Results of a Control and Eradication Program for Illegally Introduced Non-endemic Smallmouth Bass (*Micropterus dolomieu*) in Miramichi Lake, New Brunswick, 2010

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ABSTRACT

Chaput, G. and Moore, D. 2018. Results of a Control and Eradication Program for Illegally Introduced Smallmouth Bass (*Micropterus dolomieu*) in Miramichi Lake, New Brunswick, 2010. Can. Tech. Rep. Fish. Aquat. Sci. 3273: vii + 51 p.

A containment, control and eradication program based on mechanical removal to control and prevent the spawning and recruitment of Smallmouth Bass (*Micropterus dolomieu*), an illegally introduced non-endemic species in Miramichi Lake, New Brunswick, was initiated in 2010. A wide range of fishing methods were used including backpack electrofishing, boat electrofishing, fyke nets, gill nets, beach seining, and angling. Seventeen species, exclusive of Smallmouth Bass were identified from the catches with the most abundant species in the catches being Yellow Perch, White Sucker, White Perch and Fallfish. A total of 2,584 Smallmouth Bass, aged zero to ten years old, were captured and removed, of which 98% were young-of-the-year (YOY) from spawning in 2010. The objective of preventing spawning of adult bass in the spring of 2010 failed, no nests or guarding males were observed in Miramichi Lake in 2010 but large numbers of YOY were subsequently captured and destroyed. There was no evidence of depletion of adult bass with cumulative gillnetting effort, however, only 30 age-3 and older Smallmouth Bass were captured from Miramichi Lake in 2010 from all fishing gears with substantial fishing effort which suggests that the population size of adult sized bass in Miramichi Lake is quite small. Smallmouth Bass from six year classes were present in Miramichi Lake. The capture of YOY bass in 2008 to 2010 provides evidence that Smallmouth Bass can successfully reproduce in Miramichi Lake and the capture of age-1 to age-5 year old bass in 2009 and 2010 provide evidence of survival and successful recruitment to the adult stage. The few age-1 bass captured in 2010 and in previous years may indicate that overwinter survival of YOY is poor in Miramichi Lake. A population estimate for YOY based on depletion experiment is very uncertain with a coefficient of variation greater than 100%, but there is a high probability (>90%) that the population size of YOY was less than 15,000 fish in 2010. The estimated probability of capture by boat electrofishing was very low (0.0125 per 10,000 seconds of effort) and boat electrofishing alone was insufficient to effectively reduce the YOY population of Smallmouth Bass in Miramichi Lake in 2010. By September, YOY bass were captured in all shore areas of the lake. The success of an eradication program is very difficult to demonstrate. As the targeted population declines in abundance, more effort is required to capture the remaining individuals. The results from the work in 2010 suggest that it would take a very large deployment of sampling effort to be confident (90%) that the failure to catch any Smallmouth Bass in the lake is indicative of a very low abundance, let alone the absence of the species in Miramichi Lake. This assessment issue is associated with any eradication activity, even the use of rotenone.

RÉSUMÉ

Chaput, G. and Moore, D. 2018. Results of a Control and Eradication Program for Illegally Introduced Smallmouth Bass (*Micropterus dolomieu*) in Miramichi Lake, New Brunswick, 2010. Can. Tech. Rep. Fish. Aquat. Sci. 3273: vii + 51 p.

Un programme de confinement, de contrôle et d'éradication basé sur l'enlèvement mécanique pour contrôler et prévenir le frai et le recrutement de l'achigan à petite bouche (Micropterus dolomieu), un espèce non-indigène et introduit dans le lac Miramichi au Nouveau-Brunswick, a été lancé en 2010. Un large éventail de méthodes de pêche a été utilisé, incluant la pêche électrique avec unités portatifs, la pêche électrique avec bateaux, les verveux, les filets maillants, la seine 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 prises, et les espèces les plus abondantes dans les prises étant la perchaude, le meunier noir, le bar-perche, et la ouitouche. Un total de 2 584 achigan à petite bouche, âgés de zéro à dix ans, ont été capturés et enlevés dont 98 % étaient des jeunes de l'année (frai de 2010). L'objectif de prévention du frai de l'achigan adulte au printemps 2010 a échoué. Aucun nid ou gardiennage par des mâles a été observé dans le lac Miramichi en 2010 mais un grand nombre de jeunes ont été capturés et détruits par la suite. Cependant, seulement 30 achigans à petite bouche de 3 ans et plus ont été capturés dans le lac Miramichi en 2010 à partir de tous les engins de pêche et un effort de pêche important, ce qui suggère que la taille de la population d'achigans adultes dans le lac Miramichi est assez petite. Des achigans à petite bouche provenant de six cohortes étaient présent dans le lac Miramichi. Les captures des jeunes de l'année de l'achigan à petite bouche durant 2008 à 2010 démontrent que l'achigan à petite bouche a pu se reproduire avec succès dans le lac Miramichi et que la capture d'achigans âgés de 1 à 5 ans en 2009 et en 2010 témoigne de la survie et du succès du recrutement au stade adulte. Les quelques achigans d'âge 1 an capturés en 2010 et au cours des années précédentes pourraient indiquer que la survie durant l'hiver des jeunes de l'année est faible dans le lac Miramichi. Une estimation de la population pour les jeunes de l'année basée sur une expérience d'épuisement du stock est très incertaine avec un coefficient de variation supérieur à 100%, mais il y a une forte probabilité (> 90%) que la taille de la population des jeunes de l'année était inférieure à 15 000 poissons en 2010. La probabilité de capture par la pêche électrique par bateau est très faible (0,0125 par 10 000 secondes d'effort) et la pêche électrique par bateau ne suffirait pas à réduire efficacement la population de l'achigan à petite bouche au lac Miramichi en 2010. Arrivé en septembre, les jeunes achigans de l'année ont été capturés dans toutes les zones littorales du lac. Le succès d'un programme d'éradication est très difficile à démontrer. À mesure que la population ciblée diminue en abondance, il faut déployer plus d'efforts pour capturer les individus restants. Les résultats du travail en 2010 suggèrent qu'il faudrait un très grand déploiement d'effort d'échantillonnage pour être certain avec 90% de probabilité que l'échec de la capture de l'achigan à petite bouche dans le lac est révélateur d'une très faible abondance, sans parler de l'absence de l'espèce dans le lac Miramichi. Ce problème d'évaluation est associé à toute activité d'éradication, même avec l'utilisation de roténone.

INTRODUCTION

Smallmouth Bass (*Micropterus dolomieu*) is not endemic to the Maritime Provinces of eastern Canada (DFO 2009). In September 2008, the presence of Smallmouth Bass was confirmed in Miramichi Lake, a headwater lake of the Southwest Miramichi River, in New Brunswick, the first confirmed occurrence of the species in a watershed in DFO Gulf Region New Brunswick. 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.

In response to government and conservation groups concerns about the potential impact of Smallmouth Bass on Atlantic Salmon in the Miramichi River, a risk assessment of the possible impact of this non-native species introduction on Atlantic salmon and the native ecosystem was conducted (DFO 2009; Chaput and Caissie 2010). The overall risk to the aquatic biota (all species) in lakes was considered to be high with low uncertainty whereas the overall risk to ecosystem in riverine habitat, including to salmon, was considered moderate for the Southwest Miramichi River and DFO Gulf Region (DFO 2009). There was high uncertainty in the riverine risk assessment because there are few studies on the suitability of habitat in rivers like the Southwest Miramichi to accommodate Smallmouth Bass, and there were few studies on direct interactions between Smallmouth Bass and Atlantic Salmon to inform the assessment of ecological impacts (DFO 2009; Valois et al. 2009; Chaput and Caissie 2010).

Halfyard (2010), in a literature review of options for the containment, control and eradication of non-native fish species, concluded that the deployment of multiple techniques increases the probability of successful management of non-native species but that the probability of successful containment, control or eradication of undesirable fishes decreases with time post-arrival.

In 2009, the Miramichi Watershed Management Committee in collaboration with the Miramichi Salmon Association and the New Brunswick Department of Natural Resources, initiated a containment and further assessment program of Smallmouth Bass in Miramichi Lake (O'Donnell and Reid 2009). A barrier was installed at the outlet of Miramichi Lake and near the confluence of Lake Brook with the Southwest Miramichi. Control and assessment efforts in 2009 using backpack electrofishing in Lake Brook above and below the barrier, fyke nets, and gillnets resulted in the removal of 64 Smallmouth Bass represented by 26 young-of-the-year (YOY), 13 age-1 year old, and 25 age 2 to 4 year olds. The 2009 data confirmed the successful spawning and recruitment of Smallmouth Bass in Miramichi Lake.

Following on the risk assessment and the further field investigations of 2009, DFO proposed a containment, control and eradication program based on mechanical removal to control and prevent the spawning and recruitment of Smallmouth Bass in Miramichi Lake (Appendix 1). The three-year program was initiated in 2010. The plan is being executed by DFO in cooperation with the New Brunswick Department of Natural Resources and the Miramichi Watershed Management Committee.

This report presents the results of the first year's efforts (2010) to contain, control and remove Smallmouth Bass from Miramichi Lake. Information is provided on the results of the fishing activities. A first estimate of the population size of young-of-the-year Smallmouth Bass by a depletion estimator and recommendations for work in the coming years are provided.

MATERIALS AND METHODS

A number of fishing methods were employed in 2010 to capture and remove Smallmouth Bass. These included backpack electrofishing, mostly in Lake Brook and close to shore in Miramichi Lake, boat electrofishing, fyke nets, gill nets, beach seining, angling, by opportunistically snorkeling, and catches at the containment barrier.

Backpack Electrofishing

Daytime backpack electrofishing was conducted in Lake Brook (Fig. 1) in 2010 to determine if Smallmouth Bass could escape the containment barrier operated at the outlet of Miramichi Lake. Smith-Root Model LR 24 or Model 12B electrofisher units were used and the default setting used was I-5 (pulse width = 3 ms, pulse frequency = 50 Hz, standard wave form (uniform pulses),) at voltages ranging from 500 to 700V. The voltage adjustments were made as needed to adapt to changes in conductivity of the water.

Electrofishing was conducted in Lake Brook using one or two electrofishing units. When fishing with one unit, one person operated the backpack unit while another person captured fish with a dip net. Fishing was conducted down the west side of the brook to the debris dam (approximately 350 m downstream of the barrier) and then back up the east side. Later in the year a two unit method was used. When fishing with two units, two people, each with a backpack unit, would walk from the lake down to the debris dam and then fish back up to the lake with one sampler on each side. Special attention was paid to structures in the brook especially along the shoreline in slow moving water at 30 to 100 cm depths.

Electrofishing in the lake was done singly or with paired units. When done alone the fisher would zigzag along the shoreline up to 25 meters from shore targeting large structures such as rocks and logs. When done as a pair one fisher would concentrate on the immediate shoreline (up to 3 meters from shore) and the other would stay in deeper water (1-3 feet) and target large structures.

Electrofishing Boat

Electrofishing boats were used to sample shallow waters (depth less than < 2 m) along the littoral zone of Miramichi Lake. The electrofishing boat measured 4.6 m long and was equipped with a Smith-Root 7.5 GPP (Generator Powered Pulsator) electrofishing unit. Two booms measuring 3 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. The boat was configured to use the hull as the cathode.

The crew on the electrofishing boat varied between two and three people. One person operated the boat and electrofishing unit while one or two people were positioned at the bow to capture Smallmouth Bass with dip nets. The distance between the anodes was maintained at approximately 1.5 m when one dip netter was present and 2.5 m when two dip netters were present.

At the start of the year, all sampling was conducted in the late evening or after dark. Sampling was conducted along transects perpendicular to shore, beginning approximately 20 m offshore and ending at the shoreline. All fish were brought aboard for processing. Later in the year and after the first Smallmouth Bass had been captured, the sampling protocol was modified. All fish were netted and put in the live box on the boat but detailed sampling of the catch was only done for a portion of each sector sampled. From August 30th onwards, and to allow for greater sampling effort, the protocol was modified and only Smallmouth Bass were brought aboard the boat. Throughout the season transects parallel to shore were sampled and the distance from shore was recorded for these. The start time, fishing protocol (perpendicular to shore or parallel to shore), seconds of shocking time for each sampling event, and surface water temperature at sampling were recorded.

Fyke Nets

Fyke nets were intermittently fished throughout the season at various locations in Miramichi Lake. The fyke nets were constructed of 0.5 inch mesh with either 3X3 ft or 3X6 ft frames. The 3 by 3 ft nets had wings and a leader of either 80 ft, 180 ft or 280 ft depending upon fishing location. The 3 by 6 ft nets had a 100 ft leader but no wings.

When setting a net the first step was to anchor the lead, usually on shore by tying it off to a tree and then placing large cobble to hold the line flush with the lake bottom but sometimes leads were anchored off shore to allow for greater depth at the actual trap site. Once the lead was anchored it was stretched out by boat in reverse. The wings (if applicable) were thrown out to either side with anchors and buoys attached. The trap and lead were then pulled tight by boat and anchored. The wings were then individually pulled tight by boat at approximately 45 degree angles.

Two methods were used to fish the traps. The first was by two crew members pulling the entire trap to shore by the wings after removing the trap anchor. The trap would then be untied and emptied into a bin where the catch would be tallied by species and then all non-bass would be released and the trap reset by the original method. The second method was to pull in the trap anchor by the buoy line directly into the boat. The catch was then emptied into the bins and the trap was reset by the original method.

Beach Seining

A beach seine measuring 50 m in length, 2 m deep with a 12 mm mesh was used. Each sector was seined for its entire length by seining 150 to 200 m sweeps depending on algae and other debris that weighted the net down. In good conditions (low algae and debris) 200 m sweeps were used but would be cut short in bad conditions.

Initially, one end of the seine net was held by a person on shore while the other end was discharged from a boat and fished in a loop. Afterwards, the seine net was fished manually. One person took the net approximately 50 feet offshore and with the other person on or near shore, the net was dragged along the shoreline. After travelling about 150 to 200 m along the shore, the outer portion of the net was worked back to shore completing a closed loop. The net was then pulled carefully onto shore while keeping the lead line on bottom. A third person followed the seiners to free the net from any structure it caught on while fishing the net and pulling it to shore. Once most of the net was pulled to shore from both ends a bag was formed in the net. This bag was used to lift and dump the catch into bins. Smallmouth Bass were separated from all other species and retained. All non-bass species were released back into the lake.

Gill Nets

A number of gillnets of variable mesh sizes were used in 2010. The nets used were grey, white or green multifilament, of mesh sizes 2, 2.5, 2.75, 3, 3.25, 3.5, 4, and 5 inch stretched mesh. Most nets were 30 m in length but a few were 23 m in length. All nets were 2 m deep. Nets were set anchored at both ends with steel anchors or cinder blocks and buoys. The net was deployed from the boat and stretched in a straight line. Another anchor was then attached to the lead line on the opposite end and dropped into the lake. Holding onto the buoy on the second anchor with the boat in reverse the net was pulled tight and released.

Gillnets were fished in two ways; if the weather was poor (windy and rough) the net, anchors, and buoys were hauled into the boat and taken ashore to clean, sort and sample the catch. If the weather was good, the nets were processed on site and immediately reset without pulling both anchors.

Angling

Angling was undertaken opportunistically at various locations in the lake using cast and spinning gear with various lures.

Snorkelling

Snorkeling was conducted along the beaches and near the fence and YOY Smallmouth Bass observed were opportunistically captured with dipnets.

Processing of Catches

All Smallmouth Bass captured were killed and sampled before shipment to the lab. Bass were sampled for fork length (mm), scale sampled for interpretation of age, some were weighed (g) and sex determined by dissection. All dead by-catch after processing was placed in bins, frozen, and disposed of at facilities in either Miramichi or Fredericton.

Depletion Estimate of Young-of-the-Year Smallmouth Bass Abundance

Catches and effort from boat electrofishing were examined for their utility in deriving a population estimate using a depletion estimator. The assumptions of the method were considered to have been reasonably respected and include:

- A closed population (Miramichi Lake), and
- Probability of a fish being sampled is independent and identically distributed.

It was assumed that the probability of capture of a YOY per unit of effort was similar for all fish over the period of study. This assumption can be respected if the fish are randomly distributed in Miramichi Lake or if sampling is random within Miramichi Lake. It is unlikely that young-of-the-year were randomly distributed around the lake. Although they were found in all shore locations sampled, it was unlikely that they were so active and able to be randomly re-distributed along the shoreline after each removal event. The sampling protocols in 2010 were assumed to be sufficient to respect the assumption of random sampling. In a number of sampling periods encompassing several days, most of the shoreline areas were sampled by the electrofishing boat. To further ensure that the probability of capture was similar across sampling events, the sampling periods only included those for which the temperature was conducive to YOY activity and feeding (temperature >= 14ºC).

With the above sampling effort restrictions, four depletion samples were used (periods 6, 9, 10, and 11 in Table 21).

A simple depletion model was used (Appendix 2). It assumed that the catches of YOY by boat electrofishing in a sampling period (multiple days, multiple transects at multiple sectors within Miramichi Lake) followed a Poisson distribution with the mean defined as the product of the probability of capture, effort (seconds) and the available population size (number of fish):

$$C \sim \text{Poisson}(c.rho_i) \qquad (1)$$

$$c.rho = \text{Effort}_i * N_i * \mu.rho \qquad (2)$$

where µ.rho is the probability of capturing a fish for a given unit of effort (sec^{-1}) and N_i is the population available for capture at sampling period i.

For i > 1, the available population was the total population (N_0) prior to any removals minus the cumulative removals to sampling period i:

$$N_i = N_0 - \sum_0^{i-1} C_i + C_i^{other} \quad (3)$$

Where C_i is the removal of YOY Smallmouth Bass by boat electrofishing in period i, and C_i^{other} is the removal of YOY Smallmouth Bass by all other methods in period i.

No losses other than by fishing were considered to have occurred (i.e. natural mortality was null).

The model was adjusted in OpenBUGS (Version 3.1.2) using Monte Carlo Markov Chain (MCMC) with Gibbs sampling (Spiegelhalter et al. 2010). The posterior distributions of N_0 and µ.rho and the predicted catches at period were summarized from the posterior distributions. The prior for N_0 was assumed uniform (between 100 and 100,000) and the prior on µ.rho was assumed gamma with non-informative shape and inverse-scale parameters ($\alpha = \beta = 0.01$).

RESULTS

Miramichi Lake is approximately 2.8 km in length by 0.8 km in width with an estimated surface area of 2.21 km² (221 ha) (Fig. 1). The maximum depth is 7.05 m and the majority of the lake is less than 3.25 m deep (Fig. 1).

In 2010, fishing effort totaled 337 thousand seconds of backpack electrofishing, 294 thousand seconds of boat electrofishing, 1,150 net days of gillnetting effort, 263 sets of fyke nets, and 102 beach seining sampling events (Table 1). A diverse fish fauna was sampled in Miramichi Lake. The most abundant species tabulated, in decreasing order of abundance, were White Sucker (*Catostomus commersoni*), Yellow Perch (*Perca flavescens*), White Perch (*Morone americana*), Fallfish (*Semotilus corporalis*) and numerous cyprinid species (Table 2). Anadromous species enumerated from Miramichi Lake included Sea Lamprey (*Petromyzon marinus*), gaspereau (alewife, *Alosa pseudoharengus*), Atlantic Salmon (*Salmo salar*), and American Eel (*Anguilla rostrata*) (Table 2). Atlantic Salmon of the southern Gulf of St. Lawrence / Gaspe Designatable Unit has been evaluated by COSEWIC as Special Concern (COSEWIC 2010) whereas the status of the American Eel in eastern Canada has been assessed as threatened (COSEWIC 2012). Banded Killifish (*Fundulus diaphanous*) mainland population was assessed Not at Risk by COSEWIC.

Over all sampling effort, a total of 2,584 Smallmouth Bass were captured and removed, 2,532 of these (98%) were young-of-the-year (YOY) from spawning in 2010 (Table 3). The largest number of YOY were captured by the boat electrofisher followed by beach seining. The largest number of age-2 and older Smallmouth Bass were captured with gillnets (Table 3). The largest Smallmouth Bass captured was in a fyke net, at 477 mm, and most of the Smallmouth Bass greater than 200 mm in fork length were captured with gillnets (Fig. 2).

Gear-Specific Effort and Catches

Backpack electrofishing

Backpack electrofishing was used to sample Lake Brook, below the barrier, and the shoreline of Miramichi Lake (Table 4). Sampling in Lake Brook occurred monthly from May to November 2010. A total of 56,315 seconds of electroshocking time was expended resulting in a catch and removal of five Smallmouth Bass of which four were age-1 and one was a YOY (Table 4). Three of the four age-1 bass were captured in May and are considered to have moved into Lake Brook prior to the installation of the containment barrier.

Most of the shoreline of Miramichi Lake was sampled by backpack electrofishing during July and August (Table 5). 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 5). The first YOY was captured on July 15 and between July 15 and 20, YOY were captured in all sectors sampled (sectors 15, 16, 1, 2, 5, 6, and 8) (Fig. 1). Most YOY were captured and removed in August (Table 5).

Boat electrofishing

Boat electrofishing effort began in May and continued into October. In 2010, a total of 294,124 seconds of electrofishing effort was deployed in the lake, the majority in the two sectors bordering the outlet to Lake Brook (sectors 16 and 1) (Table 6; Fig. 1). The largest effort was deployed in September, October and August, after the YOY were detected and catchable with the gear. The majority of the effort was conducted after sunset but daytime sampling effort increased in September and October as catches of YOY bass were sustained and weather conditions became more difficult for boat electrofishing (Table 7). Sector and day specific sampling effort with the electrofishing boat ranged from a low of 279 seconds to 10,510 seconds, the average effort over all days per sector was 1,671 seconds (Fig. 3).

A diverse fish fauna was sampled with the boat electrofisher, the most abundant species enumerated were Yellow Perch and White Perch (Table 8). A total of 1,294 Smallmouth Bass were captured and removed with the boat electrofisher, the majority (99%) were YOY bass (Table 9). The majority of the YOY bass were captured and removed in September, followed by August and October. The first YOY was captured on July 12 in Sector 3. By September, YOY were captured in all sectors sampled around the lake (Table 9). In terms of relative abundance (CPUE, catch per electrofishing effort) and based on the data from September, YOY were relatively more abundant in sector 8 and of high abundance in sectors 6, 7, 9, 10 (southern shoreline sectors) as well as 16 and 1 (the sectors bordering Lake Brook) (Table 10).

Age-1 and older bass were captured in May, July and August, all within the vicinity of Lake Brook, sectors 1 and 2 (Table 9).

Fyke nets

Fyke nets were initially deployed in late April and were fished into October with a total effort (expressed as fyke net sets of variable duration) of 263 sets (Table 11). Most of the effort was deployed in July to September, concentrated in sectors 16 and 1 in the vicinity of Lake Brook (Table 11; Fig. 4).

As with the other gears, a diverse fish fauna was captured in the fyke nets, the most abundant species enumerated were White Sucker, Yellow Perch, and White Perch (Table 12). A total of 196 Smallmouth Bass were captured and removed with the fyke nets, the majority (95%) were YOY bass (Table 13). The majority of the YOY bass were captured and removed in July and August and October (Fig. 5). The first YOY was captured on July 16 in Sector 1. YOY were caught in all sectors except in sector 12 (Table 13).

A total of ten age-1 and older bass were captured in July and August, mostly within the vicinity of Lake Brook, sectors 16 and 1 (Table 13; Fig. 5).

Beach seining

Beach seining was mostly conducted in August and September in most sectors around the lake (Table 14). A total of 102 beach seine events were conducted. A total of 815 YOY Smallmouth Bass were captured and removed, mostly in August (Table 15). The largest catches of YOY Smallmouth Bass were taken from sector 5 and vicinity (5 to 10) and in sector 1 (Table 15). The first YOY was captured on August 10 in Sector 16. The other species captured by beach seining were not tabulated.

Gill nets

Gillnets were fished from April to October. In 2010, a total of 1,150 net-days of effort were recorded, with the highest effort in October and September (Table 16; Fig. 6). The most frequently used gillnets were of 3 inch, 3.5 inch, and 4 inch mesh (Table 16). Most of the effort was deployed in sector 1 with lesser effort in sectors 16, 3, 6, 5, and 9 (Fig. 7).

A diverse fish fauna was captured in the gillnets, the most abundant species enumerated were White Sucker, White Perch, and Yellow Perch (Table 17). The most abundant bycatch was recorded in the smaller mesh sizes (Table 18).

A total of 26 Smallmouth Bass were captured and removed with the gillnets, the first capture was on May 20, the highest daily catch was recorded on July 19 (six fish) and the last captures on Oct. 12 (Table 17; Fig. 6). The largest catches were obtained in sectors 1 and 3 in 3 inch mesh nets (Figs. 7, 8). The highest catch rate (fish per net-day) was obtained with 3.25 inch net at 0.69 fish per 10 net-days of effort (Fig. 8). The Smallmouth Bass captured with the gillnets ranged in size from 225 mm to 438 mm fork length, the widest range in size was captured in 3 inch mesh nets but the largest were captured in the 4 inch mesh nets (Fig. 9). The range in sizes of Smallmouth Bass captured by gillnets increased over the season, some of this could be attributed to growth of bass during the season and in particular growth of age-2 bass into catchable sizes by the fall (Fig. 10).

There was no evidence of depletion of Smallmouth Bass with the gillnets, the cumulative catch of bass and the cumulative effort follow parallel trends after mid-July with the catches accumulating at a similar rate to effort (Fig. 11). Over the season, it took on average 46 net days of effort to catch a bass. This low catch rate is interpreted as representing a low abundance of these older fish in Miramichi Lake.

Other capture methods

Smallmouth Bass were also captured and removed by angling and snorkelling (and fishing with a dipnet). Two Smallmouth Bass measuring 226 mm and 409 mm fork length were angled on June 21 and July 14, respectively, in sector 1 of the lake. A total of 57 YOY Smallmouth Bass were captured with small dipnets while snorkelling, all in sector 3 in the vicinity of the boat wharf near the camps, from July 28 to September 2 (Table 3).

Four YOY were recovered dead and washed up against the containment barrier and one YOY was removed during monitoring of downstream movements of YOY gaspereau at the fence.

Biological Characteristics of Smallmouth Bass

There was a strong allometric association between fork length and whole weight of Smallmouth Bass from Miramichi Lake (Fig. 12). A 200 mm bass has a predicted weight of 125 g, a 300 mm bass has a predicted weight of 464 g and the predicted weight rises to 1,178 g for a 400 mm long bass (Fig. 12). The two largest Smallmouth Bass captured in 2010 measured 438 and 477 mm, and weighed 1,750 and 1,853 g respectively.

Of the 2,584 Smallmouth Bass captured and removed in Miramichi Lake and Lake Brook in 2010, 98% were YOY (spawned in 2010). Based on interpretation of ages from scales, Smallmouth Bass aged one to ten years old were captured and removed, representing the 2001, 2003, and 2005 to 2009 cohorts (Table 19). There were slightly more males in the catches of age 3 and older bass but there were equal proportions of males and females in the age-2 bass (Table 19). The median length of age-2 bass was 211 mm, with a minimum to maximum range of 131 to 240 mm (Table 19). The median lengths of age-3 to age-5 bass were 255 mm, 290 mm and 337 mm, respectively (Table 19). The age-8 and age-10 bass were all longer than 400 mm (Table 19; Fig. 13).

Growth in length through the season was noted in bass age-1 to age-3 and less so in age-4 and age-5 (Fig. 13). The rate of growth in length was approximately 0.72 mm per day, 0.75 mm per day, and 0.63 mm per day for age-1 to age-3 bass, respectively (Fig. 13). The growth in length for age-4 bass was 0.24 mm per day but the relationship was weak ($r^3 = 0.13$) (Fig. 13). For age-5 and older bass, there is a visual impression of increased length over the season but the sample size is very small (Fig. 13).

YOY Smallmouth Bass grew well through the season, from a median fork length of 42 mm in July, and a minimum length of 23 mm, to a median length of 71 mm by October, and a maximum fork length of 110 mm (Table 20; Fig. 14). By October 2010, 25% of the captured YOY were longer than 80 mm fork length and 5% of the YOY were longer than 90 mm (Table 19; Fig. 14). It is notable that the three age-1 Smallmouth Bass sampled between May 19 and May 25 2010 measured between 72 and 85 mm fork length (Fig. 13), which corresponds to the fork lengths of 25% to 50% of the YOY in October 2010 (Table 20).

There was a very broad length range for the YOY in all months in 2010 (Fig. 15). There was an indication of bimodality in the July samples which was not apparent in August and September but which reappeared in the samples from October. Spawning times and events in 2010 are unknown as no nests or brood-guarding males were observed.

Depletion Estimate of the Population Size of YOY Smallmouth Bass in 2010

Based on the sampling effort in different sectors of Miramichi Lake, four periods were considered for the depletion experiment (Table 21). In period 6 (30 Aug. to 2 Sept.) and periods 9 to 11 (20-23 Sept., 27-30 Sept. and 4-7 Oct.), between 11 and 14 of the 16 sectors in Miramichi Lake were sampled with the boat electrofisher (Table 21; Fig. 3). During that time, surface water temperatures were above 20ºC during period 6 and varying between 14.0 and 19.8ºC in periods 9 to 11 (Table 21; Fig. 16). Although a large number of sectors were also sampled during Oct. 12-14 (period 12) and Oct. 19-20 (period 13), water temperatures in the lake were much cooler and less than 14ºC, and these periods were excluded. Sampling in all other periods was considered insufficient in terms of the number of sectors covered by boat electrofishing (Fig. 3) and were also excluded from the experiment, although removals of YOY bass in those periods by all methods were incorporated in the model to adjust the population size available for each sampling period (Table 21).

There was a high autocorrelation between successive Monte Carlo Markov Chain samples of the model parameters and consequently thinning by a factor of 100 was used (Fig. 17). An initial burn-in of 25,000 MCMC draws (after thinning) was discarded and the marginal posterior distributions for the population size of YOY bass (N_0 in the model), the probability of capture of a YOY (mu.rho in the model) are summarized using percentiles from a second draw of 25,000 simulations (after thinning).

The model fit was considered adequate. Convergence was considered to have been achieved after 10,000 MCMC draws (Fig. 17). The distributions of the posterior predicted catch by time period adequately covered the realized catch in each sampling period (Table 22). The data were not sufficiently informative to exclude the possibility of some very low probabilities of capture and corresponding high population sizes (banana shape in the scatter plot of corresponding parameter estimates in Figure 17). This is also noted in the bimodality in the density plot of mu.rho in Figure 17.

The population size of YOY in Miramichi Lake in 2010 was estimated at 7,000 fish (median) with a 95% Bayesian Credibility Interval of 5,000 to 56,000 (Table 22). The estimate has very high uncertainty, with a coefficient of variation of 122%. The posterior distribution was highly skewed but there was a 90% probability that the population size was less than 15,000 fish (Table 22).

There is a very small probability (<2.5%) that the population size was less than 5,000 YOY. Based on the total removals of YOY from all sources in 2010 (2,532 fish), between 8% and 53% of the YOY in 2010 were estimated to have been captured and killed (90% B.C.I.).

The probability of capture of YOY bass with the boat electrofisher in Miramichi Lake in 2010 was about 0.013 per 10,000 seconds of electrofishing boat effort (median value, Table 22). With 294,000 seconds of electrofishing effort in 2010, 37% of the population would be expected to have been removed.

Sampling Requirements to Assess Effectiveness of the Control and Eradication Activities

All the indicators of the effectiveness of the control and eradication program in Miramichi Lake are derived from partial capture techniques. Based on the estimated probability of capture of YOY with the boat electrofisher, it is possible to estimate the probabilities of obtaining null catches of YOY for different levels of effort and concluding falsely that there were no YOY in Miramichi Lake. The probability of capture for boat electrofishing in 2010 was very low. If the population of YOY in Miramichi Lake was 100 fish, there is a greater than 10% probability that no YOY would be captured with sampling efforts of less than 19,000 seconds (Fig. 18). The sampling effort required to achieve a probability of less than 10% of not catching any YOY when the population in the lake is 50 rises to 40,000 seconds of effort and at a population level of only 10 YOY in the lake, the sampling effort required is greater than 180,000 seconds (Fig. 18).

The same analysis was done for the gillnets. In this case, it was not possible to estimate the probability of capture in the gillnets but if we make an assumption about the size of the population of age-2 and older Smallmouth Bass in Miramichi Lake in 2010, we can calculate the probability of capture from the catches and the effort expended in 2010. Using the deterministic solution to the mean catch equation (C = Effort * N * mu.rho), substituting with the data from 2010, and assuming N = 100 fish, then mu.rho equals 0.000217 net day^{-1}. In this scenario, if the population of Smallmouth Bass in the lake was 10 fish, there is less than 10% chance of obtaining a null catch if the sampling effort is greater than 1,060 net days (Fig. 19). If the population in the lake is two fish, a sampling effort of 5,300 net days or more would be required to have a less than 10% chance of realizing a null catch. For a population size of one fish, the sampling effort required is at least 11,000 net days (Fig. 19).

DISCUSSION

The objectives of the three-year containment and eradication plan were to contain introduced and non-endemic Smallmouth Bass within Miramichi Lake while depleting its abundance with the ultimate goal of eradication by eliminating spawning and recruitment of future spawners. Other defined goals included the estimation of the population size and age structure of Smallmouth Bass in Miramichi Lake and a measure of the effectiveness of the removal strategy at the end of each season.

The containment barrier at Lake Brook was operated from April to November in 2010 and it was considered to have provided adequate containment; details of the barrier operation are not provided in this report.

The objective of preventing spawning of adult bass in the spring of 2010 failed, no nests or guarding males were observed in Miramichi Lake in 2010 but large numbers of YOY were subsequently captured and destroyed. The control and depletion efforts in 2010 resulted in the capture and removal of 2,584 Smallmouth Bass with the majority (98%) being young-of-the-year. Adult sized Smallmouth Bass were captured from July to October and some of these were likely part of the spawning stock that produced the recruitment in 2010.

To what extent the adult spawning stock has been reduced in Miramichi Lake is unknown. There was no evidence of depletion of adult bass with cumulative gillnetting effort. However, only 30 age-3 and older Smallmouth Bass were captured from Miramichi Lake in 2010 from all fishing gears with substantial fishing effort. In September 2008, personnel from the New Brunswick Dept. of Natural Resources captured two Smallmouth Bass in one gillnet set in Miramichi Lake (C. Connell, NB DNR Unpublished data). In 2009, O'Donnell and Reid (2009) reported capturing two Smallmouth Bass in 331 hours of gillnetting effort in August and in 336 hours of gillnetting effort in September and October, another 15 Smallmouth Bass were captured. In 2010, 1,150 net days (almost 28,000 hours of effort) of gillnetting effort resulted in the capture of 25 Smallmouth Bass. This suggests that the population size of adult sized bass in Miramichi Lake is quite small, although the possibility that Smallmouth Bass are very difficult to capture cannot be excluded.

Sampling in 2010 confirmed the presence of six year classes which were likely spawned in Miramichi Lake although the details of the introduction of bass in the lake (actual time or times, the number of fish and their characteristics) are unknown. The gap in Smallmouth Bass aged 6, 7, and 9 years of age in 2010 suggests that it could likely have been fish from the 2002 (8 year old bass in 2010) and the 2000 (10 year old bass in 2010) year classes which were part of the introductions.

The capture of YOY in 2008, 2009 and now 2010 demonstrates that Smallmouth Bass can successfully reproduce in Miramichi Lake and the capture of age-1 to age-5 bass in 2009 and 2010 provide evidence of survival and successful recruitment to the adult stage in Miramichi Lake.

The lengths at age of the Smallmouth Bass in Miramichi Lake are similar to those from other introduced populations in Nova Scotia (McNeil 1995; LeBlanc 2010). 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 and the distribution of Smallmouth Bass in northern Ontario was related to the length of the growth period relative to the length of the starvation period. Curry et al. (2005) noted that there was a size-dependent overwinter survival in Smallmouth Bass with most YOY smallmouth bass < 50 mm dying over the winter. The majority of the YOY bass in Miramichi Lake in 2010 were longer than 50 mm fork length. From limited sampling in 2009, YOY bass fork lengths ranged from 49 to 87 mm (O'Donnell and Reid 2009). The three one-year old bass captured in May 2010, survivors of the 2009-2010 winter, measured 72 to 85 mm fork length, and are within the range of sizes of YOY sampled in the fall of 2009. In the fall 2010, over half of the population of YOY exceeded 70 mm fork length and would presumably be of sufficient size to have survived the winter of 2009-2010.

The only age group in Miramichi Lake for which a population estimate could be derived was the YOY Smallmouth Bass. The population estimate is very uncertain, a coefficient of variation of greater than 100%, but there is a high probability (>90%) that the population size of YOY was less than 15,000 fish in 2010. The estimated probability of capture by boat electrofishing is very low (0.0125 per 10,000 seconds of effort) and the estimated proportion of the population of YOY removed by sampling period by boat electrofishing alone was 5% during the sampling event in late August and 2% to 3% in late September and October (Table 21, 22). To achieve a probability of capture of 50% of the population in a sampling period of 3 to 4 days, the sampling intensity would have to be in the order of 400 thousand seconds (111 hours). Boat electrofishing alone would be insufficient to effectively reduce the YOY population of Smallmouth Bass in Miramichi Lake.

A sufficiently high boat electrofishing effort over all sectors of Miramichi Lake could generate appropriate depletion data for estimating the size of the YOY population. The assumptions of the depletion experiment would have to be respected and since it cannot be assumed that Smallmouth Bass are randomly distributed in Miramichi Lake, it is the sampling effort which would have to be randomized. The depletion data would have to be collected from all the sectors of the lake (as presently defined) and the effort would have to be proportional to the size of the sectors.

Alternatively, a mark and recapture experiment could be considered for estimating the probability of capture of YOY by boat electrofishing and older Smallmouth Bass in other sampling gear. Appropriate mark and recapture data may be difficult to collect given the low probability of capture with boat electrofishing and the small mark and catch sample sizes of the age-1 and older bass obtained in 2009 and 2010. Mark and recapture methods seem to be the only means of assessing the population size of these older age groups as depletion data are weakly informative and result in large uncertainties. However, it may be difficult to convince managers to capture, mark and release Smallmouth Bass back into Miramichi Lake when the objective is to control and eradicate the species from the lake.

The above discussion raises the question of how to assess the effectiveness of control and eradication programs when presence and abundance cannot be absolutely quantified. All the indicators of the control and eradication program effectiveness in Miramichi Lake are based on partial capture techniques. Failure of an eradication program is easy to demonstrate. If a poison was used in Miramichi Lake, failure could be quickly suspected if any fish, regardless of species, was captured soon after treatment; any fish surviving the treatment implies that the eradication program was less than 100% effective. A recent effort to eradicate Round Goby in Ontario demonstrates how quickly a failure can be documented (Dimond et al. 2010).

The success of an eradication program on the other hand is very difficult to demonstrate. As the population declines in abundance, more effort is required to capture the remaining individuals. How much fishing effort with null catches of Smallmouth Bass would be sufficient for managers to conclude that the Smallmouth Bass in Miramichi Lake was eradicated? The results from the work in 2010 suggest that it would take a very large expenditure of sampling effort to be reasonably confident (say 90% certainty) that the failure to catch any Smallmouth Bass in the lake is indicative of a very low abundance, let alone the absence of the species in Miramichi Lake. This assessment issue is associated with any eradication activity, even with the use of rotenone.

CONCLUSIONS

The field efforts in Miramichi Lake in 2010 provided valuable information regarding the characteristics, behaviour and abundance of Smallmouth Bass in Miramichi Lake. No single capture technique is sufficient to reduce and control the population of Smallmouth Bass in the lake. Electrofishing and beach seining captured a large number of YOY while gillnets, in particular those of mesh sizes of 3 inches and larger, captured the most adult sized bass. Sustained and further enhanced gillnetting effort with the large mesh nets would be important in 2011 to further reduce the adult sized bass population. The few age-1 bass captured in 2010 and in previous years 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. Overwinter survival of YOY is not expected to be exceptionally good but it is sufficient to have resulted in the presence of bass from the 2005 to 2009 year classes in the lake.

Boat electrofishing and gillnetting are two techniques for which the effort can be quantified and deployed according to an experimental design. Design-based sampling allows for the capture and removal of target species as well as the estimation of characteristics of the population of the target species; in the case of Smallmouth Bass in Miramichi Lake, the estimation of the population size and the effectiveness of the sampling gears. Depletion estimates of population size of YOY appear feasible with the boat electrofisher as long as random sampling of the lake area is respected. By random sampling, we mean that either all the sectors around the lake are completely fished with effort proportional to the size of the sector or that sampling within a sector and the sectors fished are randomly selected so that any location of unit size in the lake has an equal probability of being sampled. In any event, a large amount of sampling effort will be required to deplete the population and for the data to be informative. In 2010, less than 5% of the population of YOY bass was removed in depletion efforts over a 3 to 4 day sampling period. Such a low rate of removal requires a large number of depletion samples to provide any information on the population size and the probability of capture, two parameters whose estimation are confounded in the depletion estimation model.

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TABLES

Table 1. Summary of total fishing effort by fishing method and month in Miramichi Lake in 2010. In the table, na signifies not observed.

Fishing gear	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Total
Backpack electrofishing (seconds)	na	11,979	7,676	45,942	206,043	55,609	8,000	2,000	337,249
Boat electrofishing (seconds)	na	30,755	6,470	19,331	57,458	116,945	63,165	na	294,124
Gillnet (net-days)	26	90	137	121	160	261	355	na	1,150
Fyke net (sets)	4	33	na	71	89	56	10	na	263
Beach seine (sampling events)	na	na	na	na	48	53	1	na	102

Table 2. Summary of enumerated catches by species by fishing methods in Miramichi Lake in 2010. In the table, na signifies not observed, nd signifies not tabulated.

Species	Backpack electrofisher	Boat electrofisher	Gillnet	Fyke net	Beach seine
Smallmouth Bass	183	1,294	25	202	816
Lamprey	nd	na	na	1	nd
American Eel	nd	8	na	153	nd
Banded Killifish	nd	517	na	41	nd
Brown Bullhead	nd	55	75	648	nd
Atlantic Salmon	nd	na	na	1	nd
Brook Trout	nd	2	12	76	nd
Fallfish	nd	598	146	3,825	nd
Gaspereau	nd	477	69	1,005	nd
Creek Chub	nd	8	na	13	nd
Lake Chub	nd	na	na	1	nd
Common Shiner	nd	532	na	1,648	nd
Golden Shiner	nd	369	16	550	nd
Lake Chub	nd	6	na	na	nd
Pearl Dace	nd	1	na	na	nd
White Perch	nd	2,302	1,968	5,073	nd
White Sucker	nd	1,405	3,541	23,171	nd
Yellow Perch	nd	10,129	993	19,566	nd
Tadpole	nd	416	na	1,059	nd

Table 3. Removals (number of fish) of Smallmouth Bass by age from all sampling methods in Miramichi Lake in 2010. In the table, na signifies not observed.

	Gear								
Age	Angling	Backpack electrofisher	Boat electrofisher	Fyke net	Gill Net	Beach Seine[1]	Snorkeling	Barrier	Total
0	na	179	1,285	190	na	816	57	5	2,532
1	na	4	na	1	na	na	na	na	5
2	na	na	6	5	5	na	na	na	16
3	1	na	1	5	6	na	na	na	13
4	na	na	1	na	7	na	na	na	8
5	na	na	1	na	5	na	na	na	6
8	1	na	na	na	2	na	na	na	3
10	na	na	na	1		na	na	na	1
Total	2	183	1,294	202	25	816	57	5	2,584

[1] one age 0 was recorded caught by hand but included in beach seine catch

Table 4. Number of sampling events, sampling effort (seconds of electrofishing activation), and catch of Smallmouth Bass (for age-0, age-1) by backpack electrofishing in the outlet of Miramichi Lake (Lake Brook) by month, in 2010.

Sampling characteristic	Month							Total
	May	June	July	Aug.	Sept.	Oct.	Nov.	
Sampling events	4	4	5	4	5	4	1	
Seconds	11,979	7,676	9,418	7,800	9,442	8,000	2,000	56,315
Catch age-0	0	0	0	0	1	0	0	1
Catch age-1	3	0	0	0	1	0	0	4

Table 5. Number of sampling events, sampling effort (seconds of electrofishing activation), and catch of Smallmouth Bass young of the year (YOY) by backpack electrofishing within sector by month in Miramichi Lake in 2010. See Figure 1 for locations of sectors around the lake. In the columns for catch, a dash indicates no sampling.

Sector	Sampling events			Sampling effort (seconds)			Catch of YOY smallmouth bass		
	July	Aug.	Sept.	July	Aug.	Sept.	July	Aug.	Sept.
1	1	5	1	18,000	128,079	30,012	9	54	12
2	1	6	0	2,400	16,251	0	3	16	-
3	0	6	1	0	22,508	13,755	-	28	7
4	0	5	0	0	15,723	0	-	17	-
5	1	0	0	1,266	0	0	1	-	-
6	1	0	0	1,600	0	0	2	-	-
8	1	0	0	800	0	0	1	-	-
9	0	1	0	0	400	0	-	1	-
10	0	1	0	0	1,920	0	-	2	-
11	0	1	0	0	146	0	-	1	-
12	1	1	0	1,594	2,688	0	1	4	-
13	1	0	0	800	0	0	1	-	-
15	1	0	0	800	0	0	1	-	-
16	1	2	1	9,264	10,528	2,400	6	8	3
Total	9	28	3	36,524	198,243	46,167	25	131	22

Table 6. Boat electrofishing effort (seconds of shocking time) by shore sector and month in Miramichi Lake in 2010. The sectors are arranged sequentially around the lake, centered around sectors 16 and 1 which border Lake Brook, the outlet to Miramichi Lake.

Shore	Month						
Sector	May	June	July	Aug.	Sept.	Oct.	Total
10	4,068	348	2,135	0	4,550	5,653	25,726
11		0	0	1,398	4,372	3,202	
12	0	336	733	1,271	3,617	4,422	10,379
13	0	288	0	1,152	2,633	3,147	7,220
14	0	0	0	0	4,782	4,017	8,799
15	3,100	0	0	0	12,664	3,460	19,224
16	2,745	315	1,085	4,181	19,732	10,130	38,188
1	9,176	2,669	4,645	45,287	40,092	9,111	110,980
2	0	336	3,506	1,404	935	1,633	7,814
3	0	0	2,283	0	0	0	2,283
4	0	0	1,716	280	0	0	1,996
5	2,500	673	1,423	853	8,220	5,483	19,152
6	800	0	0	0	6,223	3,866	10,889
7	5,651	0	0	0	3,078	1,822	10,551
8	300	509	1,805	908	2,863	3,197	9,582
9	2,415	996	0	724	3,184	4,022	11,341
Total	30,755	6,470	19,331	57,458	116,945	63,165	294,124

Table 7. Boat electrofishing effort (seconds of shocking time) by period of the day (day, night) and month in Miramichi Lake in 2010.

Month	Day	Night	Total
May	711	30,044	30,755
June	0	6,470	6,470
July	1,085	18,246	19,331
August	1,551	55,907	57,458
September	33,111	83,834	116,945
October	32,054	31,111	63,165
Total	68,512	225,612	294,124

Table 8. Summary of enumerated catches by species using boat electrofishing by month in Miramichi Lake in 2010. In September and October (*), catches of species other than Smallmouth Bass were not enumerated (nd).

	Month						
Species	May	June	July	Aug.	Sept.	Oct.	Total
Smallmouth Bass	4	0	20	337	677	256	1,294
American Eel	0	2	1	5	nd	nd	8
Banded Killifish	31	23	33	430	nd	nd	517
Brown Bullhead	0	2	15	38	nd	nd	55
Brook Trout	1	0	0	1	nd	nd	2
Creek Chub	0	8	0	0	nd	nd	8
Common Shiner	193	84	29	226	nd	nd	532
Fallfish	139	89	72	298	nd	nd	598
Gaspereau	0	4	72	401	nd	nd	477
Golden Shiner	1	12	78	278	nd	nd	369
Lake Chub	6	0	0	0	nd	nd	6
Pearl Dace	0	0	0	1	nd	nd	1
White Perch	143	137	758	1,264	nd	nd	2,302
White Sucker	281	118	378	628	nd	nd	1,405
Yellow Perch	709	504	2,510	6,406	nd	nd	10,129
Bullfrog Tadpole	0	0	416	0	nd	nd	416
Total	1,508	983	4,382	10,313	677*	256*	18,119

Table 9. Catches of Smallmouth Bass (upper table - young of the year; lower table – age 1 and older) using boat electrofishing by sector and month in Miramichi Lake in 2010. The sectors are arranged sequentially around the lake, centered around sectors 16 and 1 which border Lake Brook, the outlet to Miramichi Lake. Cells with ns are sectors and months which were not sampled by boat electrofishing (see Table 6).

Young of the year Smallmouth Bass

	Month						
Sector	May	June	July	August	September	October	Total
9	0	0	ns	4	21	26	51
10	0	0	0	ns	35	35	70
11	0	ns		4	7	6	17
12	ns	0	0	1	11	9	21
13	ns	0	ns	1	5	25	31
14	ns	ns	ns	ns	16	16	32
15	0	ns	ns	ns	48	13	61
16	0	0	3	23	120	33	179
1	0	0	6	289	298	58	651
2	ns	0	6	0	2	5	13
3	ns	ns	2	ns	ns	ns	2
4	ns	ns	1	3	ns	ns	4
5	0	0	1	3	18	11	33
6	0	ns	ns	ns	37	5	42
7	0	ns	ns	ns	21	4	25
8	0	0	0	5	38	10	53
Total	0	0	19	333	677	256	1,285

Age-1 and older Smallmouth Bass

	Month						
Sector	May	June	July	August	September	October	Total
9	0	0	ns	0	0	0	0
10	0	0	0	ns	0	0	0
11	0	ns	ns	0	0	0	0
12	ns	0	0	0	0	0	0
13	ns	0	ns	0	0	0	0
14	ns	ns	ns	ns	0	0	0
15	0	ns	ns	ns	0	0	0
16	0	0	0	0	0	0	0
1	4	0	0	4	0	0	8
2	ns	0	1	0	0	0	1
3	ns	ns	0	ns	ns	ns	0
4	ns	ns	0	0	ns	ns	0
5	0	0	0	0	0	0	0
6	0	ns	ns	ns	0	0	0
7	0	ns	ns	ns	0	0	0
8	0	0	0	0	0	0	0
Total	4	0	1	4	0	0	9

Table 10. Catch per unit effort (fish per 100 seconds of boat electrofishing effort) of young-of-the-year Smallmouth Bass by sector and month in Miramichi Lake for 2010. Cells with ns are sectors and months which were not sampled by boat electrofishing (see Table 6).

	Month					
Sector	May	June	July	Aug.	Sept.	Oct.
9	0	0	ns	0.55	0.66	0.65
10	0	0	0	ns	0.77	0.62
11	ns	ns	ns	0.29	0.16	0.19
12	ns	0	0	0.08	0.30	0.20
13	ns	0	ns	0.09	0.19	0.79
14	ns	ns	ns	ns	0.33	0.40
15	0	ns	ns	ns	0.38	0.38
16	0	0	0.28	0.55	0.61	0.33
1	0	0	0.13	0.64	0.74	0.64
2	ns	0	0.17	0.00	0.21	0.31
3	ns	ns	0.09	ns	ns	ns
4	ns	ns	0.06	1.07	ns	ns
5	0	0	0.07	0.35	0.22	0.20
6	0	ns	ns	ns	0.59	0.13
7	0	ns	ns	ns	0.68	0.22
8	0	0	0	0.55	1.33	0.31

Table 11. Fyke net effort (number of fyke net sets) by shore sector and month in Miramichi Lake in 2010. "ns" refers to no sampling effort in the shore sector for the month.

	Month							
Shore Sector	April	May	June	July	Aug.	Sept.	Oct.	Total
12	2	7	ns	ns	ns	ns	ns	9
13	ns	ns	ns	ns	13	8	ns	21
14	ns	ns	ns	ns	13	8	ns	21
15	ns	ns	ns	ns	13	8	ns	21
16	2	13	ns	25	12	16	ns	68
13,14,15,16	ns	ns	ns	ns	2	2	ns	4
1,16	ns	ns	ns	1	1	ns	ns	2
1,2,5	ns	ns	ns	ns	1	ns	ns	1
1	ns	11	ns	39	20	14	10	94
2	ns	ns	ns	5	4	ns	ns	9
4	ns	ns	ns	ns	6	ns	ns	6
5	ns	ns	ns	ns	4	ns	ns	4
not specified	ns	2	ns	1	ns	ns	ns	3
Total	4	33	ns	71	89	56	10	263

Table 12. Summary of enumerated catches by species in fyke nets by month in Miramichi Lake in 2010. After May, catches of species other than Smallmouth Bass were not completely enumerated (nd) and total catches other than for Smallmouth Bass are underestimates for the season. "ns" refers to no sampling effort in the shore sector for the month and "na" refers to not identified in the catches.

	Month							
Species	April	May	June	July*	Aug.*	Sept.*	Oct.*	Total*
Smallmouth Bass	0	0	ns	100	74	22	0	196
Lamprey	na	1	ns	nd	nd	nd	nd	1
Gaspereau	na	na	ns	518	200	287	nd	1,005
Atlantic Salmon	na	2	ns	nd	nd	nd	nd	1
Brook Trout	31	45	ns	nd	nd	nd	nd	76
American Eel	1	68	ns	80	nd	3	1	153
Banded Killifish	na	4	ns	37	nd		nd	41
White Sucker	601	21,075	ns	1,462	nd	5	28	23,171
Creek Chub	na	13	ns	nd	nd	nd	nd	13
Lake Chub	na	1	ns	nd	nd	nd	nd	1
Fallfish	255	2,779	ns	726	nd	42	23	3,825
Common Shiner	29	1,281	ns	316	nd	16	6	1,648
Golden Shiner	2	112	ns	409	nd	27	nd	550
Brown Bullhead	1	150	ns	444	nd	52	1	648
White Perch	na	1,973	ns	3,087	1	4	8	5,073
Yellow Perch	664	12,173	ns	6,662	nd	51	16	19,566
Tadpole	7	614	ns	438	nd	nd	nd	1,059
Total*	1,591	40,291	ns	14,279	275	509	83	57,028

* incomplete count of catches by species (other than Smallmouth Bass) from the large catches

Table 13. Catches of Smallmouth Bass by age and shore sector in fyke nets in Miramichi Lake in 2010.

	Estimated age			
Shore Sector	0	1	2	age 3 and older
12	0	0	0	0
13	23	0	0	0
14	27	0	0	0
15	4	0	0	0
16	27	0	1	4
13,14,15,16	5	0	0	0
1,16	6	0	0	0
1,2,5		0	0	0
1	78	0	1	2
2	7	0	0	1
4	4	0	0	0
5	5	1	0	0
Total	186	1	2	7

Table 14. Beach seining effort (sampling events) by lake sector and month in Miramichi Lake in 2010.

Sector	Month			Total
	August	September	October	
4	4	5	0	9
4, 5, and 6	1	0	0	1
5	8	14	0	22
5 and 6	0	1	0	1
6	4	5	0	9
4, 5, 6, and 7	1	0	0	1
5, 6, and 7	1	0	0	1
7	2	1	0	3
8	2	1	0	3
9	2	7	0	9
5, 6, 7, 8, 9, and 10	1	0	0	1
9 and 10	1	0	0	1
10	3	6	0	9
11	1	0	0	1
12	2	0	0	2
13	3	3	0	6
14	1	1	0	2
16	5	2	0	7
1	3	6	0	9
2	1	0	0	1
3	2	1	0	3
not specified	0	0	1	1
Total	48	53	1	102

Table 15. Catches of YOY Smallmouth Bass in beach seining by sector and month in Miramichi Lake in 2010.

Sector	Month			Total
	August	September	October	
4	60	12	ns	72
4, 5, and 6	45	ns	ns	45
5	98	75	ns	173
5 and 6	ns	33	ns	33
6	56	40	ns	96
4, 5, 6, and 7	66	ns	ns	66
5, 6, and 7	35	ns	ns	35
7	7	0	ns	7
8	6	0	ns	6
9	13	12	ns	25
5, 6, 7, 8, 9, and 10	81	ns	ns	81
9 and 10	10	ns	ns	10
10	11	3	ns	14
11	1	ns	ns	1
12	2	ns	ns	2
13	10	4	ns	14
14	1	0	ns	1
16	8	0	ns	8
1	4	86	ns	90
2	0	ns	ns	0
3	36	0	ns	36
not specified	ns	ns	0	0
Total	550	265	0	815

Table 16. Gillnet fishing effort (net days) by mesh size and month in Miramichi Lake in 2010.

Mesh Size (inches)	Month							Total
	April	May	June	July	Aug.	Sept.	Oct.	
2	2	8	9	10	10	1	0	40
2.25	1	0	0	0	0	0	4	5
2.5	2	8	9	10	10	7	28	74
2.75	1	0	0	0	0	3	11	15
3	1	24	43	40	56	110	138	412
3.25	1	5	10	10	14	15	17	72
3.5	6	21	43	41	56	117	125	409
4	7	22	23	10	14	8	32	116
5	5	2	0	0	0	0	0	7
Total	26	90	137	121	160	261	355	1,150

Table 17. Summary of enumerated catches by species in gillnets by month in Miramichi Lake in 2010. After July, catches of species other than Smallmouth Bass were not completely enumerated.

	Month							
Species	April	May	June	July	Aug.	Sept.	Oct.	Total
Smallmouth Bass	0	1	1	8	3	8	5	26
Brown Bullhead	0	7	3	10	49	4	2	75
Brook Trout	0	9	2	0	nd	1	nd	12
Fallfish	2	112	2	4	5	7	14	146
Gaspereau	0	0	38	29	1	nd	1	69
Golden Shiner	3	9	3	0	1	nd	nd	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 18. Summary of enumerated catches by species by mesh size in gillnets in Miramichi Lake in 2010. After July, catches of species other than Smallmouth Bass were not completely enumerated.

	Mesh size (inches)									Unspe-
Species	2	2.25	2.5	2.75	3	3.25	3.5	4	5	cified
Smallmouth Bass	0	0	4	0	12	0	2	1	0	7
Brown Bullhead	9	0	7	0	4	0	1	0	0	54
Brook Trout	2	0	4	0	2	0	2	0	0	2
Fallfish	19	0	28	12	30	0	15	14	0	28
Gaspereau	13	0	29	1	15	0		1	0	10
Golden Shiner	8	0	0	0	0	0	0	0	0	8
White Perch	895	1	145	16	108	9	77	74	16	627
White Suckers	664	79	895	283	341	15	119	9	3	1,133
Yellow Perch	114	1	68	7	11	2	7	0	0	783
Total	1,724	81	1,180	319	523	26	223	99	19	2,652

Table 19. Biological characteristics of Smallmouth Bass captured by all gear types and all months in Miramichi Lake in 2010.

	Catch by sex				Fork length (mm)			
Age (years)	Female	Male	Unknown	Total	Median	Min.	Max.	N
0	0	0	2,532	2,532	55	23	110	2,451
1	1	1	3	5	85	72	174	5
2	8	8	0	16	211	131	240	16
3	5	8	0	13	255	213	303	13
4	3	4	1	8	290	239	321	8
5	2	4	0	6	337	317	375	6
8	1	2	0	3	410	409	438	3
10	1	0	0	1	477	477	477	1
Total	21	27	1	2,584	na	na	na	na

Table 20. Summary of length distributions by month of YOY Smallmouth Bass sampled in Miramichi Lake in 2010.

			Percentiles					
Month	N	Min.	2.5th	25th	Median	75th	97.5th	Max.
July	133	23	31	38	42	50	61	62
Aug.	1,075	31	34	45	52	61	81	95
Sept.	987	41	46	51	57	70	89	105
Oct.	256	47	49	60	71	80	93	110

Table 21. Data for depletion model estimation of abundance of YOY Smallmouth Bass using boat electrofishing catches and effort by sampling period. Other catch refers to removals of YOY bass by other means and during other days between sampling periods and during the period of sampling (for ex. period 6, other catch is the number of YOY bass removed by all other gears between Aug. 30 and Sept. 6 inclusive). The catch and effort data from boat electrofishing during periods 6, 9, 10, and 11 are used in the depletion experiment estimate.

			Electrofishing boat				
Period	Start	End	Number of sectors fished	Effort (seconds)	Catch	Other catch	Temperature
1	12-Jul	13-Jul	5	5,551	4	67	25.5 - 27.1
2	26-Jul	29-Jul	5	5,903	15	74	21.3 - 23.5
3	3-Aug	6-Aug	3	12,817	49	30	22.5 - 24.3
4	9-Aug	12-Aug	2	16,550	98	329	22 - 22.7
5	18-Aug	20-Aug	5	8,796	22	299	23.4 - 24.2
6	30-Aug	2-Sep	14	42,877	319	178	23.4 - 25.6
7	7-Sep	9-Sep	4	18,476	137	158	18.6 - 19.3
8	13-Sep	16-Sep	3	27,593	122	106	15.0 - 16.8
9	20-Sep	23-Sep	11	22,844	138	4	14.2 - 15.2
10	27-Sep	30-Sep	13	24,450	125	2	14.6 - 19.8
11	4-Oct	7-Oct	12	17,690	101	0	14.0 - 16.8
12	12-Oct	14-Oct	13	28,999	113	0	8.6 - 17.6
13	19-Oct	20-Oct	14	16,476	42		7.0 - 8.1

Table 22. Marginal posterior distributions of the depletion model variables of interest, including the predicted catch. The posterior distributions were derived from MCMC with Gibbs sampling. Two chains of initial values were used and the MCMC draws were thinned by 100. The first 25,000 simulations (burn-in) were discarded and posterior distributions were summarized from 25,000 subsequent simulations from the two chains.

Posterior distribution characteristics	Variables of interest		Predicted catches conditional on modelled parameter values			
	N_0	µ.rho	Period 6	Period 9	Period 10	Period 11
mean	10,360	1.22 E-06	308	136	141	99
Std. Dev.	12,650	5.35 E-07	26.3	13.4	14.4	12.1
CV	122%	44%	8.5%	9.9%	10.2%	12.2%
Percentiles						
2.5	4,550	0.116 E-06	257	110	113	77
5.0	4,750	0.219 E-06	265	114	118	80
10.0	5,027	0.467 E-06	274	119	122	84
25.0	5,655	0.878 E-06	290	126	131	91
median	6,723	1.25 E-06	307	135	140	99
75.0	8,863	1.59 E-06	325	144	150	107
90.0	15,210	1.89 E-06	342	153	159	115
95.0	30,560	2.07 E-06	351	158	165	119
97.5	56,360	2.22 E-06	360	162	170	124
observed			319	138	125	101

FIGURES

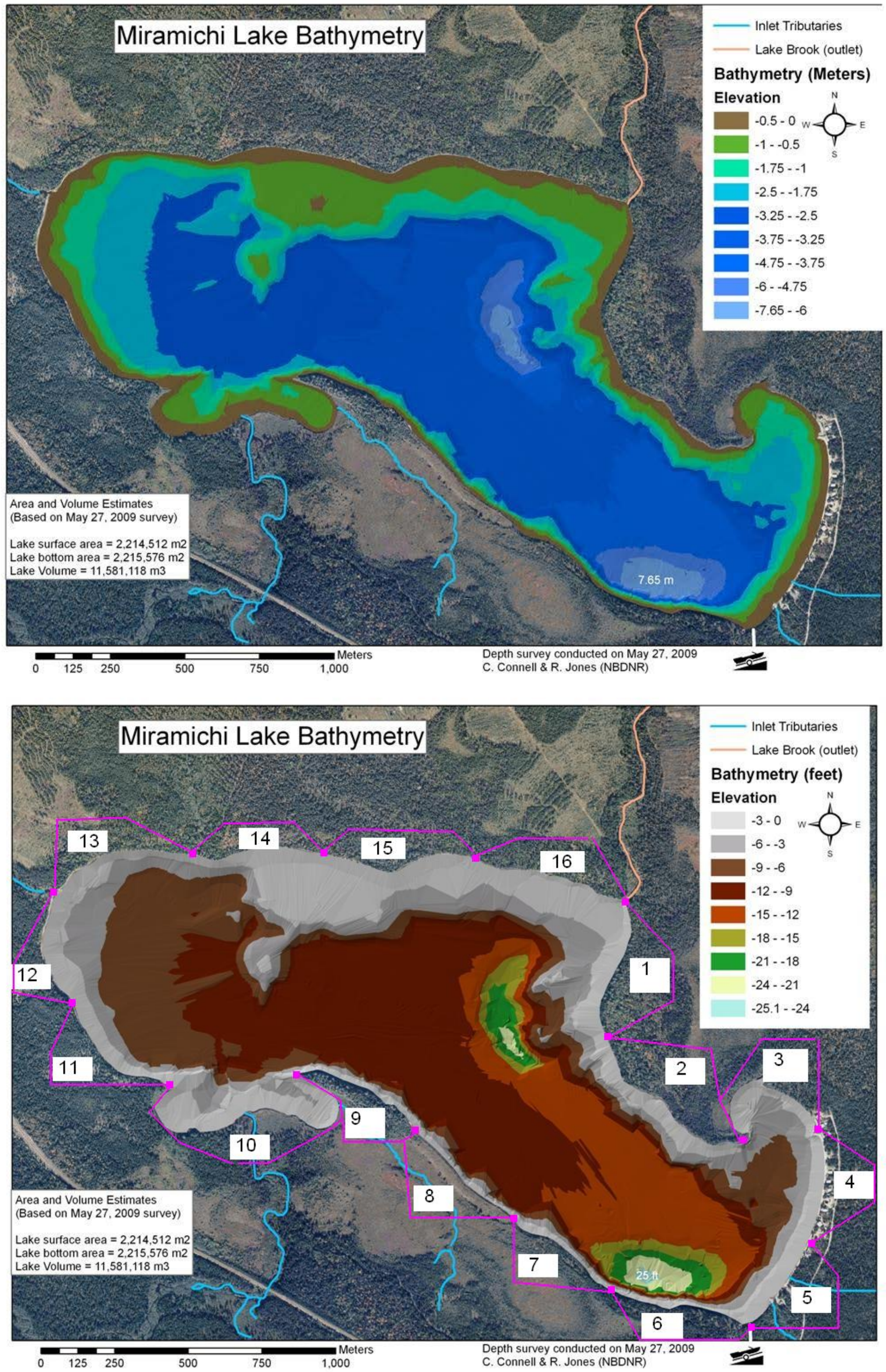

Figure 1. Bathymmetry profile of Miramichi Lake (metres, upper panel) (in feet, lower panel) and location of sectors and sector boundaries (lower panel). Bathymetric data and profiles were provided by C. Connell and R. Jones, New Brunswick Department of Natural Resources.

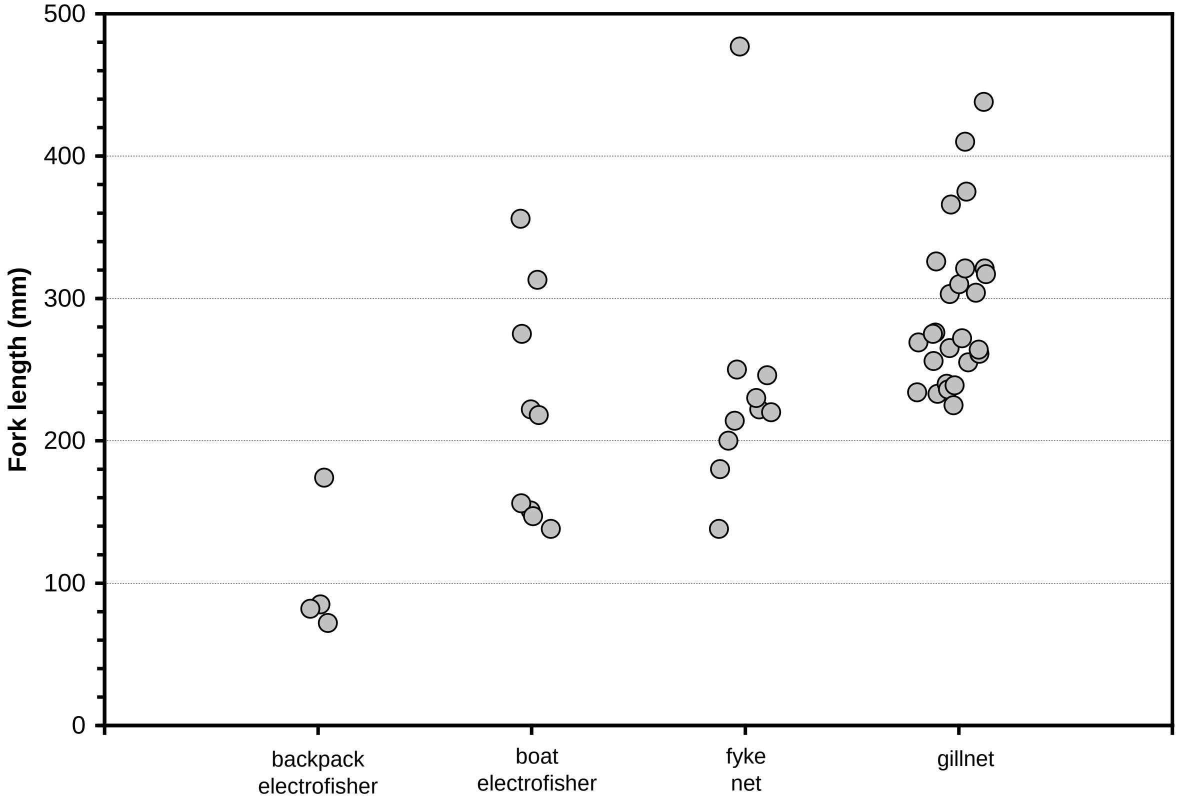

Figure 2. Fork length (mm) of Smallmouth Bass age-1 year and older by sampling gear from Miramichi Lake in 2010.

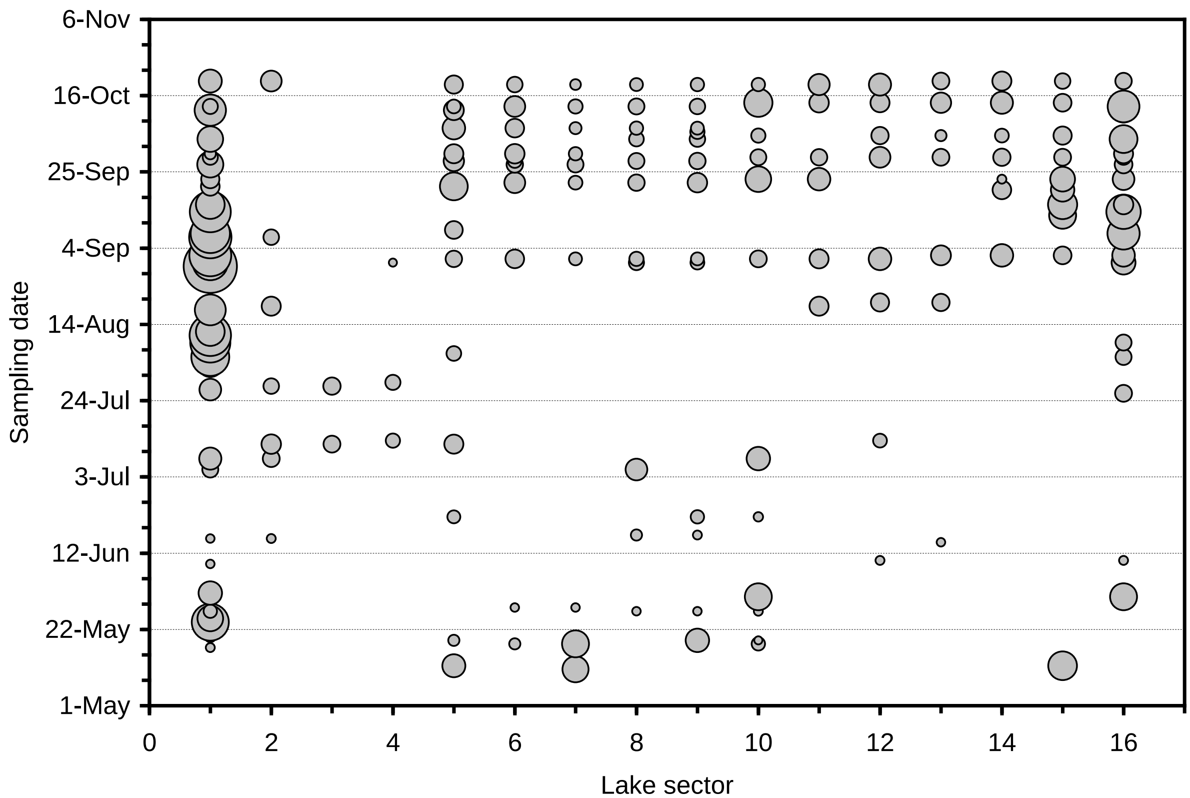

Figure 3. Relative sampling effort by sector and sampling date using the boat electrofisher. Bubble area is scaled to sampling effort, minimum effort was 279 seconds (19 May, Sector 10) and maximum effort was 10,510 seconds (August 30, Sector 1). See Figure 1 for locations of sectors around the lake.

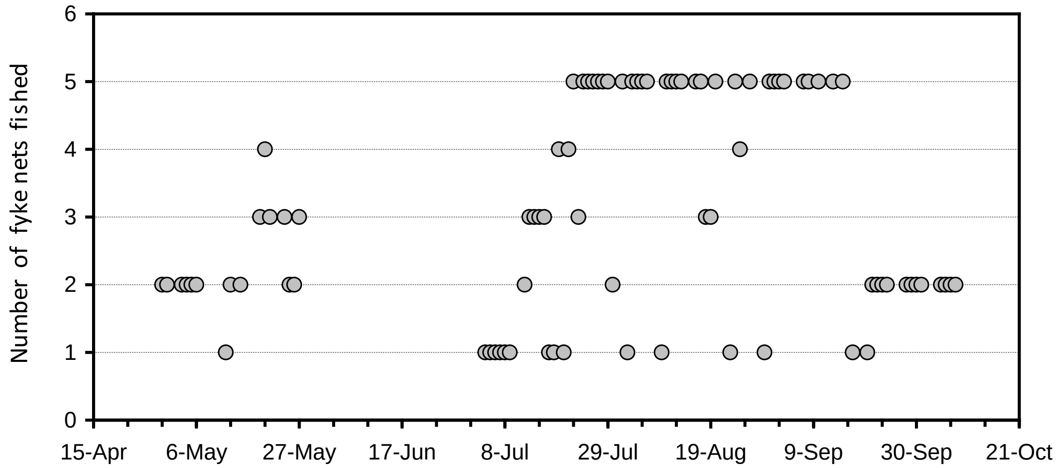

Figure 4. Number of fyke net sets by date in Miramichi Lake in 2010.

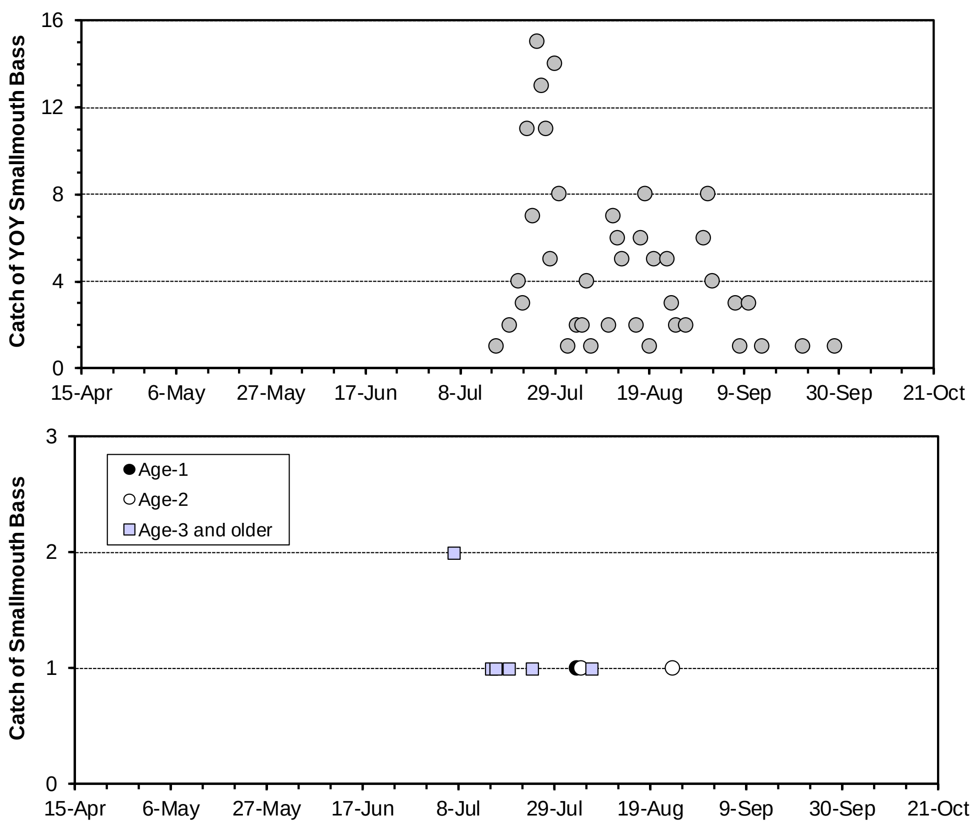

Figure 5. Catches of young-of-the-year (YOY) (upper) and older (lower) Smallmouth Bass in fyke nets in Miramichi Lake in 2010.

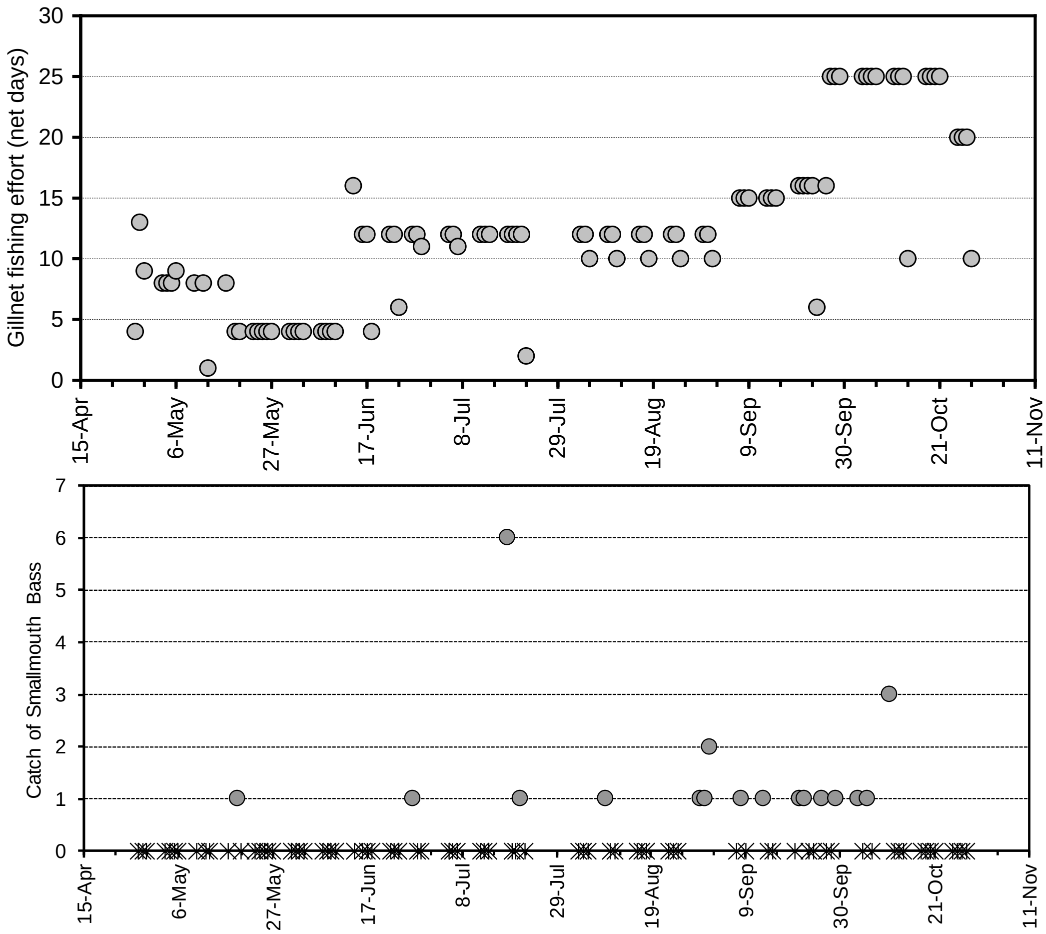

Figure 6. Gillnet fishing effort (number of net days; upper panel) and catches of Smallmouth Bass (lower panel) in Miramichi Lake in 2010.

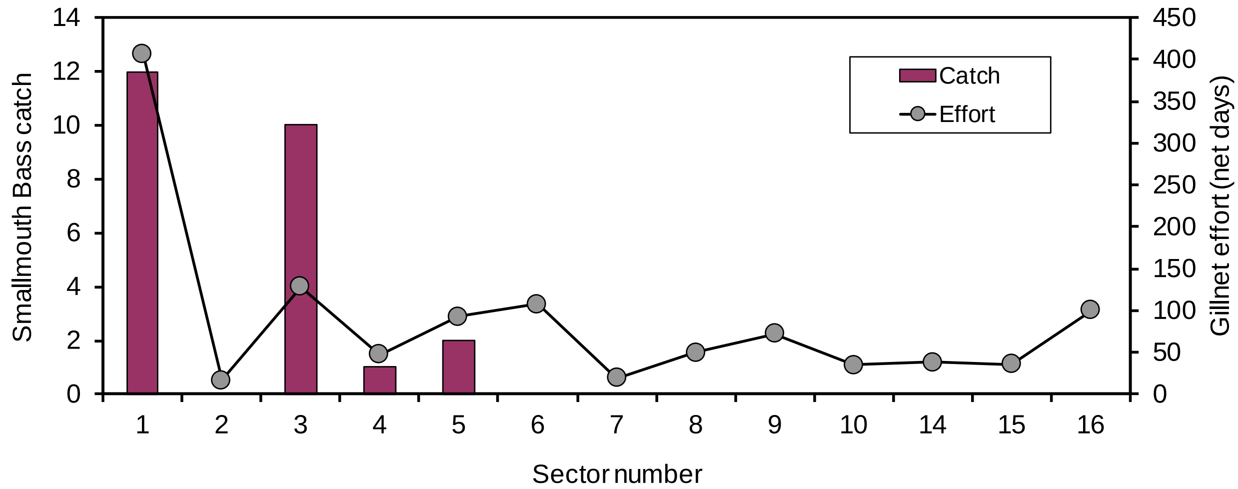

Figure 7. Total Smallmouth Bass catch and total gillnet effort (net days) by geographic sector in Miramichi Lake in 2010. Lake sectors are shown in Figure 1.

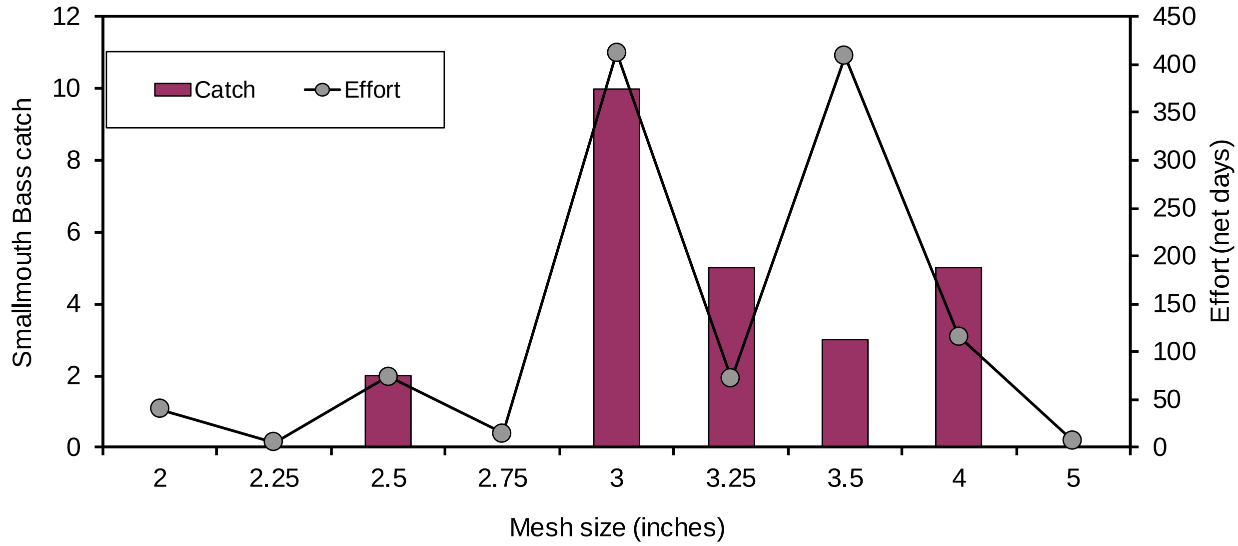

Figure 8. Total Smallmouth Bass catch and total gillnet effort (net days) by mesh size (inches) of gillnets used in Miramichi Lake in 2010.

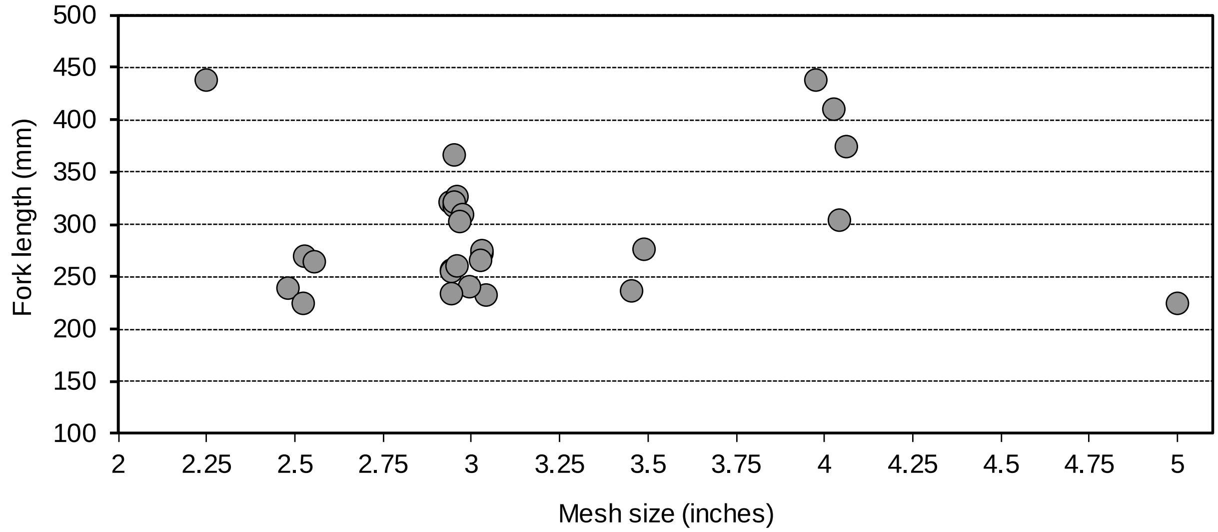

Figure 9. Fork length (mm) of Smallmouth Bass versus mesh size (inches) of the gillnet in Miramichi Lake in 2010. The points have been jittered around the mesh sizes for clarity. Gillnet mesh sizes used in 2010 included: 2, 2.25, 2.5, 2.75, 3, 3.25, 3.5, 4, and 5 inches.

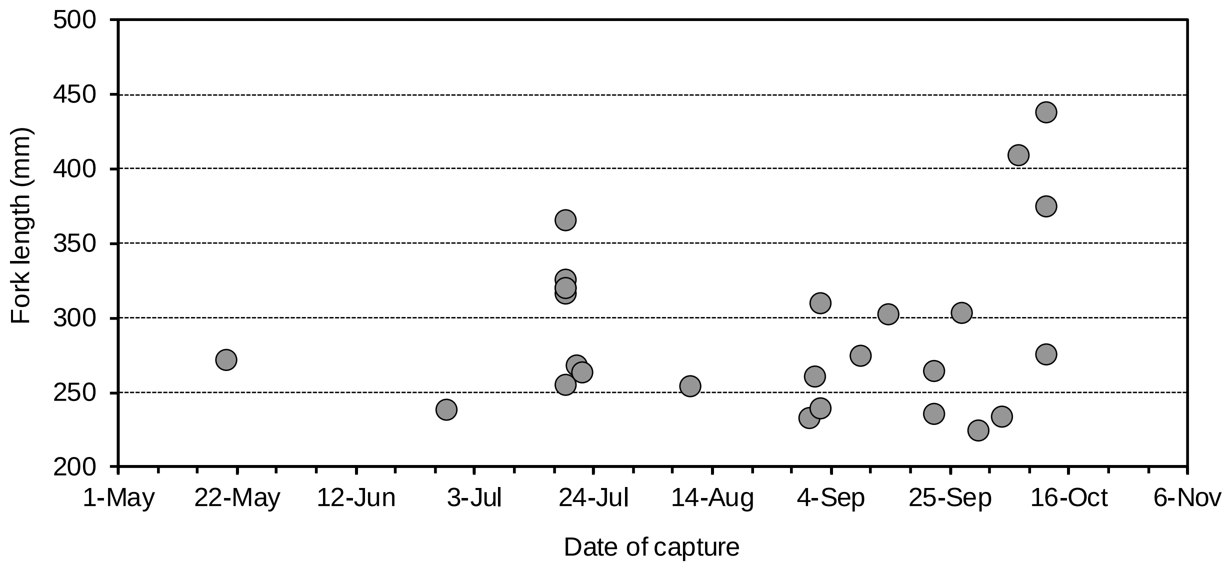

Figure 10. Fork length (mm) of Smallmouth Bass captured in gillnets versus date of capture in Miramichi Lake in 2010. The points have been jittered around the date for clarity.

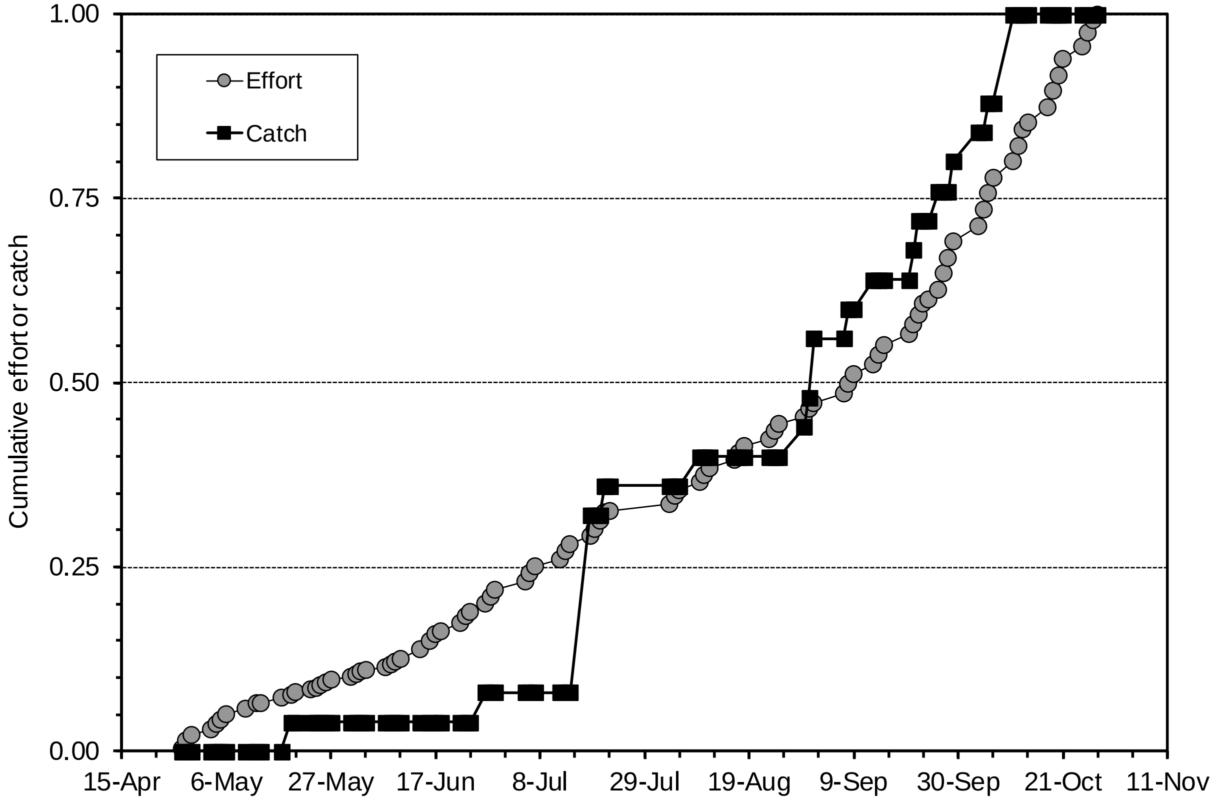

Figure 11. Cumulative gillnet effort (net days) and cumulative catch of Smallmouth Bass by date from Miramichi Lake in 2010.

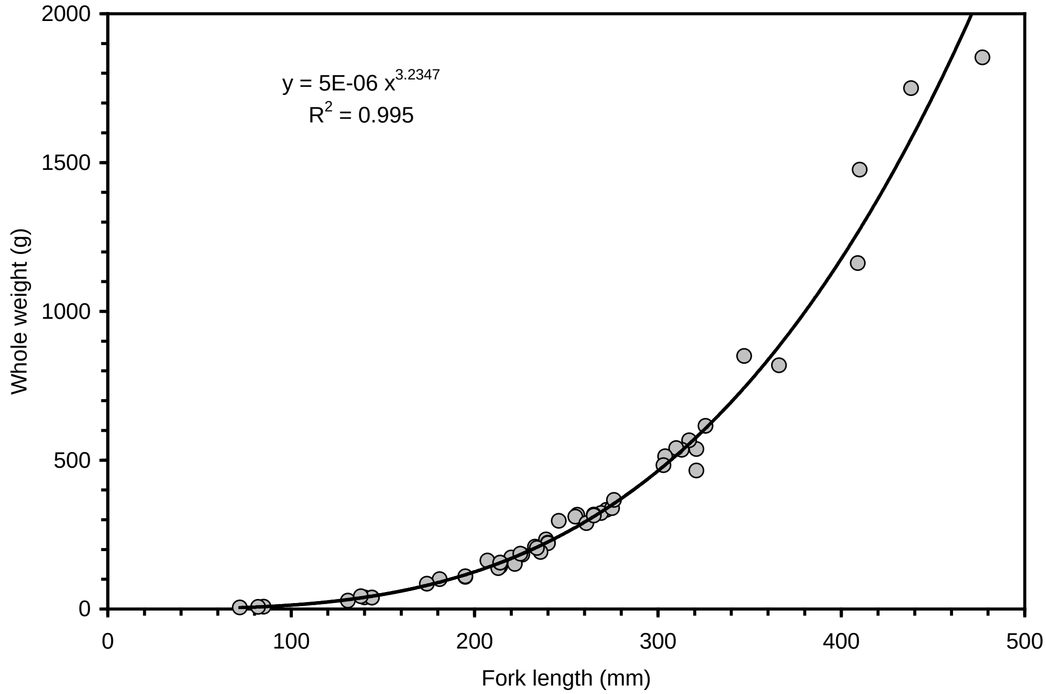

Figure 12. Fork length (mm) to whole weight (g) relationship for Smallmouth Bass captured in Miramichi Lake in 2010.

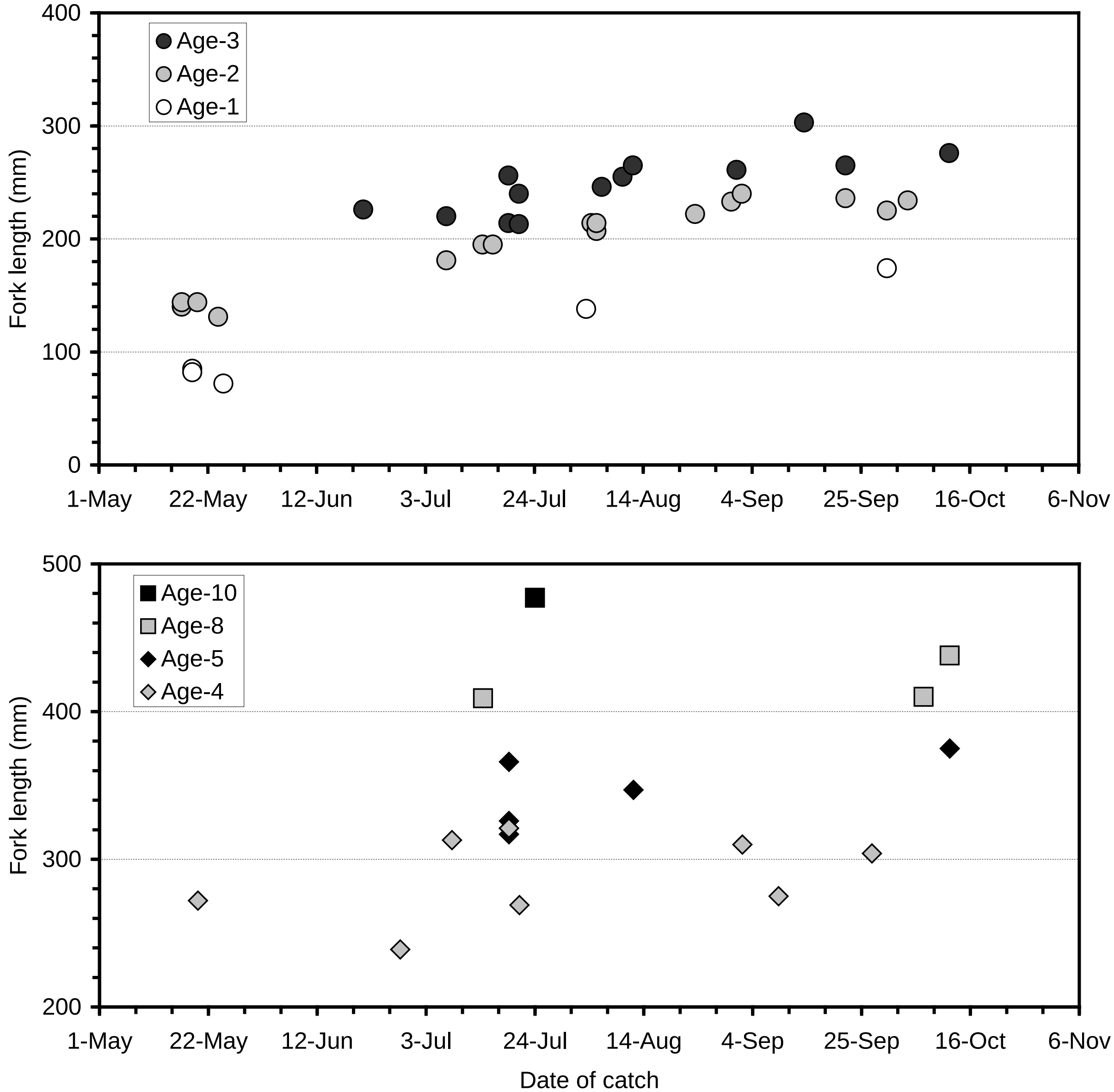

Figure 13. Fork length (mm) of Smallmouth Bass by age (1 to 3 years in upper panel, older than 3 years in lower panel) and date of capture from Miramichi Lake in 2010.

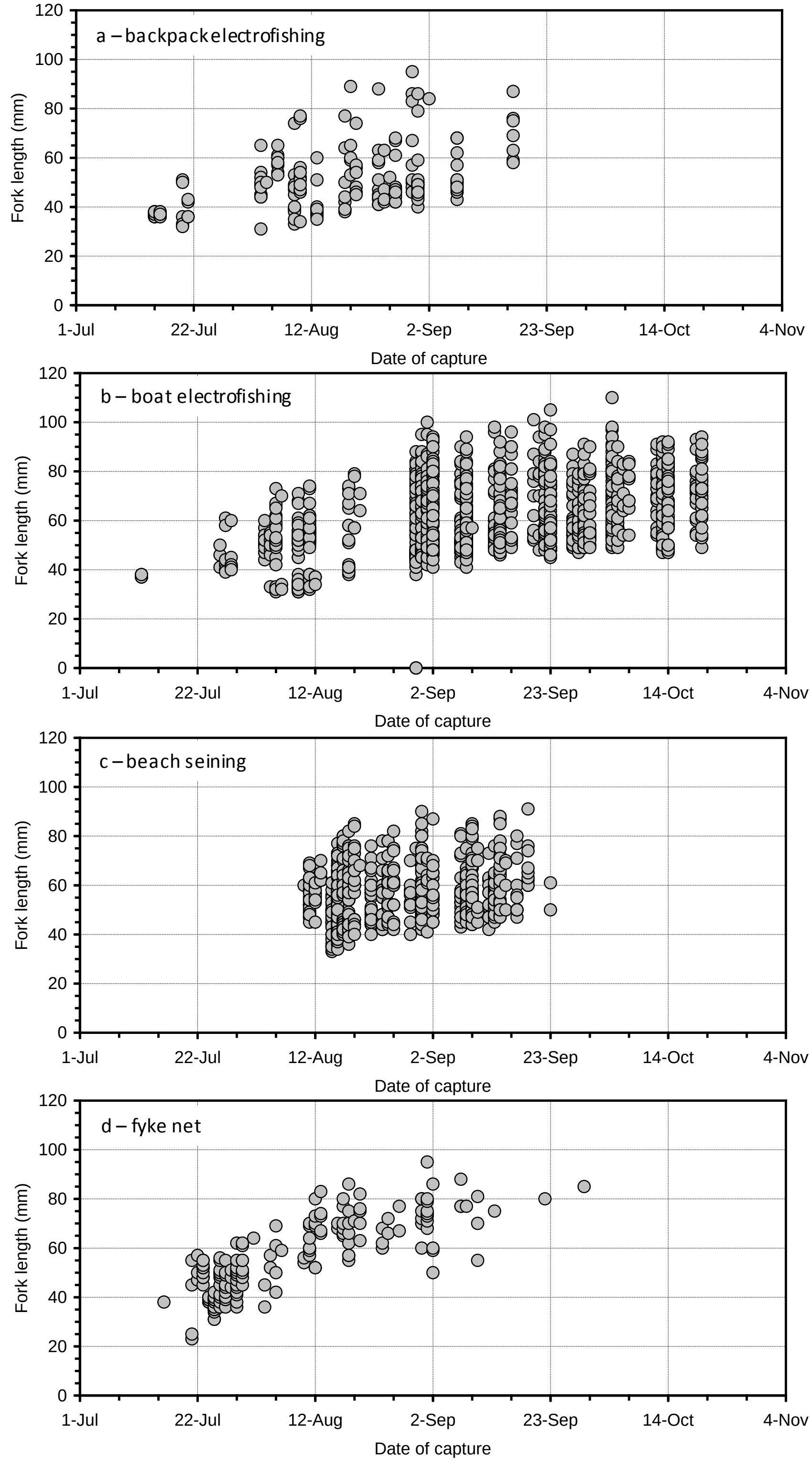

Figure 14. Fork lengths of YOY Smallmouth Bass by date captured in various gears (a - backpack electrofishing; b – boat electrofishing; c – beach seining; d – fyke net) in Miramichi Lake in 2010. Symbol at fork length of zero represents a fish not sampled for length.

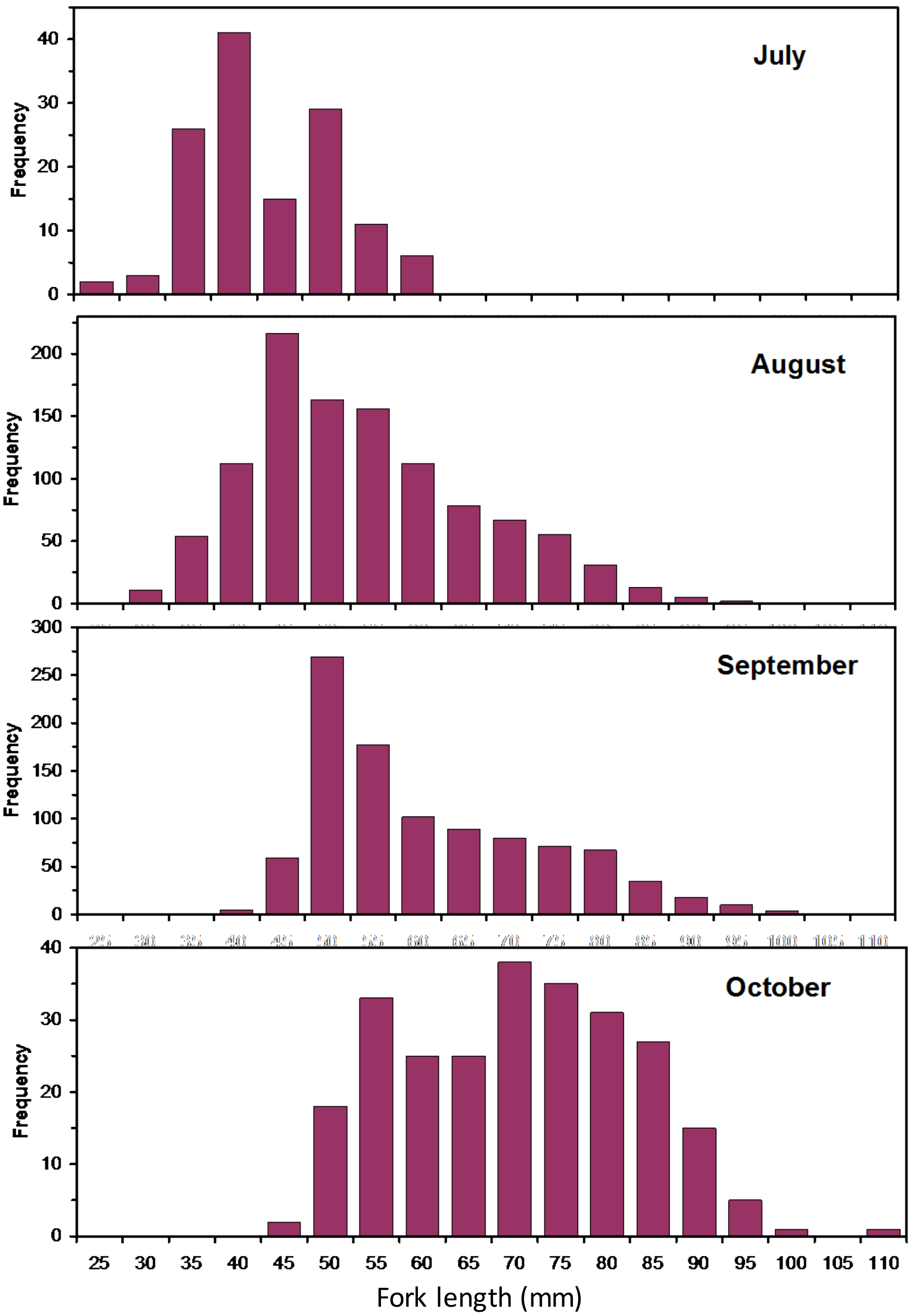

Figure 15. Fork length (mm) distributions by 5 mm length bins by month (July to October) of YOY Smallmouth Bass captured in all gears in Miramichi Lake in 2010.

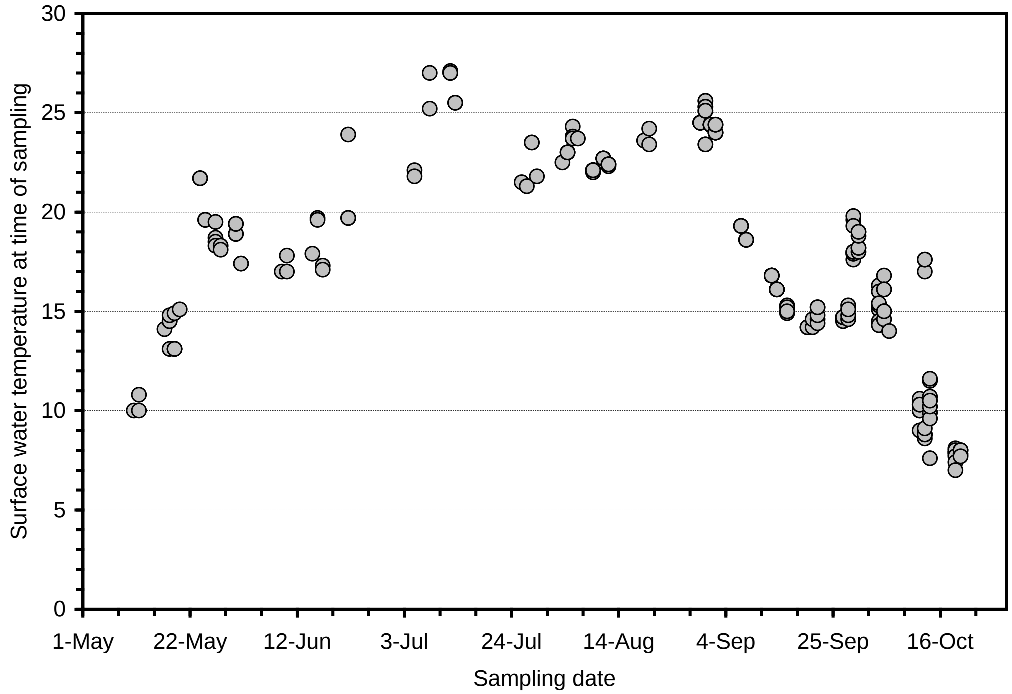

Figure 16. Mean surface water temperature (ºC) by date at time of sampling in Miramichi Lake in 2010.

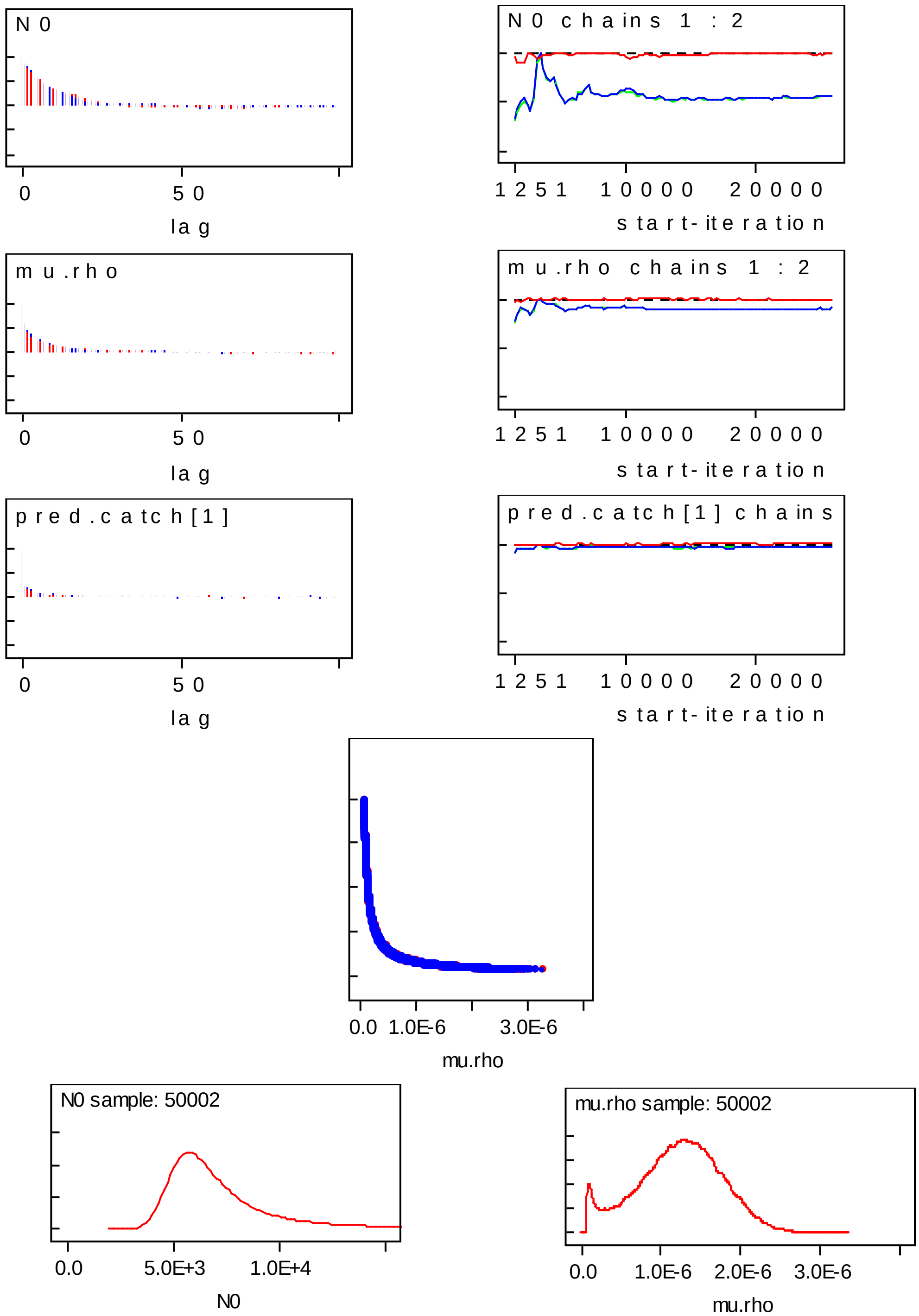

Figure 17. Diagnostics of the depletion model fitting in OpenBUGS with MCMC Gibbs sampling. All the results are based on two chains of initial values and thinning by 100.

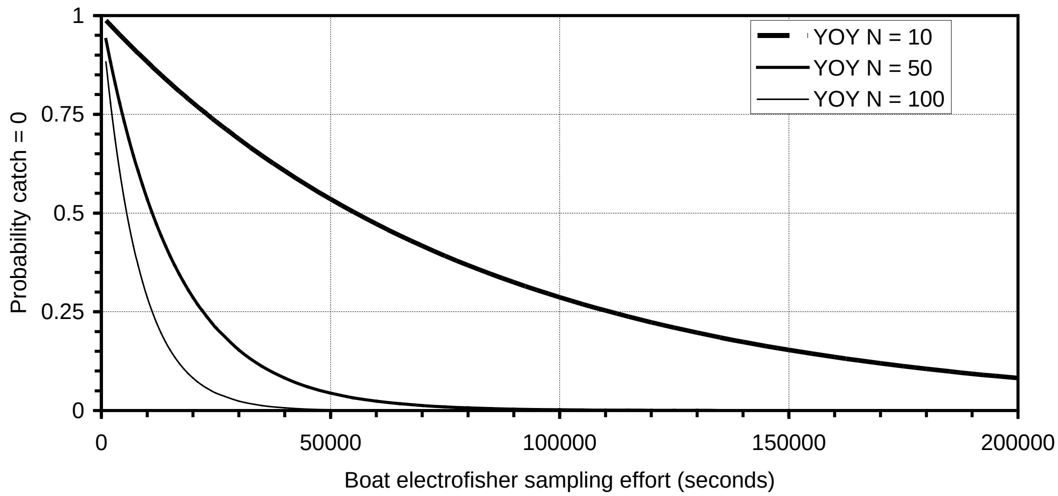

Figure 18. Probability of obtaining a null catch of YOY for different levels of sampling effort with the boat electrofisher for YOY Smallmouth Bass populations in Miramichi Lake of 10, 50 and 100 fish. The probability of capture per unit of effort (seconds) is the median of the posterior distribution from the 2010 depletion estimate with the boat electrofisher ($1.25 * 10^{-6}$).

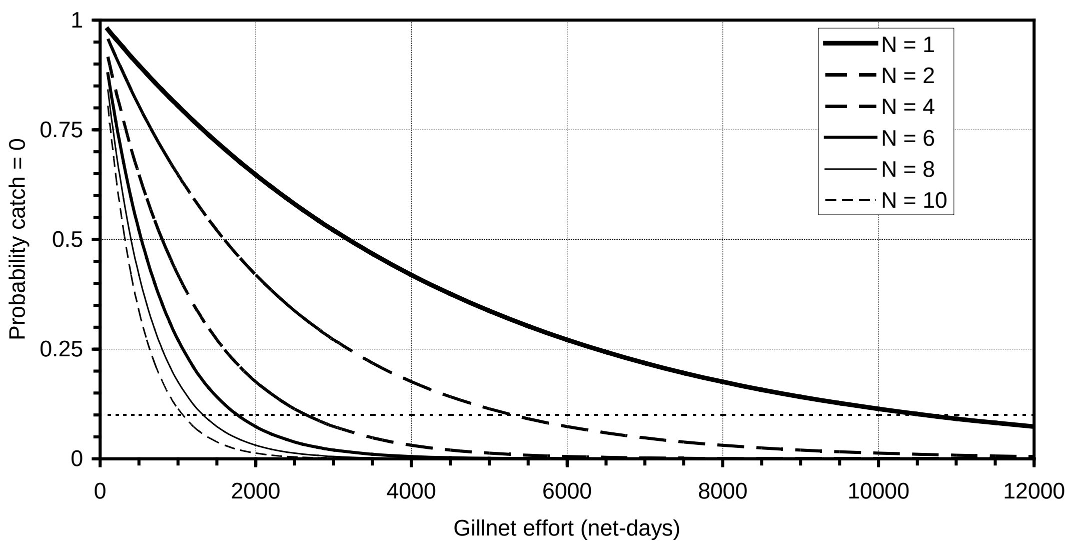

Figure 19. Probability of obtaining a null catch of large Smallmouth Bass for different levels of gillnet fishing effort with different population sizes of Smallmouth Bass in Miramichi Lake. The probability of capture per unit of effort (net-day) is derived from the catch and effort data of 2010 and assuming that the population size of large Smallmouth Bass in the lake in 2010 was 100 fish. The estimated probability of capture is $2.17 * 10^{-4}$ net day^{-1}.

APPENDICES

Appendix 1. Proposed Control and Eradication Plan for Smallmouth Bass in Miramichi Lake

Introduction

Smallmouth Bass (SMB) presence in Miramichi Lake was reported to NB Dept. of Natural Resources and Energy (DNRE) in late summer 2008. Fish and Wildlife Branch biologists confirmed their presence by successful capturing young-of-the-year (YOY) SMB in early fall. Since that time barriers have been installed to contain the SMB in Miramichi Lake. Surveys of the outlet stream and the Southwest Miramichi River near the outlet stream have failed to detect any SMB except in the upper 350 meters of the outlet stream which is effectively an extension of the lake. Any SMB encountered in this stream section have been removed by weekly backpack electrofishing.

Five year classes, ages 0+, 1+, 2+, 3+, and 4+, were found in the 64 SMB captured during extensive fishing in Miramichi Lake during 2009. Although spawning appears to have been successful for several years in succession, abundance remains low.

This field plan is a strategy to maintain containment while depleting the SMB in Miramichi Lake with the goal of eradication. Other important goals are to estimate the population size and age structure of SMB in Miramichi Lake and with this provide a measure of the effectiveness of the removal strategy at the end of each season.

Beginning as soon as roads are passable and Miramichi Lake is ice free measures will be taken to ensure the SMB in Miramichi Lake are prevented from moving into the Southwest Miramichi River. This will involve installation of a single barrier with a fine mesh liner at the head of Lake Brook as in 2009.

A variety of fishing techniques will be employed to capture and remove SMB from the lake. It must be emphasized that this fishing will be intensive and bycatch of other fish species is unavoidable. As much as possible live release of bycatch will be practiced. Gear selections detailed in the methods below will be modified as needed during the field season to maximize the catch and removal of SMB from Miramichi Lake.

Methods and Equipment

<u>Training</u>

All field staff will need to be trained in first aid and cardiopulmonary resuscitation (CPR). Boat operators must be trained to the standard for their organization (DFO standard = Small Vessel Operator Proficiency for commercial vessels up to 12 meters / 13 tons , Transport Canada Standard for water bodies the size of Miramichi Lake = Pleasure Craft Operator Proficiency).

Electrofishing crews will need to be led by crew leaders certified in backpack / boat electrofishing and all crew members must be given orientation on safety procedures in advance.

<u>Designating Shoreline Sections</u>

The shoreline of Miramichi Lake is 8,000 meters long. This will need to be divided into sixteen 500 meter long segments with shoreline markers beginning at Lake Brook and proceeding clockwise around the lake. The markers should be large enough to be clearly visible from 200 meters and have retro-reflective tape for viewing during night electrofishing operations.

<u>Staff and Facilities</u>

Proposed manpower for the program would be three field staff from the Miramichi Watershed Management Committee. In addition a graduate student would be living on site leading the team for the field season. These staff would be assisted by a DFO project coordinator who would help with field programs and equipment as required, especially for the first weeks and/or months until field staff can receive required training.

Additional help from collaborators (DFO, DNRE, University of New Brunswick Canadian Rivers Institute, and Miramichi Salmon Association) would be welcome especially during May – June for intensive boat electrofishing.

The graduate student and DFO coordinator would need use of the DFO Conservation and Protection camp in Juniper for accommodations, freezers, phones, and internet. It is hoped that a camp on Miramichi Lake could be rented for at least part of the season for accommodations, plus be a convenient boat and equipment storage site.

<u>Containment Barrier</u>

The barrier materials are still on site from 2008/09. The barrier requires some modifications to allow better passage of adult gaspereau into the lake to spawn. It also will require additional modifications to allow downstream migration of YOY gaspereau while preventing coincidental escape of SMB. Initial drawings of the required structures are in separate attachments and can be discussed.

Also it must be noted that cleaning the barriers does take time. During high water events or when debris is present (algae, leaves, etc) the barrier must be checked multiple times per day. In those instances cleaning the barrier can take up to 4 hours per day. On a good day with no debris cleaning the barrier will take 1 hour.

Daily records of barrier data will be completed (barrier data sheet attached) documenting status of the barrier and fish moved upstream (into the lake) and downstream (into the outlet stream.

<u>Boats</u>

An electrofishing boat plus an all purpose boat (johnboat or robust scow with a 15-25 HP outboard motor) would be required. The all purpose boat will be used daily from ice out until November and should remain in the lake for that period. The electrofishing boat would be required from May until October when the water cools and SMB have moved to deep water.

<u>Backpack Electrofishing</u>

The upper 350 meter section of Lake Brook which is below the barrier but above a debris dam needs to be electrofished to remove any YOY or Age 1+ SMB which get past the barrier. This was found to be necessary in 2008 and 2009 and should be continued in 2010. Frequency should be once every week.

<u>Boat Electrofishing</u>

Other programs aimed at capturing SMB in lakes have found that boat electrofishing is the most effective method for capturing bass (Weidel et al 2007). In addition the technique allows live release of non target species so impact is minimized.

SMB would be vulnerable to boat electrofishing from May when the lake water reaches temperatures above 10 degrees C and greater until fall when water temperatures drop below 10 degrees (Armour 1993).

A major effort should be placed on boat electrofishing from May until the end of June to target spawning fish and males guarding nests. This is the best opportunity to prevent / minimize successful reproduction of SMB by removing greater than 90% of the spawning population.

What level of effort is needed to prevent successful spawning

In an Adirondak Lake (Northern New York State) an estimated removal rate of 72% did not result in collapsing the population (Zipkin 2008). An evaluation of boat electrofishing removal rates estimated that, on average, 36% of the SMB population was removed per sweep (Odenkirk and Smith 2005). If this efficiency is achieved in Miramichi Lake, the removal rates would follow the table below:

Removal Rate Per Sweep			36%
Initial Population			250
Sweep	Removed	Free	Total % Removed
1	90	160	36.0%
2	58	102	59.0%
3	37	66	73.8%
4	24	42	83.2%
5	15	27	89.3%
6	10	17	93.1%
7	6	11	95.6%
8	4	7	97.2%
9	3	5	98.2%
10	2	3	98.8%
11	1	2	99.3%
12	1	1	99.5%
13	0	1	99.7%
14	0	0	99.8%
15	0	0	99.9%

We propose a target removal rate of 90% of SMB spawners during the May – June reproduction period for SMB which would require 6 sweeps. If the efficiency is lower (26%) this would result in 8 sweeps being needed however higher efficiency (46%) would result in the need for only 4 sweeps. Regardless of the removal rate the amount of boat electrofishing effort needs to be large and 6 or more sweeps of the littoral zone will likely be needed.

Boat electrofishing is effective in depths of 2 meters or less (Brousseau et al 2005). In small lakes in Nova Scotia SMB successful spawning occurred within 20 meters of shore at depths of 0.1 to 1.6 meters (Jason LeBlanc, Government of Nova Scotia, pers comm.). Therefore a sweep for the May – June period would include all waters within 20 m of shore and depths less than 2 meters – the entire shoreline of the lake.

Boat electrofishing is carried out at a boat speed of 0.3 m / sec and proceeds by approaching the shore from offshore, then backing out over the same territory and repeating the process on the adjacent strip of shoreline. Adapting the protocol from DFO Great Lakes Laboratory (Brousseau et al 2005) it is estimated that the initial sweep of Miramichi Lake could take 40 hours. Subsequent sweeps could eliminate areas where SMB were not found decreasing the sweep time by 50% for sweep 2, and an additional 10% for each successive sweep. Using this approach produces an estimate of 100 – 120 hours of boat electrofishing time for the 6 sweeps of Miramichi Lake needed to remove over 90% of SMB.

Electrofishing catch rates for SMB at night have been found to be 2.1 to 4.1 times the catch rates during daylight (Paragamian 1989). Nighttime operations are recommended to improve gear efficiency and increase the number of SMB removed per hour. The electrofishing boat must be equipped with lights to allow electrofishing after dark.

After spawning season

Boat electrofishing is likely going to remain the most effective method for capturing and removing SMB. The abundance will be much reduced and the objective should be to complete a sweep of the entire lake each week, targeting areas where SMB have been captured earlier in the season.

September-October

Typically this has been the time when boat electrofishing surveys were done on lakes as capture rates are highest at this time of year. Young-of-the-year SMB will be caught, if early efforts were insufficient to prevent successful reproduction. Note that YOY disperse short distances (88 +/- 61 meters) from their natal nests (Gross and Kapuscinski 1997).

Nest Location Verification and Destruction

All locations where SMB adults are captured will be recorded by GPS during boat electrofishing. Each of these sites will be visited during daylight hours when these potential nest sites are visually examined by snorkeling. Upon verification of an existing nest any eggs or larvae remaining will be removed by slurp gun. The snorkeling will also allow additional removal of adults (pole spear) and nest destruction.

Fyke netting

A commercial approach to fishing this gear is recommended. This would involve having one index fyke net where all species are sorted and counted plus SMB removed. All other fyke nets would have SMB removed and counted but other species released without sorting and counting. Two additional fyke nets with 50-100 ft leaders should be purchased to bring the total nets available to 4.

Fyke nets will be deployed once water temperatures have reached 10 degrees C until fall when the water temperatures fall below 10 degrees and SMB are no longer catchable. Initially, vents allowing smaller fish to escape will be installed to decrease the bycatch and target larger spawning adult SMB. In June the escape vents will be removed but if bycatch is unmanageable then decisions will need to be made in the field as to how many nets w/o escape vents can be operated.

Fyke nets are fished in the same shallow water habitat where boat electrofishing is taking place. Information on the location of SMB from boat electrofishing will be used to place fyke nets in areas where SMB are found.

Gillnetting

Gillnets are the gear for targeting SMB in deeper (3 to 7 meters) part of Miramichi Lake. They can be deployed for the entire length of the field season since SMB move to deep water when water temperatures are below 10 degrees C but use deep lake waters in summer.

Gillnet fishing intensity will vary throughout the season. Initially effort will be high to remove as many adult SMB as possible before spawning begins in late May. Adult SMB will be moving from deep holes to shallow spawning sites and should be vulnerable to capture. Overnight sets will be used. However if bycatch is unmanageable gillnets sets could be restricted to daylight hours to decrease the bycatch (Honda and Fujita 2005). Upon arrival of adult gaspereau in late May or early June the gillnetting effort would be reduced to only the 4 and 5 inch mesh nets which would not retain gaspereau.

A commercial approach to fishing gillnets is recommended with the addition of one index gillnet set/day where all species are sorted and counted. Mesh sizes will be from 2 to 5 inches to target the 20 to 50 cm adult SMB in the lake (table below from Fujita et al 2007).

Mesh Size (inches)	Mesh Size (cm)	Total Length (cm)
0.8	2	8
1.2	3	12
1.6	4	16
2.0	5	20
2.4	6	24
2.8	7	28
3.1	8	32
3.5	9	36
3.9	10	40
4.3	11	44
4.7	12	48
5.1	13	52

Angling

Angling will not be part of the program as abundance of SMB is too low for good angling success.

Evaluation

Regular consultations with the Miramichi Lake Working Group (MLWG) will be held via teleconference throughout the field season (May to October). These will provide updates of removals (catches) of SMB by age group and time period and allow input from MLWG on changes in field operations (less/more fyke netting, gill netting, boat electrofishing, etc). A report of all operations on Miramichi Lake will be provided to MLWG after the end of field operations in November – December.

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Appendix Table 1. Schedule of activities.

Activity	Time	Equipment	Reasons
Barrier: Install barrier and fine mesh liner to contain small bass Extra barrier maintenance Allow controlled downstream passage of juvenile gaspereau w/o YOY SMB escapees Removal	April / early May various July 26-Aug 13 November	Barrier fence material supplied by JD Irving Downstream passage installed on barrier	Ensure containment before water warms and SMB leave deep holes in lake. During periods of high discharge, high debris, and late summer algal accumulation on liner YOY SMB escaped from the lake when barrier nets were lifted to allow juvenile gaspereau to pass in 2009 SMB inactive due to low water temperature
Backpack electrofishing: upper 300 meters of Lake Brook once per week.	May thru November	Backpack Electrofisher, sampling gear	YOY and Age 1+ SMB were found in this area in 2008 and 2009. They need to be removed.
Designating shoreline sectors:	Early May	Utility boat, surveyors tape, retro-reflective signs	To enable boat electrofishing and net captures of SMB to be easily geo referenced
Boat electrofishing: Entire lake littoral zone shoreline 3 -5 or more days per week	mid-May, all of June July-Oct	Electrofishing boat and portable GPS	Remove 90% of males on nests, remove a large % of all other age/sex classes Continue to remove all ages of remaining SMB – detect presence of YOY SMB
Verifying and Destroying Nests:	May - June	Utility boat, snorkel gear, GPS, slurp gun	Verify location of SMB nests initially indicated from boat electrofishing – remove eggs / larvae
Fyke netting:	May - June Aug-Sept -Oct	4 fyke nets and escape vents Attempt netting w/o escape vents	Adult bass moving around looking for spawning sites Target juveniles in areas where they are caught with efishing boat
Gillnetting: Lake – 3-5 days / week - 24hr sets	Early May June July - October	Monofilament gillnets mesh sizes from 2 to 5 inches, boat, sampling gear only 4 and 5 inch mesh Mesh sizes from 2 to 5 inch	Target adults prior to spawning –moving from deep water to shallows Target females after spawning Target deep areas which cannot be reached with other gears.
Data analysis, report preparation	November- December		

Appendix 2. Openbugs Depletion Estimate Program Code.

```
Model {
N[1] <- N0 - 987
# 987 is the catch of YOY from all sources in periods 1 to 5, before depletion experiment

for (x in 1:4){
	Catch[x] ~ dpois(c.rho[x])
	c.rho[x] <- Effort[x] * N[x] * mu.rho
	N[x+1] <- N[x] - Catch[x] - Other.catch[x]
	pred.catch[x] ~ dpois(pred.c.rho[x])
	pred.c.rho[x] <- Effort[x] * N[x] * mu.rho}

N0 ~ dunif(100, 100000)
mu.rho ~ dgamma(0.01, 0.01)

}

# data
# Other.catch, first entry of 701 is the removal of YOY by all methods during period 6, 7, and 8
#  plus the removals by boat electrofishing in periods 7 and 8
list(
Catch = c(319, 138, 125, 101),
Other.catch = c(701, 4, 2, 0),
Effort = c(42877, 22844, 24450, 17690))

# inits chain 1
list(
N0 = 5000,
mu.rho = 0.01,
pred.catch = c(
2.874E+6, 4.575E+6, 1.848E+6, 2.874E+6))

# inits chain 2
list(
N0 = 50000,
mu.rho = 0.1,
pred.catch = c(
2.874E+6, 4.575E+6, 1.848E+6, 2.874E+6))
```