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Risk assessment of smallmouth bass (*Micropterus dolomieu*) introductions to rivers of Gulf Region with special consideration to the Miramichi River (N.B.)

Évaluation des risques de l'introduction de l'achigan à petite bouche (*Micropterus dolomieu*) dans les rivières de la Région du Golfe et en particulier pour la rivière Miramichi (N.-B.)

G. Chaput and D. Caissie

Fisheries and Oceans Canada / Pêches et Océans Canada
P.O. Box 5030 / C.P. 5030
Moncton (NB)
E1C 9B6

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ABSTRACT

This document presents the risk assessment of the possible impact of non-native smallmouth bass (*Micropterus dolomieu*) on Atlantic salmon (*Salmo salar*) and the native aquatic ecosystem of the rivers of the DFO Gulf Region. Information in this document includes a summary of smallmouth bass biology and its environmental requirements. The risk assessment consists of two components: (1) estimation of the probability of widespread establishment (defined as the sequence of arrival, survival and reproduction, and spread), and (2) the determination of impact once introduced, in terms of its ecological impacts on existing aquatic communities. A timeframe of ten years was chosen for the risk assessment. The probability of widespread establishment for rivers of Gulf Region, and for the Miramichi River specifically, is considered high with low uncertainty. The impacts of smallmouth bass on the ecosystem and specifically to Atlantic salmon were considered to be different between the lake versus the river environments. For lakes, the overall risk assessment of smallmouth bass is high (i.e. smallmouth bass becomes a dominant component of the food web and causes significant widespread reductions in native biota) with low uncertainty. For the riverine environment, the overall risk is considered moderate (i.e. a measurable decrease in abundance of native populations is likely to occur in some locations with smallmouth bass likely becoming a dominant component of the food web) with high uncertainty. There are no features of smallmouth bass ecology which would be positive for Atlantic salmon survival and production, and any interactions with salmon will either be neutral or most likely negative to salmon.

RÉSUMÉ

Ce document présente l'analyse des risques des impacts potentiels d'une espèce non-endémique, l'achigan à petite bouche (*Micropterus dolomieu*), sur le saumon atlantique (*Salmo salar*) et sur l'écosystème aquatique endémique des rivières de la région du Golfe (MPO). Un sommaire de la biologie de l'achigan à petite bouche et des impératifs environnementaux est inclus. L'analyse des risques comprend deux échelons : (1) un estimation de la probabilité de l'établissement généralisé (dont la séquence d'arrivée, de survie et reproduction, et de propagation), et (2) l'évaluation des répercussions écologiques de l'espèce une fois introduite, sur l'écosystème aquatique existant. La période choisie pour cette évaluation est de dix ans. Il est fort probable que l'achigan à petite bouche s'établisse de façon généralisée dans la rivière Miramichi et les rivières de la Région du Golfe. L'incertitude est considérée comme faible. Les répercussions écologiques de l'achigan à petite bouche sur l'écosystème aquatique et en particulier, sur le saumon atlantique est différent pour le milieu lacustre (lac) comparativement au milieu fluvial (rivière). Les répercussions écologiques des introductions d'achigan à petite bouche dans les écosystèmes lacustres sont élevées (l'achigan à petite bouche pourrait devenir un chaînon dominant du réseau alimentaire et induire des réductions significatives de la faune existante). L'incertitude de ces conséquences est faible. Les répercussions écologiques dans les écosystèmes de rivières sont jugées modérées (l'achigan à petite bouche pourrait induire une diminution mesurable dans l'abondance des populations indigènes dans la majorité des endroits). L'incertitude de ces conséquences est élevée. Aucunes caractéristiques de l'écologie de l'achigan à petite bouche est favorable pour le saumon atlantique. Les interactions potentielles entre l'achigan à petite bouche et le saumon seraient neutres ou négatives pour le saumon.

INTRODUCTION

Smallmouth bass (*Micropterus dolomieu)* are not endemic to the Maritime provinces of eastern Canada. In September 2008 smallmouth bass were found in Miramichi Lake, a headwater lake of the Southwest Miramichi, in New Brunswick (Appendix 1). Field assessments conducted in late fall of 2008 captured a total of eight young-of-the-year (YOY) bass and three older bass. The presence of YOY bass in Miramichi Lake was interpreted as having come from spawning of adult smallmouth bass in Miramichi Lake in 2008. This is the first confirmed report of smallmouth bass in a New Brunswick river system within the DFO Gulf Region.

In response to government and conservation groups concerns about the potential impact of smallmouth bass on Atlantic salmon in the Miramichi River, a science peer review process was conducted to inform management on possible impact of this non-native species introduction on Atlantic salmon and the native ecosystem. This document summarizes the information which was used to inform the risk assessment, the risk assessment itself, and the conclusions of the risk assessment of smallmouth bass on the aquatic ecosystem of the rivers of the DFO Gulf Region. The advisory report of the risk assessment is available as DFO (2009).

The document is organized as follows:

1) review of smallmouth bass biology and environmental requirements,
2) introduction to the risk assessment,
3) review of information which can be used to inform each component of the risk assessment, and
4) conclusions of the risk assessment.

BIOLOGY AND ENVIRONMENTAL REQUIREMENTS

The following information on biology and environmental requirements of smallmouth bass are broadly taken from Kerr and Grant (1999) and Brown et al. (2009).

Reproduction

Smallmouth bass spawn during spring and early summer, May to July, when water temperatures approach 12º-15ºC but the actual temperature when spawning occurs varies with location. Male bass select and prepare nest sites near areas with cover in water from 0.3 to 6.1 m deep and with bottom material comprised of gravel, rock or, less frequently, sand (Kerr and Grant 1999). More than one female can spawn in the nest of a single male and the fertilized eggs are adhesive and stick to the nest substrate. The male guards the nest from predators, protecting the eggs and fry for up to two weeks post-hatch. The female does not participate in the guarding of the nest or fry. Hatching period shortens as temperature increases; hatching occurs within nine to twelve days at 12.8ºC but within two to three days at temperatures of 23º-25ºC (Kerr and Grant 1999). The newly hatched fry are about 6 mm long. The fry remain together under the protection of the male for about two weeks until the yolk sac is absorbed. The fry disperse from the nest when they reach about 25 mm in length.

Growth, size, and age

Growth is temperature-dependent. Dunlop and Shuter (2006) found relationships between growth and several climatic variables, with a significant positive relationship between air temperature and early growth. McNeill (1995) indicated that smallmouth bass from Nova Scotia grew slowly relative to more southern populations and bass were 5 to 6 years old before they reached 30 cm in length. Smallmouth bass in Lake Ainslie (NS), the most northern population in NS, reach 23 cm by age 3, 32 cm by age 6 and approximately 35 cm at ages 8 to 9 (LeBlanc 2010). Maximum size of smallmouth bass reported from Nova Scotia was just above 50 cm total length and maximum age interpreted was 17 years (Anon. 2008). The world record for an angler caught smallmouth bass is 69 cm (5.41 kg) reported from the eastern US and dating to 1955 (Machacek 2009) and the Canadian record has been reported at 4.46 kg, caught in Ontario in 1954 (Scott and Crossman 1973).

Smallmouth bass become sexually mature at two to four years old (Kerr and Grant 1999; Brown et al. 2009).

Food and diet

Planktonic crustaceans remain an important food item of bass YOY until they reach 40 mm in length (Kerr and Grant 1999). Smallmouth bass YOY feed mainly on midge larva, mayfly nymphs and occasionally small fish. In general, the food of large juveniles and adult smallmouth bass consists of insects, crayfish and fishes, with crayfish being the preferred food of older smallmouth bass. Prey fish species are varied, including numerous species of cyprinids (Kerr and Grant 1999). Smallmouth bass are also known to be cannibalistic.

Habitat

Smallmouth bass inhabit natural and man-made lakes characterized by clear, clean water as well as cool streams with moderate current and rocky or gravel bottoms (Kerr and Grant 1999). In streams, habitat use by smallmouth bass is related to substrate type, water depth and currents. Bass tend to avoid areas with sand or silt bottoms, prefer areas deeper than 45 cm and avoid strong currents. Smallmouth bass can be found in streams with moderate gradients (0.75-4.7 m/km) that provide alternating pools and riffles (Brown et al. 2009).

The habitat of YOY and juvenile smallmouth bass is mainly shallow, quiet waters under brush or rocks. There are several different types of habitats or home ranges used by smallmouth bass over the course of a year. In spring, adult bass move into the littoral areas of lakes and rivers to spawn. The summer habitat consists of rocky areas in moderately shallow water whereas in streams, smallmouth bass are found around logjams, rootwads and boulders (Kerr and Grant 1999). At temperatures below 15ºC smallmouth bass are found in areas of deep, dark water devoid of current or into rock crevices or larger openings for the winter months. In streams, smallmouth bass prefer quiet rocky pools that are at least 3.7 m deep. Smallmouth bass reportedly burrow into the substrate when water temperatures drop below 7ºC (Kerr and Grant 1999).

Environmental requirements

A summary of general habitat and water quality requirements for smallmouth bass is provided by Kerr and Grant (1999) and by Brown et al. (2009). Preferred water temperatures cited in the literature range from 19.4ºC to 30.8ºC. Upper lethal temperatures of 32.2ºC to 35ºC have been reported. YOY smallmouth bass prefer temperatures of 19ºC to 24ºC and optimum growth temperature for juveniles is at 26ºC (Kerr and Grant 1999).

Populations of smallmouth bass may be adversely affected by high flow conditions during the nesting period, and by high winter discharge (Brown et al. 2009). Floods have a lesser impact on larger fish. Reproductive success of smallmouth bass depends on stable water levels and temperatures. Nesting success is best when stream flows are relatively stable through the spawning and nursery seasons.

Optimal smallmouth bass habitat is found within non-turbid water. Smallmouth bass are considered to be intolerant of high silt and turbidity. Smallmouth bass are highly sensitive to elevated aluminum concentrations at low pH. A pH of 5.1 adversely affects YOY smallmouth bass, and the addition of aluminum makes a low pH (5.5) much more toxic (Brown et al. 2009).

Optimal dissolved oxygen levels for smallmouth bass vary by life stage. Normal activities require > 6 mg l^{-1}, spawning requires > 7 mg l^{-1}, and embryo/larvae development requires > 6.5 mg l^{-1} (Brown et al. 2009).

Shuter et al. (1980) noted that the critical size of YOY required at the end of the growing season to survive the winter was dependent upon the length of the starvation period. The distribution of smallmouth bass in northern Ontario appears related to the length of the growth period relative to the length of the starvation period (Shuter et al. 1980). Curry et al. (2005) noted that there was a size-dependent survival with most YOY smallmouth bass < 50 mm dying over the winter. However, the relationship between size and survival was not consistent with predictions from size-dependent mortality.

PROCEDURE FOR CONDUCTING THE RISK ASSESSMENT OF SMALLMOUTH BASS INTRODUCTIONS ON ATLANTIC SALMON AND NATIVE ECOSYSTEMS

The risk assessment was conducted following the national guidelines developed by the Centre of Expertise for Aquatic Risk Assessment and informed by the risk assessment applied to smallmouth bass in British Columbia (Mandrak and Cudmore 2008; Tovey et al. 2009).

The National Guidelines consider the risk assessment as two components:

(1) estimation of the probability of establishment (defined as the sequence of arrival, survival and reproduction, and spread), and

(2) the determination of impact once introduced, in terms of its ecological and genetic impact on existing aquatic communities.

The assessment is conducted relative to the species of interest, in this case smallmouth bass and would also be repeated for any pathogens or “fellow travelers” that may be associated with the invader. No information on the latter component is provided and the conclusions on this point were taken from the risk assessment from British Columbia (Tovey et al. 2009).

The first component of the risk assessment is conducted sequentially:

- likelihood of arrival of the species,
- survival and reproduction when non-native species has arrived,
- spread conditional on the non-native species having arrived, survived and reproduced.

A timeframe for the risk assessment must also be defined. For this case, a timeframe of ten years was chosen for the following reasons:

- corresponds to about three generations for the species, based on an age at maturity of 3 years, and

- this is sufficient to guide management decisions. This may lead to an underestimation of the consequences as time for establishment and restructuring of the ecosystem may manifest itself over a period much longer than 10 years.

The guidelines recommend that an evaluation of the weight of evidence (or uncertainty) for the assessment of risk be provided. Tovey et al. (2009) suggested that there are at least two components of uncertainty: the natural biological and ecological variability associated with stochastic events, and the scientific uncertainty resulting from a lack of evidence. Their proposed scale for the uncertainty measure focused on scientific understanding. Scientific uncertainty is lowest when there are studies on the target species in similar ecosystems; uncertainty is high when an analogue species must be used or when impacts must be inferred from dissimilar or distant ecosystems or experiments.

The constructed scale for the evaluation of uncertainty in the risk assessment ratings was (Tovey et al. 2009):

Rank	Interpretation of uncertainty
Very low	Demonstrated: outcome known with certainty.
Low	Similar: case studies in similar ecosystems for the target species.
Moderate	Expected: inferred from knowledge of the species in its native range.
High	Plausible: based on ecological principles, life histories, or experiments.
Very high	Unknown: little information to guide assessment.

RISK ASSESSMENT OF THE PROBABILITY OF ESTABLISHMENT FOR SMALLMOUTH BASS

The assessment of the probability of establishment consists of three parts: arrival, survival and reproduction, and spread.

Arrival

Arrival in the region depends on the presence of populations in adjacent regions, the likelihood of spread (especially downstream) from adjacent regions, and the likelihood that the species would be spread by unauthorized introduction. Tovey et al. (2009) proposed the following descriptors to guide the ranking of probability of arrival:

Element Rank	Descriptor
Very Low	No connected waterways, no nearby donor populations and/or little human influence in the region.
Low	Source populations not close and/or low human density.
Moderate	Some populations in adjacent regions and/or potential for human translocation.
High	Source populations common in adjacent region, recent history of introductions in adjacent regions.
Very High	Almost certain to occur: source populations upstream and likely to spread by natural means and/or a species that is commonly introduced by unauthorized means and has populations in nearby regions.
Arrived	Already present in the region being assessed.

As per Tovey et al. (2009), if the species is already present, a risk rating of 'Arrived' was entered in the tables.

Maritime provinces

The earliest known record of smallmouth bass in New Brunswick waters is from Chiputneticook Lakes (St. Croix drainage) around 1869 (Sabine 2009). The species arrived in New Brunswick via the St. Croix River, border waters of Maine and New Brunswick following an illegal introduction into connected private waters in Maine. Within twenty years, smallmouth bass were found within the lower tributaries of the Saint John River (Sabine 2009). Sanctioned introductions of smallmouth bass were undertaken by the Dominion Department of Fisheries between 1905 and 1948, for the purpose of providing recreational opportunities in areas which were considered unfavourable to indigenous species. During the 1950's to 1980, the number of lakes recorded with smallmouth bass more than doubled, with lakes of the middle Saint John River drainage being colonized (Sabine 2009). The majority of the presence records from lakes in New Brunswick were recorded within the last 30 years, with most lakes relatively close to previously known populations of smallmouth bass. Since the late 1990's, smallmouth bass were discovered much farther away from previously known sites, including the Petitcodiac and East Fundy drainages, several tributaries along the length of the Saint John River, and the upper reaches of the Saint John River above Grand Falls by the early 2000's. Smallmouth bass are now present in 69 lakes and 34 rivers of New Brunswick (Table 1; Fig. 1).

The first record of smallmouth bass in Nova Scotia is from Bunkers Lake, Yarmouth County, dating to 1942, site of a sanctioned introduction by the federal authority of the day (LeBlanc 2010). During 1944 to 1953, ten lakes in Nova Scotia were stocked with smallmouth bass of which six established populations (McNeill 1995). By 1966, there were 23 known occurrences of smallmouth bass in Nova Scotia and the species is presently found in 13 of 18 counties in Nova Scotia (LeBlanc 2010). As of 2008, there are 188 lakes/rivers which contain smallmouth bass in Nova Scotia (Table 1; Fig. 2).

Gulf Region

The first recorded occurrence of smallmouth bass in DFO Gulf Region waters of New Brunswick was in September 2008 from Miramichi Lake. Miramichi Lake is a headwater lake of the Southwest Miramichi River, located about 160 km above the head of tide (Appendix 1). Field assessments conducted into the late fall of 2008 captured a total of eight YOY bass and three older bass. The presence of YOY bass in Miramichi Lake was interpreted as having come from spawning of adult smallmouth bass in Miramichi Lake in 2008. The larger bass captured in 2008 measured over 30 cm total length. The YOY bass measured between 5.5 and 8.8 cm total length (Sabine 2009).

In Nova Scotia, smallmouth bass have been reported from Cumberland County since 1999, and most recently from Lake Ainslie (Inverness County) Cape Breton in 2000 (LeBlanc 2010). Smallmouth bass have been found in the following locations in Gulf Nova Scotia:

County	River system	Lake name
Cumberland	Pugwash River	Big Lake
Cumberland	Dewar River	Angevine Lake
Cumberland	Mattatal Lake Brook	Mattatal Lake
Colchester	Donaldson Mill Brook	Round Lake
Pictou	Middle River	Middle River Reservoir
Pictou	Middle River	Lansdowne Lake
Inverness	Margaree River	Lake Ainslie

For smallmouth bass in the Maritimes, the following summary for probability of arrival is attributed to the different regions of the Maritime provinces.

	Probability of arrival	Uncertainty	Reason
Maritime provinces	Arrived	Very Low	Present in 188 lakes in NS and 69 lakes in NB
Gulf Region	Arrived	Very Low	Documented in eight lakes in the region, one in NB and seven in NS
Southwest Miramichi River	Arrived	Very Low	Documented in one lake in the headwaters of the Southwest Miramichi

Survival and reproduction

The proposed ranking and corresponding descriptors for the ranks of probability of survival and reproduction consider the outcome after arrival based on conditions for survival and reproduction.

Probability of Survival and Reproduction	
Element Rank	**Descriptor**
Very Low	Smallmouth bass are very unlikely to be present without repeated introduction
Low	Smallmouth bass are likely to be present but at low abundance with infrequent reproduction
Moderate	Smallmouth bass are likely to be present at detectable levels with frequent successful reproduction
High	Smallmouth bass are likely to be common with regular year class production that ensures sustained recruitment
Very High	Smallmouth bass are likely to be very abundant, have consistent reproduction, and will likely become an important component of the ecosystem

This matrix characterizes an outcome resulting from the integration of a number of elements that will condition survival and reproduction.

Factors which would be considered in assessing the likelihood for this outcome include the habitat requirements and availability. An alternate element descriptor for smallmouth bass that focuses on assessment of suitable conditions for survival and reproduction was proposed (based on expert opinion) during the risk assessment meeting but not used directly. These factors could, however, be used to assist in evaluating the probability of survival and reproduction for smallmouth bass.

Element Rank	**Descriptor**
Very Low	Unsuitable habitat and conditions (high gradient, coldwater, no lakes / reservoirs, minimal low-gradient wide-riverine habitat)
Low	Cool water environment *(rarely exceeds 25°C maximum in July and August, less than 100 Frost Free Days (FFD))* with none to few "accessible lakes / reservoirs" or "low-gradient wide-riverine habitat", AND is not a lake or reservoir
Moderate	Cool water environment with "accessible lakes or reservoirs" or "low-gradient wide-riverine habitat" OR is a lake / reservoir
High	Warm water environment (*frequently exceeds 25°C maximum in July and August, greater than 100 FFDs*) with none to few "accessible lakes or reservoirs" or "low-gradient wide-riverine habitat", AND is not a lake or reservoir
Very High	Warm water environment with "accessible lakes / reservoirs" or "low-gradient wide-riverine habitat" OR is a lake / reservoir

Tovey at al. (2009) presented the results of a Habitat Suitability Model to predict the proportion of lakes that were suitable for smallmouth bass for each region of British Columbia. The final model, used five variables to predict suitability of lakes to smallmouth bass: surface area, maximum depth, and September, October, and November air temperatures. The variables with the highest contribution to the final BC model were September air temperature, lake area, and October air temperature (Tovey at al. 2009). They found that the model correctly predicted the suitability of 28 of the 37 invaded lakes.

Characteristics of Lakes in NB and NS

Characteristics of lakes in New Brunswick and Nova Scotia were taken from provincial data sources (for New Brunswick – NB lake Survey Report, Department of Natural Resources, available from http://nbwaters.unb.ca/reports.html; for Nova Scotia, database file provided by J. LeBlanc, NS Dept. of Fisheries and Aquaculture). It was noted that for the New Brunswick database, the depths reported for the lakes are in units of feet whereas the area is in units of hectares. In this document, feet measurements were converted to meters.

Ranges of lake area and maximum lake depth are similar in New Brunswick and Nova Scotia. Lake areas in the databases range from 1 to over 7,000 ha in New Brunswick and just over 1 to just under 6,000 ha for Nova Scotia (Fig. 3). Maximum depths for New Brunswick lakes ranged from 0.3 to 78 m and for Nova Scotia between 1 and 70 m (Fig. 3). For Gulf Region New Brunswick, 92% of the lakes have maximum depths less than 10 m, this contrasts with the Bay of Fundy area (Maritimes New Brunswick) for which 69% of the lakes have maximum depths less than 10 m (Fig. 3). For Nova Scotia, 75% of the lakes in Gulf Region are less than 10 m maximum depth similar to the DFO Maritimes Region of Nova Scotia, 74% are less than 10 m maximum depth (Fig. 3).

In New Brunswick, smallmouth bass have only been reported from lakes with surface areas > 10 ha and average depths of > 3 m (Fig. 4). In Nova Scotia, smallmouth bass have been reported in lakes < 4 ha and average depths of 1 m and greater (Fig. 5).

Smallmouth bass are predominately present within the southern part of the province of Nova Scotia (Fig. 2). Within the Gulf Region portion of Nova Scotia, 7 of 70 lakes (10%) have had confirmed reports of smallmouth bass. Within the Maritime Region of NS, 103 of 998 lakes (about 10%) have confirmed reports of smallmouth bass. For New Brunswick, smallmouth bass are predominately found in the southern portion, in the vicinity of the initial introductions of smallmouth bass. The most intensively occupied area is the outer Fundy area (rivers south of the Saint John River) in which 20 of 71 lakes (28%) have smallmouth bass present. The Saint John River system has smallmouth bass in 13 of 64 lakes and reservoirs (20%).

Miramichi Lake is the third largest lake in New Brunswick (Gulf Region) and the largest lake within the Southwest Miramichi River. Smallmouth bass have been reported from Lake Ainslie, the largest natural freshwater lake in Nova Scotia. Lake Ainslie is relatively shallow with a maximum depth of 18 m and an average depth of 5.7 m.

LeBlanc (2010) found significant correlations in the presence data of smallmouth bass with several physical lake characteristics including surface area, mean depth, maximum depth and the shoreline development index. The data from Nova Scotia (NS) suggest that the probability of bass establishing populations in small, shallow (<1 m) lakes is low, although there are confirmed bass populations in such lakes.

Temperature limitations

Shuter et al. (1980) developed a model that related first year survival of smallmouth bass to temperature indices. The model predicted that mean winter survival would be essentially zero for areas where the mean July air temperature was 16.6°C or less. Further, as the mean July air temperature drops below 18°C, Shuter et al. (1980) suggested that there is an increase in the relative number of lakes where average winter survival is too low to permit the existence of self-reproducing populations. The rough plot of the 18.3ºC isotherm (see Figure 27 in Shuter et al. 1980) places large portions of New Brunswick and Nova Scotia in a region with mean July temperatures > 18.3ºC, with the exception of the coastal areas of the Bay of Fundy and the Atlantic coast of Nova Scotia. All of the Maritime provinces are within a region with mean July temperatures > 16.6ºC (Shuter et al. 1980). Jackson and Mandrak (2002) provide a figure of the current distribution of smallmouth bass in Ontario relative to the mean July air temperature which shows that smallmouth bass are found in areas with mean temperatures > 16ºC. Shuter and Post (1990) indicated that relative mean year class strength of smallmouth bass is maximum at mean annual air temperature regimes of > 7ºC, is halved at temperatures between 3 and 4ºC and is near zero at mean air temperatures of < 0ºC.

Shuter et al. (1980) noted that the critical size required at the end of the growing season to survive the winter was dependent upon the length of the starvation period. Curry et al. (2005) noted that there was a size-dependent survival with most YOY smallmouth bass < 50 mm dying over the winter but the relationship between size and survival was not consistent with predictions from size-dependent mortality.

Maritime provinces

Climate normals were obtained for the weather stations in the Maritime provinces for the years 1971 to 2000 (http://www.climate.weatheroffice.ec.gc.ca/climate_normals/index_e.html). Summary data of interest included the mean air temperatures for July and for the entire year (Table 2). Mean air temperature for July was greater than 16.6ºC throughout the Maritimes with the exception of the coastal stations in the Bay of Fundy and the Atlantic coast of Nova Scotia (Fig. 6). Only one inland station, Upsalquitch Lake in northern New Brunswick, had mean July air temperatures < 16.6ºC. At the majority of stations (73 of 113), mean air temperature in July was greater than 18.3ºC (Fig. 6).

Water temperature conditions for Lake Ainslie, Nova Scotia

Smallmouth bass were first reported from Lake Ainslie in 2000 and have established and successfully reproduced (LeBlanc 2010). Lake Ainslie (46.13ºN, 61.18ºW) is the largest natural freshwater lake in the province of Nova Scotia. It has a surface area of 5,736 ha, a maximum depth of 18 m and a mean depth of 5.7 m (LeBlanc 2010). Water temperature data were collected using a continuous data logger (VEMCO minilog) placed on the lake bottom at a fixed station in Loch Ban of Lake Ainslie during 1993 to 2002. Water temperature data are also available from in-river sites in the Margaree River.

Mean daily water temperature at Loch Ban exceeded 10ºC in the spring from mid to late May but did not continually exceed 15ºC until the middle of June in most years (Table 3; Fig. 7). Mean water temperature generally declined below 10ºC by the middle of October (Fig. 7) and the number of days in the calendar year when the mean temperature equaled or exceeded 10ºC varied between 147 and 171 days (Table 3). Winter conditions in Lake Ainslie in 2001-2002 were quite cold, with mean daily water temperature remaining below 5ºC for 162 days and maximum daily temperature was less than 10ºC for 194 days during the period of November 6 (2001) to June 18 (2002) (Fig. 8).

Within the Margaree River, the warmest of four monitored sites in 2001 was the main stem of the Southwest Margaree, which is the outlet river of Lake Ainslie. At this site in 2001, mean daily water temperature never exceeded 25ºC (Fig. 9). This pattern of temperatures is consistent for the Margaree River; mean daily water temperatures rarely if ever exceeded 25 ºC and in the Northeast Margaree, mean temperatures rarely exceeded 20ºC (Fig. 10).

Hydrological conditions and water temperatures for Miramichi Lake and the Miramichi River

The present section provides information pertaining to the Miramichi Lake in order to help in the assessment of the potential risk associated with establishment and survival of smallmouth bass within the lake. As such, distance from Miramichi Lake to other lakes within the Southwest Miramichi River system are presented as well as data on hydrology and river water temperature at sites close to the Miramichi Lake.

Calculations of the drainage basin and lake surface areas for Miramichi Lake were obtained from a 1:50 000 scale map. The drainage basin area upstream of the lake outflow was calculated at 46.5 km^2 whereas the drainage basin area of the whole basin (including Lake Brook) was 60.6 km^2. The surface area of Miramichi Lake was calculated at 2.25 km^2 (225 ha) and the lake is approximately 2.8 km in length by 0.8 km in width. The maximum depth of

Miramichi Lake was reported as 7.3 m (24 feet). The drainage area for the Southwest Miramichi River above the confluence with Lake Brook is 764 km^2 (Chris Connell, NBDNR, pers. comm.).

Discharge values were obtained using the NB regional equations (Caissie and Robichaud 2009). The calculation of the mean annual flow can be obtained using the regional equation for NB, which is given by:

[1] $$MAF = 0.0247\ A^{0.980}$$

where *A* represents the area (km^2) and MAF the discharge (m^3/s).

The mean annual flow at the selected sites is approximately:

MAF (Miramichi Lake outflow) = 1.06 m^3/s
MAF (Miramichi Lake and Lake Brook) = 1.38 m^3/s
MAF (Southwest Miramichi River at confluence with Lake Brook) = 16.5 m^3/s

Discharge of the Southwest Miramichi River at the confluence with the Miramichi Lake and Lake Brook has a factor of 12 (16.5/1.38).

The 2-year flood, which is also very close to the bankfull discharge, can also be obtained using similar regional equations for NB. The 2-year flood equation for NB is given by:

[2] $$Q_{2y} = 0.3296\ A^{0.924}$$

Therefore the 2-year flood at the selected sites is approximately:

Q_{2y} (Miramichi Lake outflow) = 11.4 m^3/s
Q_{2y} (Miramichi Lake and Lake Brook) = 14.6 m^3/s
Q_{2y} (Southwest Miramichi at confluence with Lake Brook) = 152 m^3/s

A 2-year low flow estimation for these sites was calculated with the following equation:

[3] $$Q_{2low} = 4.954\ x\, 10^{-4}\ A^{1.2047}$$

where low flows are estimated at each site as:

Q_{2low} (Miramichi Lake outflow) = 0.051 m^3/s
Q_{2low} (Miramichi Lake and Lake Brook) = 0.070 m^3/s
Q_{2low} (Southwest Miramichi at confluence with Lake Brook) = 1.47 m^3/s

River water temperature was collected at two sites near Miramichi Lake, namely the site on the Taxis River and on the Southwest Miramichi River at the confluence with Burntland Brook. The water temperature time series on the Taxis River was very similar to that at the Southwest Miramichi River at the confluence with Burntland Brook, therefore only Taxis River (more complete time series) is presented (Table 4). Figure 10 shows the water temperature data between 2005 and 2008, with the mean value trend line based on the average of the two sites and smoothed using a 15 day moving average. Temperature reached peak values in mid-summer and then generally declined during the period of September to November. The average temperature at the beginning of September (day 244) is approximately 17°C and reached 0°C by the end of November (day 334) (Fig. 10). Water temperatures in Miramichi Lake in late fall 2008 were warmer than the temperatures in the rivers (Fig. 10).

Water temperatures in 2001 were also recorded at four index sites within the Miramichi River (Fig. 10). Mean daily water temperatures in 2001 occasionally exceeded 25ºC at the two Southwest Miramichi sites and exceeded 20ºC for an extended period of time in July and

August (Fig. 10). Water temperatures generally reached 15ºC by early June and declined to less than 15ºC by late September (Fig. 10).

Conclusions on suitability of environmental conditions for survival and reproduction of smallmouth bass in the Maritime provinces

Data on lake characteristics in the Maritimes as it relates to suitability for survival and reproduction of smallmouth bass are biased as the presence/absence data are not related to suitability of the lakes/rivers for smallmouth bass but reflect in large part where introductions have occurred. Given that smallmouth bass have established in lakes with a broad range of depths and surface areas in both New Brunswick and Nova Scotia, there do not appear to be any characteristics of lakes in the Maritimes which would constrain smallmouth bass colonization.

Based on the climate indices and the water temperature data from locations in the Gulf Region which have smallmouth bass, smallmouth bass could colonize all areas of the Maritime provinces with yearclass success potentially constrained by cooler temperatures in northern areas of New Brunswick.

For smallmouth bass in the Maritimes, the following assessment is proposed:

Region	Probability of survival and reproduction	Uncertainty	Reason
Maritime provinces	Very high	Very Low	o Established populations in NS and NB, important recreational fisheries established in many lakes in NS and NB. o Climate indices are favourable for smallmouth bass survival and reproduction. o Range of habitat conditions available with large portions of the Maritimes having warm water and there are large numbers of lakes/reservoirs. Several large rivers with low gradient habitat available. o Low uncertainty based on history of introductions and successful colonizations.
Gulf Region watersheds	High	Moderate	o Lake Ainslie population has multiple years of confirmed reproduction and a developing recreational fishery. o Most of the region has suitable climate indices for smallmouth bass survival and reproduction. o Range of habitat conditions available, large portions of the Gulf Region rivers have warm water. Several large rivers with low gradient habitat. o Moderate uncertainty – assumed from native range of bass, presumed similar in Gulf Region. Fewer cases of introductions and colonizations to judge how easily smallmouth bass would establish in watersheds in this area

Southwest Miramichi River	High	Moderate	o Recent confirmed report of smallmouth bass in one lake with presence of YOY interpreted as evidence of successful reproduction in 2008. o Water temperatures in spring and summer, at least in portions of the river, are favourable to smallmouth bass growth and survival. Lake temperatures warmer than river temperatures into the fall. o A large and long main stem of low to moderate gradient, high gradient tributaries on north side, lower gradient tributaries on south side, main stem portion and some tributaries can have warm water conditions in summer. o Moderate uncertainty – assumed from native range of bass, presumed similar in Southwest Miramichi. Short time series of observations due to recent introduction.

Spread

The final element in the analysis of establishment of the species considered the spread of the species within the region once it is introduced. Tovey et al. (2009) considered the combined effects of natural and human spread. Things to consider in this evaluation include the degree of connectedness within a watershed, and connectedness of suitable waterways within the broader region that would allow the species to spread naturally from its point of origin. The potential for spread by human vectors is also included. For this risk assessment, the recent pattern of introductions has a large influence on the probability of spread across watersheds.

The constructed scale for the probability of spread once introduced into a region was taken from Tovey et al. (2009).

Element Rank	Descriptor
Very Low	o No connected waterways of suitable habitats o Little human influence
Low	o Waterways not well connected o Unlikely to be introduced by humans
Moderate	o Can spread within the watershed or to adjacent waterways but may not be a successful colonizer o Limited interest in introduction of species
High	o Will likely spread to connected waterways and become established o Likely to be introduced at a number of locations or a number of times in the region
Very High	o Very well connected waterways and/or species has been noted to spread widely in other regions o Human population density or visitations of sport fishers very high within the region

Maritime Provinces

Both Sabine (2009) and LeBlanc (2010) indicated that there was an acceleration in the reports of smallmouth bass occurrence in the recent decade in both NB and NS. The increased number of confirmed locations with smallmouth bass may be due to increased reporting but some of it is attributed to increased illegal transfers. Increased interest in bass fishing, as demonstrated by the large number of angling shows on television and the increased popularity of bass fishing derbies in the Maritimes, points to a likely increase in unauthorized effort to distribute smallmouth bass in more lakes and watersheds. Decreased abundance of traditionally important recreational fish species such as Atlantic salmon in large portions of the Maritime provinces has lead to an alternate interest by anglers to popularized recreational species such as smallmouth bass with higher angler success rates.

Many watersheds in the Maritimes have a number of interconnected lakes within or in close proximity to the main stem of the river. Smallmouth bass introduced in the headwater lake of the Magaguadavic River were presumed to have spread downstream, succeeded in being distributed throughout the watershed, and are presently reported from 10 of its 15 lakes (Carr and Whoriskey 2009; DNR database). The other watersheds in NB with multiple lakes containing smallmouth bass include: Saint John River system with 18 lakes colonized, St. Croix River system with 16 lakes colonized, Musquash River with four lakes, and Bocabec system with four lakes. Watersheds with only one reported location include Lepreau River, Digdeguash River, and Petitcodiac River.

Gulf Region and Southwest Miramichi River

The rivers in the Gulf shore of Nova Scotia with confirmed populations of smallmouth bass include several small lakes within the central portion, and Lake Ainslie in western Cape Breton Island. The presence of smallmouth bass is attributed to unsanctioned introductions by people (LeBlanc 2010). In some rivers of Gulf Nova Scotia, there are a number of interconnected lakes which would provide opportunity for spread within the rivers. In New Brunswick, the presence of smallmouth bass in Miramichi Lake is the first confirmed report of this species in Gulf New Brunswick watersheds. An earlier unsanctioned introduction of chain pickerel (*Esox niger*) in Despres Lake, tributary of the Cains River (Southwest Miramichi River) (Connell et al. 2002) is indicative of previous and ongoing unsanctioned transfers of fish within the Miramichi River and likely elsewhere.

Miramichi Lake is situated in a headwater tributary of the Southwest Miramichi River. Miramichi Lake is connected to the Southwest Miramichi via the 4.3 km Lake Brook (Appendix 1). Spread of smallmouth bass out of Miramichi Lake and into the Southwest Miramichi River is likely. A synoptic survey conducted in October 2008 did not find evidence of any smallmouth bass in the inlet streams nor in the Southwest Miramichi River upstream and downstream of Lake Brook (Appendix 1). There are no intermittent lakes within the main stem of the Southwest Miramichi. Lakes which could be colonized by smallmouth bass are located relatively long distances downstream of Miramichi Lake but would also require long migrations upstream to access them (Fig. 11). Colonizing lakes in upstream direction is possible as inferred from the history of the Magaguadavic River (Carr and Whoriskey 2009). Upstream movements of adult smallmouth bass are also observed in the Nashwaak River (lower tributary of the Saint John River) and juvenile smallmouth bass have been captured in rotary screw traps in the spring (Chaput and Jones 2004).

For the element “spread”, the following assessment is proposed:

Region	Probability of spread	Uncertainty	Reason
Maritime provinces	Very high	Very Low	o Widespread climate suitability. o Dominated by human vector. Increased reports of smallmouth bass dispersal in recent years. High risk of unauthorized stocking, ample access to lakes and large promotional angling campaigns. o Very certain based on recent history.
Gulf Region watersheds	High	Low	o Dominated by human vector. Recent (10 years) introductions, angling opportunities in nearby region, easy access to lakes throughout the region, recent history of introductions. o Atlantic salmon angling remains a high profile activity which may limit unsanctioned introductions. o Low uncertainty based on recent history.
Southwest Miramichi River	High	Low	o Natural spread into main stem and low gradient tributaries is very likely, natural spread into high gradient tributaries and associated headwater lakes less likely without human intervention. o Illegal introductions in other headwater lakes of readily accessible but isolated areas is very likely based on past history. Broad use of ATVs provides access to previously difficult to access headwaters and previous history of unsanctioned introduction of chain pickerel in another lake in Southwest Miramichi River. o High profile Atlantic salmon river with public pressure against such activities. o Low uncertainty based on recent history.

Overall rating of probability of Widespread Establishment Once Arrived (WEOA)

Combining the three elements above, a final rating of the probability of widespread establishment once arrived (WEOA) was developed. Tovey et al. (2009) proposed the following:

Element Rank	Descriptor
Very Low	Unlikely to become established in the region.
Low	Species will likely be restricted to isolated waterbodies within the region.
Moderate	Species may become established in a few watersheds within the region.
High	Species likely to become established at multiple locations within the region and concentrated in certain areas.
Very High	Likely to become widespread in the region, occupying many of the suitable lakes and rivers.

For the smallmouth bass risk analysis, the final rating is summarized below.

Element	Maritime Provinces		Gulf Region		Southwest Miramichi River	
	Probability	Uncertainty	Probability	Uncertainty	Probability	Uncertainty
Arrival	Arrived		Arrived		Arrived	
Survival and reproduction	Very high	Very Low	High	Moderate	High	Moderate
Spread	Very High	Very Low	High	Low	High	Low
WEOA	Very High	Very Low	High	Low	High	Low

RISK ASSESSMENT OF ECOLOGICAL IMPACT

The second component of the risk assessment considers the magnitude of consequences of the introduction on native biotic and abiotic resources (Mandrak and Cudmore 2008). The primary focus in this assessment is the impact on Atlantic salmon although consideration is made to the impact on other species within the ecosystem.

Tovey et al. (2009) originally proposed the following categorization for ecological impacts.

Element Rank	Descriptor of impact
Very Low	Species integrates into aquatic community and has no discernable impact on existing biota or genetic exchange with native populations impossible.
Low	Native species are sometimes impacted by predation, competition, disease, or habitat alteration as a result of the invasion or genetic exchange with native populations highly unlikely.
Moderate	A measurable decrease in abundance of native populations is likely to occur in most locations or genetic exchange with native populations may occur in some instances and cause harm.
High	The introduced species becomes a dominant component of the food web and causes significant reductions in existing biota or genetic exchange with native populations likely to occur in some circumstances and cause harm.
Very High	Extirpation of native populations likely. Food webs are highly altered or genetic exchange is likely to be widespread or seriously deleterious.

Based on discussions during the science review of the risk assessment, the following descriptors for the ranks of the element of ecological impacts were developed.

Element Rank	Descriptor of impact
Very Low	Smallmouth bass integrates into the aquatic community and has no discernable impact on native biota.
Low	Native species may sometimes be impacted by predation, competition in portions of the area.
Moderate	A measurable decrease in abundance of native populations is likely to occur in some locations with smallmouth bass likely becoming a dominant component of the food web.
High	Smallmouth bass becomes a dominant component of the food web and causes significant widespread reductions in native biota.
Very High	Large reductions in native biota throughout the area, likely leading to localized extirpations of some native biota.

Reports on the impacts of smallmouth bass introductions are dominated by observations from lake ecosystems. Introductions often result in shifts in forage fish assemblages resulting from declines in abundance and decreases in diversity (Valois et al. 2009). When smallmouth bass are introduced into a water body, they prey heavily on smaller fish. In watersheds of the Maritime provinces, this would be a limited diversity of small-bodied cyprinid species including dace, shiners, chub, suckers, perch, sculpins, trout and occasionally juvenile Atlantic salmon (Valois et al. 2009). A total of 13 fish species, excluding smallmouth bass, were sampled at the downstream sampling rotary screw trap in the Nashwaak River during spring (Chaput and Jones 2004). Smallmouth bass comprised 0.7% of the total catch which was dominated by Atlantic salmon (75%) followed by common shiner (11%). The Miramichi River has a moderately diverse fish fauna with 23 fish species reported from freshwater (Randall et al. 1989). Sampling in the tributaries and the main stem of the Southwest Miramichi around Lake Brook captured 13 fish species (Appendix 1).

Although the potential for direct competitive interactions between juvenile smallmouth bass and Atlantic salmon in streams has not been demonstrated, it is likely since juvenile smallmouth bass habitat in rivers overlaps with that of Atlantic salmon juveniles (Carr and Whoriskey 2009; Valois et al. 2009). Carr and Whoriskey (2009) reported generally lower densities of juvenile salmon in sites with smallmouth bass compared to sites without.

Juvenile salmon as fry or parr are the most vulnerable stages to predation but habitat of juveniles and of suitably sized smallmouth bass to eat them generally does not overlap. Recent field studies indicate that competition is most likely to occur between YOY of both species, which can occupy similar habitats, but only for a brief period of time in the late summer (Valois et al. 2009).

Overlying both predation and competition potential is the preference and tolerance of warmer water and lower water velocities of smallmouth bass relative to Atlantic salmon. The period of maximum interaction is likely to be mid to late summer in eastern Canadian rivers when water levels are low, fishes concentrate, and warm temperatures increase the thermal stress on Atlantic salmon (Valois et al. 2009).

The most important impacts of smallmouth bass on Atlantic salmon are likely to occur in rivers where salmon smolts or fall pre-smolts must migrate through lakes or reservoirs, in areas where smolts spill over dams or pass through turbines, which make them more vulnerable to fish predators. Additionally, impacts of smallmouth bass on Atlantic salmon are likely to occur in lower sections of large rivers which provide lake type habitat for smallmouth bass.

Juvenile salmon growth characteristics Margaree River

Atlantic salmon juveniles are found throughout the Margaree River system including the main stem and tributaries of the Southwest Margaree and Lake Ainslie. Some salmon juveniles are known to spend an extended period of time in Lake Ainslie, as inferred from reports of salmon being angled from the outlet of Lake Ainslie and from catches of long-bodied smolts at the rotary screw trap in the main stem of the Margaree River in the spring. These smolts are long bodied, measuring up to 23 cm fork length, compared with the most common size range of smolts, 11 to 15 cm fork length (Clément et al. 2007). Seasonal growth of salmon juveniles was monitored at four sites within the Margaree River in 2001; a main stem and a tributary site in the Southwest Margaree, a main stem and tributary site in the Northeast Margaree (Strothotte et al. 2005). YOY salmon reached mean fork lengths > 5 cm by mid-August at all sites with the exception of the headwater tributary site in the Northeast Margaree (Fig. 12). One-year old parr came out of their first winter at > 6 cm fork length and had attained fork lengths > 8 cm by the first week of August, except for the tributary site of the Northeast Margaree which were smaller, similar to YOY (Fig. 12). Growth was best at the warm water site of the main stem of the Southwest Margaree although the mean daily water temperature never exceeded 25ºC in 2001, even at the warmest site (Fig. 9).

Limited data from Lake Ainslie indicated that one-year old smallmouth bass were about 10 cm total length (LeBlanc 2010). Dunlop and Shuter (2006), based on back-calculated size at age from scales, gave mean growth increments in the first year ranging from 5.3 to 9.8 cm, for thirteen lake populations from Nova Scotia. Smallmouth bass in lakes from Nova Scotia grow more rapidly than Atlantic salmon in their first year.

Juvenile salmon growth characteristics Miramichi River

Smallmouth bass presumed to be young-of-the-year sampled in October from Miramichi Lake and the outlet measured between 6.8 and 8.8 cm total length.

Atlantic salmon juveniles are found throughout the Miramichi River system including the main stem and tributaries of the Southwest Miramichi. Lake rearing of salmon juveniles is considered to be minimal in the Miramichi River although lakes have not been sampled for juvenile salmon rearing potential. Annual electrofishing surveys throughout the Miramichi River show that the fork lengths of Atlantic salmon YOY are generally between 4.5 and 6 cm at the time of sampling (July to September) and for age-1 parr, the fork lengths range from 6 to less than 11 cm (Moore and Chaput 2007). Seasonal growth of salmon juveniles was monitored at four sites within the Miramichi River in 2001 and 2002; two sites within the Northwest Miramichi and at two tributary sites within the Southwest Miramichi (Burntland Brook and Taxis River). YOY salmon reached mean fork lengths of 4 to 5 cm by the first week of August and were largest at the Burntland Brook site (Fig. 13). One-year old parr came out of their first winter at about 6 cm fork length and had attained fork lengths > 8 cm at the Burntland Brook site by late July (Fig. 13). Growth was best at the warmer water sites, mean daily water temperature occasionally exceeded 25ºC at the two Southwest Miramichi sites and exceeded 20ºC for an extended period of time in July and August (Fig. 10).

Conclusions on ecological impacts of smallmouth bass

There are no features of smallmouth bass ecology which would be positive for Atlantic salmon survival and production, and any interactions with salmon will either be neutral or, most likely, negative to salmon.

Based on the evidence, the impacts of smallmouth bass on the ecosystem and specifically to Atlantic salmon were considered to be different between the lake versus the river environments.

The overall risk to the aquatic biota in lakes is considered to be high with low uncertainty. The overall risk for riverine environments is considered to be moderate but with high uncertainty. The high uncertainty in the riverine assessment results from limited studies on the suitability of habitat in rivers like the Southwest Miramichi River to accommodate smallmouth bass, and very few studies on direct interactions between smallmouth bass and Atlantic salmon are available to inform the assessment of ecological impacts.

Gulf Region watersheds			
Habitat	**Ecological Impact**	**Uncertainty**	**Reason**
Lacustrine	High	Low	o Species diversity in lakes is moderate (fewer than 20), but bass will likely become dominant component of food web. o Uncertainty is low based on empirical evidence.
Riverine	Moderate	High	o Riverine habitats presently occupied by salmon at full capacity in most rivers. Bass will compete for habitat and reduce carrying capacity for salmon. Scale of interaction expected to remain localized to main stem portion of rivers. o Uncertainty high due to limited empirical evidence.

Southwest Miramichi River			
Habitat	**Ecological Impact**	**Uncertainty**	**Reason**
Lacustrine	High	Low	o Species diversity in lakes is moderate (10 or more), but bass will likely become dominant component of food web. o Uncerainty is low based on empirical evidence.
Riverine	Moderate	High	o Riverine habitats are presently occupied by salmon at full capacity. Bass will likely compete for habitat and reduce carrying capacity for salmon. Complex shoreline habitat may provide refuge for native biota from bass predation. Scale of interaction expected to moderate to high at some locations. o Uncertainty high due to limited empirical evidence.

CONSEQUENCES TO GENETICS AND OF PATHOGENS, PARASITES OR FELLOW TRAVELERS

Tovey et al. (2009) and Mandrak and Cudmore (2008) identified two other elements of a risk assessment, which were not considered in this review and assessment: the consequences to genetics and the consequences of pathogens, parasites, or fellow travelers on the introduced species becoming widely established once they have arrived.

Tovey et al. (2009) gave a very low rating to the magnitude of the genetic impact of smallmouth bass on native populations in British Columbia since there were no native populations of smallmouth bass in British Columbia or other species of bass with which to hybridize. The same situation applies to the Maritime provinces.

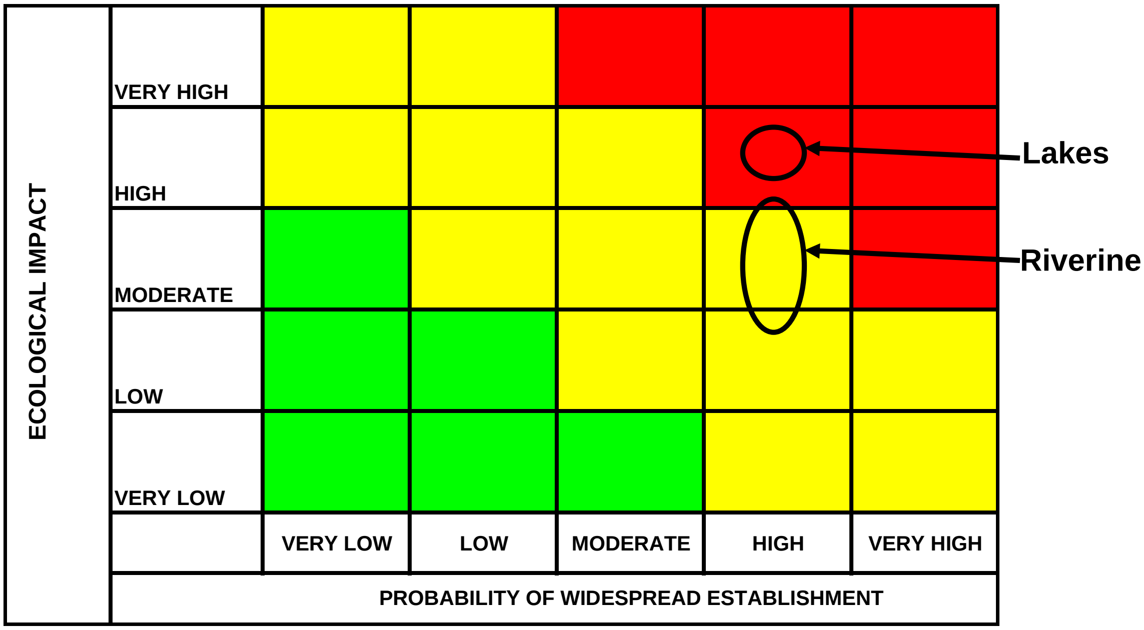
As for the ecological impact of parasites and pathogens, it was considered difficult to quantify but rated low for British Columbia with a very high degree of uncertainty (Brown et al. 2009; Tovey et al. 2009). Concerns about transfer of pathogens and diseases between watersheds in the Maritimes are legitimate as some Atlantic salmon pathogens have different strains among watersheds in NB and NS. Request for stocking fish in the wild requires a review of the application, including information on the suitable health status of the fish to be released, before authorization is given. Illegal introductions are not subject to these controls and could therefore be a vector for disease and parasites across watersheds.

OVERALL RISK ASSESSMENT OF SMALLMOUTH BASS

The summary ranks for the probability of widespread establishment (WEOA) and the ecological or genetic consequences are combined to obtain an overall risk rating. Tovey et al. (2009) presented the summary in a “heat matrix” and drew ellipses whose size reflected the uncertainty associated with the risk evaluation. Green indicates low risk, yellow indicates moderate risk, and the red region represents the conditions for a high risk designation (Mandrak and Cudmore 2008).

The descriptors used for assessing ecological impacts are used to describe the overall risk assessment. For lakes, the overall risk assessment of smallmouth bass is high (i.e. smallmouth bass becomes a dominant component of the food web and causes significant widespread reductions in native biota) with low uncertainty. For the riverine environment, the overall risk is considered moderate (i.e. a measurable decrease in abundance of native populations is likely to occur in some locations with smallmouth bass likely becoming a dominant component of the food web) with high uncertainty.

Southwest Miramichi River and Gulf Region



The ecological impacts to Atlantic salmon specifically are reflected in the rank for riverine habitat as the majority of Atlantic salmon juvenile production in Gulf Region and for the Southwest Miramichi River occurs in riverine habitat.

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REFERENCES

Anon. 2008. Smallmouth bass report: Shubenacadie (Grand) Lake. Nova Scotia Dept. of Fisheries and Aquaculture, August 2008. (http://www.gov.ns.ca/fish/).

Brown, T.G., Runciman, B., Pollard, S., Grant, A.D.A., and Bradford, M.J. 2009. Biological synopsis of smallmouth bass (*Micropterus dolomieu*). Can. Manuscr. Rep. Fish. Aquat. Sci. 2887: v + 50 p.

Caissie, D., and Robichaud, S. 2009. Towards a better understanding of the natural flow regimes and streamflow characteristics of rivers of the Maritime Provinces. Can. Tech. Rep. Fish. Aquat. Sci. 2843: viii + 53p.

Carr, J. W., and Whoriskey, F. G. 2009. Atlantic salmon (*Salmo salar*) and smallmouth bass (*Micropterus dolomieu*) interactions in the Magaguadavic River, New Brunswick. DFO Can. Sci. Adv. Secr. Res. Doc. 2009/074. iv + 10 p.

Chaput, G. J., and Jones, R. A. 2004. Catches of downstream migrating fish in fast-flowing rivers using rotary screw traps. Can. Manuscr. Rep. Fish. Aquat. Sci. 2688: v + 14 p.

Clément, M., Chaput, G., and Leblanc, P. 2007. Atlantic salmon (*Salmo salar*) smolt migration from the Margaree River, 2001 to 2003. Can. Tech. Rep. Fish. Aquat. Sci. 2693: x + 60p.

Connell, C. B., Dubee, B. L., and Cronin, P. J. 2002. Using rotenone to eradicate chain pickerel, *Esox niger*, from Despres Lake, New Brunswick, Canada. NB DNRE. Fisheries Management Report 2002-01-E.

Curry, R. A., Currie, S. L., Arndt, S. K., and Bielak, A. T. 2005. Winter survival of age-0 smallmouth bass, *Micropterus dolomieu*, in north eastern lakes. Envir. Biol. Fishes 72: 111–122.

DFO. 2009. Potential Impact of Smallmouth Bass Introductions on Atlantic Salmon: A Risk Assessment. DFO Can.Sci. Advis. Sec. Sci. Advis. Rep. 2009/003.

Dunlop, E. S., and Shuter, B. J. 2006. Native and introduced populations of smallmouth bass differ in concordance between climate and somatic growth. Trans. Amer. Fish. Soc. 135: 1175–1190.

Jackson, D. A., and Mandrak, N. E. 2002. Changing fish biodiversity: predicting the loss of cyprinid biodiversity due to global climate change. Fisheries in a Changing Climate, Am. Fish. Soc. Symp. 32: 89-98.

Kerr, S. J., and Grant, R. E. 1999. Ecological impacts of fish introductions: evaluating the risk. Fish and Wildlife Branch, Ontario Ministry of Natural Resources, Peterborough, Ontario.

LeBlanc, J. E. 2010. Geographic distribution of smallmouth bass, *Micropterus dolomieu*, in Nova Scotia: history of early introductions and factors affecting current range. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/028. iv + 25 p.

Machacek, H. 2009. World Records Freshwater Fishing. http://www.fishing-worldrecords.com/.

Mandrak, N. E., and Cudmore, B. 2008. National detailed level risk assessment guidelines: assessing the biological risk of aquatic invasive species in Canada. Centre of Expertise for Aquatic Risk Assessment, June 2008 Draft. Fisheries and Oceans Canada, 867 Lakeshore Road, Burlington ON, Canada, L7R 4A6. 22 p.

McNeill, A. J. 1995. An overview of the smallmouth bass in Nova Scotia. N. Amer. J. Fish. Manage. 15: 680-687.

Moore, D., and Chaput, G. 2007. Juvenile Atlantic salmon (*Salmo salar*) surveys in the Miramichi River watershed from 1970 to 2004. Can. Data Rep. Fish. Aquat. Sci. No. 1188. viii + 117 p.

Randall, R. G., O'Connell, M. F., and Chadwick, E. M. P. 1989. Fish production in two large Atlantic coast rivers: Miramichi and Exploits, p. 292-308. *In* D. P. Dodge [ed.] Proceedings of the International Large River Symposium. Can. Spec. Publ. Fish. Aquat. Sci. 106.

Sabine, M. 2009. Smallmouth bass distribution in New Brunswick. Working paper presented at the DFO Regional Science Advisory Process of January 27-28, 2009.

Scott, W. B., and Crossman, E. J. 1973. Freshwater Fishes of Canada. Fish. Res. Board Can. Bull. 184.

Shuter, B. J., MacLean, J. A., Fry, F. E. J., and Regier, H. A. 1980. Stochastic simulation of temperature effects on first-year survival of smallmouth bass. Trans. Amer. Fish. Soc. 109: 1-34.

Shuter, B. J., and Post, J. R. 1990. Climate, population viability, and the zoogeography of temperate fishes. Trans. Amer. Fish. Soc. 119: 314-336.

Strothotte, E., Chaput, G. J., and Rosenthalt, H. 2005. Seasonal growth of wild Atlantic salmon (*Salmo salar* L.) juveniles and implications on age at smoltification. J. Fish Biol. 67: 1585-1602.

Tovey, C. P., Bradford, M. J., and Herborg, L.-M. 2009. Biological risk assessment for smallmouth bass (*Micropterus dolomieu*) and largemouth bass (*Micropterus salmoides*) in British Columbia. DFO Can. Sci. Adv. Secr. Res. Doc. 2008/075.

Valois, A., Curry, R. A., and Coghlan, S. M. 2009. Smallmouth bass (*Micropterus dolomieu*) invasion of Gulf Region rivers: evaluating the impact on Atlantic salmon (*Salmo salar*) populations. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/075. vi + 22 p.

TABLES

Table 1. *Chronology of reports of smallmouth bass from the Maritimes provinces.*

	Maritime provinces			Gulf Region	
	New Brunswick		Nova Scotia	New Brunswick	Nova Scotia
Time period	Lakes	Rivers	Lakes and rivers	Lakes	Lakes
1869 - 1900	5	4	0		
1901 - 1951	8		8		
1952 - 1980	16		42		
1981 - 1993	19	30	30		
1994 - 2008	21		108	1	7
Total	69	34	188	1	7

Table 2. *Mean monthly and annual air temperatures from selected meteorological stations in the Maritime provinces. Values are climate normals for 1971 to 2000 obtained from http://www.climate.weatheroffice.ec.gc.ca/climate_normals/index_e.html.*

Station	Prov.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Sep-Nov
Charlo	NB	-12.8	-11.1	-5.1	1.6	8.6	14.7	17.9	16.8	11.6	5.5	-0.9	-8.6	3.2	5.4
Fredericton	NB	-9.8	-8.2	-2.4	4.3	11.1	16.2	19.3	18.4	13.1	7.0	1.1	-6.3	5.3	7.1
Doaktown	NB	-10.7	-9.4	-3.3	3.5	10.6	16.0	19.1	18.1	13.0	6.7	0.5	-7.1	4.8	6.7
Aroostook	NB	-12.5	-10.8	-3.9	3.5	10.9	16.1	18.8	17.7	12.7	6.4	-0.1	-8.3	4.2	6.3
Miramichi	NB	-10.7	-9.1	-3.3	3.1	10.0	15.9	19.2	18.3	13.0	6.6	0.5	-6.9	4.7	6.7
Moncton	NB	-8.9	-8.0	-2.9	3.2	9.9	15.1	18.6	17.9	13.0	7.1	1.4	-5.5	5.1	7.2
Saint John	NB	-8.1	-7.3	-2.5	3.6	9.4	14.0	17.1	16.9	12.8	7.3	2.0	-4.7	5.0	7.4
Summerside	PEI	-7.9	-7.3	-2.8	2.8	9.4	15.0	19.1	18.6	13.9	8.1	2.4	-4.2	5.6	8.1
Charlottetown	PEI	-8.0	-7.8	-3.1	2.7	9.1	14.6	18.5	18.1	13.6	7.8	2.3	-4.1	5.3	7.9
Halifax	NS	-6.0	-5.6	-1.4	4.0	9.8	15.0	18.6	18.4	14.1	8.3	3.1	-2.8	6.3	8.5
Kejimkujik	NS	-6.1	-5.6	-1.1	4.7	10.5	15.2	18.4	17.9	13.3	7.9	3.2	-2.8	6.3	8.1
Cheticamp	NS	-4.9	-6.3	-2.2	3.1	9.0	14.3	18.3	18.0	13.8	8.7	4.0	-1.3	6.2	8.8
Deming	NS	-4.1	-4.5	-1.5	2.4	6.4	10.9	14.5	17.1	14.7	9.6	4.6	-0.8	5.8	9.6
Truro	NS	-6.9	-6.5	-1.8	3.9	9.8	14.7	18.4	17.8	13.4	7.7	2.8	-3.5	5.8	8.0
Sydney	NS	-5.7	-6.5	-2.7	2.1	7.8	13.3	17.7	17.7	13.4	8.0	3.3	-2.1	5.5	8.2
Yarmouth	NS	-3.0	-3.0	0.3	4.9	9.7	13.7	16.5	16.9	13.8	9.1	4.8	-0.2	7.0	9.2

Table 3. *First date when water temperature continually met or exceeded 10ºC or 15ºC and days with mean water temperature greater than or equal to 10ºC, at the Loch Ban station in Lake Ainslie, 1993 to 2002 (excluding 1994, 2001).*

Year	First date when mean water temperature continually met or exceeded		Days with mean water temperature >= 10ºC
	10ºC	15ºC	
1993	18-May	15-Jun	153
1994			
1995	21-May	11-Jun	
1996	22-May	6-Jun	150
1997	30-May	15-Jun	147
1998	5-May	13-Jun	171
1999	7-May	27-May	161
2000	17-May	15-Jun	161
2001			
2002	22-May	> 19 June	

Table 4. *Mean monthly water temperature (°C) for sites close to Miramichi Lake.*

Month	Sites	2004	2005	2006	2007
July	Taxis River		21.1	18.9	20.4
	SW Miramichi at Burntland Bk		18.9		18.0
Aug.	Taxis River		20.4	17.6	19.6
	SW Miramichi at Burntland Bk		18.6		18.4
Sept.	Taxis River		14.8	14.6	14.7
	SW Miramichi at Burntland Bk		14.1		14.4
Oct.	Taxis River		8.4	7.6	9.1
	SW Miramichi at Burntland Bk			7.6	9.1
Nov.	Taxis River	1.0	2.6	3.6	2.1
	SW Miramichi at Burntland Bk	1.3		4.1	2.7

FIGURES

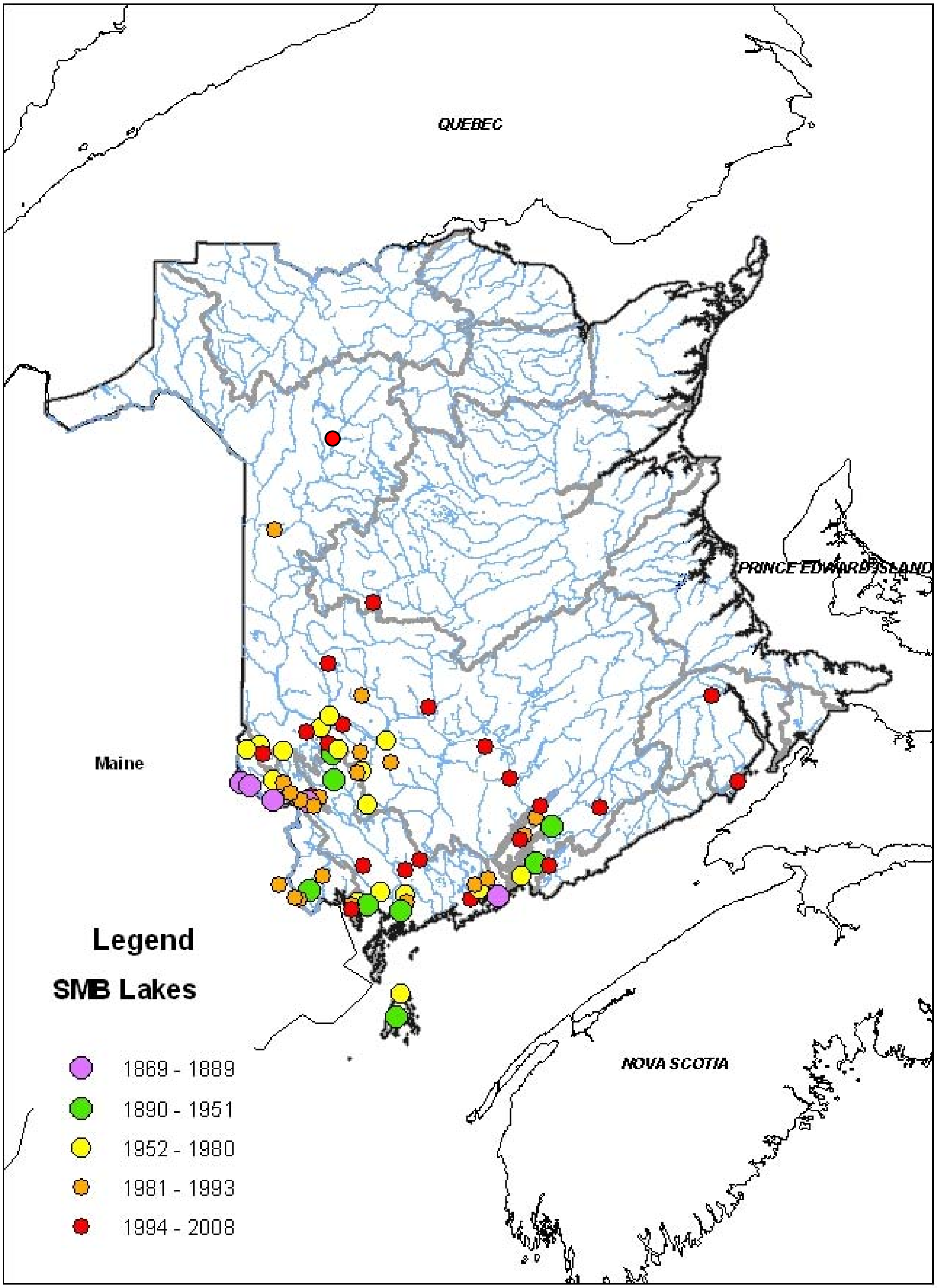


Figure 1: *Occurrences of smallmouth bass by time period in New Brunswick (Figure from Sabine (2009)). The most northern red symbol (Tobique River) is based on Chaput and Jones (2004).*

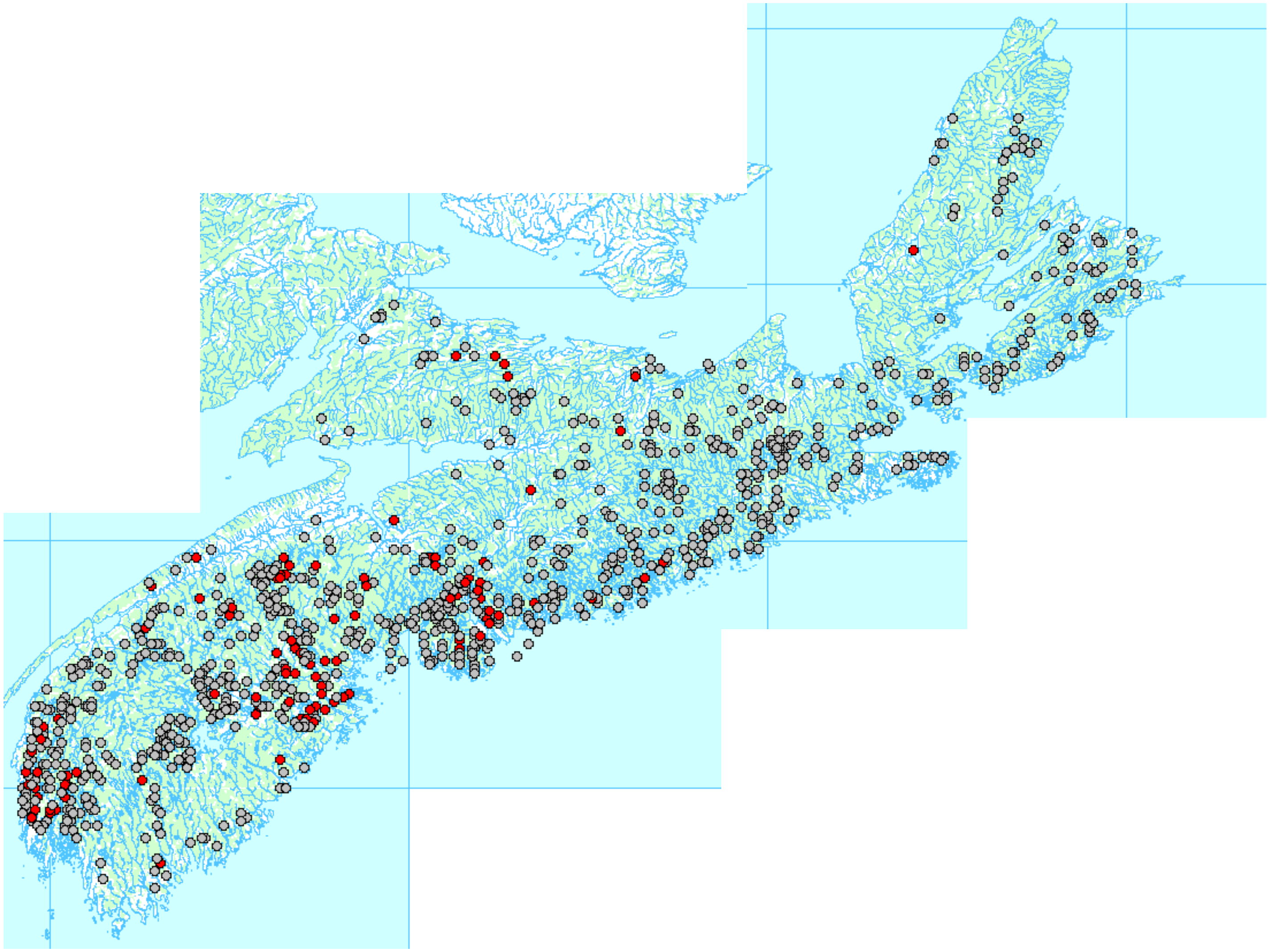


Figure 2: *Distribution of lakes (grey and red symbols) with confirmed presence (red symbols) of smallmouth bass in Nova Scotia. Data were provided by Jason LeBlanc, Province of Nova Scotia.*

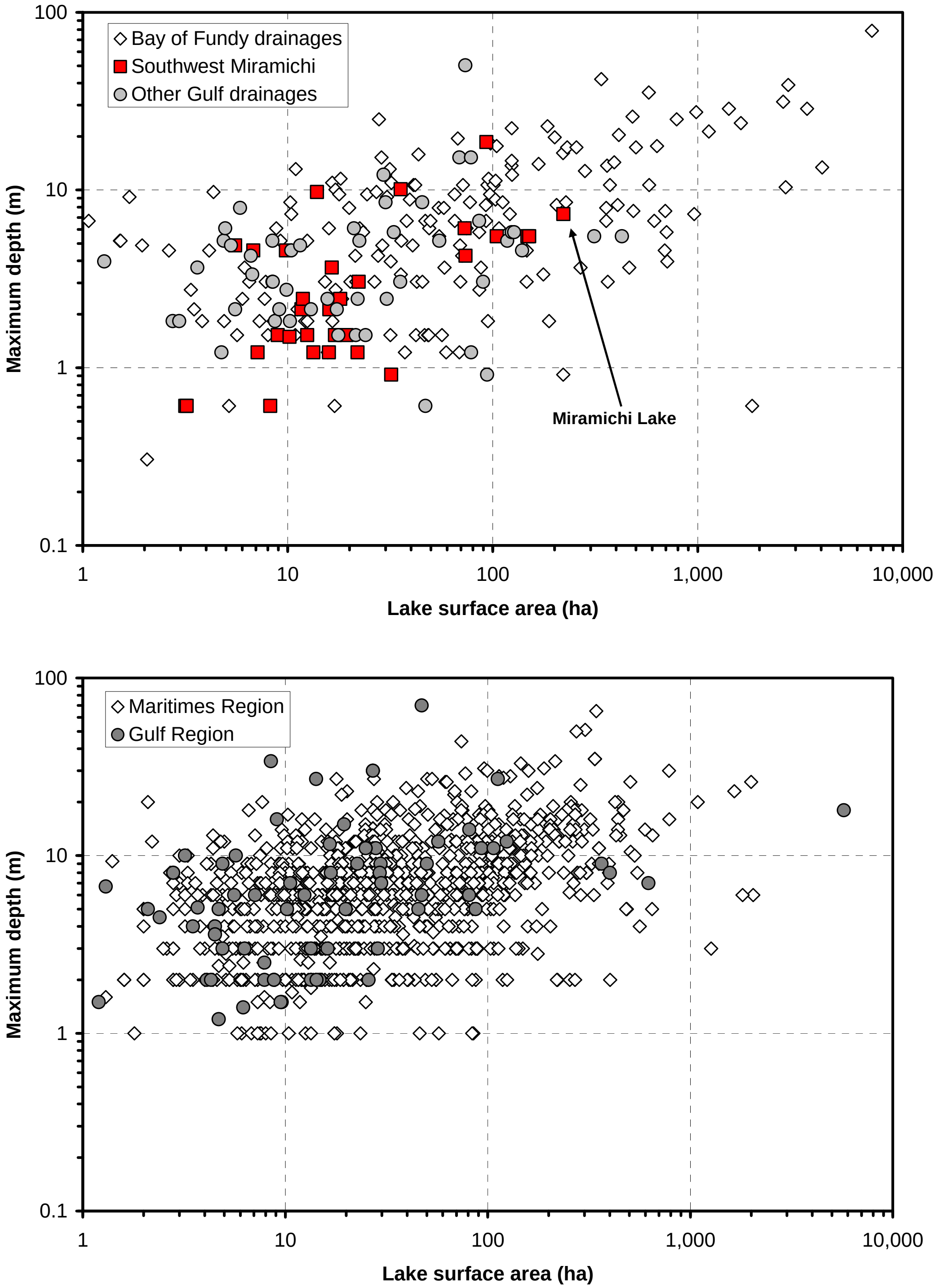


Figure 3: *Surface area (ha) to maximum depth (m) relationships for lakes in New Brunswick (upper) and Nova Scotia (lower).*

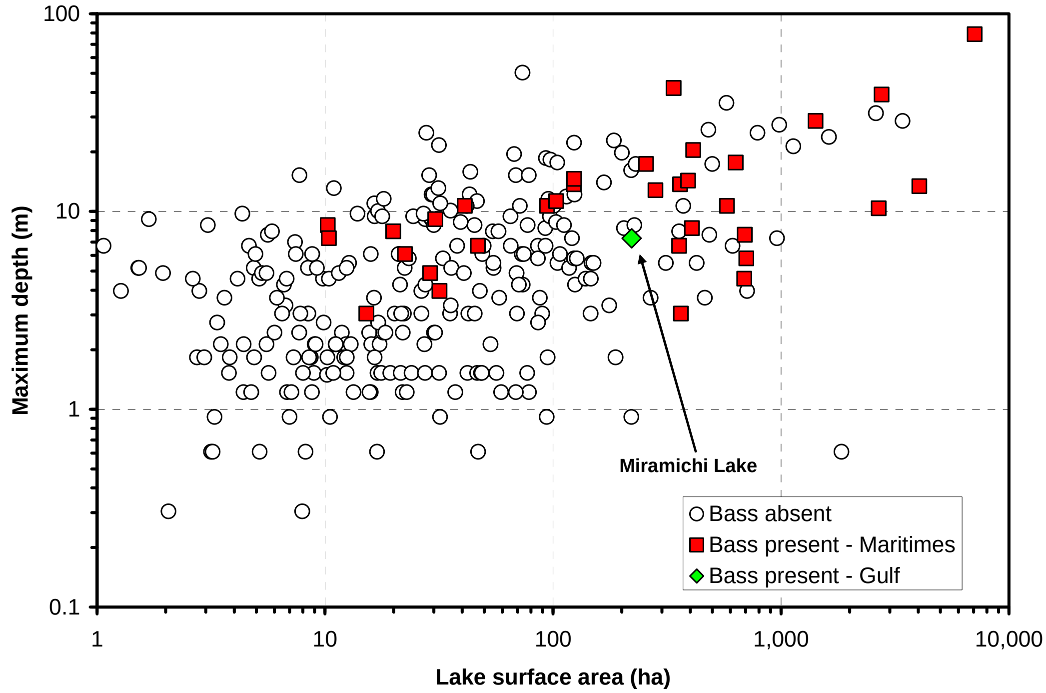


Figure 4: *Lake characteristics relative to presence of smallmouth bass in New Brunswick. Only lakes with reported surface area and maximum depth data are shown.*

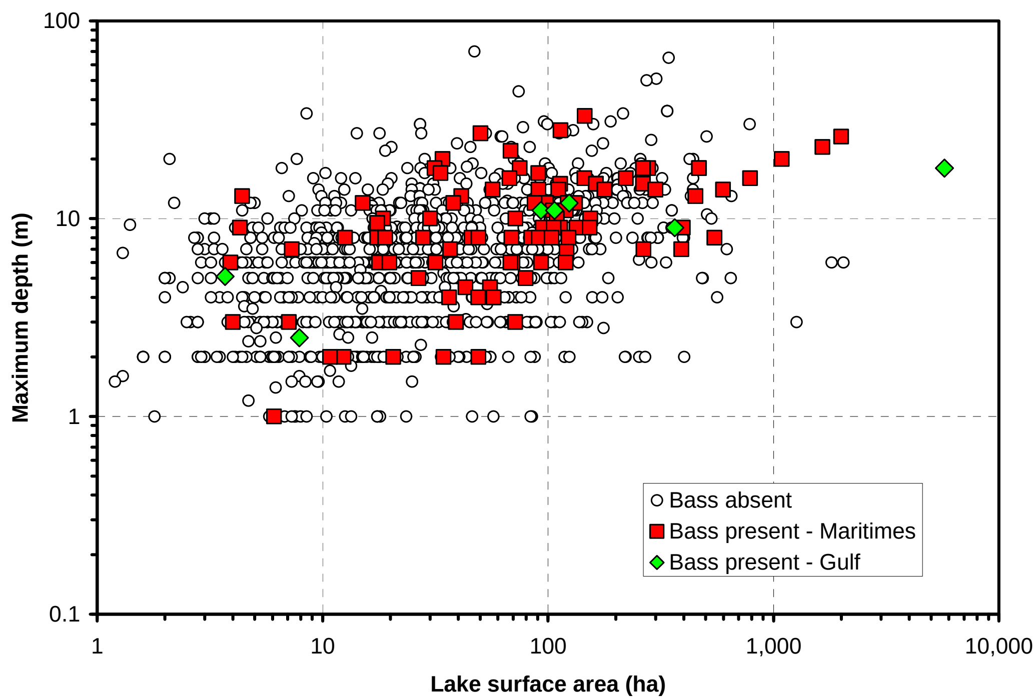


Figure 5: *Lake characteristics relative to presence of smallmouth bass in Nova Scotia. Only lakes with surface area and maximum depth data are shown.*

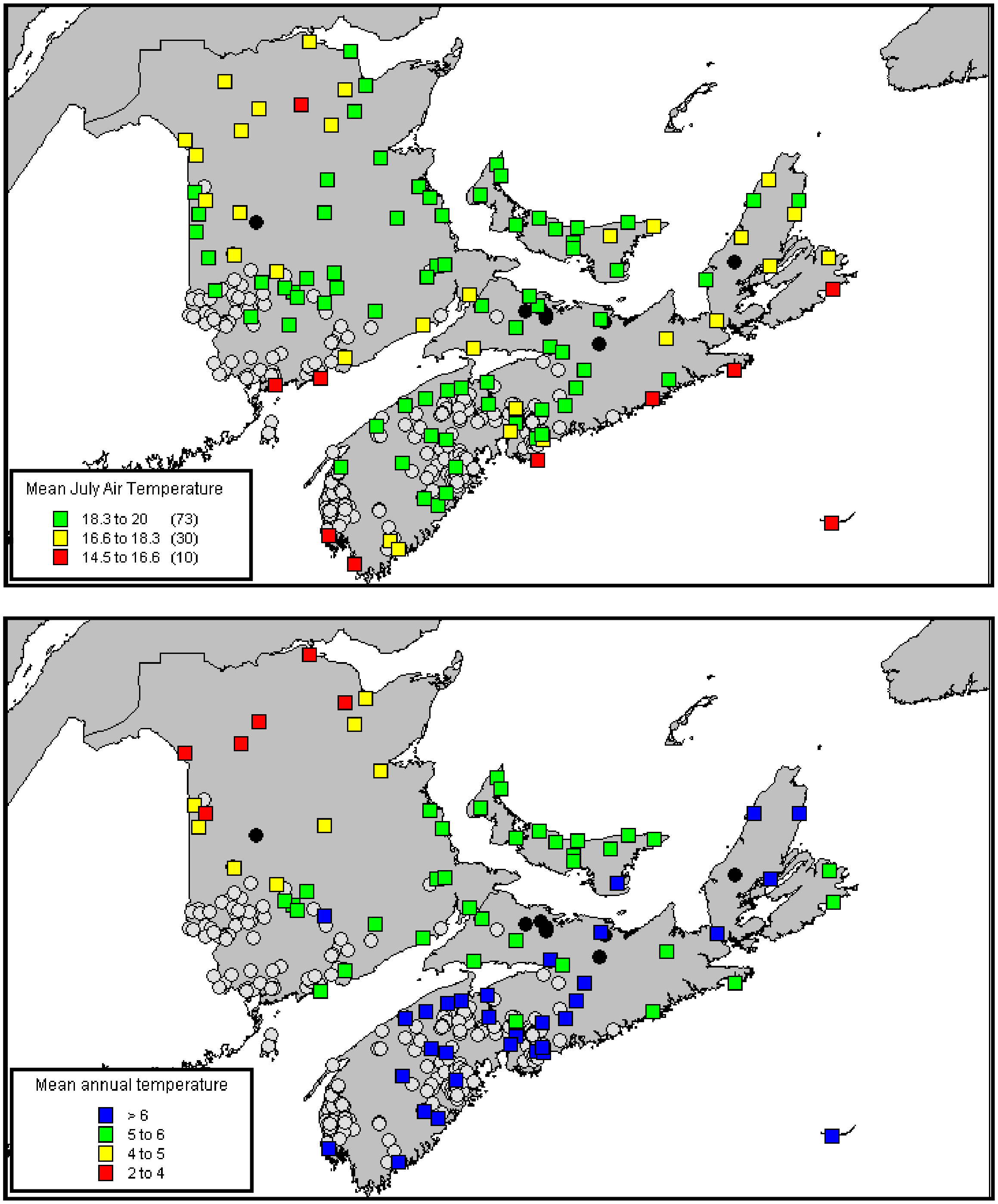


Figure 6. *Distribution of smallmouth bass in the Maritime Provinces relative to the mean air temperature for July (upper panel) and for the year (lower panel). Open circles are locations of smallmouth bass in the DFO Maritimes region, black circles are locations of smallmouth bass in DFO Gulf Region.*

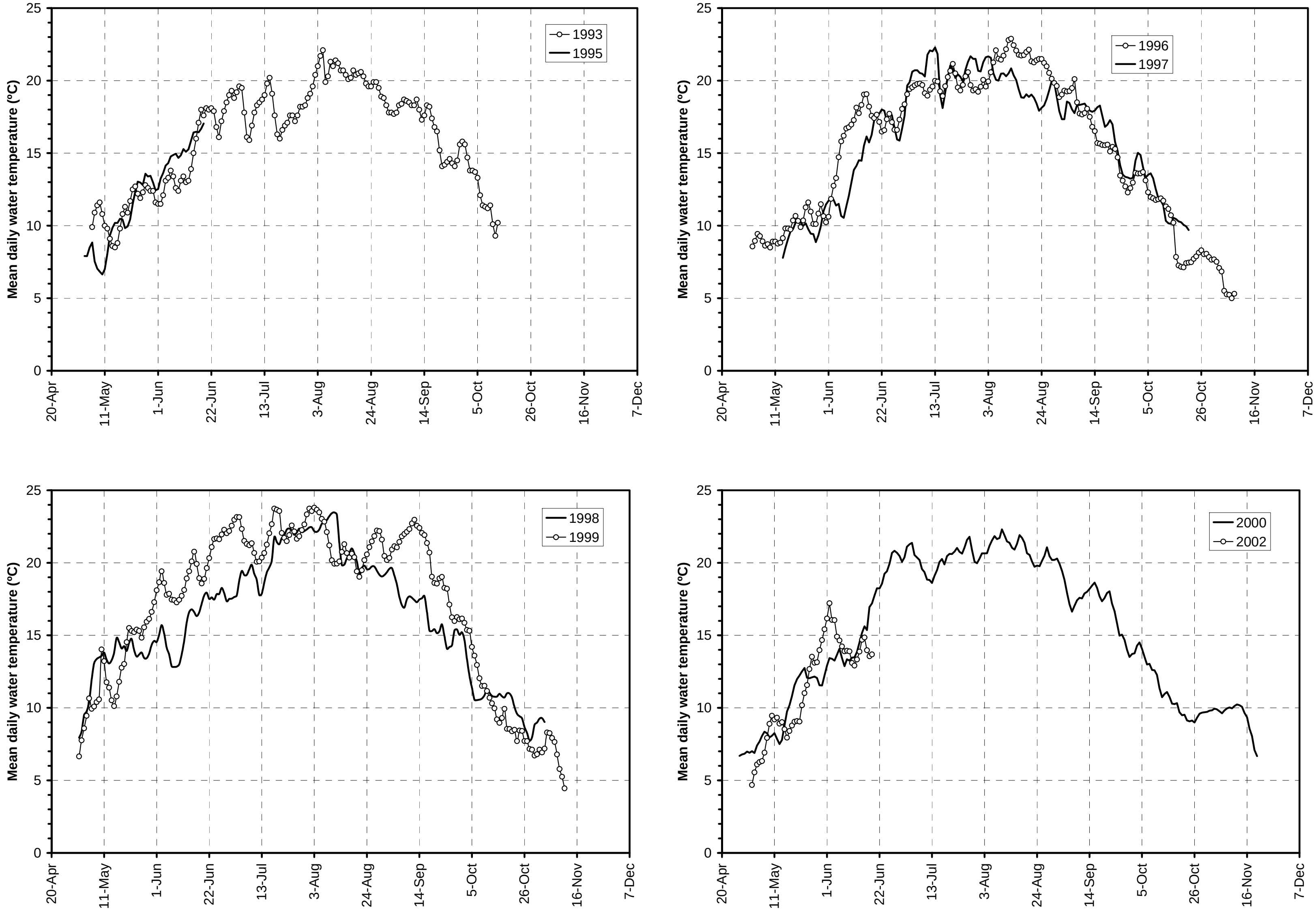


Figure 7. *Spring to fall mean daily water temperatures at the Loch Ban site in Lake Ainslie, Margaree River (NS), 1993 to 2002.*

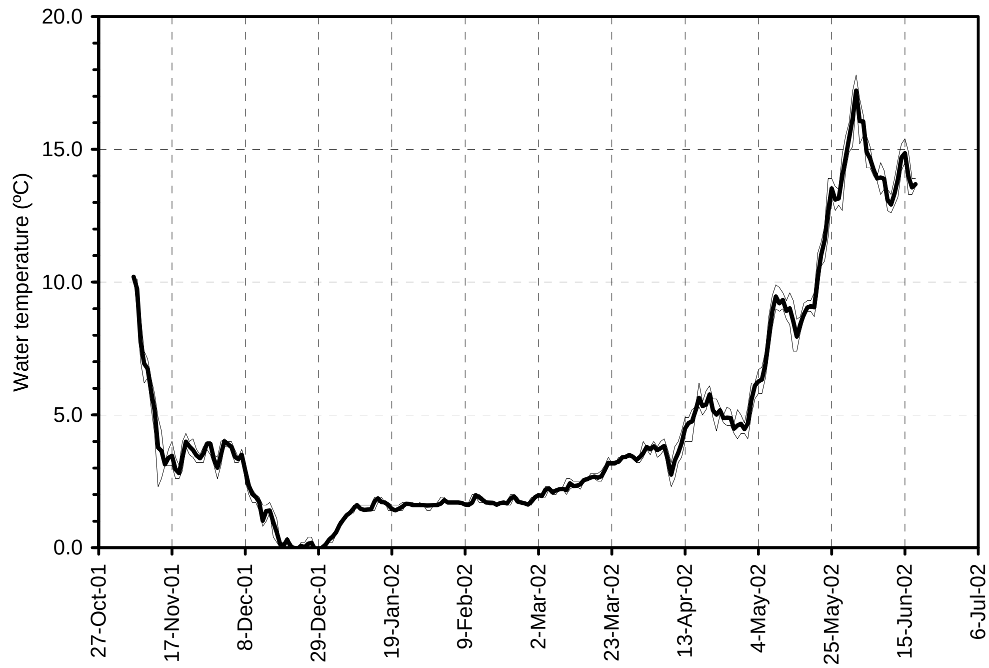


Figure 8. *Seasonal pattern of water temperatures in Lake Ainslie (mean, minimum and maximum) recorded in Loch Ban in 2001 to 2002.*

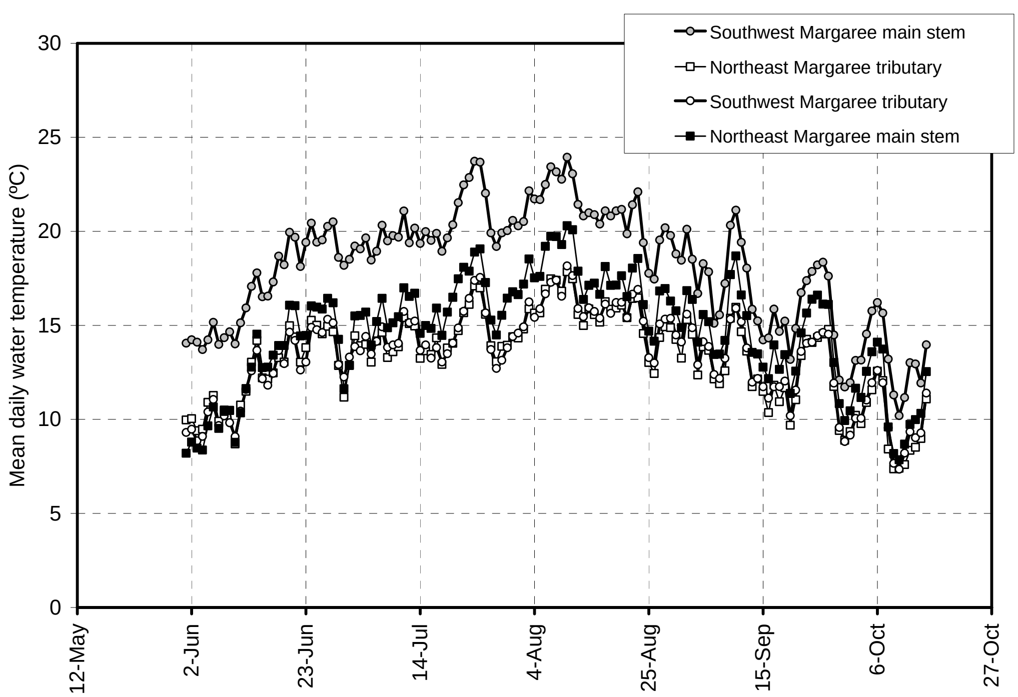


Figure 9. *Mean daily water temperature at main stem and tributary sites in the Northeast and Southwest Margaree rivers in 2001.*

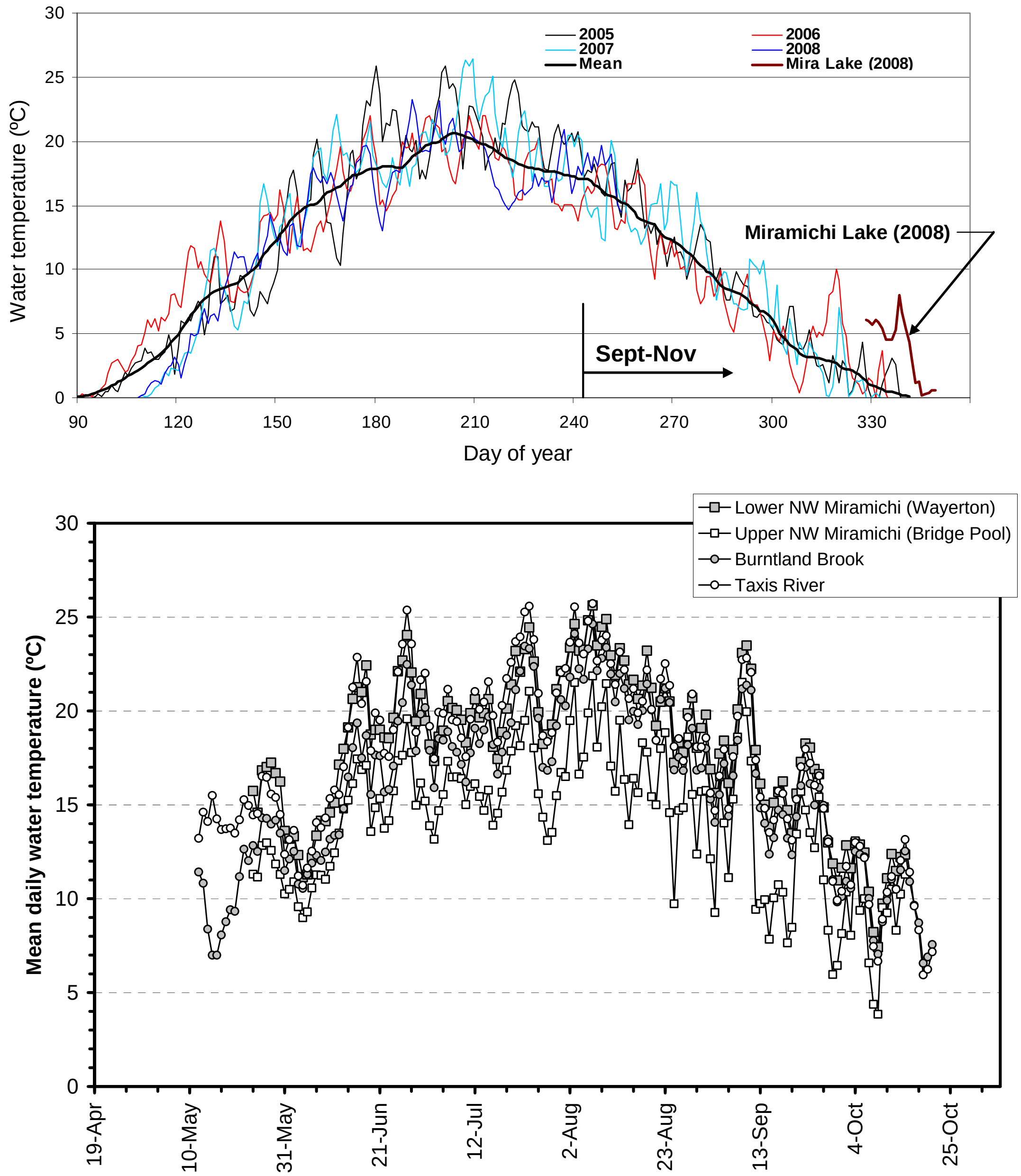


Figure 10. *Mean daily water temperature (2005 to 2008) at the Taxis River site and data collected in Miramichi Lake in 2008 (upper panel) and from selected sites in the Miramichi River in 2001 (lower panel).*

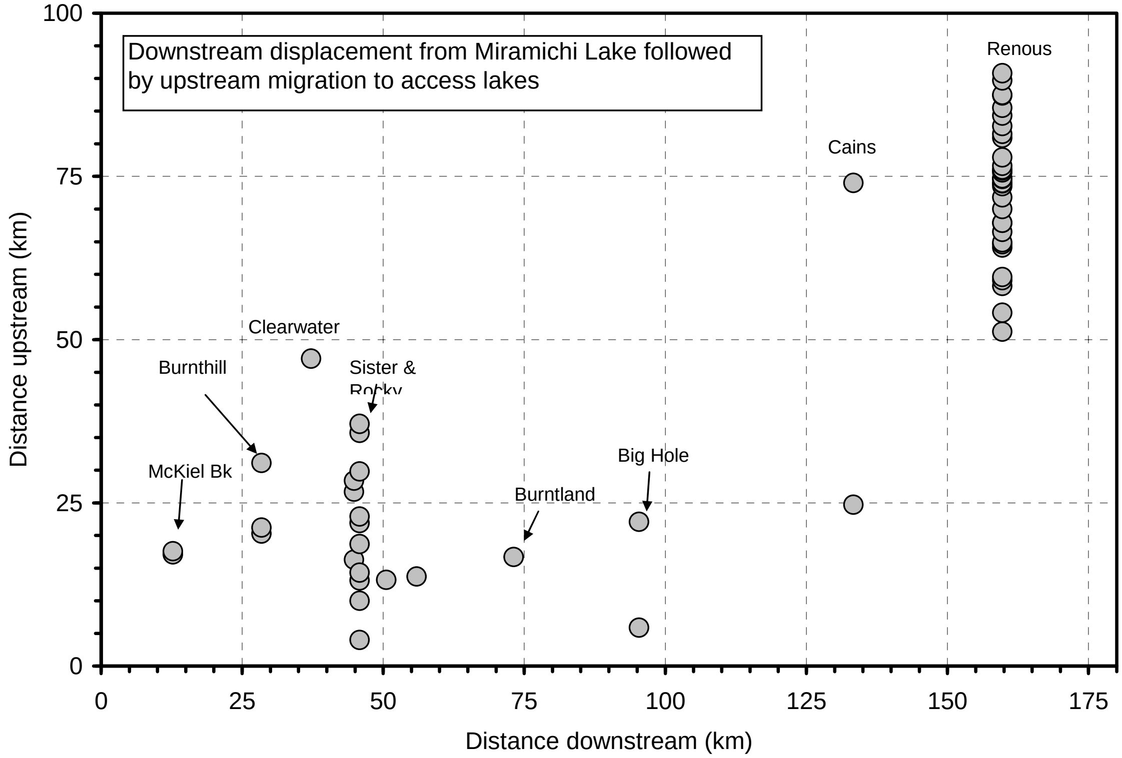


Figure 11. *Distance from Miramichi Lake to other lakes within the Southwest Miramichi River. There are no lakes available upstream of Lake Brook in the Southwest Miramichi River.*

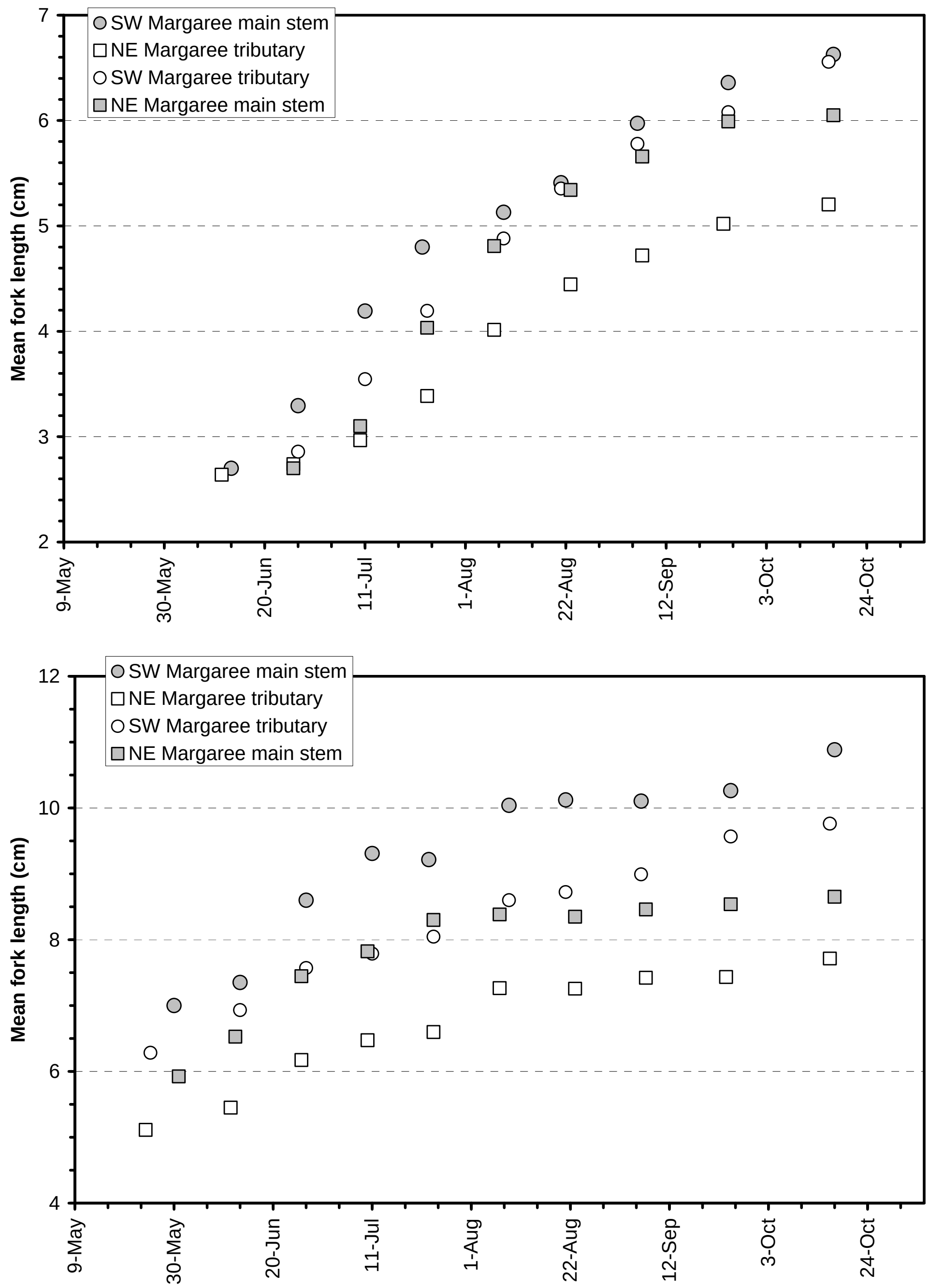


Figure 12. *Mean fork length of young of the year (upper panel) and age-1 parr (lower panel) Atlantic salmon juveniles by sampling date at main stem and tributary sites in the Northeast and Southwest Margaree rivers, 2001.*

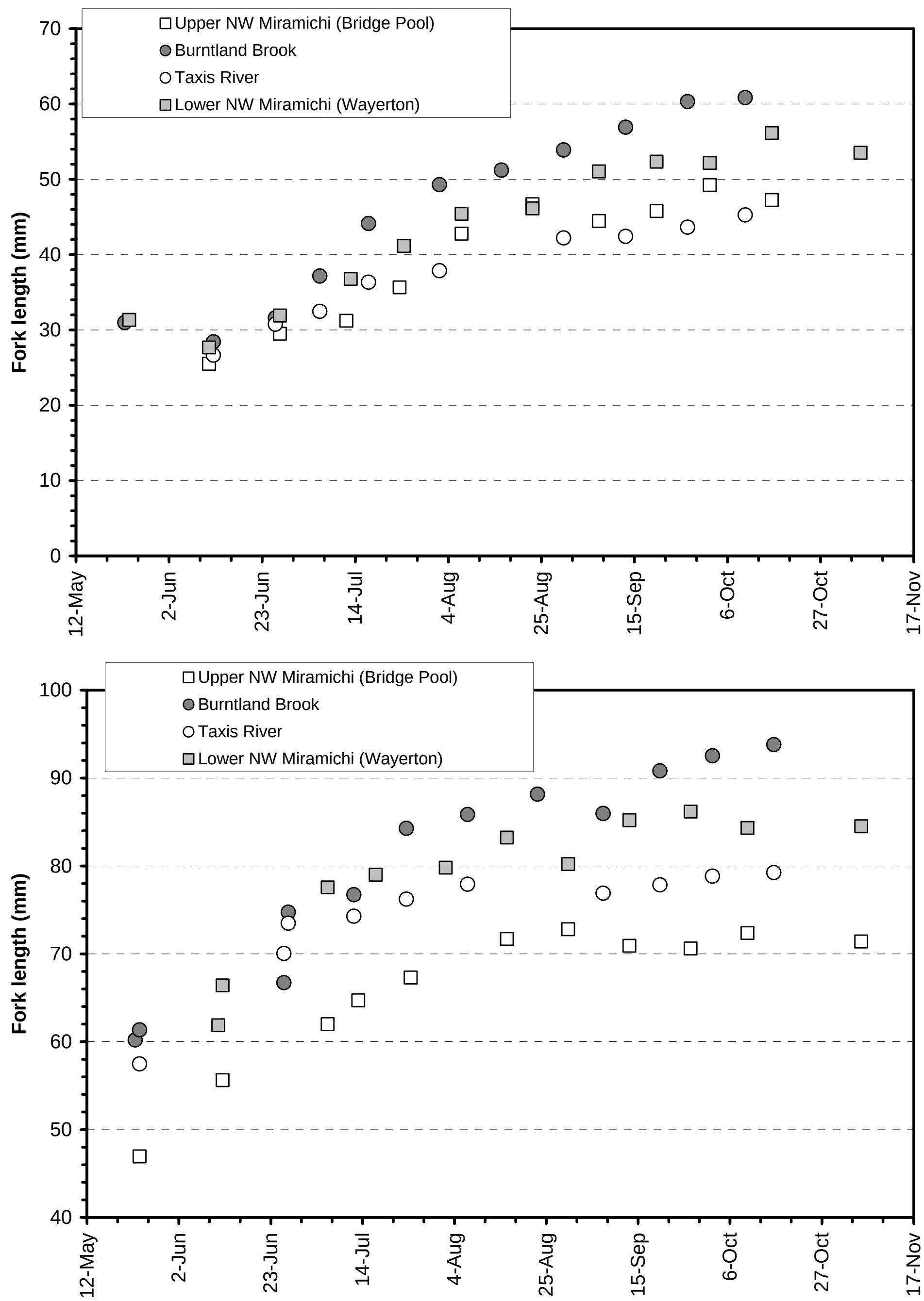


Figure 13. *Seasonal growth characteristics of young of the year (upper panel) and age-1 parr (lower panel) Atlantic salmon juveniles at selected sites in the Northwest Miramichi and Southwest Miramichi rivers, 2001.*

APPENDIX

Appendix 1. Electrofishing surveys to assess extent of distribution of smallmouth bass in Miramichi Lake and the Southwest Miramichi River.

Dave Moore
Fisheries and Oceans Canada
Oceans and Science Branch
Gulf Region
P.O. Box 5030
Moncton, NB
E1C 9B6

The following summarizes the results of electrofishing surveys conducted on October 8-10, 2008 to determine the abundance and distribution of smallmouth bass in the Southwest Miramichi watershed adjacent to Miramichi Lake (Appendix Fig. 1.1). The sampling was a cooperative effort between DFO Oceans and Science, DFO Conservation & Protection, the Miramichi Salmon Association, and JD Irving Ltd.

The Southwest Miramichi River was surveyed in the immediate vicinity of Lake Brook (the outflow stream from Miramichi Lake), as well as in Lake Brook, and in two unnamed 1st order streams flowing into Miramichi Lake (Appendix Table 1.1; Appendix Fig. 1.1). The surveys were conducted with backpack electrofishers using open site CPUE techniques (Chaput et al. 2005). Procedures were directed towards the determination of presence or absence of smallmouth bass but the catches of all species are also reported (Appendix Table 1.2). Surveys were concentrated on riffle and run habitat. Water levels at the time of the surveys were 20-40 cm higher than normal. However, samplers were confident that smallmouth bass would have been captured had they been present in the sites surveyed.

No smallmouth bass were captured at any of the nine sites surveyed. Thirteen other fish species were sampled with the most abundant catches being Atlantic salmon juveniles, blacknose dace and common shiner (Appendix Table 1.2).

<u>Reference</u>

Chaput, G., D. Moore, and D. Peterson. 2005. Predicting Atlantic salmon (*Salmo salar*) juvenile densities using catch per unit effort open site electrofishing. Can. Tech. Rep. Fish. Aquat. Sci. 2600: v + 25 p.

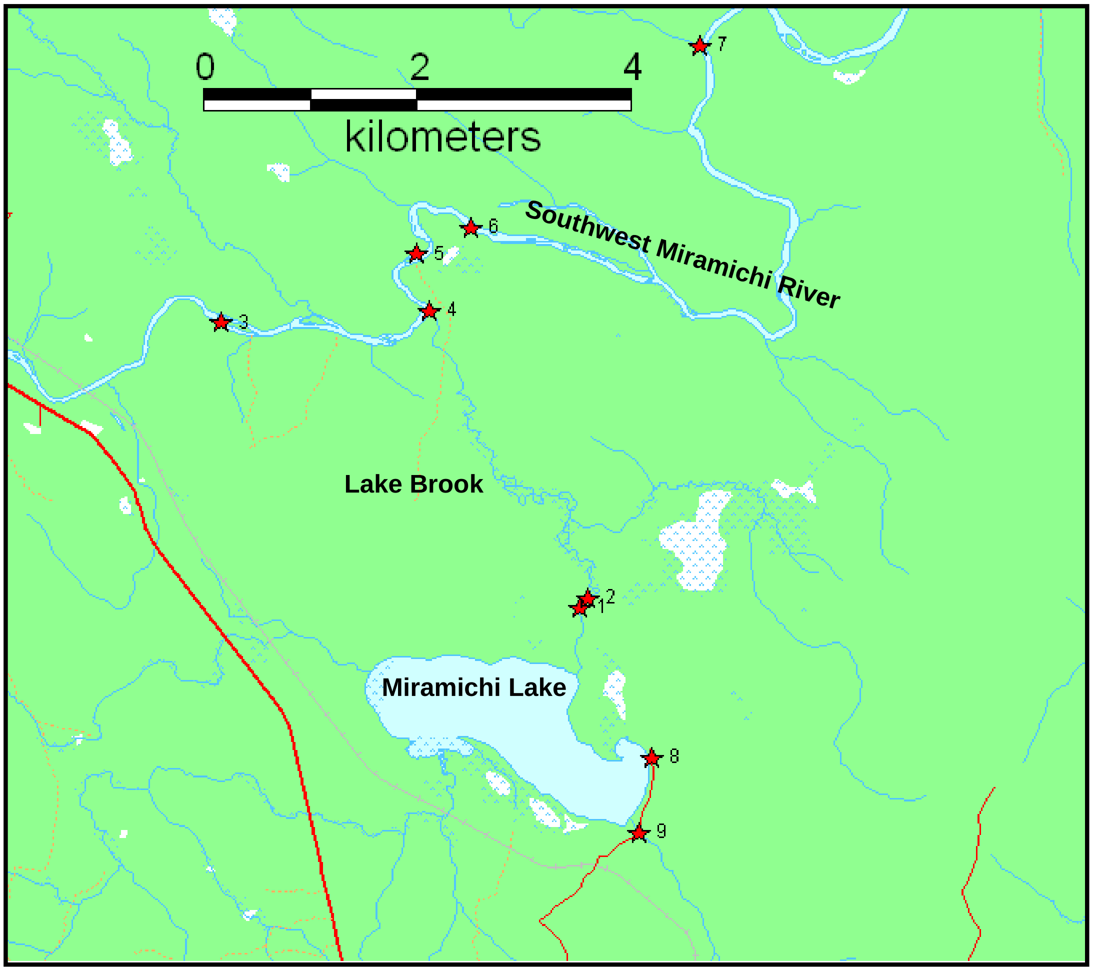
Appendix Table 1.1. *Locations of electrofishing stations in the Southwest Miramichi River, Lake Brook, and 1st order streams flowing into Miramichi Lake, 2008.*

Site	Degree decimal Lat.	Long.	Location	Stream Order
1	46.46919	66.96453	Lake Brook - 0.75 km downstream from Miramichi Lake	2
2	46.46999	66.96365	Lake Brook - 0.92 km downstream from Miramichi Lake	2
3	46.49328	67.00838	Southwest Miramichi River - 2.1 km upstream from Lake Brook	5
4	46.49427	66.98297	Southwest Miramichi River at the mouth of Lake Brook	5
5	46.49908	66.98446	Southwest Miramichi River - 0.7 km downstream from Lake Brook	5
6	46.50131	66.97794	Southwest Miramichi River - 1.9 km downstream from Lake Brook	5
7	46.51667	66.94986	Southwest Miramichi River - 8.5 km downstream from Lake Brook	5
8	46.45652	66.95579	Unnamed stream flowing into Miramichi Lake - 100 m from Lake	1
9	46.45015	66.9573	Unnamed stream flowing into Miramichi Lake - 165 m from Lake	1

Appendix Table 1.2. *Effort and catch for each of the surveys. Smallmouth bass catch is reported first then species are listed in decreasing order of abundance.*

Site	Seconds of Electrofishing	Smallmouth Bass	Blacknose Dace	Salmon Parr	Salmon YOY	Common Shiner	Bk Trout	White Sucker	Creek Chub
1	485	0	8	35	0	1	0	3	0
2	567	0	20	30	5	20	0	1	0
3	831	0	6	2	12	0	0	1	0
4	1509	0	21	7	14	27	0	5	7
5	788	0	12	10	11	1	0	0	1
6	917	0	20	7	14	0	0	0	0
7	1146	0	17	10	15	5	0	0	0
8	720	0	0	0	0	0	1	0	1
9	906	0	1	1	0	0	40	0	0

Site	Seconds of Electrofishing	Lamprey	Lake Chub	Yellow Perch	Banded Killifish	Fallfish	Stream Stickleback	American Eel
1	485	0	0	0	0	0	0	1
2	567	1	0	7	0	4	0	0
3	831	0	0	0	0	0	0	0
4	1509	0	0	0	7	0	3	0
5	788	0	0	0	0	0	0	0
6	917	0	0	0	0	0	0	0
7	1146	0	0	0	0	0	0	0
8	720	5	7	0	0	0	0	0
9	906	1	0	0	0	0	0	0



Appendix Figure 1.1. *Location of electrofishing sites on the Southwest Miramichi River, Lake Brook, and 1st order streams flowing into Miramichi Lake.*