen the maintenance of viable populations of Striped Bass have in turn provided a new fishery to anglers in some areas come to demand for sustaining the Striped Bass fishery (Baker et al. 2009). A successful Striped Bass fishery can provide many millions of dollars to regional economies, e.g., In reservoirs of the southeastern United States, the stocking of Striped Bass facilitates successful and profitable pelagic sport fisheries (Sutton, Rose, & Ney, 2000).

Ecosystem Scale Concerns

Various stakeholders and researchers have voiced concerns regarding Striped Bass as a predator of or competitor with other valued recreational species in reservoirs, e.g., largemouth bass, white bass, black bass, walleye, crappie and shad. Van Horn (2012) examined stomach contents and observed very few incidences of these piscivorous species in the diet of striped Bass. Raborn et al. (2002) created models that projected the impact on the fish community from a total removal of Striped Bass from a reservoir in the southeastern United States. They reported no measurable increase in the biomass of sport and other prey fish species. In one example, the intensive stocking of Striped Bass in the Lake Osborne, Florida did not have any significant impact on gizzard shad, which were the main prey species of the Striped Bass (Morello, 1984).

Conclusion

There are numerous occurrences of successful Striped Bass fisheries that exist in reservoirs in North America. The Striped Bass is able live its full life in freshwater and often times occupies a relatively empty niche of pelagic predators in such reservoirs. Striped bass fisheries in most cases must be assisted by via the continual stocking of fingerlings, as Striped Bass spawn in long flowing stretches of rivers instead of reservoirs. Successful Striped Bass fisheries are credited with provided millions, if not billions, of dollars to regional economies. Concerns regarding potential harm to other fish species through excessive competition or predation from Striped Bass have are currently deemed to be unlikely.

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Tables

TABLE 1. Captures of Striped Bass at the Mactaquac Dam fish lift since its construction in 1968 until 1999 as accounted by eight sources. Grey bands indicate years in which large discrepancies are present between records of the exact same counts. Differences in 1980-1981 between Ingram 1985, Hooper 1991 and Douglas et al. 2003 may be due to author typos.

Year	Meth (1972)	Williamson (1974)	Smith (1979)	Ingram (1980)	Ingram (1985)	Jessop (1990)	Hooper (1991)	Douglas (2003)
1968	872	855	872+			800	872	873
1969	142	99	52+250				307	367
1970	127	133	127				127	130
1971	13	26	13				13	13
1972		67					5	5
1973		11					49	54
1974				5			0	0
1975				49			17	166
1976				0			0	0
1977				17	0		0	0
1978				0	54		54	74
1979					16	<25	16	19
1980					6	<25	6	187
1981					187		187	6
1982					141		141	146
1983							22	22
1984							12	14
1985						<25	32	32
1986							15	12
1987							80	79
1988							20	17
1989							29	30
1990							26	27
1991								253
1992								29
1993								108
1994								14
1995								49
1996								151
1997								450
1998								715
1999								217
2000								142
2001								44
2002								227

TABLE 2. Successful and unsuccessful surveys of Striped Bass eggs and spawning conducted within the Saint John River. Four successful surveys were conducted 1972- 1975 during, which gravid adults or spawned Striped Bass eggs were collected. Three unsuccessful surveys were conducted from 1992-1994 throughout the Saint John River during, which no gravid Striped Bass or eggs were captured.

	Year	Sampling period	Findings	Sampling details and gear	Location(s)	Reference
Successful surveys	1972	May	Striped Bass spawning run successfully intercepted	Gill net	Belleisle Creek	Dadswell (1976)
	1974	May	Striped Bass spawning run successfully intercepted, 40 Striped Bass of both sexes captured that were ripe and ready to spawn	Gill net	Belleisle Creek	"
	1975	May	Striped Bass spawning run successfully intercepted	Gill net	Belleisle Creek	"
	1975	May 13-May 19	1800 Striped Bass eggs caught in plankton nets, spawning confirmed	Plankton nets set and checked daily	Belleisle Creek	"
Unsuccessful surveys	1992	Late June	No Striped Bass eggs were collected	Tows and sets of a 1m diameter plankton net	Kennebecasis and Hammond tributaries	Jessop (1995)
	1973	Last 2 weeks of May	No evidence of spawning found	plankton nets set, unable to check them frequently enough	Belleisle Creek	(M. J. Dadswell)
	1994	June 6- June 25	No Striped Bass eggs were collected	Bi-daily, 15 minute tows of a 1m diameter plankton net, mesh size 1mm at sampling locations. A plankton net was also set in Belleisle Creek and checked every 48 hours	Fredericton Area, Hammond, Kennebecasis, Belleisle Creek, lower section of the Canaan River	Ingram and Burnley (date unknown), Jessop (1995)

TABLE 3. Successful and unsuccessful surveys of Juvenile Striped Bass conducted within the Saint John River. Three successful surveys were conducted in 1967, 1982 and 2014 during, which at least one juvenile was captured. Five unsuccessful beach seine surveys were conducted from 1974-2001 throughout the Saint John River during, which no juveniles were captured.

	Year	Sampling period	Findings	Sampling details and gear	Location(s)	Reference
Successful surveys	1967	May-June	A single 1 year old Striped Bass was captured	Commercial Gaspereau Nets	Lower Saint John River	Hooper (1967)
	1979	Unknown	(Unknown number) of 1 year old Striped Bass captured	Unknown	Unknown	Dadswell (1982)
	2008	Unknown	14 juveniles age 1 and 2 determined to be of Shubenacadie River origin	Unknown	Lower Saint John River	Bentzen and Paterson (2008) COSEWIC (2012) DFO (2014; 2015)
Unsuccessful surveys	1974	August and September	No juvenile Striped Bass were collected	Beach seining survey (sein, 16m long, 1m deep, 1.3cm mesh), occasional electrofishing	Unknown	Williamson (1974)
	1992	Late August	No juvenile Striped Bass were collected	Beach seining survey	Upper Kennebecasis (5 sites) and known spawning sites in Belleisle Bay (6 sites)	Jessop (1995)
	1994	July 27- August 19	No Juvenile Striped Bass were captured	Weekly Beach seining survey, 50m beach sein 1/4-inch mesh	Oak point, Grand lake, Salmon River, Fredericton area, Hammond River, Kennebecasis, Belleisle Creek, Lower region of Canaan River.	Ingram and Burnley (date unknown) Jessop (1995)
	2000	Summer	No juvenile Striped Bass were captured	Beach seining survey	Throughout the Saint John River	DFO (2007; 2009)
	2001	Summer	No juvenile Striped Bass were captured	Beach seining survey	Throughout the Saint John River	DFO (2007; 2009)

TABLE 4. Summary of six mark-recapture studies totaling 952 tagged fish marked within the Saint John River and recaptures of those tagged fish both within and outside of the Saint John River. One tagging study conducted in the United States is also included as one of the marked fish was recaptured in the SJR in 1976.

Tagging site	N	Release date	Recaptures	Recapture site	Recapture date	Days at large	Distance travelled	Reference
Tagged and Re-captured in the Saint John River								
Saint in John River (lower)	100	Summer 1968	8	Belleisle Bay	January-March 1969	< 1 year		Moss (1970)
Grand Bay Westfield	26	Sept. 21, 1971	1	Belleisle Bay	January 31, 1972	133	20 miles	Williamson (1974)
"		Sept. 29, 1971	1	Belleisle Bay	February 3, 1972	128	20 miles	"
"		Sept. 30, 1971	1	Belleisle Bay	January 17, 1972	109	20 miles	"
"		Sept. 17, 1972	1	Belleisle Bay	December 29, 1972	83	20 miles	"
"		Oct. 3, 1972	1	Belleisle Bay	January 20, 1973	109	20 miles	"
Darlings Lake	70	Spring	3	Hammond River area	Summer			Dadswell (1976) Melvin (1976)
Belleisle Bay		May 1, 1975	3	Reversing Falls	Summer			"
Reversing Falls		August	6	Belleisle Bay	Winter			"
Mactaquac Dam	189	1999	2	Mactaquac Dam	1999			Douglas (2003)
Mactaquac Dam	137	2000	7[a]	Mactaquac Dam	2000			"
Mactaquac Dam	44	2001	3[a]	Mactaquac Dam	2001			"
Mactaquac Dam	225	2002	2[a]	Mactaquac Dam	2002			"
Swan Creek, Grand lake, Otanabog	51	2010-2011	None	NA	NA			Wallace (2012)
Tagged in the Saint John River and Re-captured in the United States								
Saint John River	110	1964	1	Massachusetts				O'Donnell (1967)
"		"	1	New Jersey				"
"		"	1	Delaware				"
"		"	1	Maryland				"
Darlings Lake		June 5, 1969	1	Montauk, NY	November 19, 1969	167	500 miles	Moss (1970)
Westfield		Sept. 12, 1972	1	Blackstone River, RI	October 23, 1972	36	500 miles	Williamson (1974)
Reversing Falls		August 7, 1973	1	Southampton, NY	November 1973	90	600 miles	Dadswell (1976)
Tagged in the United States and Re-captured in the Saint John River								
Nanticoke River Maryland	1,375	April 14, 1973	1	Reversing Falls NB	October 25, 1976	1,279		J. Boone in (Rulifson and Dadswell 1975)

[a] Recaptures from previous year of tagging

Appendix

TABLE A.1. Annual landings (kg) of Striped Bass by county captured in the Saint John River commercial fisheries both as marketable by-catch before (pre-1930) and by-catch/targeted catch (post-1930) after the opening of the directed winter commercial fishery in Belleisle Bay (Kings County) until its closure in 1978. Catches incurred in Queens County (post-1930) would have been taken as by-catch, those reported for Kings County would have been predominately targeted captures. After the fishery closure Striped Bass were still harvested as by-catch in other fisheries until 1996; data on retained commercial by-catch (1978-96) is unavailable.

Year	Carleton	York	Sunbury	Queens	Kings	Saint John	Total	Source
1871	0	0	0	0	0	816.47	816.47	DMF 1871
1872	544.31	2267.96	362.87			979.77	4154.91	DMF 1872
1873	5170.95	226.80	19504.46			680.39	25582.59	DMF 1873
1874	3567.05	3855.53	2308.78			1360.79	11092.15	DMF 1874
1875	0	247.66	1247.38			1814.38	3309.42	DMF 1875
1876	317.51	544.31	1678.29		1814.37	13607.85	17962.33	DMF 1876
1877	0	0	997.90		3628.74	12700.66	17327.30	DMF 1877
1878	0	0	6486.37		1410.67	13607.85	21504.89	DMF 1878
1879	136.08	0	3175.14		1093.16	9071.90	13476.28	DMF 1879
1880	0	204.12	9979.02	907.18	1161.20	2267.98	14519.49	DMF 1880
1881	0	0	4581.28	4173.05	635.03	2721.57	12110.92	DMF 1881
1882	0	0	18597.27	181.44	1564.89	1360.79	21704.39	DMF 1882
1883	0	2721.55	4490.56	272.16	3406.48	907.19	11797.93	DMF 1883
1884	0	907.18	3855.53	680.39	2267.96	453.60	8164.66	DMF 1884
1885	0	2267.96	3855.53	0	1338.10	1814.38	9275.97	DMF 1885
1886	0	2177.24	3855.53	136.08	1133.98	1814.38	9117.21	DMF 1886
1887	0	2326.93	12836.65	181.44	1241.03	2267.98	18854.02	DMF 1887
1888	0	453.59	6395.65	635.03	45359.20	1814.38	54657.85	DMF 1888
1889	0	907.18	4490.56	1043.26	22861.04	1360.79	30662.83	DMF 1889
1890	0	1814.37	272.16	1088.62	31751.44	0	34926.58	DMF 1890
1891	0	0	0	453.59	6390.66	0	6844.25	DMF 1891
1892	Fishery Closed May 1st							DMF 1892 (No Data)
1893	Fishery Closed							DMF 1893 (1892-1893)
1894	Fishery Closed							DMF 1894
1895	Fishery re-opened in winter 1895 - catches reported in 1896							DMF 1895
1896	0	0	0	0	755.23	0	755.23	DMF 1896
1897	0	0	0	0	1133.98	0	1133.98	DMF 1897
1898	0	0	0	0	1360.78	0	1360.78	DMF 1898
1899	0	0	0	0	4535.92	0	4535.92	DMF 1899
1900	0	0	0	0	4082.33	0	4082.33	DMF 1900
1901	0	0	0	0	3628.74	0	3628.74	DMF 1901
1902	0	0	0	0	2267.96	0	2267.96	DMF 1902
1903	0	0	0	0	226.80	0	226.80	DMF 1903

Year	Carleton	York	Sunbury	Queens	Kings	Saint John	Total	Source
1904	0	0	0	0	113.40	0	113.40	DMF 1904
1905	0	0	0	0	113.40	0	113.40	DMF 1905
1906	0	0	0	0	90.72	0	90.72	DMF 1906
1907	0	0	0	0	907.18	0	907.18	DMF 1907
1908	0	0	0	0	2267.96	0	2267.96	DMF 1908
1909	0	0	0	0	45.36	0	45.36	DMF 1909
1910	0	136.08	0	0	0	0	136.08	DMF 1910
1911	0	181.44	0	90.72	0	0	272.16	DMF 1911
1912	0	181.44	0	45.36	907.18	0	1133.98	DMF 1912
1913	0	181.44	0	680.39	6350.29	0	7212.11	DMF 1913
1914	0	589.67	0	226.80	2086.52	0	2902.99	DMF 1914
1915	0	453.59	0	272.16	1133.98	0	1859.73	DMF 1915
1916	0	453.59	0	272.16	1587.57	0	2313.32	DMF 1916
1917	0	226.80	0	680.39	816.47	0	1723.65	DMF 1917
1918	0	226.80	0	362.87	226.80	0	816.47	DFSC 1918
1919	0	226.80	0	362.87	136.08	0	725.75	DFSC 1919
1920	0	0	0	226.80	0	0	226.80	DFSC 1920
1921	0	0	0	226.80	90.72	0	317.51	DFSC 1921
1922	0	0	0	181.44	90.72	0	272.16	DFSC 1922
1923	0	0	0	680.39	90.72	0	771.11	DFSC 1923
1924	0	0	0	544.31	226.80	0	771.11	DFSC 1924
1925	0	0	0	226.80	90.72	0	317.51	DFSC 1925
1926	0	0	0	0	9616.15	0	9616.15	DFSC 1926
1927	0	0	0	0	544.31	0	544.31	DFSC 1927
1928	0	0	0	90.72	408.23	0	498.95	DFSC 1928
1929	0	0	0	90.72	272.16	0	362.87	DFSC 1929
1930	0	0	0	90.72	226.80	0	317.51	DFSC 1930
1931	0	0	0	635.03	1678.29	0	2313.32	DFSC 1931
1932	0	0	0	1360.78	2494.76	0	3855.53	DFSC 1932
1933	0	0	0	816.47	498.95	0	1315.42	DFSC 1933
1934	0	0	0	1133.98	40823.28	0	41957.26	DFSC 1934
1935	0	0	0	680.39	3628.74	0	4309.12	DFSC 1935
1936	0	0	0	181.44	1360.78	0	1542.21	DFSC 1936
1937	0	0	0	907.18	2721.55	0	3628.74	DFSC 1937
1938	0	0	0	45.36	3583.38	0	3628.74	DFSC 1938
1939	0	0	0	226.80	2358.68	0	2585.47	DFSC 1939
1940	0	0	0	136.08	1315.42	0	1451.49	DFSC 1940
1941	0	0	0	90.72	317.51	0	408.23	DFSC 1941
1942	0	0	0	45.36	4309.12	0	4354.48	DFSC 1942
1943	0	0	0	136.08	8708.97	0	8845.04	DFSC 1943
1944	0	0	0	226.80	5533.82	0	5760.62	DFSC 1944
1945	0	0	0	0	1088.62	0	1088.62	DFSC 1945
1946	0	0	0	0	3356.58	0	3356.58	DFSC 1946
1947	0	0	0	453.59	3175.14	0	3628.74	DFSC 1947
1948	0	0	0	0	453.59	0	453.59	DFSC 1948

Year	Carleton	York	Sunbury	Queens	Kings	Saint John	Total	Source
1949	0	0	0	453.59	907.18	0	1360.78	DFSC 1949
1950	0	0	0	0	3175.14	0	3175.14	DFSC 1950
1951	0	0	0	453.59	907.18	0	1360.78	DFSC 1951
1952	0	0	0	2267.96	5443.10	0	7711.06	DFNB 1952
1953	0	0	0	1360.78	4535.92	0	5896.70	DFNB 1953
1954	0	0	0	1360.78	907.18	0	2267.96	DFNB 1954
1955	0	0	0	1360.78	2721.55	0	4082.33	DFNB 1955
1956	0	0	0	453.59	907.18	0	1360.78	DFNB 1956
1957	0	0	0	129.27	2721.55	0	2850.83	DFNB 1957
1958	0	0	0	453.59	19504.46	0	19958.05	DFNB 1958
1959	0	0	0	453.59	43544.83	0	43998.42	DFNB 1959
1960	0	0	0	164.65	4989.51	0	5154.17	DFNB 1960
1961	0	0	0	362.87	907.18	0	1270.06	DFNB 1961
1962	0	0	0	236.32	5443.10	0	5679.43	DFNB 1962
1963	0	0	0	0	2721.55	0	2721.55	SCNB 1963
1964	0	0	0	453.59	5443.10	0	5896.70	SCNB 1964
1965	0	0	0	453.59	453.59	0	907.18	SCNB 1965
1966	0	0	0	453.59	20865.23	0	21318.82	SCNB 1966
1967	0	0	0	453.59	8164.66	0	8618.25	SCNB 1967
1968	0	0	0	453.59	3628.74	0	4082.33	SCNB 1968
1969	0	0	0	0	5896.70	0	5896.70	SCNB 1969
1970	0	0	0	0	10886.21	0	10886.21	SCNB 1970
1971	0	0	0	0	5896.70	0	5896.70	SCNB 1971
1972	0	0	0	0	1814.37	0	1814.37	SCNB 1972
1973	0	0	0	0	769.75	0	769.75	SCNB 1973
1974	0	0	0	0	730.74	0	730.74	SCNB 1974
1975	0	0	0	0	987.92	0	987.92	SCNB 1975
1976	0	0	0	0	453.59	0	453.59	SCNB 1976
1977	0	0	0	0	342.92	0	342.92	Reid (1978)
1978	Fishery Closed							NA

Figures

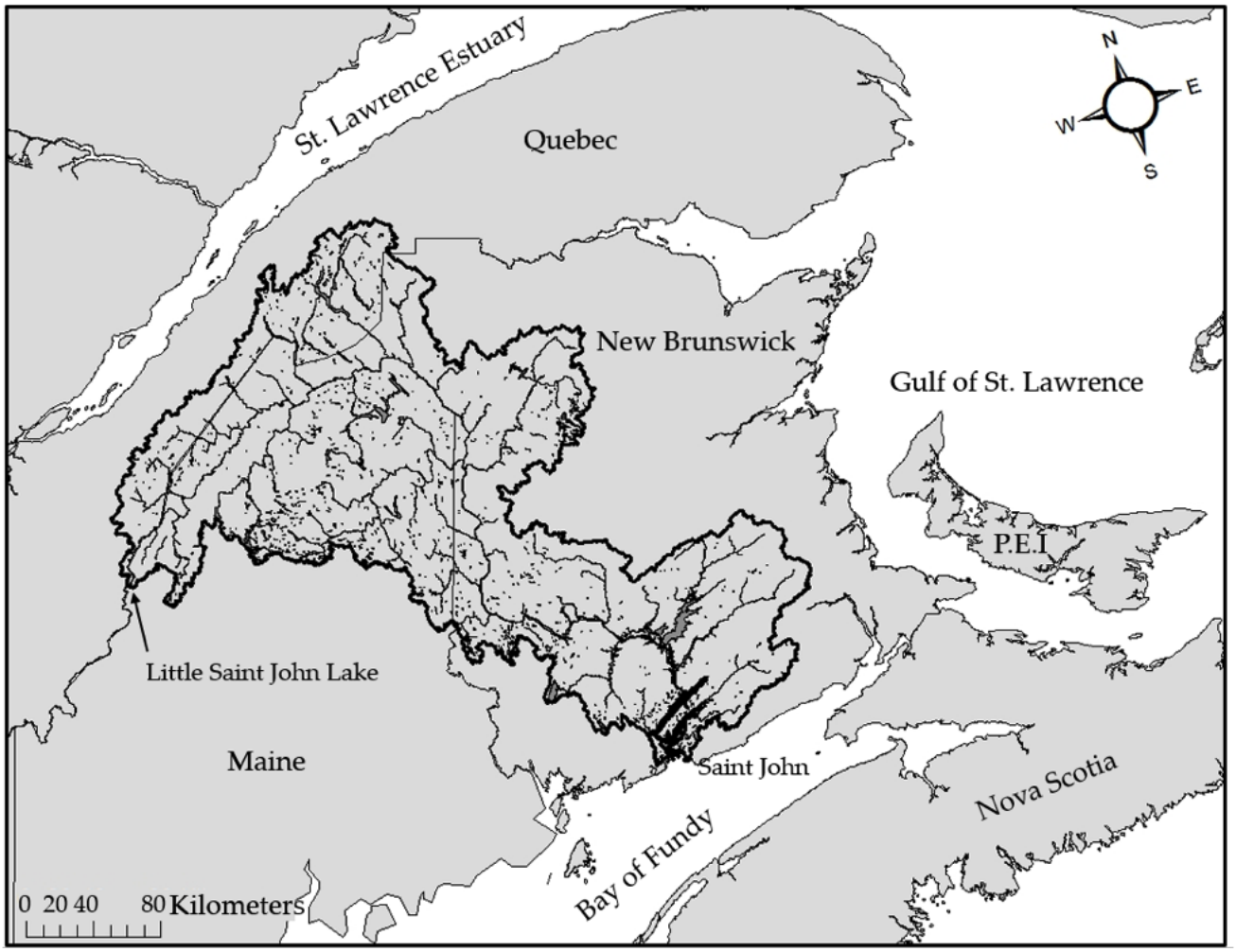

Figure 1. The Saint John River.

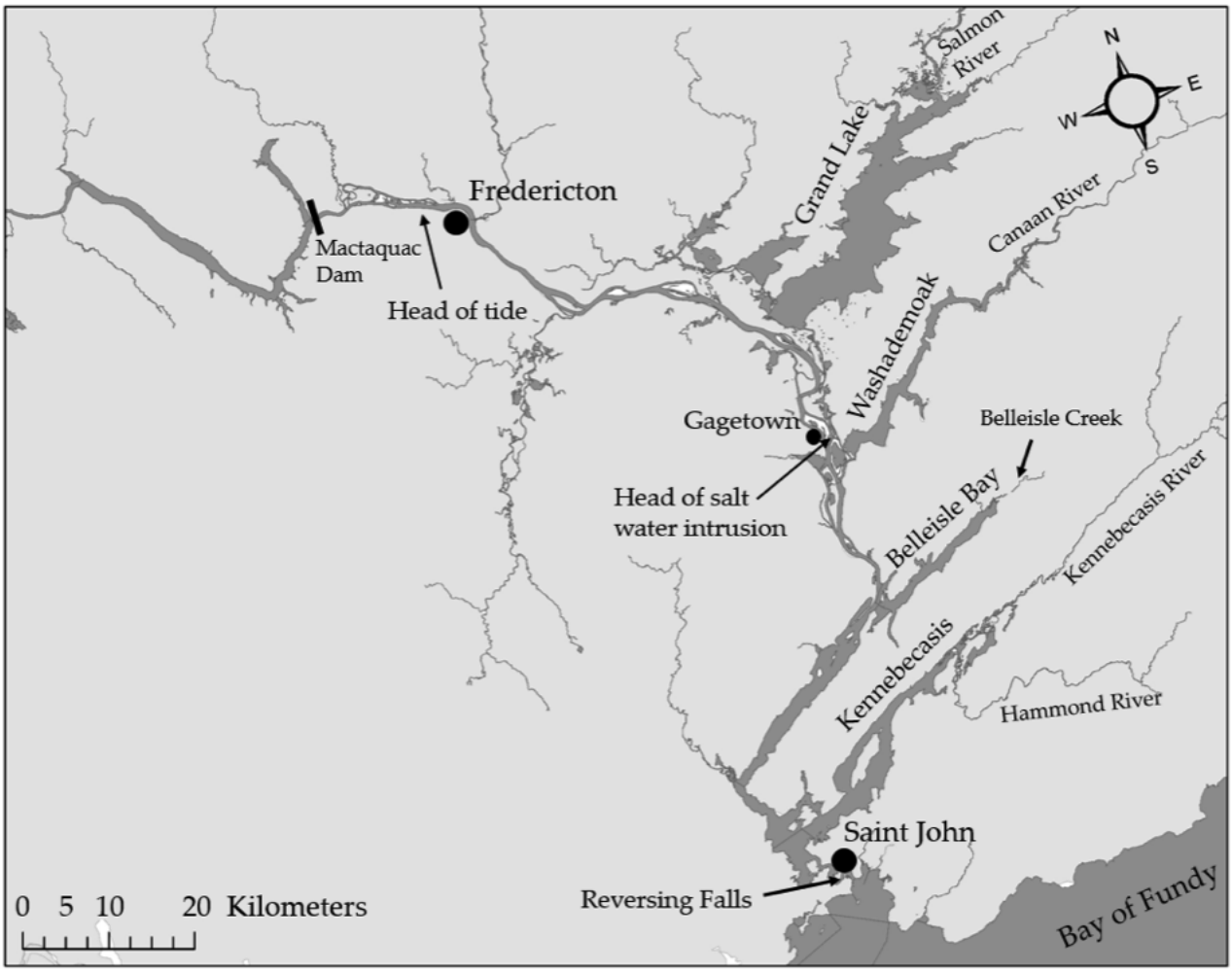

Figure 2. The Saint John River estuary.

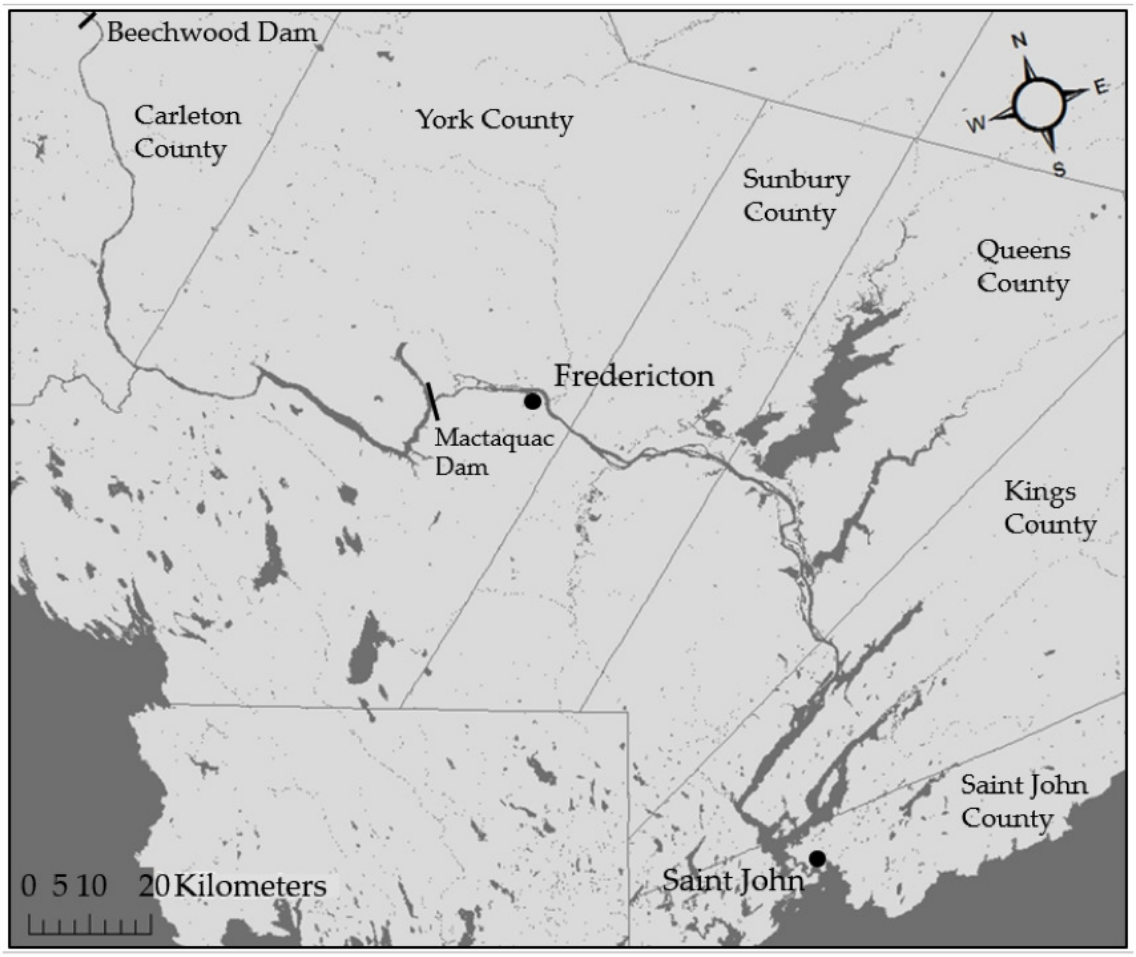

Figure 3. The Saint John River showing the Mactaquac and Beechwood dams.

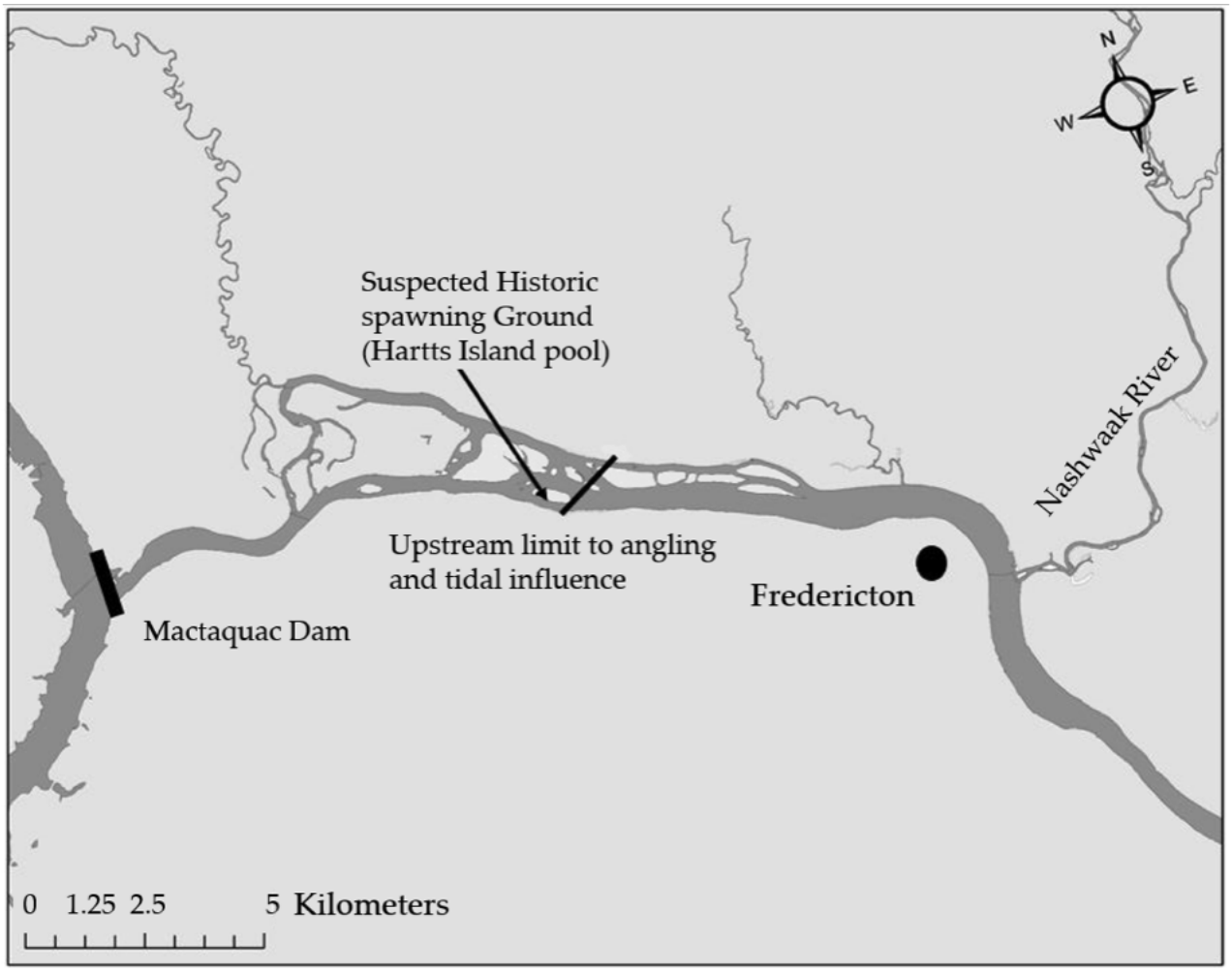

Figure 4. Suspected, historic spawning grounds of the Striped Bass in the Saint Jon River.

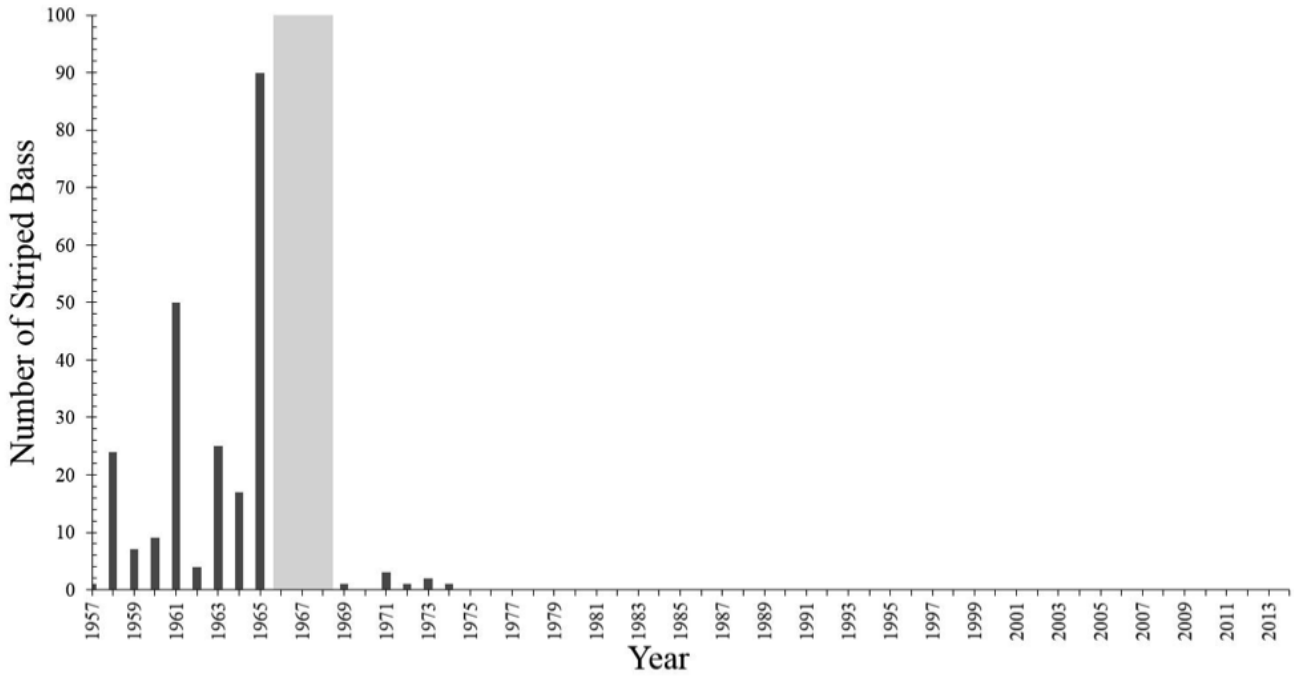

Figure 5. Numbers of Striped Bass captured at the Beechwood Dam and subsequently, the Mactaquac Dam

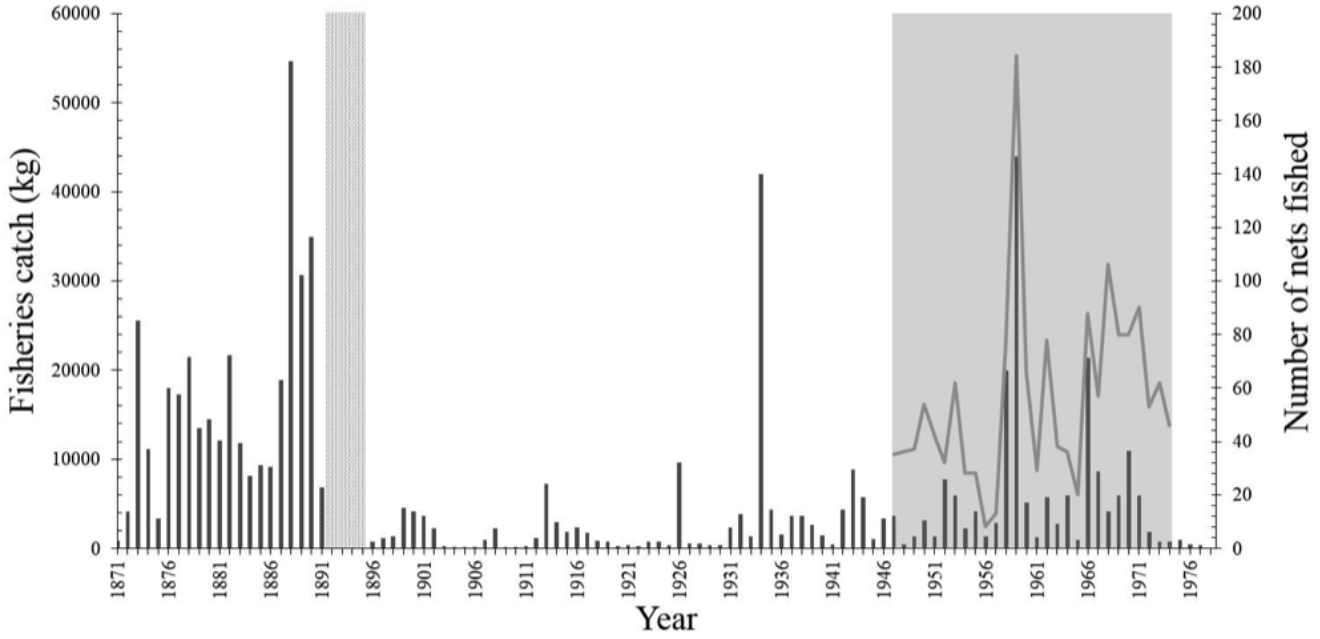

Figure 6. Fisheries statistics for Striped Bass in the Saint John River.

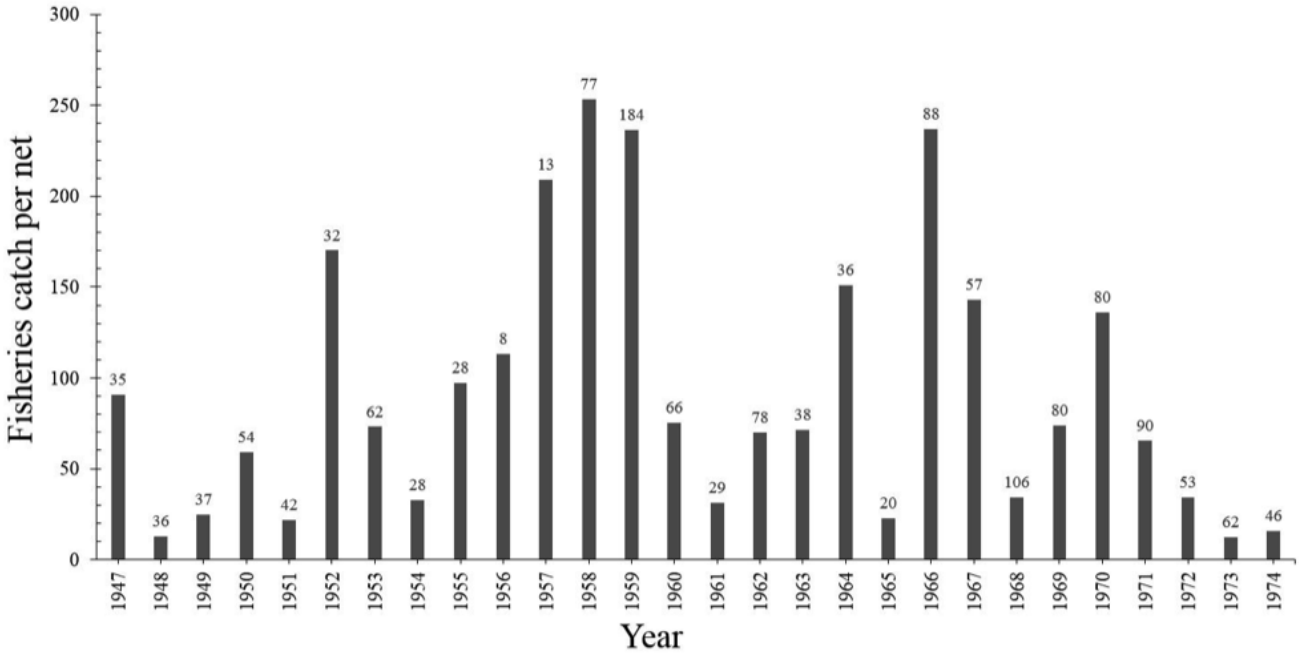

Figure 7. Fisheries catches for Striped Bass in the Saint John River.