

**REVIEW OF THE CONTROL AND MONITORING  
ACTIVITIES FOR SMALLMOUTH BASS  
(*MICROPTERUS DOLOMIEU*) IN MIRAMICHI LAKE,  
NEW BRUNSWICK, FROM 2009 TO 2017**

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**2018**

**CANADIAN MANUSCRIPT REPORT OF  
FISHERIES AND AQUATIC SCIENCES 3166**



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Cat. NoFs97-4/3165E-PDF ISBN 978-0-660-28515-3 ISSN 1488-5387

Correct citation for this publication:

Biron, M. 2018. Review of the control and monitoring activities for Smallmouth Bass (*Micropterus dolomieu*) in Miramichi Lake, New Brunswick, in 2009 to 2017. Can. Manuscr. Rep. Fish. Aquat. Sci. No. 3166: ix + 38 p.

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## ABSTRACT

Biron, M. 2018. Review of the control and monitoring activities for Smallmouth Bass (*Micropterus dolomieu*) in Miramichi Lake, New Brunswick, in 2009 to 2017. Can. Manuscr. Rep. Fish. Aquat. Sci. No. 3166: ix + 38 p.

The present manuscript is a review of the containment, control and monitoring activities of a non-indigenous fish, Smallmouth Bass (*Micropterus dolomieu*), in Miramichi Lake during 2008 to 2017. A wide range of fishing methods were used including backpack and boat electrofishing, fyke nets, gill nets, beach seining, and angling. Seventeen species, exclusive of Smallmouth Bass, were identified from the catches. The most abundant species in the catches being Yellow Perch (*Perca flavescens*), White Sucker (*Catostomus commersoni*), White Perch (*Morone americana*) and Fallfish (*Semotilus corporalis*).

A total of 7,419 Smallmouth Bass were captured and removed from Miramichi Lake since 2009, of which 97% were young-of-the-year (YOY). The population size of adult Smallmouth Bass is unknown but low catch rates from all measurable indicators each year suggest that the population size of adult Smallmouth Bass is quite small in Miramichi Lake. There is evidence of depletion of Smallmouth Bass in Miramichi Lake but the catches of YOY Smallmouth Bass since 2010 indicate annually successful reproduction and recruitment to the bass population in Miramichi Lake. Recent Smallmouth Bass catches also seem to indicate a small increase in all age groups since 2015-2016.

## RÉSUMÉ

Biron, M. 2018. Review of the control and monitoring activities for Smallmouth Bass (*Micropterus dolomieu*) in Miramichi Lake, New Brunswick, in 2009 to 2017. Can. Manuscr. Rep. Fish. Aquat. Sci. No. 3166: ix + 38 p.

Le présent manuscrit passe en revue les activités de confinement, de contrôle et de surveillance d'un poisson non indigène, l'achigan à petite bouche (*Micropterus dolomieu*), pêché dans le lac Miramichi entre 2008 et 2017. Un large éventail de méthodes de pêche a été utilisé, notamment la pêche électrique avec unité portatif et en bateau, les verveux, les filets maillants, la pêche à la senne de plage et la pêche à la ligne. Dix-sept espèces, à l'exclusion de l'achigan à petite bouche, ont été identifiées parmi les captures, et les espèces les plus abondantes dans les captures étant la perchaude (*Perca flavescens*), le meunier noir (*Catostomus commersoni*), le bar-perche (*Morone americana*) et l'ouitouche (*Semotilus corporalis*).

Au total, 7 419 achigan à petite bouche ont été capturés et retirés du lac Miramichi depuis 2009, dont 97% étaient des jeunes de l'année. La taille de la population de l'achigan à petite bouche adulte est inconnue, mais les faibles taux de capture de tous les indicateurs mesurables chaque année suggèrent que la taille de la population adulte de l'achigan à petite bouche est assez petite dans le lac Miramichi. Il y a des signes de réduction de la population de l'achigan à petite bouche dans le lac Miramichi, mais les captures des jeunes de l'année depuis 2010 indiquent que la reproduction et le recrutement de la population de bars dans le lac Miramichi sont réussis chaque année. Les prises récentes d'achigan à petite bouche semblent également indiquer une légère augmentation dans tous les groupes d'âge depuis 2015-2016.

## 1.0 INTRODUCTION

An angler fishing Miramichi Lake, New Brunswick, in September 2008 reported the capture of a 20 cm Smallmouth Bass (*Micropterus dolomieu*) to the New Brunswick Department of Natural Resources (NBDNR) (DFO 2009; Halfyard 2010). This was the first report of this invasive species in the Miramichi River system (DFO 2009). To confirm the presence of Smallmouth Bass, NBDNR conducted a survey of the lake at the end of September 2008. Five young-of-the-year (YOY) were captured using backpack electrofishers and two other Smallmouth Bass of unknown age with gillnets (DFO 2009; Halfyard 2010). To assess the extent of the dispersal of Smallmouth Bass from Miramichi Lake into other parts of the watershed, a backpack electrofishing survey was conducted in selected areas of Lake Brook and Southwest Miramichi River in early October 2008. Three YOY Smallmouth Bass and one of unknown age were discovered downstream from Miramichi Lake in the first 300 m of Lake Brook (Halfyard 2010). In a temporary effort to limit the spread of Smallmouth Bass after its discovery in Miramichi Lake, the Miramichi Watershed Management Committee with other partners erected a portable counting fence fitted with 1.9 cm mesh on Lake Brook from mid-October to the end of November 2008 (Halfyard 2010).

Ever since the first Smallmouth Bass was captured in Miramichi Lake in September 2008, considerable effort has been deployed to control and contain this invasive species (DFO 2013; Biron et al. 2014). The strategy to control the Smallmouth Bass population is based on mechanical removal using multiple fishing methods (Halfyard 2010; DFO 2013), combined with anticipated low survival rate of the YOY during the winter months (Shuter et al. 1980; Biron et al. 2014). The strategy to contain Smallmouth Bass in the lake is based on the maintenance of a physical barrier at the mouth of its single outlet, Lake Brook, combined with reduction of Smallmouth Bass population in the lake (Halfyard 2010; DFO 2013).

The scope and risk of the Smallmouth Bass introduction on the Atlantic Salmon (*Salmo salar*) population in the Miramichi River (Chaput and Caissie 2010; DFO 2009; Valois et al. 2009) and proposed control plan (Halfyard 2010; DFO 2013; Biron et al. 2014), as well as results of these control measures on the Smallmouth Bass population in Miramichi Lake for 2010 (Chaput and Moore 2018) to 2014 (Biron et al. 2014; Biron 2015) have been published, but not the exploratory field work that occurred in 2009. Detailed information was being recorded for all species captured during 2009 and early 2010, a practice abandoned in late 2010 to maximize the removal of Smallmouth Bass from Miramichi Lake (Biron et al. 2014).

The present manuscript summarizes the containment and control activities that have taken place in Miramichi Lake from 2008 to 2017. The report includes data and results from the unpublished report by O'Donnell and Reid (2009) as well as field notes. It also updates the information for the years 2015 to 2017 which have not been published previously. The objective of the report is to provide a better understanding of the current interpretation of the data, address issues related to the lack of estimation of the Smallmouth Bass population size in Miramichi Lake, and discuss the effectiveness of the containment and removal strategy.

## 2.0 METHODS

Miramichi Lake is located in the headwater of the Southwest Miramichi River basin in New Brunswick. It is approximately 2.8 km in length by 0.8 km in width with an estimated surface area of 2.21 km<sup>2</sup> (221 ha). It is a relatively shallow lake, the majority of the lake is less than 3.75 m deep with two deep holes of maximum depth less than 7.65 m (Figure 1). Miramichi Lake has one outlet, Lake Brook, which extends over 5 km to join the Southwest Miramichi River. In 2010, the lake was divided into 16 sectors to facilitate localization on the lake during fishing effort. The sectors arranged sequentially around the lake from a random starting point soon became centered on sectors 16 and 1 (Figure 1), the inferred preferred spawning and rearing areas located next to Lake Brook (DFO 2013).

### 2.1 BARRIER ON OUTLET (LAKE BROOK)

In 2009, two barrier fences were installed in Lake Brook; the upper barrier was placed at the outlet of Miramichi Lake, where it enters Lake Brook, while the lower barrier was located 500 m above where the brook flows into the Main Southwest Miramichi River (Figure 2). Both the upper and lower barriers were composed of a series of steel bars spaced at 12 mm intervals covered with a 12 mm mesh net.

Since 2010, only one containment barrier has been installed, at the outlet of Miramichi Lake where it enters Lake Brook, as soon after the ice cover disappeared from the lake. The containment barrier consisted of two fences; the first one made of steel bars installed at 12 mm intervals and lined with a 12 mm mesh net, while the second fence (or debris fence) was installed two to three meters upstream of the first fence and was constructed with rebars installed at two foot intervals and also lined with a 12 mm mesh net. The containment barrier was usually checked daily, and all Smallmouth Bass captured were removed from the system.

Gaspereau (*Alosa pseudoharengus*) and other species migrating up Lake Brook to spawn in Miramichi Lake, or out of Miramichi Lake after spawning, accumulated at the barrier and were let through the fence on a daily basis. To allow movement in and out of the lake, the upstream or downstream barriers were opened and fish were trapped between the two fences. Beach seining was then conducted between the two fences to capture and manually transport fish either upstream or downstream of the barrier. All fish captured between the two fences were examined to ensure that no Smallmouth Bass were released. Another safety measure was to beach seine the front of the debris barrier before letting fish migrate downstream once the YOY Smallmouth Bass were observed in the lake.

A modification to the process of moving fish downstream was implemented following the high mortality rate observed from manipulating YOY Gaspereau in 2009 and 2010. Once YOY Gaspereau gathered in large numbers (i.e. thousands) upstream of the barrier to move out of the lake, safe passage was achieved by lowering a small section of the debris fence and lifting the net from a small section of the barrier fence, in the opposite corner, to let the fish through without manipulation (Figure 3). Control of the species and size of fish passing through the barrier was achieved by making the fish travel over shallow areas while being actively monitored by crew members, ready to block the route if required. The juveniles were not counted due to the large numbers, but rough estimates were taken daily.

### 2.2 BOAT ELECTROFISHING

The boat electrofishing protocol was adapted from the Fisheries and Oceans Canada Great Lake Laboratory (Brousseau et al. 2005). Boat electrofishing was carried out at depths of two meters or less and at boat speed of  $\pm 0.3 \text{ m sec}^{-1}$  (Brousseau et al. 2005), mostly at night (Paragamian 1989), and preferably when water temperature was above 10 °C (Armour 1993).

Two electrofishing boats were used to sample shallow waters (depth less than 1.5 m) along the littoral zone of the lake: 'Boat A' in 2010 and 2011 and 'Boat B' from 2011 to 2016. 'Boat A' measured 4.6 m long and was equipped with a Smith-Root 7.5 GPP (Generator Powered Pulsator) electrofishing unit. Two booms measuring three m long were positioned at each corner of the bow and held the anode arrays. Anode arrays were configured as six droppers arranged in a 91 cm (36 inch) circular pattern. 'Boat B' measured five m long and was also equipped with a Smith-Root 7.5 GPP electrofisher with similar booms and anode arrays made of six droppers. Each boat was configured to use the hull as the cathode although 'Boat B' was equipped with additional cathode dropper wires attached along the sides and front of the fishing deck. The voltage was set at 1000 V at a frequency of 60 Hz. One person operated the boat and unit and two people positioned at the bow used dipnets to recover the fish. Boat electrofishing was mostly conducted in late evening or after dark. Some daytime electrofishing was conducted when the lake was calm and visibility was good but these conditions were rare.

At the beginning of the boat electrofishing program in 2010, all the fish species were brought aboard, put in a live box, and a sub-sample was processed for detailed sampling of the catch per sectors. However, from August 30<sup>th</sup>, 2010, onward, and to allow for greater sampling effort, only Smallmouth Bass were targeted and brought onboard.

In 2010 to 2012, the sampling protocol called for the entire near shoreline of the lake to be electrofished at least once per week, from May to November, to identify the distribution of Smallmouth Bass along the littoral zone of the lake. Two nights with favourable conditions were required to electrofish the entire near shore of the lake. During the remainder of the week, electrofishing effort focused on areas where Smallmouth Bass were observed that week. During the spawning period (May - June), increased electrofishing efforts were directed toward the spawning grounds (sectors 1 and 16; Figure 1) to capture spawning adults or males guarding nests. The location of the spawning grounds was inferred based on the presence of adults and the location of first YOY occurrence in previous years.

For 2013 to 2016, boat electrofishing effort was reduced to four weeks of sampling effort: two weeks in June and two weeks in August in 2013 and 2014, and four consecutive weeks at the end of July - beginning of August in 2015 and 2016.

No boat electrofishing occurred in 2017.

### **2.3 BACKPACK ELECTROFISHING**

Smith-Root Model LR 24 or Model 12B backpack electrofisher units were used and the default setting was I-5 (pulse width = 3 ms, pulse frequency = 50 Hz, standard wave form (uniform pulses) at voltages ranging from 500 to 700 V. The voltage adjustments were made as needed to adapt to changes in conductivity of the water.

Lake Brook was divided into two sections for the purpose of backpack electrofishing: the upper section was from the barrier fence at the outlet of Miramichi Lake to a natural debris barrier located approximately 300 m down the brook (reported to be 270 m in 2009 and 350 m in 2010), and the lower section from the natural debris barrier to the Southwest Miramichi River. The natural debris barrier washed away in 2011, and thereafter, electrofishing in the upper section of Lake Brook was conducted from the containment barrier to a riffle located approximately 400 m downstream. Special attention was paid to structures in the brook, especially along the shoreline in slow moving water at depths of 30 to 100 cm. One to three electrofishing units were used at a time. In 2009 and 2010, the deepest areas of the lower section were covered by operating the backpack from a canoe.

Backpack electrofishing was also conducted in Miramichi Lake and mainly targeted the YOY in the shallow near shore area of the lake. One to three units were used at a time. The

electrofisher crew moved in a zigzag pattern along the shoreline (up to 20 - 25 m from shore) and targeted large structures such as rocks and logs.

No backpack electrofishing occurred in 2017.

## **2.4 ROTARY SCREW TRAP**

In 2009, a rotary screw trap was installed downstream from the lower barrier fence as a secondary capture method and operated on a daily basis.

## **2.5 GILL NETS**

In August 2009, a weekly gillnetting program was conducted in Miramichi Lake that sampled three depth categories (shallow, medium and deep) and three time categories (day, evening and night). Up to ten gill nets were deployed, with nine of the nets being 70 ft to 100 ft long, and the other was a 300 ft variable panel net, with mesh sizes of one to four inches. In September 2009, a change was made to the sampling protocol because of the large amount of time associated with the sampling in August. The new sampling protocol consisted of a 24 hour a day gill net set using three to nine 70 ft nets with mesh sizes ranging from three to five inches.

In 2010 to 2014, between 17 and 23 gillnets constructed of grey, white or green multifilament, or clear monofilament, with mesh sizes of 3, 3.25, 3.5, 4, and 5 in stretched mesh were used in 24 hour a day sets. Most nets were 30 m in length but nine nets were 22.9 m in length and four nets were 45.8 m in length. All nets were two m deep. Gillnet fishing effort focused in areas of the lake known to support adult Smallmouth Bass from previous years and were mostly installed near the two deep holes of the lake and near shore in sectors 1, 4, 5 and 16. After July 2010, catches of species other than Smallmouth Bass were not always reported or counted to allow for greater sampling effort towards Smallmouth Bass. Since 2015, the old grey, white or green multifilament gillnets are slowly (three to five per year) being replaced by new clear monofilament of 2.5 and 3 inches mesh size only. The fishing techniques on the shallow area also changed in 2017, and nets were set with a 45° angle along the shore.

A modified gill net sampling protocol occurred in 2011 with the goal to estimate the adult Smallmouth Bass population. A 20-day random sampling program was initiated that spread the fishing effort throughout the lake and ensured that no areas that potentially supported adult Smallmouth Bass were overlooked. The lake was divided into a grid of 22 squares of 250 m<sup>2</sup> each (Figure 4). Twelve gillnets were assigned randomly to a fishing zone using the Microsoft Excel's random number generator. On each day, gillnets were fished, removed and reset to a new random location.

## **2.6 FYKE NETS**

Since 2009, fyke nets were intermittently fished throughout the field season in all sectors of Miramichi Lake. Daily fyke-netting effort varied between four and eight nets (only two fyke nets fished in 2009) and was concentrated in areas known to support Smallmouth Bass along the shallow areas of the lake. The fyke nets were constructed of 0.5 inch mesh with either 3 x 3 ft or 3 x 6 ft frames. The 3 x 3 ft nets had wings and a leader of 80 ft, 180 ft or 280 ft depending upon fishing location. The 3 x 6 ft nets had a 100 ft leader but no wings.

There is a period of time from mid-July to mid-August when large numbers of juvenile Gaspereau made fishing fyke nets impossible. For example, a single set that occurred on July 28, 2009 was estimated to contain over 50,000 YOY Gaspereau (O'Donnell and Reid 2009). Therefore, since July 28, 2009, fyke nets have not been fished between mid-July to mid-August or have been set in areas with fewer YOY Gaspereau.

A large fyke net was also regularly fished in 2010 to 2012 below the containment barrier as a secondary safety measure to catch possible Smallmouth Bass escapees.

## **2.7 BEACH SEINING**

From 2010 to 2015, beach seining was initiated soon after YOY Smallmouth Bass emergence had been first observed from other fishing method such as boat electrofishing, backpack electrofishing or fyke nets. Since 2016, beach seining started in mid-July. A beach seine measuring 50 m long, 2 m deep with a 12 mm mesh was used in areas that had suitable depth and substrate for beach seining, or were known to support YOY Smallmouth Bass from previous years. Smallmouth Bass were separated from all other species and retained; all other species were released back into the lake without further biological sampling.

## **2.8 OTHER CAPTURE METHODS**

Opportunistic angling was conducted each year on spawning grounds and near large boulders and structures in Miramichi Lake throughout the summer, as well as the entire Lake Brook tributary and part of the inlets.

Angling effort was greatly increased on June 3, 2011, with the help of the experienced “pro” bass anglers from the NB Sport Fishing Association. Seven boats with a total of 16 anglers participated, with calm conditions throughout the entire day.

Opportunistic snorkelling (with dip net) occurred late in July-August around docks, boats and diving platforms to target possible YOY Smallmouth Bass hiding under these structures in Sectors 1, 3 and 4.

In 2011, a test-trial using a purse-seine was conducted in the two deep holes to capture Smallmouth Bass  $\geq$  age 1 which are expected to move into deep areas of the lake to overwinter. The purse seine (250 feet long, 23 feet deep and 1 $\frac{3}{8}$  inch mesh) was made according to Levi (1981). The purse seine was operated using two Boston Whalers (16 feet long).

## **3.0 RESULTS**

Of the 7,419 Smallmouth Bass captured and removed in Miramichi Lake and Lake Brook since 2009, 97% were YOY (Table 1). There are two ways to consider the Smallmouth Bass catch data: total removal in number of fish which puts emphasis on the capture of YOY each year, or removal in terms of total biomass which emphasizes the capture of adults each year (Figure 5). All geo-localized adult Smallmouth Bass captures since 2010 were made in sectors 14 to 5 (Figure 1), with 65% of all adult caught in sectors 1 and 16 (Table 2). All geo-localized juvenile Smallmouth Bass captures since 2010 were made in sectors 15 to 2, sector 5 and sectors 9 and 10, with 78% of all juvenile caught in sectors 1 and 16 (Table 2). The YOY Smallmouth Bass were captured in all sectors during the early years (2010-2011), but since 2012 the majority (99.75%) have been captured in sectors 12 to 6 (i.e., the all-day sun exposed side of the lake) (Table 2).

During 2010 to 2016 (i.e., when all sampling methods were in use), the largest numbers of YOY Smallmouth Bass were captured by beach seining (46% of catch) followed by electrofishing boat (43%). The largest numbers of juveniles were captured with fyke nets (45%) and electrofishing boat (37%) and the largest numbers of adults were captured with gill nets (44%) and electrofishing boat (36%) (Table 3).

Three of the 17 native species (i.e. excluding Smallmouth Bass) captured in Lake Brook and Miramichi Lake would be considered top predators; Brook Trout, White Perch and Yellow Perch (Table 4).

### **3.1 BARRIER ON OUTLET (LAKE BROOK)**

In 2009, the upper barrier in Lake Brook was operated from May 11 to November 3, while the lower barrier was operated from May 18 to September 30 (Figure 2). The upper barrier was not breached in any high water event while the lower barrier was breached in May when high water pushed the barrier back 2.5 m. Since 2010, only the upper containment barrier has been installed in the outlet of Miramichi Lake, where it enters Lake Brook, and operated from early May to late October (Table 5). One YOY Smallmouth Bass was captured between the two fences of the barrier during monitoring of downstream movements of YOY Gaspereau in 2010.

Fourteen species of fish were passed over the barriers at Miramichi Lake in 2009 (Table 6). Adult Gaspereau began to migrate up Lake Brook to Miramichi Lake on May 29, and leave the lake on June 18, 2009. Approximately 1 million juvenile Gaspereau left Miramichi Lake between July 26 and August 3, 2009 (O'Donnell and Reid 2009).

Based on the 2010 to 2017 field notes from the barrier crew supervisor, the bulk of the Gaspereau run entered the lake each year at the end of May, and began to trickle out of the lake by mid-June while some unspent adult were still coming in. Young-of-the-year Gaspereau exiting the lake appeared to leave in successive waves over the summer from mid-July to late September, with the peak being in late July-early August (up to 200,000 fish/day). The latest YOY Gaspereau to have left the lake was reported on October 5, 2010 when a group of 5,000 Gaspereau measuring between 75 and 90 mm were let out of the lake and into the brook.

### **3.2 BACKPACK ELECTROFISHING**

#### **3.2.1 Lake Brook**

The upper section of Lake Brook was backpack electrofished on a weekly basis from June to October in 2009 and from May to October in 2010 to 2012 (Table 7). Multiple electrofishing units (two to three) were used in 2009 to 2011, but only one unit was used in 2012. In 2013 to 2016, backpack electrofishing in the upper section of Lake Brook occurred one or two times in August using three electrofishing units (Table 7). A total of 25 YOY and seven juvenile Smallmouth Bass were caught in the upper section of Lake Brook with the majority (n=30) captured in 2008 to 2010 (Table 7).

The lower section of Lake Brook was electrofished on four occasions by the Miramichi Salmon Association in 2009 (June 2 and 17, July 16 and August 13), once by Fisheries and Oceans in 2010 and, once by the Province of New Brunswick in 2016. No Smallmouth Bass were captured in the lower section of Lake Brook.

In 2009, seventeen species of fish were captured in Lake Brook during electrofishing (Table 6).

#### **3.2.2 Shore of Miramichi Lake**

The Miramichi Salmon Association electrofished 2.25 km of Miramichi Lake shoreline habitat on July 9, 2009 and did not find any Smallmouth Bass. In 2010, most of the shoreline of Miramichi Lake was sampled by backpack electrofishing during July and August (Table 8). A total of 280,934 seconds of shocking time were recorded resulting in the capture of 178 YOY Smallmouth Bass in most of the sectors around the lake (Table 8). In 2011 and 2012, electrofishing targeted only areas known to support YOY Smallmouth Bass based on 2010 knowledge, however, the effort (shocking seconds) and sectors were not always recorded. In total, 52 YOY Smallmouth Bass were captured in 2011 and 10 in 2012 (Table 8). From 2013 onward, backpack electrofishing along the shores of Miramichi Lake was reduced to a couple of events in August in sectors 1, 15 and 16, with only one YOY Smallmouth Bass caught in sector 1 in 2016. During that period, other YOY Smallmouth Bass were observed but were seemingly unaffected by the various settings of the backpack electrofisher while all other species were

being stunned. It was suggested that water temperature reaching 23.5°C or more at the edge of the lake in August may be too warm for this technique to be efficient at capturing YOY Smallmouth Bass (Biron 2015).

### **3.3 ROTARY SCREW TRAP**

A rotary screw trap was installed downstream of the lower barrier fence as a secondary capture method and operated from May 13 to July 28, 2009. Low water conditions impeded with the wheel rotation on May 15, 26 and 27, June 12 and July 10, 2009. A total of 16 species were collected in the rotary screw trap (Table 6). A total of 29 Atlantic Salmon smolts were captured between May 13 and May 20, 2009.

### **3.4 BOAT ELECTROFISHING**

Boat electrofishing effort averaged 130 hours per year between 2010 and 2012, and 35 hours per year between 2013 and 2016 (Table 9). Catches were not compiled according to the vessel used and it was not possible to compare capture efficiency between boats. After acquiring the new electrofishing 'Boat B' in 2011, a wider and more stable working platform, 'Boat A' was used only when enough crew members were present at the lake to operate a second electrofishing vessel or when 'Boat B' was unavailable. The majority of the effort was conducted after sunset and daytime sampling effort was abandoned after 2014 (Table 10). Day-time catch-per-unit-effort was generally lower than night-time (Table 11). Boat electrofishing catches varied between 11% (2013) to 67% (2015) of the total annual Smallmouth Bass catches, contributing to 43% of the total catch between 2010 and 2016 (Table 3).

From 2010 to 2012, and with very few exceptions due to mechanical problems or uncooperative weather, the near shore of the lake was entirely electrofished every week to quantify the distribution of Smallmouth Bass. The sectors known to support Smallmouth Bass were thereafter electrofished more intensively (sectors 1 and 16; Table 12). The capture of juveniles and adults was sporadic throughout the sampling period and occurred mostly from May to July in sectors located near the spawning grounds (sectors 1, 15 and 16). In 2012, all catches of YOY Smallmouth Bass were restricted to sectors 1 and 16 (Table 12).

In 2010, a diverse fish fauna was sampled with the boat electrofisher and the most abundant species enumerated were Yellow Perch and White Perch (Table 13).

### **3.5 GILL NETS**

Staff from the New Brunswick Department of Natural Resources set 2.5 inch mesh gill nets on July 8 and 9, 2009 and captured two adult Smallmouth Bass, one was an unspent female and the other was of unknown sex.

Forty gill net sets were done by the Miramichi Salmon Association in August 2009, with a total of 330.9 hours of net time in the water. The 40 net sets yielded eight species and 755 individual fish. Most fish were captured during the daytime (Table 14a), in the smaller mesh sizes (1-2"), with less fish being captured as mesh size increased (Table 14b), and in shallow and deep sets (Table 14c). Two female adult Smallmouth Bass were captured in gillnets, both in 4" mesh on August 5, 2009.

Sixteen Smallmouth Bass were captured in gill nets during the 24 hour sets in September 2009. Total in water time for all 24 hour gill nets was 2,424 hours. All of the Smallmouth Bass captured in gill nets were from the deep hole nearest the upper barrier. The other deep hole located in Sectors 5 and 6 was thoroughly sampled but no Smallmouth Bass were captured.

Beginning in 2010, gillnets with 3, 3.5, and 4 inch mesh size were fished from May to October. Most of the effort was deployed in sector 1 with lesser effort in sectors 3, 5, 6, 9 and 16. The



total catch-per-unit-effort decreased from 0.02 fish net-day<sup>-1</sup> in 2010 to 0.004 fish net-day<sup>-1</sup> in 2011 and 0.00 fish net-day<sup>-1</sup> in 2012 (Table 15). Unsuccessful gill net sets for the capture of Smallmouth Bass were not always recorded after 2012.

A total of 233 net-days of effort were applied in a randomized fashion throughout the lake in 2011 to determine the distribution and population size of adult Smallmouth Bass (Figure 4). This effort resulted in no catch of Smallmouth Bass.

In 2010, a diverse fish fauna was captured in gillnets, the most abundant species enumerated were White Sucker, White Perch, and Yellow Perch (Table 16).

### **3.6 FYKE NETS**

On July 9, 2009, one fyke net was installed in what is now sector 16 and was in place until July 28, 2009, when large numbers of juvenile Gaspereau made fishing the net impossible. The net was reinstalled on August 25, 2009, with little juvenile Gaspereau catch (<200 per day). A total of 37 Smallmouth Bass were captured in the fyke nets in 2009, with 33 Smallmouth Bass being captured in what is now sector 16 and four being captured on the west side of the lake in sector 13 (i.e. location of second fyke net).

From 2010 onward, fyke nets were deployed in early May and were fished into October with a total effort (expressed as fyke net sets of variable duration) of 263 to 988 sets annually. Most of the effort was deployed in August to October, concentrated in sectors 16 and 1 in the vicinity of Lake Brook. A total of 489 Smallmouth Bass were captured and removed with the fyke nets since 2009, and the majority (88%) were YOY (Table 3).

No Smallmouth Bass was captured in the fyke net located downstream of the containment barrier in 2010 to 2012.

As with the other gears, a diverse fish fauna was captured in the fyke nets in 2009 and 2010, and the most abundant species enumerated were White Sucker, Yellow Perch and White Perch (Tables 17 and 18).

### **3.7 BEACH SEINING**

No beach seining was conducted in 2009.

In 2010 to 2015, beach seining was initiated soon after YOY Smallmouth Bass had been first observed from other fishing methods (Table 19). The amount of beach seining effort (number of sweeps) and location were not always recorded when the Smallmouth Bass catch was null, or catch undifferentiated by sweep when captured in the same sector. Catch-per-unit-of-effort could not be calculated. An indirect measure of effort was estimated by the number of 'successful' events needed to capture the reported catch (sum of the number sectors with catch per given day) which does not account for sweeps with null catch nor multiple sweeps in same sector on the same day (Table 20). The highest total catch of Smallmouth Bass per beach seining event was usually found in Sector 1, 2 and 16 each year except in 2010 where it was found in Sector 3, 4 and 5 (Table 20). The other species captured by beach seining were not tabulated.

### **3.8 OTHER CAPTURE METHODS**

Angling effort conducted on spawning grounds and around large boulders and structures resulted in the capture of two adult Smallmouth Bass in 2010 in Sector 1 (age 3 and 8), six adult Smallmouth Bass in 2011 in Sector 1, 3 and 16 (age 3 to 6), and one adult in 2012 in Sector 16 (age 3). Angling in Miramichi Lake also occurred in 2009 and 2013 to 2016 but no bass were captured. The entire Lake Brook tributary was angled in 2012 and 2016, as well as part of two

inlets (Four Miles Brook and Five Miles Brook) in 2011 and 2012 but no Smallmouth Bass were captured.

No Smallmouth Bass were caught by the experienced anglers on June 3, 2011.

A total of 57 YOY Smallmouth Bass were captured with small dip nets while snorkelling, all in sector 3 in the vicinity of the boat wharf near the camps, from July 28 to September 2, 2010 (Table 3).

A first field operation was carried out on October 27, 2011 with a purse-seine (250 feet long, 23 feet deep and 1 $\frac{3}{8}$  inch mesh). This test-trial resulted in no capture of Smallmouth Bass.

### **3.9 BIOLOGICAL CHARACTERISTICS OF SMALLMOUTH BASS**

Based on interpretation of ages from scales (2009 to 2012) and the size-age relationship (2013 to 2017), Smallmouth Bass aged 0+ to 11+ years old were captured, from the 2000, 2002, and 2004 to 2017 cohorts (Figure 6). There were slightly more females (55%) in the catches of age 2 and older (Table 21). The average length of age-1 bass was 123 mm, with a minimum to maximum range of 72 to 174 mm (Table 21). The average lengths of age-2 to age-5 bass were 178 mm, 251 mm, 295 mm and 335 mm, respectively (Table 21). There was a strong allometric association between fork length and whole weight of Smallmouth Bass from Miramichi Lake (Figure 7).

The capture of the first YOY Smallmouth Bass each year varied between July 12 (2010) and July 31 (2015), with the median date being July 18.

YOY Smallmouth Bass grew well through the season, from an average fork length of 37 mm in July, and a minimum length of 12 mm, to an average length of 70 mm by October, and a maximum fork length of 110 mm (Table 22; Figure 8). By October, 9% of the captured YOY were shorter than 50 mm fork length and 7% of the YOY were longer than 90 mm.

Growth in length through the season was noted in bass age-1 to age-5 (Figure 9). The sample size was too small to denote growth in length during the season for age-5 and older bass.

## **4.0 DISCUSSION**

The sampling effort in 2009 was exploratory and intended to determine the location and spread of Smallmouth Bass in Miramichi Lake and its single outlet, Lake Brook (Figure 2). Efforts were made to sample areas where Smallmouth Bass would likely be found (i.e. shoals, deep drop off, structure) which resulted in over 15% of all adults and juveniles captured to date in Miramichi Lake being removed that year (Table 6). The main reason few YOY Smallmouth Bass were captured in 2009 (n=26) is likely because the fishing methods used at that time were inadequate, ill-placed or ill-timed for that age group such as backpack electrofishing the shore of Miramichi Lake too early.

The Containment, Control and Eradication Plan for Smallmouth Bass in Miramichi Lake in 2010 to 2012 stated that the main objective of the three year program was to contain and eradicate Smallmouth Bass in Miramichi Lake (Biron et al. 2014). This period saw an increase in personnel to the Miramichi Lake program with six people working full time from May to November, and an increase in fishing methods with the introduction of beach seining (best method for catching YOY Smallmouth Bass based on capture data) and electrofishing boat (second best method for catching all stages of Smallmouth Bass based on capture data). A marked decrease in all age group of Smallmouth Bass was observed during that period as indicated by fishery indicators (Tables 8, 12, 15 and 20). Over 66% of all adults and 52% of all juvenile Smallmouth Bass captured to date were caught between 2009 and 2011 (Table 1; Figure 5).

Substantial new knowledge on Smallmouth Bass in Miramichi Lake was gained from the work conducted during 2009 to 2012. A preferred spawning area has been inferred which was used to focus future activities. Based on the location and timing of capture of adult and YOY Smallmouth Bass, there is strong evidence that the favoured spawning area is situated in sectors 1 and 16, more specifically along the shallow grounds between the shoreline and the deep hole located in that area (Figure 1).

The Containment, Control and Eradication plan of 2010 to 2012 was replaced by a Containment, Control and Monitoring program during the 2013 to 2017 period. This period saw a decrease in personnel effort dedicated to the Miramichi Lake program with the electrofishing crew (three people) conducting backpack and boat electrofishing over a four week period. The reduction in numbers of the Smallmouth Bass in Miramichi Lake between 2009 and 2012 was still apparent in 2013 to 2015 with lower catches of all age groups being reported from targeted effort (Tables 1 and 2; Figure 5). An increase in Smallmouth Bass captures has been observed since 2015.

#### **4.1 BIOLOGICAL CHARACTERISTICS OF SMALLMOUTH BASS**

The fork lengths and weights at age of Smallmouth Bass in Miramichi Lake are similar to those from other introduced populations in Nova Scotia (Tables 21 and 22; Figures 7, 8 and 9) (McNeil 1995; LeBlanc 2010). Their rapid growth and higher relative weight are characteristics of newly introduced species (LeBlanc 2010). Curry et al. (2005) noted that there was a size-dependent overwinter survival in Smallmouth Bass with most YOY bass < 50 mm dying over the winter. YOY Smallmouth Bass < 50 mm represented less than 5% of the catch in October every year except 2009 (16%) and 2013 (44%). The relatively few juveniles (ages 1 and 2) captured since 2009 may indicate that overwinter survival of YOY bass is poor in Miramichi Lake or that this age and size group is difficult to capture with the fishing gears deployed. The capture of adults every year provides evidence of survival and successful recruitment to the adult stage in Miramichi Lake however the cumulative number of bass by year class, other than YOY, has declined over time. The cumulative catches of Smallmouth Bass, older than YOY, from the 2009 to 2014 year classes have been < 20 bass compared to > 20 bass of the 2006 to 2008 year classes (Figure 6).

#### **4.2 INTERPRETATION OF THE SMALLMOUTH BASS CATCH DATA**

It became obvious after 2010 that the ultimate goal of eradication had priority over any other objectives, and modifications to the experimental sampling design were made as needed to maximize the removal of Smallmouth Bass from Miramichi Lake. As protocols were changed, sampling began to target specific areas based on better knowledge of Smallmouth Bass distribution in the lake.

Therefore, Smallmouth Bass catch data from Miramichi Lake is in part an indication of population size but also reflects variations in effort being deployed annually, and the fact that crews are simply getting better at targeting areas where Smallmouth Bass are likely to be found. No Smallmouth Bass nests were found in 2009 and 2010 but since then complete nests (defined as one guarding male with YOY) and remnants of nests (defined as group of same size YOY Smallmouth Bass captured together but no adult) have been found in Sector 12 to 1 (Figure 1). The minimum size of the first YOY Smallmouth Bass captured each year dropped from 31 mm in 2010 to 22 mm in 2013, to 12 mm in 2017 (i.e.: the sooner a nest or remnants of a nest is discovered, the higher the number of fish captured).

#### **4.3 CONTAINMENT OF SMALLMOUTH BASS**

The main barrier was not breached during any high water events. In 2010, one YOY Smallmouth Bass was captured in the enclosure between the main barrier and the debris fence.

Over 38% of all the YOY Smallmouth Bass captured in the Miramichi Lake since 2010 were caught in the immediate shallow areas bordering the outlet to Lake Brook (sector 15 and 16). Young-of-the-year and juvenile Smallmouth Bass were captured against the front of the barrier, either by hand while cleaning the debris fence, or during boat and backpack electrofishing. And it is believed that some of the one-year old juvenile bass captured downstream of the barrier in 2011 moved into Lake Brook prior to the installation of the containment barrier (Biron et al. 2014).

Although the barrier may have become permeable to YOY for short periods of time, particularly during the process of moving YOY Gaspereau downstream (Figure 3), it seems to have successfully prevented the passage of larger bass. No Smallmouth Bass two years of age or older were captured in the upper section of Lake Brook (Table 7). No Smallmouth Bass of any size were observed in the lower section during repeated backpack electrofishing in 2009, 2010 and 2016 or angling in 2012 and 2016. No Smallmouth Bass were captured at the lower barrier near the mouth of Lake Brook or at the rotary screw trap operated in 2009 (Table 6). It should be noted that the upper section of Lake Brook acted more like an extension of Miramichi Lake from 2009 until 2011 due to the slowing of the water by a debris dam below the barrier. The debris dam washed out prior to the season in 2012 and that section of the brook became fast flowing. It is therefore possible that the only recorded catch of a single YOY in 2016 behind the barrier (first since 2012) may be the result of Smallmouth Bass being harder to find and capture in rapid water compared to the relatively calmer water of 2009 to 2011. Different habitat in the upper section of Lake Brook combined with a lower density of Smallmouth Bass in Miramichi Lake could have reduced the likelihood of bass moving out of the lake. There have been no verifiable observations or reports of Smallmouth Bass from other parts of the Miramichi watershed.

#### **4.4 POPULATION SIZE OF SMALLMOUTH BASS**

The population size of adult Smallmouth Bass in Miramichi Lake is unknown, but low catch rates from all measurable indicators each year such as boat electrofishing, fyke nets or gill nets suggest that the population size of adult Smallmouth Bass is quite small (Tables 8, 12, 15 and 20) (DFO 2013; Biron et al. 2014; Chaput and Moore 2018). Substantial fishing effort from all gear resulted in the capture of only 126 adults age 3 and older over a period of nine years, an average of 14 fish per year. The angling blitz from 16 professional bass anglers in June 2011 and the 20-day random intensive gillnetting program in August 2011 that randomly spread the fishing effort throughout the lake resulted in no catch of Smallmouth Bass.

The original experimental design-based sampling in 2010 anticipated using a simple depletion estimator based on partial captures from techniques employed to reduce the Smallmouth Bass population to estimate the population size in Miramichi Lake (Chaput and Moore 2018). Each year since 2010 there was no evidence of depletion of juvenile or adult bass in the seasonal data from the cumulative effort of a same gear (i.e. boat electrofishing, or gill nets, or fyke nets) mainly because of the low number of fish captured for these two stages; low captures that were also spread over the entire season.

A population estimate for YOY Smallmouth Bass was provided for 2010 but was very uncertain, with a coefficient of variation greater than 100%, but with high probability (>90%) that the population size of YOY was less than 15,000 fish (Chaput and Moore 2018). Based on the total removals of YOY from all sources in 2010 (2,532 fish), between 8% and 53% of the YOY were estimated to have been captured and killed in 2010 (Chaput and Moore 2018). Although the sampling protocols in 2010 were assumed to be sufficient to respect the assumption of random sampling, basic assumptions were not met in successive years since Smallmouth Bass were

found not to be randomly distributed in Miramichi Lake, nor was the fishing effort constant and randomly applied to all sectors (Biron et al. 2014).

There is evidence of depletion of Smallmouth Bass in Miramichi Lake since 2010 but the extent of the reduction is unknown. The lower catch of Smallmouth Bass, lower catch-per-unit-effort from electrofishing boat, gillnets and beach seining, as well as the reduced distribution of Smallmouth Bass in the lake all supports this conclusion (Biron et al. 2014). However, the number of Smallmouth Bass that survived to older ages and have been captured since 2009 indicates a stable cumulative adult recruitment level of < 20 fish per year class, a level lower than from the 2006 to 2008 year classes in Miramichi Lake. There has been a small increase in catches of all age groups since 2015 and 2016.

#### **4.5 OTHER SPECIES**

A diverse fish fauna was captured and identified in Miramichi Lake (Tables 4, 13, 14, 16, 17 and 18). The most abundant species catches, by number, were White Sucker (*Catostomus commersoni*), Yellow Perch (*Perca flavescens*), White Perch (*Morone americana*), Fallfish (*Semotilus corporalis*) and numerous cyprinid species. Common anadromous species included Sea Lamprey (*Petromyzon marinus*), Gaspereau (alewife, *Alosa pseudoharengus*), Atlantic Salmon (*Salmo salar*), and American Eel (*Anguilla rostrata*). One Striped Bass (*Morone saxatilis*) was captured in 2017. Atlantic Salmon and American Eel have been evaluated by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as Special Concern. Banded Killifish (*Fundulus diaphanous*) mainland population was assessed to be Not at Risk by COSEWIC.

Miramichi Lake has a very large prey forage base and a large juvenile Gaspereau population which remains in the lake for most of the summer which may provide an ample food source for Smallmouth Bass. In water bodies in New Brunswick with abundant juvenile Gaspereau populations, larger young of the year Smallmouth Bass switched sooner from an insect based diet to a fish based diet, and juvenile Gaspereau become a significant portion of their diet (Hanson and Curry 2005).

The control program has had impacts on other species in the lake. The extensive fishing effort with large meshed gillnets resulted in a detectable reduction in the abundance of the larger sizes of the bycatch species in the lake, in particular of White Perch, White Sucker and Yellow Perch. The small size groups of these species remained abundant in the lake (DFO 2013). It is the high rates of mortality of other species and considerable processing effort combined to low catch rates of Smallmouth Bass that resulted in the abandonment of smaller mesh size gillnets, or the use of fyke nets during mid-July to mid-August, and boat electrofishing in sector 2 when the loons were nesting.

### **5.0 ACKNOWLEDGEMENTS**

Since 2010, the field program for Miramichi Lake was coordinated and delivered by Dave Moore (2010 and 2012), Marie Clément (2011) and Michel Biron (2012-2017) of Fisheries and Oceans Canada (DFO). Field support was provided by the Miramichi Watershed Management Committee (Natasha Ouellet (2012), Dave Patriquen (2010-2012), Shane Price (2010-2012), Omer Richard (2010-2017), Fred Richard (2010-2011), Jacob Richard (2012-2017)), the Miramichi Headwaters Salmon Association (Brian Richard 2010-2017) and DFO Renelle Doucette (2013-2016) and Sophie Leblanc (2014-2016). St Mary's First Nation provided help during backpack electrofishing in 2011. Chris Connell from the New Brunswick Department of Natural Resources provided the bathymetry map of Miramichi Lake. Rejean Vienneau (DFO) provided maintenance, technical support and modifications to the electrofishing boat (2010-

2017). Noella MacDonald (DFO) and Andrew Olive (DFO) interpreted the age of the Smallmouth Bass from scales.

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# TABLES

Table 1. Catches by week and year of young-of-the-year, juvenile, and adult Smallmouth Bass from Miramichi Lake, 2009 to 2017, all methods of capture combined (electrofishing, gill nets, fyke nets, beach seine, angling, others). Blank cells indicate that no activity occurred during that period; shaded cells indicate time periods when backpack and boat electrofishing were conducted in Miramichi Lake; Week is week of the year.

Week	Young-of-the-year (<1 year old)									Juveniles (1 and 2 year old)									Adults (≥ 3 year old)									Grand Total (all SMB)																	
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2009	2010	2011	2012	2013	2014	2015	2016	2017	2009	2010	2011	2012	2013	2014	2015	2016	2017	2009	2010	2011	2012	2013	2014	2015	2016	2017									
17				0								0																																	
18				0								1																																	
19				0								0																																	
20	0	0		0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0							
21	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	2	0	0	0	0				
22	0	0	0	0	0	0	0	0	0	0	2	1	0	0	1	0	0	1	0	0	0	1	0	0	1	1	0	0	0	0	2	3	0	1	1	0	1	2	0						
23	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	3	0	0	0	3	1	0	2	0	3	0	0	0	3
24	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	0	0	0	0	4	0	0	1	0	0	0	0	0	0	5	0	0	2	1	1	0	0	0					
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	2	0	0	0	2	0	0	2	0	0	2	0	1	0	
26	0	0	0	0	0	0	0	0	0	2	0	0	1	0	0	1	0	0	0	0	1	3	0	0	0	0	1	1	2	1	3	1	0	0	1	1	1	1	1	1	1	1	1		
27	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	1	2	0	0	0	0	0	2	0	1	2	1	1	1	0	0	2	0	1	2	1	1	0	0	2
28	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0	2	2	2	1	0	0	0	0	0	2	3	2	3	0	0	0	0	0	0	0	0	0	0	0	0	
29	0	21	0	0	21	8	0	0	7	0	2	0	1	0	0	1	0	7	0	1	3	1	0	0	0	0	0	0	24	3	2	21	8	1	0	14	0	0	0	0	14				
30	0	35	23	10	161	123	0	35	211	0	0	0	0	0	0	0	1	0	11	1	0	0	0	0	0	2	0	46	24	10	161	123	0	35	211	0	0	0	0	214					
31	0	103	73	12	68	216	3	404	582	0	0	1	0	1	0	2	0	0	0	0	0	0	1	0	6	3	0	0	103	74	12	70	216	11	407	582	0	0	0	582					
32	0	80	72	3	97	114	92	392	231	0	4	1	0	0	2	3	0	1	2	1	0	1	0	2	4	2	1	2	85	73	4	97	118	99	394	233	0	0	0	233					
33	0	206	41	1	19	54	29	266	183	0	0	0	0	0	1	4	0	1	0	3	0	0	0	0	0	1	0	209	41	1	19	55	33	266	185	0	0	0	185						
34	0	394	55	1	12	2	28	208	17	0	0	0	0	0	2	0	0	0	0	1	0	0	0	1	1	0	0	394	56	1	12	2	31	209	17	0	0	0	17						
35	3	138	18	0	29	27	4	7	93	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	4	139	18	0	29	28	4	7	93	0	0	0	93						
36	4	507	49	2	16	6	0	23	50	2	2	0	0	0	0	0	0	0	1	2	0	0	1	0	0	0	7	511	49	2	17	6	0	23	50	0	0	0	50						
37	1	283	21	0	14	0	0	28	108	3	0	1	0	0	0	0	0	0	8	1	0	0	0	0	0	1	12	284	22	0	14	0	0	28	109	0	0	0	109						
38	6	231	19	2	4	0	0	16	19	2	0	1	0	0	0	0	0	0	4	1	3	0	0	0	0	1	12	232	23	2	4	0	0	16	20	0	0	20							
39	5	151	59	3	0	0	0	0	3	2	1	4	0	0	0	0	0	0	1	1	1	0	0	0	0	0	8	153	64	3	0	0	0	0	0	0	0	3	3						
40	1	127	24	2	45	0	0	0	4	4	2	0	0	0	0	0	0	0	3	1	1	0	0	0	0	0	8	130	25	2	45	0	0	0	0	0	0	4	4						
41	2	101	5	0	20	0	0	0	17	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2	103	5	0	20	0	0	0	0	0	0	0	17						
42	4	112	19	0	1	5	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0	0	0	0	0	4	115	20	0	1	5	0	0	0	0	0	0	0						
43	0	43	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	43	5	0	0	0	0	0	0	0	0	0	0	0					
44			0		0	0						0		0	0						0		0	0				0		0	0														
45																																													
Total	26	2532	483	36	507	555	156	1379	1525	17	21	10	7	2	7	17	1	11	21	31	30	3	6	3	11	8	14	64	2584	523	46	515	565	184	1388	1550									



Table 2. Catches of Smallmouth Bass by lake sector (1-16) and year (2010-2017) by age a) young-of-the-year, b) juveniles (1 and 2 year old), and c) adults ( $\geq 3$  years old). Sam's rock is a small car-sized underwater boulder in Sector 2; Center is the center of the lake.

a) Young of the year

year	Sectors																1-16	Sam's Rock	Center	total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16				
2010	885	40	131	95	211	132	32	60	77	86	19	28	69	59	66	257				2247
2011	220	7	18	7	21	11	4	8	7	14		8	15	15	25	102				482
2012	28															8				36
2013	272		3		1	2	1						5		10	159	49			502
2014	327	1		3	2	12					1	1			27	168	13			555
2015	19	35														30	61			145
2016	331	11	4		5	3			1			68	1	82	53	589	220			1368
2017	643	10		1	3			8				23	22	25	153	637				1525
total	2725	104	156	106	243	160	37	76	85	100	19	128	113	181	334	1950	343	0		6860

b) Juveniles

year	Sectors																1-16	Sam's Rock	Center	total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16				
2010	14				2											1				17
2011	3				5			1	1											10
2012	4												1	1						6
2013	2																			2
2014	4														3					7
2015	3	4												1	7		1		1	17
2016															1					1
2017	9															2				11
total	39	4			7			1	1					2	15		1		1	71

c) Adults

year	Sectors																1-16	Sam's Rock	Center	total	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16					
2010	19	3	8																	1	31
2011	12		2	2	3								1	6	4						30
2012															3						3
2013	1														5						6
2014	1														1			1			3
2015															5		3		2		10
2016	3														1				4		8
2017	8	3			1										2						14
total	44	6	10	2	4									1	6	21	3	7		1	105

Table 3. Catches of Smallmouth Bass by year (2009-2017) and fishing methods for a) young-of-the-year, b) juveniles (1 and 2 year old), and c) adults ( $\geq 3$  years old).

a) Young of the year

	Angling	Backpack EF	Barrier	Beach Seine	E-Boat	Fyke Net	Gill Net	Snorkeling	Total
2009		6				20			26
2010		179	4	815	1287	190		57	2532
2011		53		96	302	32			483
2012		9		13	12	2			36
2013		1	3	416	53	34			507
2014				411	82	62			555
2015				40	108	9			157
2016		1		780	576	22			1379
2017				1464		61			1525
Total		249	7	4035	2420	432		57	7200

b) Juveniles

	Angling	Backpack EF	Barrier	Beach Seine	E-Boat	Fyke Net	Gill Net	Snorkeling	Total
2009		1				16			17
2010		4			6	6	5		21
2011					6	4			10
2012			1		4	2			7
2013				1		1			2
2014				1	2	4			7
2015					6	11			17
2016						1			1
2017				9		2			11
Total		5	1	11	24	47	5	0	93

c) Adults

	Angling	Backpack EF	Barrier	Beach Seine	E-Boat	Fyke Net	Gill Net	Snorkeling	Total
2009						1	20		21
2010	2				3	6	20		31
2011	6				12	1	11		30
2012	1				2				3
2013					5		1		6
2014					3				3
2015					9	1			10
2016					6	1	1		8
2017							14		14
Total	9				40	10	67		126

Table 4. List of the 18 species of fish captured in Miramichi Lake, 2009 to 2017.

Common names	Scientific names
American eel	<i>Anguilla rostrata</i>
Banded Killifish	<i>Fundulus diaphanous</i>
Black nose dace	<i>Rhinichthys atratulus</i>
Brown bullhead	<i>Ictalurus nebulosus</i>
Common shiner	<i>Notropis cornutus</i>
Creek chub	<i>Semotilus atromaculatus</i>
Fallfish	<i>Semotilus corporalis</i>
Gaspereau (Alewife)	<i>Alosa pseudoharengus</i>
Golden shiner	<i>Notemigonus crysoleucas</i>
Lake chub	<i>Couesius plumbeus</i>
Lamprey	<i>Petromyzon marinus</i>
Salmon	<i>Salmo salar</i>
Smallmouth bass	<i>Micropterus dolomieu</i>
Brook trout	<i>Salvelinus fontinalis</i>
White perch	<i>Morone americana</i>
White sucker	<i>Catostomus commersoni</i>
Yellow perch	<i>Perca flavescens</i>

Table 5. Installation and removal dates of Miramichi Lake 'upper' containment barrier, 2008 to 2017.

Year	Date installed	Date removed
2008	early September	November (ice-up)
2009	May 11	November 3
2010	April 25	November 3
2011	May 4	November 3
2012	May 2	November 1
2013	May 10	October 29
2014	May 15	October 29
2015	May 13	September 30
2016	May 10	October 21
2017	May 10	October 17

Table 6. Species captured in Lake Brook (by section and gear) and Miramichi Lake (by gear) in 2009 as reported in the unpublished report of O'Donnell and Reid (2009). The symbol 'x' in the table means fish were identified but the numbers were not enumerated. Scientific names are listed in Table 4.

Effort and species	Lake Brook				Miramichi Lake	
	Upper Section		Lower Section		Gill Net	Fyke Net
	Containment Barrier	Backpack Electrofishing	Rotary Screw Trap	Backpack Electrofishing		
Effort		36,589 sec.	87 days	18,983 sec.	2,755 hrs	2 nets/54 days
Alewife	x	12		1		
American Eel	x	14	13	10		304
Atlantic Salmon (parr)		333	9	76		
Atlantic Salmon (smolt)		0	29	1		
Banded Killifish	x	1	1			
Blacknose Dace		223	6	99		
Brook Trout	x	8	68	1		
Brown Bullhead	x	1	1	1	34	1,312
Common Shiner	x	927	208	119		1,785
Creek Chub	x	22	7	22		
Fallfish	x	115	166	18	11	10,035
Gaspereau	x	19	99		2	1,626
Golden Shiner	x	88	24	14	18	1,717
Lake Chub		55				
Lamprey		18	3	2		
Smallmouth Bass		7			20	37
White Perch	x	2	3		462	2,722
White Sucker	x	249	2019	81	747	4,552
Yellow Perch	x	335	146	549	116	5,976
Tadpole (amphibian)						2,684

Table 7. Backpack electrofishing sampling effort and catch of young-of-the-year (YOY) and juvenile Smallmouth Bass (SMB) in the upper section of Lake Brook, 2008 to 2016.

Characteristic	Year								
	2008	2009	2010	2011	2012	2013	2014	2015	2016
Events	na	18	23	17	20	1	1	1	2
Effort (seconds)	na	36,589	54,324	44,478	28,174	4,555	n/a	4,911	8,902
YOY	15	7	1	1	0	0	0	0	1
Juvenile (1+)	2	1	4	0	0	0	0	0	0
Total SMB	17	8	5	1	0	0	0	0	1

Table 8. Number of backpack electrofishing sampling events, sampling effort (seconds), catch of young-of-the-year Smallmouth Bass (YOY SMB), and catch per unit of effort (CPUE; number per 100 seconds) by sector in Miramichi Lake for 2010 to 2012. Effort and sectors were not always recorded in 2011 and 2012. For 2011, CPUE is calculated when the SMB catch and sampling effort were recorded, rather than the total catch (in brackets). Sectors are shown in Figure 1.

Sector	Sampling events			Sampling effort (seconds)			Catch of YOY SMB			CPUE (fish per 100 sec.)		
	2010	2011	2012	2010	2011	2012	2010	2011	2012	2010	2011	2012
9	1			400			1			0.25		
10	1	2		1,920			2	(2)		0.10		
11	1	2		146	1,819		1			0.68	0	
12	2			4,282	1,070		5	(1)		0.12	0	
13	1	3		800			1			0.13		
14												
15	1	1	3	800	2,131	690	1	1		0.13	0.05	0
16	4	3	8	22,192	635	2,468	17	5 (6)	1	0.08	0.79	0.04
1	6	3	13	176,091	2,497	11,071	75	10 (33)	9	0.04	0.40	0.08
2	7	1	1	18,651	670	215	19			0.10	0	0
3	7	4	5	36,263	1,217	1,938	35	(7)		0.10	0	0
4	5	1	1	15,723	1,023	498	17	1 (2)		0.11	0.10	0
5	1	1		1,266	172		1			0.08	0	
6	1			1,600			2			0.13		
7												
8	1			800			1			0.13		
Total	40	21	31	280,934	17,829	16,920	178	17 (52)	10	0.06	0.10	0.06

Table 9. Boat electrofishing sampling effort (hour) in Miramichi Lake, by boat used, 2010 to 2016.

Boat unit	Fishing effort (hour)						
	2010	2011	2012	2013	2014	2015	2016
Boat A	81.70	43.78	16.25	0	0	0	0
Boat B	0	139.65	108.91	34.80	34.55	32.02	38.67
Total	81.70	183.43	125.16	34.80	34.55	32.02	38.67

Table 10. Boat electrofishing sampling effort (hour) for day and night sampling in Miramichi Lake, 2010 to 2016.

Year	Fishing effort (hour)		
	Day	Night	Total
2010	19.03	62.67	81.70
2011	21.30	162.12	183.43
2012	14.92	110.24	125.16
2013	4.80	30.00	34.80
2014	5.90	28.60	34.50
2015	0	32.02	32.02
2016	0	38.67	38.67
Total	65.95	464.32	530.28

Table 11. Comparison of day-time and night-time boat electrofishing effort (hour), catch of Smallmouth Bass (SMB), and catch per unit effort (CPUE; number per hour) in Miramichi Lake, by month during 2010 to 2012 (Biron et al. 2014).

Time period	2010								
	Fishing effort (hr)		Number of SMB captured			CPUE (# SMB per hr)			
	Day	Night	Day	Night	Total	Day	Night	Total	
May	0.20	8.35	0	0	0	0	0	0	
June		1.80		0	0		0	0	
July	0.30	5.07	3	16	19	9.95	3.16	0.23	
Aug.	0.43	15.53	3	330	333	6.96	21.25	4.08	
Sept.	9.20	23.29	157	520	677	17.07	22.33	8.29	
Oct.	8.90	8.64	99	157	256	11.12	18.17	3.13	
Total	19.03	62.67	262	1023	1285	13.77	16.32	15.73	

Time period	2011								
	Fishing effort (hr)		Number of SMB captured			CPUE (# SMB per hr)			
	Day	Night	Day	Night	Total	Day	Night	Total	
May	8.83	12.46	0	3	3	0	0.24	0.02	
June	5.20	30.63	0	8	8	0	0.26	0.04	
July	5.86	40.80	24	38	62	4.09	0.93	0.34	
Aug.		26.02		93	93		3.57	0.51	
Sept.	1.41	38.67	3	128	131	2.12	3.31	0.71	
Oct.		13.54		23	23		1.70	0.13	
Total	21.30	162.12	27	293	320	1.27	1.81	1.74	

Time period	2012								
	Fishing effort (hr)		Number of SMB captured			CPUE (# SMB per hr)			
	Day	Night	Day	Night	Total	Day	Night	Total	
May	9.40	25.64	0	0	0	0	0	0.00	
June	5.52	14.58	0	1	1	0	0.07	0.01	
July		22.81		12	12		0.53	0.10	
Aug.		16.07		2	2		0.12	0.02	
Sept.		15.30		6	6		0.39	0.05	
Oct.		15.83		2	2		0.13	0.02	
Total	14.92	110.24	0	23	23	0	0.21	0.18	

Table 12. Boat electrofishing sampling effort (seconds), catch of Smallmouth Bass (SMB), and catch per unit effort (CPUE; number per 100 seconds) by sector in Miramichi Lake for a) young of the year and b) juveniles (1 and 2 year old) and adults ( $\geq 3$  years old), in 2010 to 2012. Effort was not always recorded in 2011. Sectors are shown in Figure 1.

a) Young-of-the-year SMB

Sector	Sampling effort (seconds)			Catch			CPUE (fish/100 sec.)		
	2010	2011	2012	2010	2011	2012	2010	2011	2012
9	11,341	13,536	10,106	51	7		0.45	0.05	0
10	25,726	29,223	17,508	87	12		0.34	0.04	0
11		15,828	21,732		0			0.00	0
12	10,379	23,740	24,799	21	7		0.20	0.03	0
13	7,220	21,590	15,556	31	15		0.43	0.07	0
14	8,799	28,208	18,271	32	15		0.36	0.05	0
15	19,224	57,471	27,258	61	22		0.32	0.04	0
16	38,188	95,485	68,790	179	79	6	0.47	0.08	0.01
1	110,980	205,705	152,523	651	109	6	0.59	0.05	0.004
2	7,814	8,721	9,874	13	3		0.17	0.03	0
3	2,283	10,200	5,406	2	6		0.09	0.06	0
4	1,996	2,425	5,248	4	1		0.20	0.04	0
5	19,152	32,169	24,057	33	3		0.17	0.01	0
6	10,889	19,625	23,036	42	11		0.39	0.06	0
7	10,551	10,480	11,473	25	4		0.24	0.04	0
8	9,582	14,811	14,924	53	8		0.55	0.05	0
Total	294,124	589,217	450,561	1,285	302	12	0.44	0.05	0.003

b) Juveniles and adult (in bracket) SMB

Sector	Sampling effort (seconds)			Catch			CPUE (fish/100 sec.)		
	2010	2011	2012	2010	2011	2012	2010	2011	2012
9	11,341	13,536	10,106		1		0	0.01	0
10	25,726	29,223	17,508		1		0	0.003	0
11		15,828	21,732				0	0	0
12	10,379	23,740	24,799				0	0	0
13	7,220	21,590	15,556				0	0	0
14	8,799	28,208	18,271				0	0	0
15	19,224	57,471	27,258		(5)	1	0	(0.01)	0.004
16	38,188	95,485	68,790		(1)	1 (2)	0	(0.001)	0.001 (0.003)
1	110,980	205,705	152,523	6 (2)	3 (5)	2	0.01 (0.002)	0.001 (0.002)	0.001
2	7,814	8,721	9,874	(1)			(0.01)	0	0
3	2,283	10,200	5,406				0	0	0
4	1,996	2,425	5,248		(1)		0	(.04)	0
5	19,152	32,169	24,057		1		0	0.003	0
6	10,889	19,625	23,036				0	0	0
7	10,551	10,480	11,473				0	0	0
8	9,582	14,811	14,924				0	0	0
Total	294,124	589,217	450,561	6 (3)	6 (12)	4 (2)	0.002 (0.001)	0.001 (0.002)	0.001 (0.0004)



Table 13. Summary of recorded catches by species and by month using boat electrofishing in Miramichi Lake in 2010. In September and October, catches of species other than Smallmouth Bass were not recorded. Data from Chaput and Moore (2018). Scientific names are listed in Table 4.

Species	Month						Total
	May	June	July	Aug.	Sept.	Oct.	
Smallmouth bass	4	0	20	337	677	256	1,294
American Eel		2	1	5			8
Banded Killifish	31	23	33	430			517
Brown Bullhead		2	15	38			55
Brook Trout	1			1			2
Creek Chub		8					8
Common Shiner	193	84	29	226			532
Fallfish	139	89	72	298			598
Gaspereau		4	72	401			477
Golden Shiner	1	12	78	278			369
Lake Chub	6						6
Pearl Dace				1			1
White Perch	143	137	758	1,264			2,302
White Sucker	281	118	378	628			1,405
Yellow Perch	709	504	2,510	6,406			10,129
Bullfrog Tadpole			416				416
<b>Total</b>	<b>1,504</b>	<b>983</b>	<b>4,362</b>	<b>9,976</b>			<b>18,119</b>

Table 14. Catches by species of fish in gill nets in August 2009. Data are from unpublished report of O'Donnell and Reid (2009). Scientific names are listed in Table 4.

a) Gillnet effort (hour) and species of fish captured in all sizes of gill nets during the day, evening and night sets

Effort and species	Day	Eve	Night	Total
Effort (hour)	149.2	16.2	165.6	331
Brown Bullhead		1	33	34
Fallfish	1			1
Gaspereau	1		1	2
Golden Shiner	15		3	18
Smallmouth Bass	2			2
White Perch	248	7	95	350
White Sucker	105	24	132	261
Yellow Perch	80	1	30	111
Total	452	33	294	779

b) Gillnet effort (hour) and species of fish captured by mesh size

Effort and species	Mesh Size (inches)						Total
	1	2	2.5	3	3.5	4	
Effort (hour)	5.7	86.6	71.5	37	73.4	56.7	330.9
Brown Bullhead		32	2				34
Fallfish	1						1
Gaspereau		2					2
Golden Shiner	15	3					18
Smallmouth Bass						2	2
White Perch	220	96	23	2	3	6	350
White Sucker	73	88	52	31	17		261
Yellow Perch	75	31	4			1	111
Total	384	252	81	33	20	9	779

c) Gillnet effort (hour) and species of fish captured in all gill nets set at different depths

Effort and species	Deep	Medium	Shallow	Total
Effort (hour)	92.7	96.7	141.4	330.8
Brown Bullhead		1	33	34
Fallfish	1			1
Gaspereau			2	2
Golden Shiner	15		3	18
Smallmouth Bass	1	1		2
White Perch	228	10	112	350
White Sucker	80	80	101	261
Yellow Perch	75	2	34	111
Total	400	94	285	779

Table 15. Summary of gillnetting effort (net-days), catches, and catch-per-unit-effort (CPUE, fish per net-day) of Smallmouth Bass (SMB) by month in Miramichi Lake, for 2010 to 2012 (Biron et al. 2014).

Effort and catches	2010							Total
	April	May	June	July	August	September	October	
Effort (net-days)	26	90	137	121	160	261	355	1150
Catches of SMB	0	1	1	8	3	8	5	26
Catch-per-unit-effort (# SMB per net-day)	0	0.01	0.01	0.07	0.02	0.03	0.01	0.02

Effort and catches	2011							Total
	April	May	June	July	August	September	October	
Effort (net-days)		393	300	568	518	470	483	2732
Catches of SMB		2	0	2	1	5	1	11
Catch-per-unit-effort (# SMB per net-day)		0.005	0	0.004	0.002	0.011	0.002	0.004

Effort and catches	2012							Total
	April	May	June	July	August	September	October	
Effort (net-days)	68	527	510	434	434	420	220	2613
Catches of SMB	0	0	0	0	0	0	0	0
Catch-per-unit-effort (# SMB per net-day)	0	0	0	0	0	0	0	0

Table 16. Summary of recorded catches by species and by month in gillnets set in Miramichi Lake in 2010 (Chaput and Moore 2018). After July, catches of species other than Smallmouth Bass were not completely enumerated. Scientific names are listed in Table 4.

Species	Month							Total
	April	May	June	July	Aug.	Sept.	Oct.	
Smallmouth Bass		1	1	8	3	8	5	26
Brown Bullhead		7	3	10	49	4	2	75
Brook Trout		9	2			1		12
Fallfish	2	112	2	4	5	7	14	146
Gaspereau			38	29	1		1	69
Golden Shiner	3	9	3		1			16
White Perch	251	1,061	324	205	69	21	37	1,968
White Suckers	355	1,299	537	578	174	186	412	3,541
Yellow Perch	5	897	17	40	15	4	15	993
All species total	616	3,395	927	874	317	231	486	6,846

Table 17. Most abundant species captured in fyke nets by month in 2009 in Miramichi Lake. Data are from the unpublished report of O'Donnell and Reid (2009). Scientific names are listed in Table 4.

Month	Smallmouth Bass	Fallfish	Common Shiner	Golden Shiner	White Sucker	Brown Bullhead	American Eel	Gaspereau	Yellow Perch	White Perch	Tadpole (amphibian)	Total
July	2	575	88	620	157	167	192	522	974	1384	2310	6991
August	7	550	124	70	126	116	13	639	513	253	46	2457
September	20	4032	467	852	1566	837	84	447	4069	998	156	13528
October	8	4878	1106	175	2703	192	15	18	420	87	172	9774
Total	37	10,035	1,785	1,717	4,552	1,312	304	1,626	5,976	2,722	2,684	32,746

Table 18. Summary of recorded catches by species in fyke nets by month in Miramichi Lake in 2010 (Chaput and Moore 2018). After May, catches of species other than Smallmouth Bass were not completely enumerated. Scientific names are listed in Table 4.

Species	Month							Total
	April	May	June	July*	Aug.*	Sept.*	Oct.*	
Smallmouth Bass				100	74	22		196
Lamprey		1						1
Gaspereau				518	200	287		1,005
Atlantic Salmon		2						1
Brook Trout	31	45						76
American Eel	1	68		80	*	3	1	153
Banded Killifish		4		37	*			41
White Sucker	601	21,075		1,462	*	5	28	23,171
Creek Chub		13						13
Lake Chub		1						1
Fallfish	255	2,779		726	*	42	23	3,825
Common Shiner	29	1,281		316	*	16	6	1,648
Golden Shiner	2	112		409		27		550
Brown Bullhead	1	150		444		52	1	648
White Perch		1,973		3,087	1	4	8	5,073
Yellow Perch	664	12,173		6,662	*	51	16	19,566
Tadpole	7	614		438	*			1,059
Total*	1,591	40,291		14,279	275	509	83	57,028

\* incomplete count of catches by species (other than smallmouth bass) from the large catches

Table 19. First and last day with reported Smallmouth Bass catches from beach seining, 2010 to 2017.

Year	First day	Last day
2010	Aug. 10	Sept. 23
2011	July 27	Aug. 22
2012	July 29	Au. 8
2013	July 17	Oct. 15
2014	July 15	Sept. 4
2015	Aug. 5	Aug. 25
2016	July 21	Sept. 14
2017	July 18	Oct. 13

Table 20. Number of 'successful' sampling events (i.e. resulting in a Smallmouth Bass (SMB) catch), catch of SMB, and CPUE (catch per number of events) from beach seining by sector groups in Miramichi Lake, 2010 to 2017. Sectors are shown in Figure 1.

number of events		Months				total	SMB catch		Months				total	catch / event		Months				total
Year	Sectors	July	August	September	October		Year	Sectors	July	August	September	October		Year	Sectors	July	August	September	October	
2010	1,2,16		6	6		12	1,2,16		12	86		98	1,2,16			2.0	14.3		8.2	
	3,4,5		20	11		31	3,4,5		375	86		461	3,4,5			18.8	7.8		14.9	
	6,7,8,9		15	10		25	6,7,8,9		174	44		218	6,7,8,9			11.6	4.4		8.7	
	10,11,12		6	1		7	10,11,12		20	3		23	10,11,12			3.3	3.0		3.3	
	13,14,15		4	2		6	13,14,15		11	4		15	13,14,15			2.8	2.0		2.5	
	total		51	30		81		total	592	223		815		total		11.6	7.4		10.1	
2011	1,2,16	2	14			16	1,2,16	4	68			72	1,2,16	2.0		4.9			4.5	
	3,4,5		9			9	3,4,5		22			22	3,4,5			2.4			2.4	
	6,7,8,9						6,7,8,9						6,7,8,9							
	10,11,12						10,11,12						10,11,12							
	13,14,15		2			2	13,14,15		2			2	13,14,15		1.0				1.0	
	total	2	25			27		total	4	92		96		total	2.0	3.7			3.6	
2012	1,2,16	3	3			6	1,2,16	10	3			13	1,2,16	3.3	1.0				2.2	
	3,4,5						3,4,5						3,4,5							
	6,7,8,9						6,7,8,9						6,7,8,9							
	10,11,12						10,11,12						10,11,12							
	13,14,15						13,14,15						13,14,15							
	total	3	3			6		total	10	3		13		total	3.3	1.0			2.2	
2013	1,2,16	13	21	10	9	53	1,2,16	173	146	36	39	394	1,2,16	13.3	7.0	3.6	4.3		7.4	
	3,4,5		1	1		2	3,4,5		1	3		4	3,4,5		1.0	3.0			2.0	
	6,7,8,9			2		2	6,7,8,9			3		3	6,7,8,9			1.5			1.5	
	10,11,12						10,11,12						10,11,12							
	13,14,15	1		1	2	4	13,14,15	1		4	11	16	13,14,15	1.0		4.0	5.5		4.0	
	total	14	22	14	11	61		total	174	147	46	50	417		total	12.4	6.7	3.3	4.5	6.8
2014	1,2,16	18	28	4		50	1,2,16	231	149	6		386	1,2,16	12.8	5.3	1.5			7.7	
	3,4,5		1			1	3,4,5		3			3	3,4,5			3.0			3.0	
	6,7,8,9		1			1	6,7,8,9		2			2	6,7,8,9			2.0			2.0	
	10,11,12						10,11,12						10,11,12							
	13,14,15	2	3			5	13,14,15	12	9			21	13,14,15	6.0	3.0				4.2	
	total	20	33	4		57		total	243	163	6	412		total	12.2	4.9	1.5		7.2	
2015	1,2,16		14			14	1,2,16		40			40	1,2,16			2.9			2.9	
	3,4,5						3,4,5						3,4,5							
	6,7,8,9						6,7,8,9						6,7,8,9							
	10,11,12						10,11,12						10,11,12							
	13,14,15						13,14,15						13,14,15							
	total		14			14		total	40			40		total		2.9			2.9	
2016	1,2,16	12	28	13		53	1,2,16	261	417	52		730	1,2,16	21.8	14.9	4.0			13.8	
	3,4,5		3			3	3,4,5		6			6	3,4,5			2.0			2.0	
	6,7,8,9		1			1	6,7,8,9		1			1	6,7,8,9			1.0			1.0	
	10,11,12		1			1	10,11,12		3			3	10,11,12			3.0			3.0	
	13,14,15		5			5	13,14,15		40			40	13,14,15			8.0			8.0	
	total	12	38	13		63		total	261	467	52	780		total	21.8	12.3	4.0		12.4	
2017	1,2,16	15	42	26	7	90	1,2,16	364	693	161	21	1239	1,2,16	24.3	16.5	6.2	3.0		13.8	
	3,4,5		2	1		3	3,4,5		3	1		4	3,4,5			1.5	1.0		1.3	
	6,7,8,9		1			1	6,7,8,9		8			8	6,7,8,9			8.0			8.0	
	10,11,12		3	2		5	10,11,12		21	2		23	10,11,12			7.0	1.0		4.6	
	13,14,15	2	15	5		22	13,14,15	57	128	14		199	13,14,15	28.5	8.5	2.8			9.0	
	total	17	63	34	7	121		total	421	853	178	21	1473		total	24.8	13.5	5.2	3.0	12.2

Table 21. Biological characteristics (age, sex, fork length) of Smallmouth Bass captured in Miramichi Lake, 2008 to 2017.

Age (years)	Sex			Total	Fork length (mm)			
	Female	Male	Unknown		Mean (N)	Std error	Min.	Max.
0				7200	51 (6461)	0.2	12	110
1	4	5	39	48	123 (47)	4.5	72	174
2	13	14	18	45	178 (44)	4.9	130	240
3	25	22	13	58	251 (64)	3.8	191	340
4	22	12	5	40	295 (36)	4.8	246	341
5	7	6	2	14	335 (15)	5.2	305	375
6	3	1	1	7	373 (4)	17.9	330	416
7			1	1	406 (1)			
8	1	2		3	419 (3)	9.5	409	438
9		1		1	425 (1)			
10	1			1	477 (1)			
11		1		1	460 (1)			
Total	76	64	79	7419				

Table 22. Summary of length distributions by month of young-of-the-year Smallmouth Bass sampled in Miramichi Lake in 2009 to 2017.

Month	N	Means	Std Dev.	Min.	Max.
July	1,497	37	7.9	12	62
Aug.	3,186	49	12.4	20	95
Sept.	1,436	63	13.1	28	106
Oct.	342	70	13.9	33	110



## FIGURES

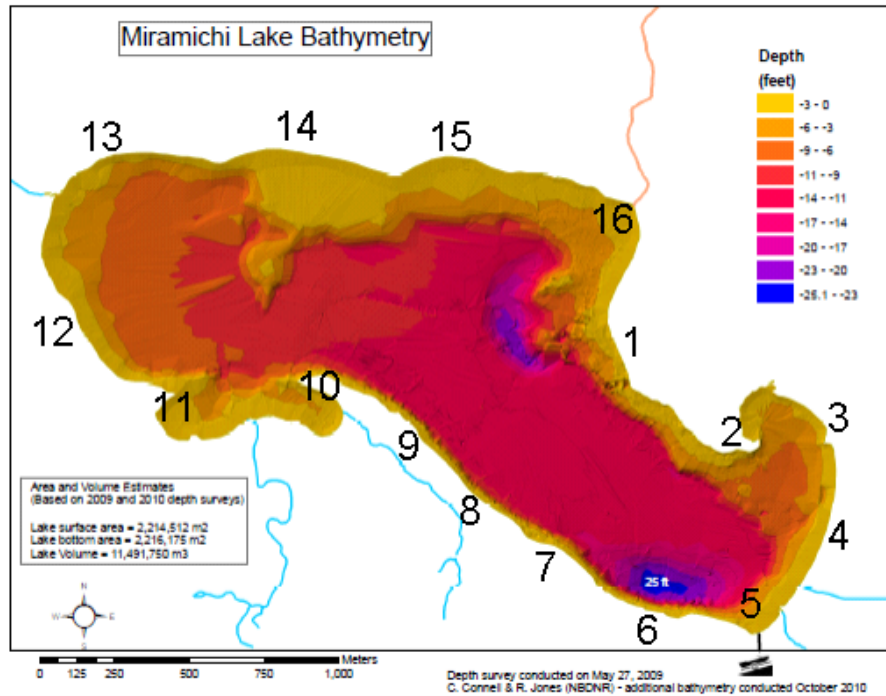
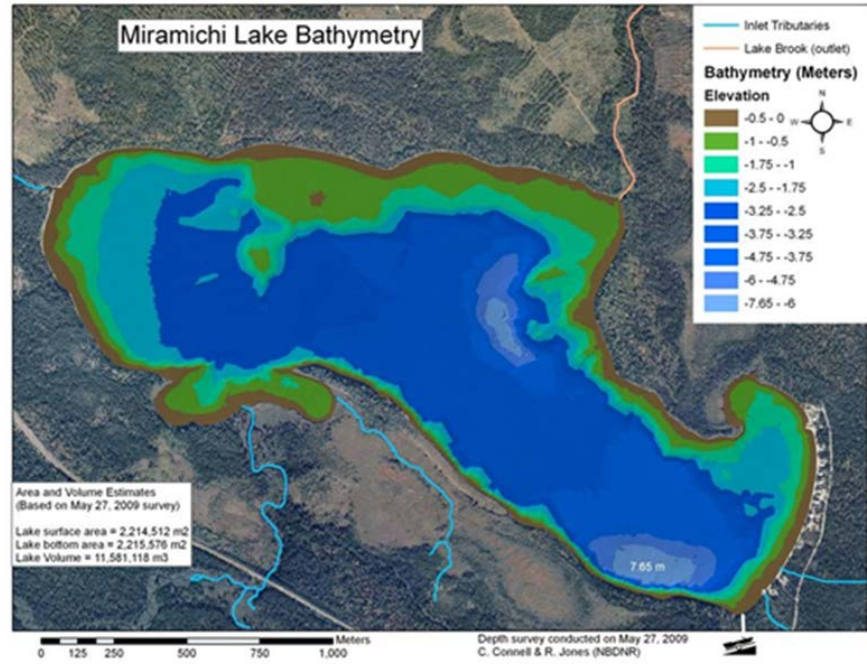


Figure 1. Bathymetry of Miramichi Lake and location of sector boundaries. Bathymetric data and profiles were provided by C. Connell and R. Jones, New Brunswick Department of Natural Resources.

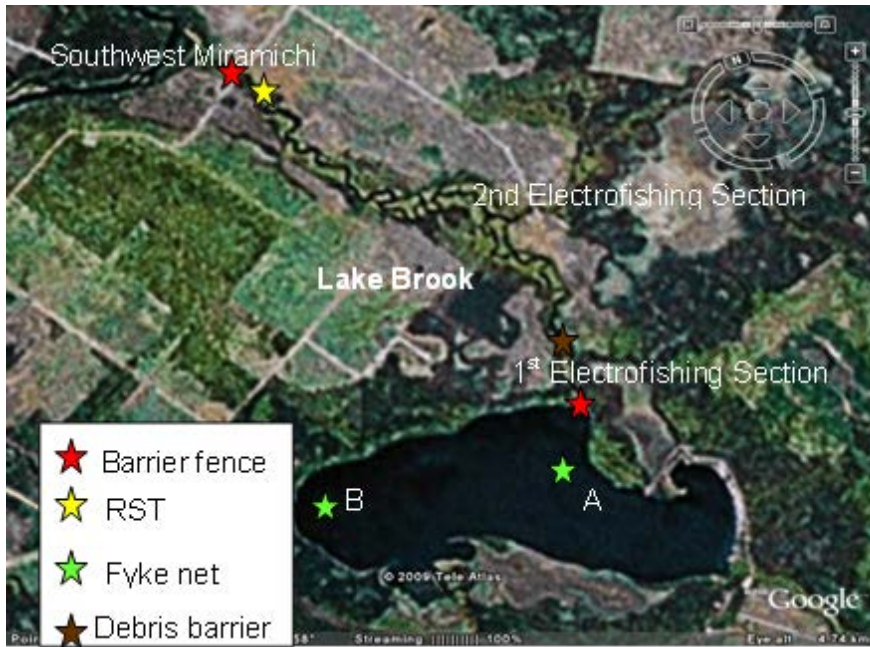


Figure 2. A map showing the location of the barrier fences on Lake Brook, the debris barrier and the first and second section of the electrofishing survey, smolt wheel and fyke nets. Figure is from the unpublished report of O'Donnell and Reid (2009).



Figure 3. Example of young-of-the-year Gaspereau being channelled through the main barrier.

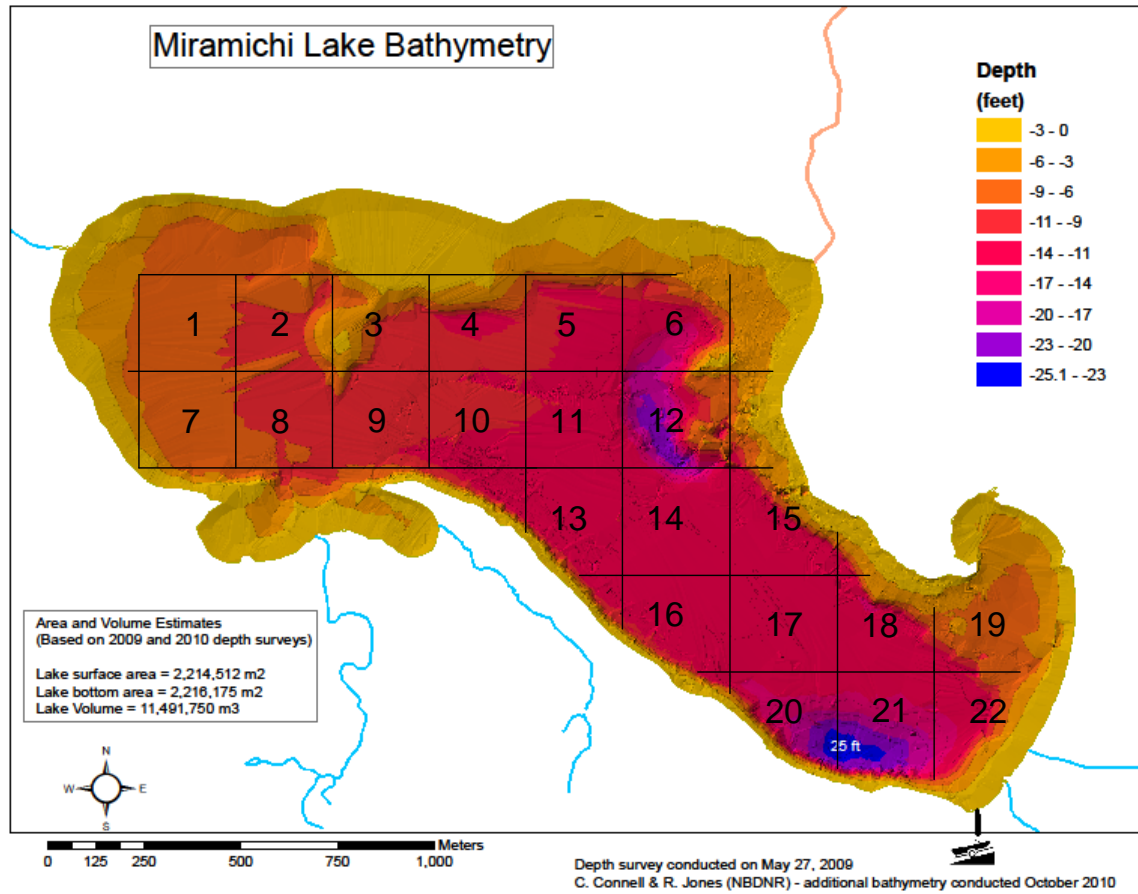


Figure 4. Gillnet random sampling program grid design to assess adult Smallmouth Bass distribution in August 2011 (Biron et al. 2014).

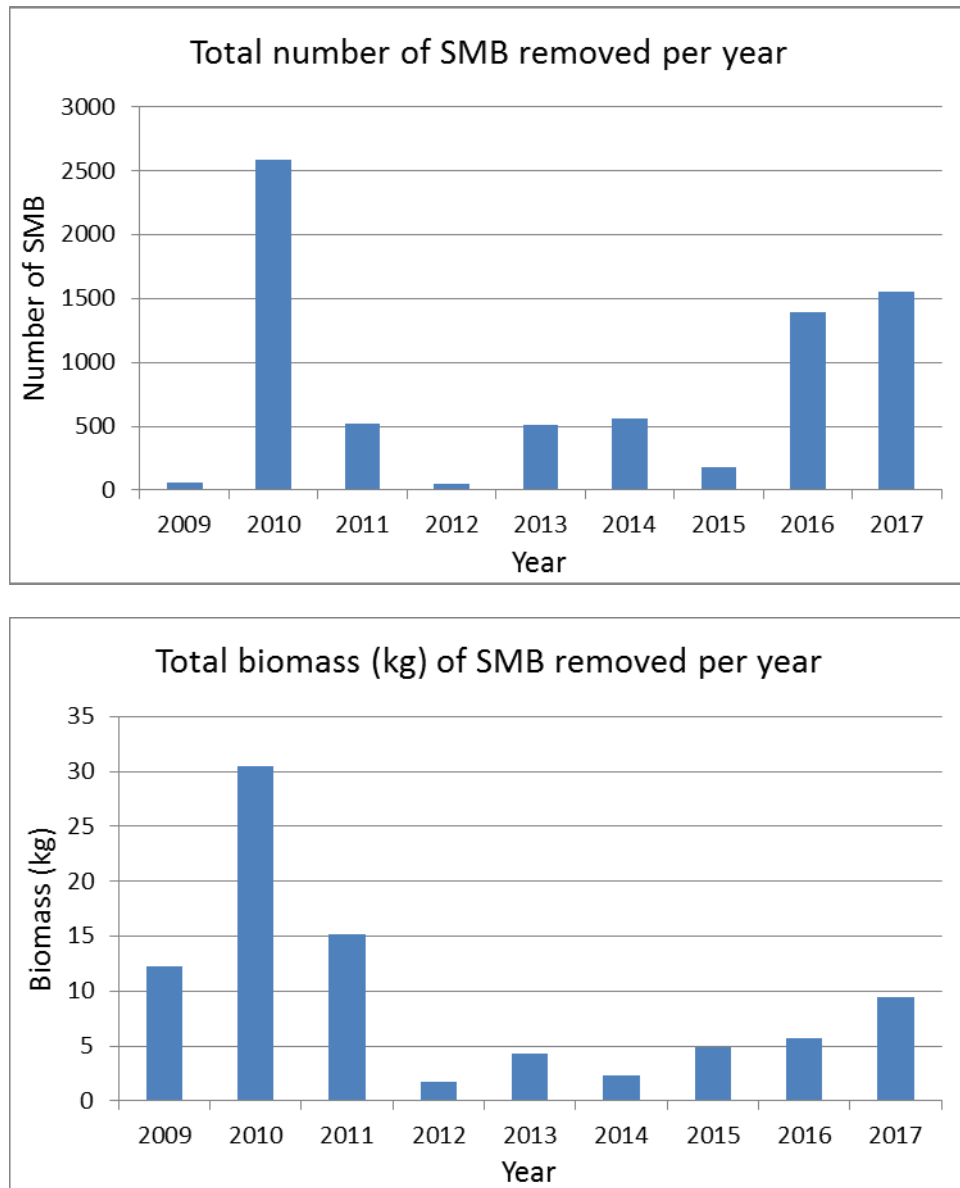


Figure 5. Total number and total biomass (kg) of Smallmouth Bass (SMB) captured and removed each year from Miramichi Lake, 2009 to 2017.

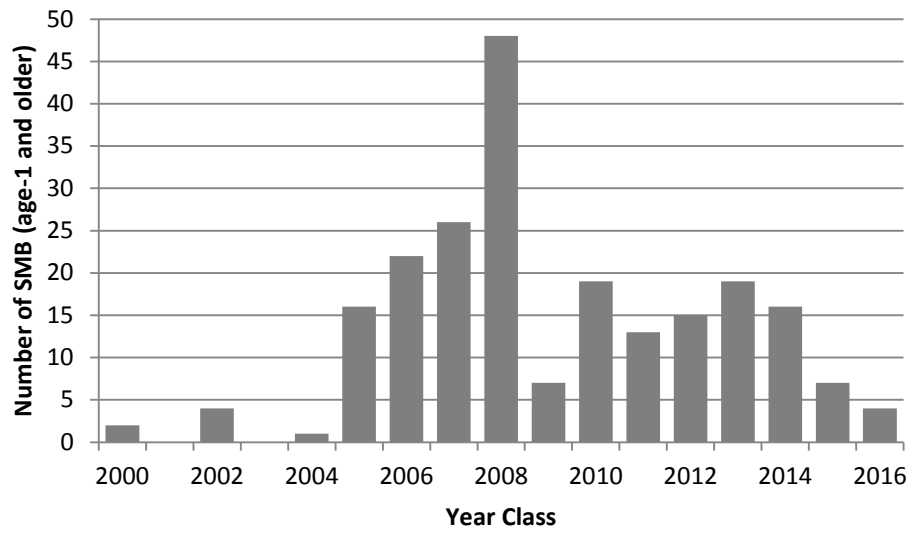


Figure 6. Cumulative catch of Smallmouth Bass (SMB), age one-year and older, by year class, in Miramichi Lake based on biological characteristics and the catches during 2009 to 2017.

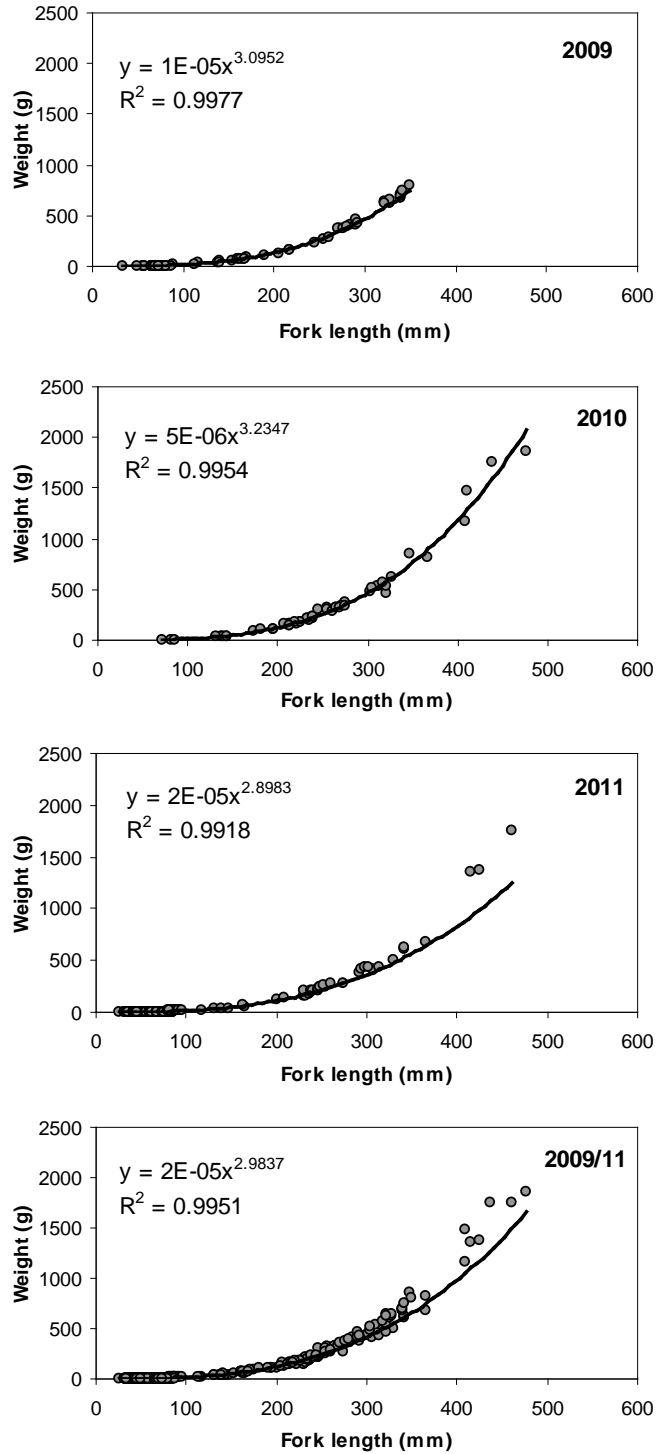


Figure 7. Fork length (mm) to weight (g) relationship for Smallmouth Bass captured in Miramichi Lake, 2009 to 2011 (Biron et al. 2014).

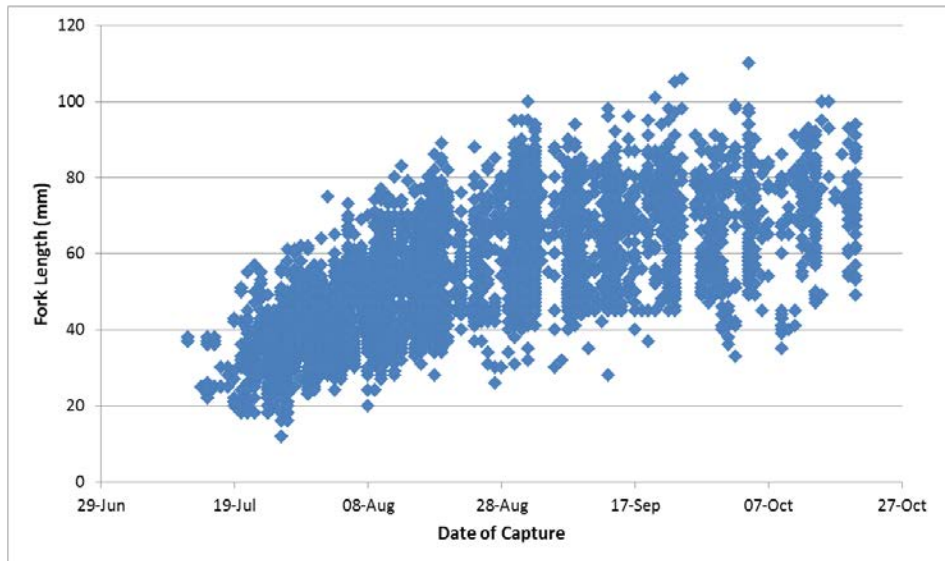


Figure 8. Fork length (mm) by date of capture of young-of-the-year (YOY) Smallmouth Bass captured in various gears in Miramichi Lake, 2009 to 2017.

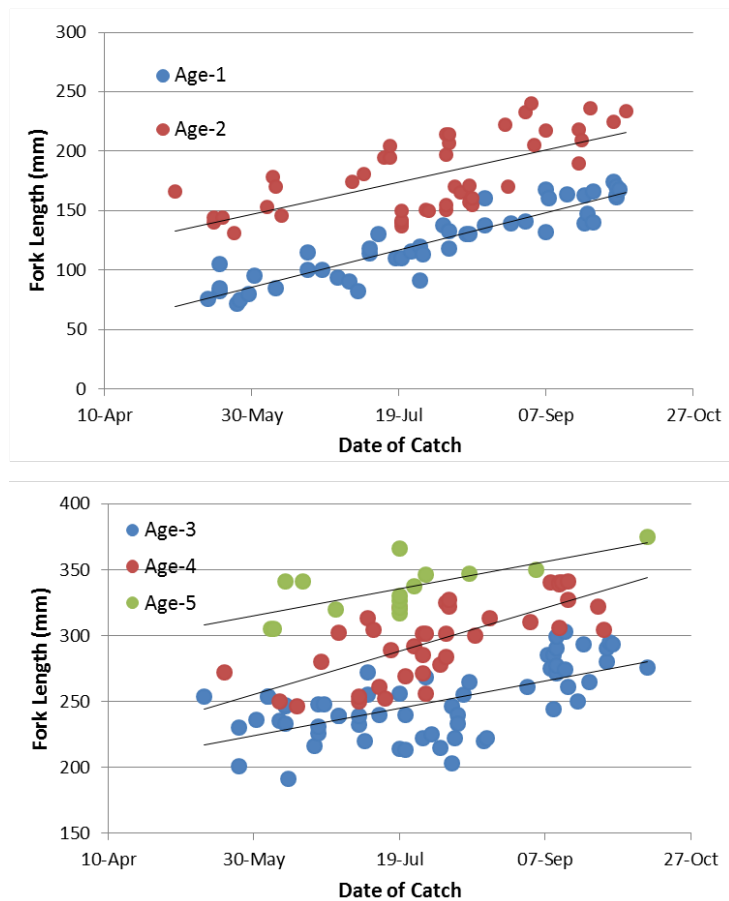


Figure 9. Fork length (mm) by age of Smallmouth Bass by date of capture from Miramichi Lake, 2009 to 2017.