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# Comparing Age, Growth, and Mortality of Brook Trout (*Salvelinus fontinalis*) sampled from Seven Lakes on the Northern Peninsula, Newfoundland to assess the efficacy of established regulations for Ten Mile Lake

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**Foreword**

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada.  As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Research documents are produced in the official language in which they are provided to the Secretariat.

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# TABLE OF CONTENTS

# ABSTRACT

The following report describes a comparative study of seven brook trout (*Salvelinus fontinalis*) lakes located on the Northern Peninsula of Newfoundland and Labrador, Canada. Six of the lakes are currently managed under a generic, island wide, management regime. The seventh, Ten Mile Lake, was placed in a special trout management area (STMA). The STMA was created in response to concerns that the brook trout population in the pond had collapsed with anecdotal evidence suggesting small catch size and low catches rates. In the STMA the harvest was severely limited. The angling season for Ten Mile Lake was shortened to 45 days in the summer, and the ice fishing season was eliminated. The STMA has been in place since 2004. Prior to the creation of the STMA baseline data was not collected and therefore it is difficult to determine whether the STMA was warranted or, if a collapse did occur, the extent of the recovery. We performed a cross-sectional comparison among the seven lake's Catch per Unit Effort (CPUE), growth rates and mortality to determine the relative status of Ten Mile Lake. Our comparison revealed that three of the seven sampled ponds had a catch composition with overall mean sizes that were larger than Ten Mile Lake. When we compared fish size-at-age, brook trout aged three and four were significantly smaller in Ten Mile Lake when compared to five of the other six lakes. Using least square regressions and an index of growth rate derived from incremental otolith growth, we determined that Ten Mile Lake brook trout had the lowest mortality and growth rates of the seven sampled lakes and it had the oldest age structure. Using the derived otolith growth chronology, we determined that the Ten Mile Lake population's growth rates have been slowing subsequent to 2004. Additionally, gill net catch rates among the seven lakes did not appreciably differ. We conclude that Ten Mile Lake has similar catch rates and composition to other popular fishing locations near its vicinity. Due to the low mortality and slowing growth rate, we believe brook trout population density for Ten Mile Lake may be increasing. The decreasing growth rates are likely in response to the increasing population density. Recommendations are made to increase the length of the angling season.

**Comparaison de l'âge, de la croissance et de la mortalité d'ombles de fontaine (*Salvelinus fontinalis*) échantillonnées dans sept lacs de la péninsule Northern sur l'île de Terre-Neuve afin d'évaluer l'efficacité des règlements établis pour le lac Ten Mile**

## RESUME

Le rapport ci-dessous décrit une étude comparative réalisée sur des ombles de fontaine (*Salvelinus fontinalis*) vivant dans sept lacs situés sur la péninsule Northern, dans l'île de Terre-Neuve, dans la province de Terre-Neuve-et-Labrador (T-N-L), au Canada. Six de ces lacs sont actuellement gérés en vertu d'un régime de gestion générique appliqué sur toute l'île. Le septième de ces lacs, le lac Ten Mile, a été inclus dans une zone particulière de gestion de la truite. Cette zone a été créée pour répondre aux préoccupations concernant l'effondrement de la population d'ombles de fontaine dans le plan d'eau, corroborées par des preuves empiriques de la petite taille des poissons capturés et des faibles taux de prise. La pêche dans la zone particulière de gestion de la truite a été très limitée. La saison de pêche dans le lac Ten Mile a été raccourcie à huit semaines durant l'été et la saison de pêche sous la glace l'hiver a été supprimée. La zone particulière de gestion de la truite est en place depuis 2004. Avant sa création, les données de base n'étaient pas recueillies et, par conséquent, il est difficile de déterminer si cette création était justifiée ou, dans le cas où un effondrement s'était produit, l'ampleur du rétablissement. Nous avons effectué une comparaison transversale des captures par unité d'effort (CPUE), taux de croissance et taux de mortalité des sept lacs afin de définir l'état relatif du lac Ten Mile. Notre comparaison a montré que la composition des prises dans trois des sept plans d'eau échantillonnés avait une taille moyenne supérieure à celle de la composition des prises du lac Ten Mile. Quand nous avons comparé la taille des poissons selon l'âge, nous avons remarqué que les ombles de fontaine âgées de trois et quatre ans étaient sensiblement plus petites dans le lac Ten Mile que dans cinq des six autres lacs. En utilisant des régressions de moindres carrés et un indice de taux de croissance dérivé d'une croissance supplémentaire des otolithes, nous avons déterminé que la population des ombles de fontaine du lac Ten Mile avait les taux de mortalité et de croissance les plus bas des sept lacs échantillonnés en dépit de sa structure selon l'âge plus élevée. En utilisant la chronologie dérivée de la croissance des otolithes, nous avons déterminé que les taux de croissance de la population du lac Ten Mile avaient ralenti après 2004. De plus, il n'y a pas de différence significative entre les taux de prise au filet maillant dans les sept lacs. Nous concluons que les taux de prise et la composition de la population du lac Ten Mile sont similaires à ceux des populations des lieux de pêche situés à proximité. En raison de la faible mortalité et du ralentissement du taux de croissance, nous pensons que la densité de la population d'ombles de fontaine du lac Ten Mile pourrait augmenter. En conséquence, la population d'ombles de fontaine du lac Ten Mile pourrait afficher des taux de croissance en déclin. Notre recommandation est d'allonger la durée de la saison de pêche.

## BACKGROUND

The following interim report summarizes fisheries data collected by the Government of Newfoundland and Labrador's, Wildlife Division during the spring of 2009 and 2010 from seven lakes located on the Northern Peninsula. The sampling program was established in response to concerns expressed by residents of the Northern Peninsula regarding a special trout management area existing on one of the seven sampled lakes (Ten Mile Lake). Specifically, residents voiced their objections through phone calls as well as a public meeting (held on 29 October, 2009) that restrictions in this special management area were too severe and, in accordance with their beliefs, unwarranted (Northern Pen. Vol. 30 No 26; Wildlife Division, Robert Perry. Pers. Comm.).

In 2004 the Federal Department of Fisheries and Oceans (DFO) altered the regulations and created a Special Trout Management Area (STMA) for Ten Mile Lake and Round Lake. The management area was initially established to address concerns of cabin owners who had held a public meeting with DFO (15 April, 2004). At the meeting residents alleged that both lakes were being over-harvested and that the brook trout (*Salvelinus fontinalis*) fishery was in a state of decline; characterized by low catch rates and declining trout sizes (DFO Berkley Slade, Pers. Comm.). In response to these concerns, DFO limited the fishing period within the STMA to 45 days (1 June until 15 July) and reduced the daily bag limit from 12 fish (or 5 lbs plus one fish) to 2 fish or 5 lbs.

## INTRODUCTION

There is a tendency for open access resources to become overexploited (Hardin 1968; Clark 1990) and management actions are often required to achieve sustainable use of renewable resources. Strategies that seek to control harvest such as, adjusting the season length, number and size of fish harvested are tools that managers use to limit the numbers of fish removed from a population (Noble and Jones 1993; Power and Power 1996; van Zyll de Jong et al. 2002; Post et al. 2003; Keefe and Perry 2010). The intent is to reduce fishing mortality to a point that ensures sustainability of the resource. Critical in using these tools effectively is an understanding of population size and the annual numbers of fish harvested from a population (van Zyll de Jong et al. 2002; Post et al. 2003). Normally, such an understanding would be achieved through the collection of both fisheries dependent (data from anglers) and independent data (standardized collections). Harvest strategies may then be adjusted to account for fluctuations in stock size; whether these are created due to natural factors or a consequence of the recreational harvest (Heino 1998).

When the STMA, was initially created, base line data was not collected from either of the ponds (Ten Mile Lake or Round Lake). This made it difficult to resolve whether the established regulations were actually warranted and to determine what influence the new STMA regulations are having on present-day brook trout populations.

One potential way to determine how brook trout populations are responding is to compare them with populations from neighbouring ponds, outside the STMA. Presumably, brook trout populations outside the STMA would exhibit different characteristics from STMA populations, because the old management regime has a liberal bag limit (Daily: 12 trout or 5 lbs + 1 fish; possession: twice daily limit) and a longer fishing season (approximately 6 month total).

# METHODS

## STUDY OBJECTIVES

1. To determine whether brook trout catch rates and catch sizes are better in the STMA relative to brook trout fisheries from neighbouring ponds existing under the old regime.

2. To compare and contrast the relative growth and mortality rates among seven ponds located on the Northern Peninsula. Six of these ponds are subject to the standard regulations (Daily: 12 trout or 5 lbs + 1 fish; possession: twice daily limit) and the seventh is subject to the new regulations (45 day season (1 June through 15 July; 2 fish or 5 lbs, and no winter angling season)).

## STUDY AREA

The seven sampled lakes are located in subregions of the Northern Peninsula Forest Ecoregion (Fig. 1, Table 1). This ecoregion is characterized by a short growing season (approximately 110 -150 d). The geomorphology is limestone with acidic rock being common on the eastern side of the peninsula. Balsam fir (*Abies balsamea*) is the dominant tree in low lying areas, but black spruce (*Picea mariana*) stands dominate on the eastern side of the Peninsula. Limestone barrens are common along the west coast, with dwarf shrub and crowberry barrens on the east coast. Plateau bogs cover extensive areas of the coastal lowlands (Meades and Moores 1994). The seven sampled lakes have surface areas ranging between 0.8 $km^2$ and 33.6 $km^2$ (National Topographic series NTDB1; Arcgis 9.3) (Table 1).

## LAKE CHARACTERISTICS

Lake bathymetric mapping was completed for all sampled lakes using standardized methods (OMNR 1987). From each of these maps lake surface area, mean depth and maximum depth were calculated. Habitat information were collected using a YSI meter and consisted of water quality parameters, including dissolved oxygen (DO), standard pH, temperature profiles, specific conductance, and total dissolved solids.

## FISH COLLECTION, AGE ESTIMATION, AND MATURITY

To collect samples that were comparable among lakes, standardized netting surveys were conducted during the spring of 2009 and 2010. The program utilizes standardized monofilament gill nets with all net gangs containing eight-gill net panels, increasing in mesh size from 1.25 cm to 9.0 cm by 1.25 cm increments. Net panels were attached in series from smallest to largest mesh size and were set at random locations, perpendicular to the shore. By using a standardized complement of mesh sizes, and randomly setting nets, bias due to gear selectivity is consistent and therefore abundance, composition, size and age classes of species are comparable among lakes. The survey also incorporated a water temperature window whereby sampling only occurred below temperatures of 12 °C. Gill net sets extended from the littoral to the pelagic zones.

Care was taken to record the panel size from which an individual fish was removed. Captured fish were collected, identified, enumerated, and measured for fork length (to the nearest mm) and weight (1.0 g). Sex and maturity were also recorded. An otolith and genetic sample was taken from each sampled fish. The procedure for mounting and replicating otoliths is as described by Casselman and Gunn (1992). Sagittal otoliths were embedded in a mixture of Araldite epoxy (#GY502) and hardener (#HY956) at a ratio of 5:1 (Ciba-Geigy Canada Ltd, Dorval, Quebec). Otoliths were sectioned transversely through the origin to a thickness of 400 to 450 μm with a Low-speed Isomet saw (Buehler Canada Ltd., Toronto, Ontario). Epoxy resin was

used to mount the sections on glass slides. To polish the surface of the sectioned otolith, abrasive sanding paper of 600, 800 and 1200 grit were used.  Polished sections were acid etched using 2 % HCl (aq). Acetate was softened by applying a drop of acetone to the surface of the section for two minutes. The etched sections were replicated by applying mild pressure to a piece of cellulose acetate.

All acetate replicates were interpreted for age. Additionally, replicates were projected onto a digitizing tablet through a microscope drawing tube at 100 X magnification. The location of each annulus was digitized using Calcified Structure Age and Growth Data Extraction Software (Casselman and Scott 2000). Increments, located on the ventral surface of the otolith cross-section, were measured along a radius that extended from the nucleus (origin) to the proximal edge.

## ANALYSIS

To determine whether there were any obvious differences in fish length among the seven lakes, each location's length distributions were subdivided into percentiles. Additionally, a three way analysis of variance (ANOVA) was performed (age, sex and lake were the explanatory variables) to determine if there was a significant difference among lakes for fish length at age. Age distributions among lakes were also compared using a chi square analysis. For this analysis only those age groups that were considered fully recruited to the gear were used. This included all ages found on the descending right limb of each lake's catch curve (Ricker 1975; Everhart et al. 1975). The test was first performed using the six lakes which were subject to the old regulations. Then the chi square analysis was repeated with Ten Mile Lake being added to the test group.

Sexual maturity of brook trout was established based on the assessment of gonad and ovary development using criteria described by Vladykov (1956) and Ricker (1970). To describe the age at which the onset of sexual maturity for brook trout occurs, samples from each lake were subdivided based on age and percent maturity for each cohort was calculated. The criterion for the determination of the onset of maturity was that at least 40 to 50 % of the cohort exhibited sexual maturation (Van Zyll de Jong et al. 1999).

## BACK-CALCULATION

To examine the pattern of growth through time, back-calculations of length at age were completed by use of the Fraser and Lee direct proportion method (Ricker 1970).

$$L - a = \frac{O_n}{O}(L - O)$$

$L_n$= length of fish when annulus was formed

$L$= length of fish at time otolith sample was obtained

$O_n$= radius of annulus '$n$' (at length '$L_n$')

$O$ = total otolith radius

$a$ = an intercept from an abscissa, which can be obtained from the linear regression for the relationship between maximum otolith radius and fish body length. Regressions were developed for each lake by fish sex:

*Length = a + b (otolith radius)*

From each lake back-calculated fish lengths at age were graphed by growth year. Subsequently, to determine whether significant differences existed among growth years for brook trout in Ten Mile Lake, a two way ANOVA was conducted using back-calculated lengths as the dependant variable and year of growth and age as the independent variables. This test was then repeated on brook trout populations from each of the six remaining lake's.

To examine differences among growth rates of the seven populations, von Berttalanffy (1938) growth equations with an additive error structure (Ricker 1975) were plotted using average length at age data collected from each population. For the purposes of standardization, the equation was fit to fish aged between one and seven years:

$$L_t = L_\infty \left[ 1 - e^{k(t-t_0)} \right] \quad \text{where:}$$

$L_t$ = predicted length at a given time

$L$ = average maximum size in the population

$K$ = the growth coefficient

$t$ = age (in years)

$t_0$ = hypothetical age (years) when the mean fish total length is zero

## MORTALITY

Least-squares regression was used to calculate mortality rates (Everhart et al. 1975; Ricker 1975). Instantaneous total mortality (Z) was estimated by the slope of the linear regression fitted to the descending right limb of each catch curve. The annual survival rate was then calculated based on the Z estimate. Robson and Chapman's estimator was also used to determine survival rates (Robson and Chapman 1961; Guy and Brown 2007). Additionally, Abrosov's index was used to determine the age of turnover (the average number of years a fish remains in the water between hatching and removal) (Abrosov 1969).

## RELATIVE ABUNDANCE

To determine if there were significant differences in relative abundance (catch rates) among the seven sampled lakes, a one way ANOVA was performed comparing CPUE among lakes.

## RESULTS

## INDEX NETTING

In total, 42 net sets were placed among the seven sampled lakes; four lakes were sampled in 2009 and three in 2010. Five species were sampled among the seven lakes including, brook trout, Atlantic salmon (*Salmo salar*), Arctic char (*Salvelinus alpinus*), rainbow smelt (*Osmerus mordax*), and the three-spine stickleback (*Gasterosteus aculeatus*) (Table 2). In total, 521brook trout were sampled. CPUE for brook trout ranged between 0.829 fish per hour to 19.6 fish per hour (Table 2). The data failed a test for normality (Shapiro-Wilk, $P < 0.050$). Therefore we conducted a Kruskal-Wallis one way analysis of variance on ranks which indicated a significant difference among catch rates (H = 16.758, df =6, $P = 0.010$). Using the Dunn's Multiple Comparison Procedure it was determined catch rates for Big Northeast Pond significantly differed from Coles Pond (Q = 3.560, $P < 0.05$). No other differences in CPUE were identified.

## GROWTH

The breakdown of age and length distributions into the various percentile groupings (Table 3) illustrate that frequencies for length groups from Ten Mile Lake are similar with two lakes operating under the old management regime. Both Angle and Forked Feeder Pond's 95th percentiles exceeded 400 mm in length. Additionally, there were three lakes that had medians and mean lengths larger than Ten Mile Lake (Angle Pond, Coles Pond, and Forked Feeder Pond) (Table 3). Results for the three way ANOVA indicated sex did not significantly influence fish length after allowing for fish age and location. Therefore, sex was dropped from the analysis and the test was repeated as a two way ANOVA, with location and age as the explanatory variables. Both age (F = 57.26, df = 9, $P < 0.001$) and lake (F = 18.23, df = 6, $P < 0.001$) demonstrated significant influence on fish length. Furthermore, there was a significant interaction between age and lake (F = 2.38, df = 34, $P < 0.001$). A Bonforroni post hoc test indicated that significant differences in length did not exist among lakes for age cohorts one and two. Significant size differences did exist among lakes for age cohorts three, four, five and six. Graphical examination revealed that Ten Mile Lake significantly differed from several of the other lakes in age cohorts three and four (Fig. 2). In both instances, mean size tended to be smallest for Ten Mile Lake. Little differences in size existed among lakes for cohorts five and six; Forked Feeder was the only pond that differed among the seven for the age five cohort (F = 5.532, df = 6, $P < 0.001$; Fig. 2). In the age six cohort only Joe Farrell's Pond statistically differed (F = 4.910, df = 6, $P < 0.001$; Fig. 2). Sample sizes were too small for a meaningful comparison beyond age six.

Age distributions were the oldest for Ten Mile Lake with the median and average fish ages being 5 years and 4.36 years, respectively (Table 3). The median for all the other ponds did not exceed 4. The age range 3 to 6 was used in the Chi square examination for determining if differences in age distributions existed among the seven lakes (older and younger ages were excluded due to insufficient sample sizes). When the test was performed with Ten Mile Lake excluded, there was no significant difference among the six lakes ($\chi^2$ = 18.08, df = 15, $P$ =0.259) however; when Ten Mile Lake was included a significant difference was found ($\chi^2$= 71.65, df = 18, $P < 0.001$). Therefore it would appear that age distributions among the six lakes under the old management regime are not significantly different but differ when compared with Ten Mile Lake's age distribution (Fig. 3). The mean age among the six lakes for the 3 to 6 range was 3.92 years (minimum: 3.50 years; maximum 4.19 years). In Ten Mile Lake, for the same age range, the average age was 4.61 years.

The two-way ANOVA using back calculations of growth from brook trout otoliths sampled from Ten Mile Lake displayed a statistically significant difference among years for growth (Age: df = 6, F = 76.065, $P < 0.001$; Growth year: df = 6, F = 2.465, $P = 0.023$; interaction: df = 19, F = 1.290, P = 0.186). Subsequent to 2004, growth rates declined (Table 4; Fig. 4). When the test was repeated for each of the additional six lakes, two lakes exhibited significant growth differences among years and four did not (Table 5). Two lakes which exhibited significant differences among growth years were Joe Farrell's Pond and Big Northeast Pond. However, when graphed, both ponds demonstrated patterns of increased growth rates (Fig. 5).

The von Berttalanffy growth equations (Table 6), fit to the length at age data, indicated that growth rate (k) was slowest for Ten Mile Lake (k = 0.1367) and fastest for Joe Farrells k = 0.5108). The rate averaged among the seven lakes was K = 0.3545. Values for length at infinity (L∞) among the sampled lakes ranged between 282.5 mm for Joe Farrell's Pond to 621.0 mm for Ten Mile Lake. The average among the seven lakes for length at infinity was k = 420.57 mm (Table 6).

## MORTALITY

Instantaneous mortality (Z) rates ranged from a high of -0.8538 for Joe Farrell's Pond to a low of -0.1620 for Ten Mile Lake. Thus, annual survival ranged from 42.0 % to 85.0 %, respectively. The average annual survival for the seven lakes was 59.0 % (Table 7). Due to the shape of the catch distribution, a significant regression for Ten Mile Lake could not be achieved using the least-squares method. However, the Robson and Chapman's survival estimator appeared to achieve a more reliable estimate. For this estimator, survival ranged from a low of 40.2 % (Joe Farrell's Pond) to a high of 64.5 % (Ten Mile Lake) (Table 7). The average annual survival for the seven lakes using the Robson-Chapman estimator was 53.9 %. The age at which 40.0 % to 50 % of the brook trout population was deemed to be sexually mature was 3 years.

## WATER CHEMISTRY

Water chemistry values for the seven sampled lakes fell within normal parameters for surface water quality for the insular portion of the province (Table 8) (Water Resource Atlas of Newfoundland 2004; www.env.gov.nl.ca/env/waterres/rti/rtwq/glossary.html). Average value for specific conductance among the seven lakes was 166 μs/cm, which is an indication of pristine conditions. The average pH value was slightly acidic, with a value of 6.68. The typical pH for rainwater is 6.5. Dissolved oxygen values ranged from 8.556 to 12.162 mg/L, with an average for the seven lakes of 9.955mg/L. Values that fall between 8 through 12mg/L are considered indicators of a healthy system.

## DISCUSSION

In accordance with our findings, size differences within brook trout age classes differ among lakes. In general, Ten Mile Lake fish interpreted at ages three and four were smaller when compared to fish from five of the other sampled lakes. Few length differences could be found among the seven sampled lakes for age classes older than four.  When comparing both age structure and growth rates significant differences also existed. Ten Mile Lake displayed the slowest growth rate among the seven lakes and the oldest age structure.

Slowing of growth rates in fish populations has been attributed to both abiotic and biotic factors which alter fish physiology, and behaviours. Abiotic factors include changes in water chemistry and temperature (Menendez 1976; Meisner 1990; Flebbe et al. 2006). For example, both egg hatchability and juvenile brook trout growth can be influenced by changes in pH levels (Menendez 1976). Robinson et al. (2010) reported limitations and declines in brook trout growth as temperatures fluctuated around a mean temperature of 20 °C.

Biotic factors that influence Fish growth include fish densities, competitive interactions and food availability. In salmonids, changes in growth rates have been documented and were attributed to high fish densities resulting from an abundance of favourable spawning habitat (Reimers 1979; Langeland 1982; Donald and Alger 1989). Additionally, changes in growth rate may occur due to intraspecific competition for food and space whereby dominant, larger fish out-compete younger subordinates for both food and territory (Caron and Beaugrand 1988; Jenkins et al. 1999; Jonsson 2001). Increased densities will lead to greater fish activity whereupon more incidences of hampering, aggression, chases and intimidation will occur (Marchand and Boisclair 1998; Ayllón et al. 2012). Thus, increased activity patterns will cause greater expenditures of energy resulting in diminished resources for fish growth (Marchand and Boisclair 1998; Carmona-Catot et al. 2010). In Ten Mile Lake it is unlikely that the decline in growth rate can be attributed to abiotic factors. Of the seven sampled lakes only Ten Mile Lake had a temporal pattern whereby brook trout growth rates were slowing. If growth was influenced by a larger abiotic environmental event, such as a temperature change, we would expect to see

the same patterns for fish growth in lakes that were in proximity to Ten Mile. Further, for all sampled lakes, we measured water chemistry and found nothing that could be considered outside the reported norms for the area ([Table 8](#)).Thus, it is more probable that the decline in growth is attributable to biotic factors.

The mortality rate for Ten Mile Lake was the lowest of the seven sampled lakes (Table 6) and therefore, it is plausible that densities in the pond are increasing. Following the introduction of the new management strategy the subsequent decline in fishing pressure would likely result in fewer mature fish being harvested. Therefore, greater numbers would survive to spawn in the fall.

Growth rates modeled using the von Bertlanffy growth equation demonstrate that Ten Mile Lake fish have the slowest rates of the seven sampled ponds. Derived lengths, back-calculated using otolith incremental deposits, demonstrated a temporal pattern of slowing growth rate for Ten Mile Lake that is coincident with the establishment of the new management regime (Fig. 4). This same pattern of slowing growth was not evident in any of the other sampled brook trout populations (Fig. 5). This declining rate has resulted in a general decline in size at age for year classes subsequent to 2003 (Table 4). Declines in brook trout growth rates have been attributed to increased competition for food and territory whereby dominant older fish appropriate the most favourable habitat (Jobling 1985; Caron and Beaugrand 1988; Milner et al. 2003; Ayllón 2012). This appropriation forces smaller subordinates to exhaust energy in a continual seeking for territory, shelter and food (Marchand and Boisclair 1998; Milner et al. 2003).

Given that there was no base line data collected prior to the creation of the STMA it is impossible to determine whether the public conjecture that elicited the management change for Ten Mile Lake was justified. Nor is it possible to determine from our observations what level of recovery has occurred. Nevertheless, our comparison of Ten Mile Lake with ponds that are in its vicinity can give us insights into the current state of the pond relative to neighbouring ponds.

It would appear that the brook trout population of Ten Mile Lake is similar in size structure to three of the ponds outside the STMA. However, due to slow growth rates, Ten Mile Lake fish take longer to reach equivalent sizes when compared to fish sampled from water bodies managed under the old regulations. Additionally, if densities of brook trout are increasing in Ten Mile Lake this has not translated into superior catch rates relative to the other sampled ponds. We did not find significant differences in catch rate among ponds when compared to Ten Mile Lake. However, catch rates can vary among ponds for several reasons including pond surface area, depth, clarity and chemistry and therefore these findings should be approached with caution (Murphy and Willis 1996). Further, our sample size was relatively small and therefore we may have not had the statistical resolution to detect a difference.

It has been documented that increasing exploitation on brook trout can be used as a means of increasing growth rates in a fish populations (Carmona-Catot et al. 2010). The hypothesis is predicated on the lake's food supply being capable of supporting larger fish but that the food supply is being shared by too many individuals and therefore secondary production is not being maximized (Ball and Hayne 1952; Donald and Alger 1989). Thus exploitation should increase growth by reducing fish density, leaving more food per fish (Reimers 1979). Reduced numbers should also lower the energy costs associated with behavioural interactions thereby allowing for greater energy availability for conversion to growth (Jobling 1985; Marchand and Boisclair 1998). This phenomenon of compensatory growth has been documented (Beckman 1942; Hanson et al 1983; Langeland 1986; Donald and Alger 1989; Jonsson 2001). Given that brook trout from Ten Mile Lake are displaying signs of diminished growth it suggests that the population can sustain small increases to the exploitation rate without seriously altering catch rates or catch size. Specifically, the potential for salmonids to express compensatory growth

and fecundity should offset the effects of the increased angling pressure (Jenkins 1999; Carmona-Catot 2010).

If the intent for the creation of the STMA for Ten Mile Lake was to allow brook trout populations to recover relative to other fishing destinations in its vicinity, this may have occurred. It would appear that the Ten Mile Lake brook trout fishery is on par with other preferred fishing destinations near its location. Compared to the other six sampled ponds, the catch rate for Ten Mile Lake did not differ. Though the mean length of Ten Mile Lakes catch composition was smaller than three other sampled ponds, the composition of its catch exhibited the oldest mean age and the lowest mortality rate. Additionally, brook trout growth rates from Ten Mile Lake were the slowest among the sampled lakes and it appears the growth rate for brook trout has been declining coincident with the establishment of the new regulations. This decline in growth rate, coupled with the low mortality rate, may be an indication that brook trout density has been increasing.

Given the uncertainty of our findings, liberalizing management restrictions on Ten Mile Lake should be done utilizing a cautionary approach. Placing excessive pressure on the resource may offset any potential recovery that might have occurred. Furthermore, removing too many restrictions may create a large influx of anglers who, being under the mistaken impression that the intensively managed area has created an exceptional fishery, gravitate to the lake.

## RECOMMENDATIONS

1.  The summer angling period for Ten Mile Lake should be expanded to encompass the period from 1 June to 7 September, inclusive (same season length as the majority of the island). This would expand the current angling season by 54 days thereby accommodating local anglers, who requested the angling season be extended for Ten Mile Lake.

2.  All additional regulations currently in effect for Ten Mile Lake and Round Pond should remain in place. This will help to ensure that fishing pressure remains distributed among neighbouring ponds.

3.  A monitoring program for the fishery should be established. This could be done using a point access creel survey during the summer angling season and occasional independent sampling. To date, little information exists that quantifies the level of effort that is being exerted on Ten Mile Lake by local anglers. Nor has there been any data collected on the fish that are being harvested. If the regulations are altered it is important to monitor how the fishery is responding to the change. The data, which has already been collected by the Provincial government, could serve as baseline data.

## ACKNOWLEDGEMENTS

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*Table 1. The names, locations (decimal degrees), surface area, and sub ecoregions (Meades and Moores 1994) of the seven lakes sampled on the Northern Peninsula of Newfoundland and Labrador during the spring of 2009 and 2010.*

| Waterbody | Longitude | Latitude | Surface Area (km$^2$) | Eco-region (Northern Peninsula Forest) |
|---|---|---|---|---|
| Angle Pond | -57.13122 | 50.50400 | 1.428720 | Coastal Plain Sub Region |
| Big Northeast Pond | -57.28073 | 50.31675 | 3.985770 | Coastal Plain Sub Region and partially within Long Range Barrens |
| Coles Pond | -56.033472 | 51.00422 | 8.724615 | Beaver Brook Limestone Sub Region |
| East Castor Pond | -56.66298 | 50.99403 | 1.891990 | Beaver Brook Limestone Sub Region |
| Forked Feeder Pond | -57.18246 | 50.52309 | 2.732890 | Coastal Plain Sub Region |
| Joe Farrells Pond | -56.08554 | 51.08878 | 0.794015 | Beaver Brook Limestone Sub Region |
| Ten Mile Lake | -56.6715 | 51.11060 | 33.55560 | Beaver Brook Limestone Sub Region |

*Table 2. Number of net sets, average temperature when sampling occurred, Catch per Unit of Effort (calculated for brook trout, Salvelinus fontinalis only), and number of fish caught per species for seven lakes sampled on the Northern Peninsula of Newfoundland and Labrador during the spring of 2009 and 2010 (Note: totals for three spine stickleback (Gasterosteus aculeatus) are not reported) (Date = month/day/year; Temp. = Temperature; m = meters; CPUE = Catch per Unit of Effort (fish per hour). CI = 95% confidence interval for CPUE).*

| Waterbody | Date | Net Sets | Temp. °C | Avg. Depth (m) | CPUE (95% CI) | Brook Trout | Arctic char | Atlantic salmon | Rainbow smelt |
|---|---|---|---|---|---|---|---|---|---|
| Angle Pond | 05/09/2010 | 6 | 7.08 | 7.08 | 1.50 (±0.908) | 65 | --- | --- | --- |
| Big Northeast Pond | 06/09/2009 | 4 | 6.85 | 10.80 | 9.82 (±9.082) | 103 | --- | --- | --- |
| Coles Pond | 05/14/2010 | 8 | 5.14 | 9.28 | 0.829 (±0.595) | 37 | 41 | 34 | 15 |
| East Castor Pond | 05/11/2010 | 4 | 4.35 | 8.21 | 19.61 (±53.370) | 107 | --- | 81 | --- |
| Forked Feeder Pond | 06/07/2009 | 8 | 11.30 | 5.49 | 1.61 (±1.467) | 33 | --- | --- | --- |
| Joe Farrells Pond | 05/15/2010 | 4 | 5.98 | 2.11 | 1.34 (±1.615) | 82 | --- | 94 | --- |
| Ten Mile Lake | 06/05/2009 | 8 | 7.50 | 22.54 | 1.36 (±0.3939) | 94 | --- | 83 | --- |

*Table 3. Brook trout, Salvelinus fontinalis length and age percentiles for seven lakes sampled on the Northern Peninsula of Newfoundland and Labrador during the spring of 2009 and 2010. Sample size and total sample mean are also included (mm = millimeters; N = sample number).*

Length Percentiles (mm)

| Waterbody | N | 5 | 10 | 25 | Median | 75 | 90 | 95 | mean |
|---|---|---|---|---|---|---|---|---|---|
| Angle Pond | 69 | 173.5 | 227.0 | 266.5 | 322.0 | 372.5 | 409.0 | 418.5 | 315.10 |
| Big Northeast Pond | 104 | 171.0 | 179.5 | 193.3 | 247.0 | 295.3 | 318.0 | 344.0 | 245.88 |
| Coles Pond | 36 | 130.7 | 189.9 | 275.3 | 317.5 | 340.3 | 383.5 | 394.4 | 299.86 |
| East Castor Pond | 153 | 116.4 | 150.8 | 224.5 | 261.0 | 311.5 | 335.6 | 350.0 | 258.07 |
| Forked Feeder Pond | 33 | 245.2 | 294.4 | 324.5 | 356.0 | 385.0 | 435.4 | 462.6 | 356.48 |
| Joe Farrells Pond | 87 | 164.4 | 176.6 | 200.0 | 228.0 | 250.0 | 287.6 | 309.4 | 225.77 |
| Ten Mile Lake | 93 | 122.7 | 162.4 | 197.5 | 292.0 | 363.5 | 417.2 | 444.3 | 283.71 |

Age Percentiles (years)

| Waterbody | N | 5 | 10 | 25 | Median | 75 | 90 | 95 | mean |
|---|---|---|---|---|---|---|---|---|---|
| Angle Pond | 69 | 1.40 | 2.00 | 3.00 | 4.00 | 5.00 | 6.00 | 6.60 | 4.04 |
| Big Northeast Pond | 104 | 2.00 | 3.00 | 3.00 | 4.00 | 4.00 | 5.90 | 6.00 | 3.84 |
| Coles Pond | 36 | 2.70 | 3.00 | 3.00 | 4.00 | 5.00 | 6.00 | 7.30 | 4.19 |
| East Castor Pond | 153 | 1.00 | 2.00 | 3.00 | 4.00 | 5.00 | 6.00 | 6.00 | 3.75 |
| Forked Feeder Pond | 33 | 2.30 | 3.00 | 3.00 | 3.00 | 4.00 | 5.00 | 6.35 | 3.53 |
| Joe Farrells Pond | 87 | 2.00 | 2.00 | 3.00 | 3.00 | 4.00 | 5.00 | 5.00 | 3.28 |
| Ten Mile Lake | 93 | 1.00 | 2.00 | 3.00 | 5.00 | 6.00 | 6.00 | 7.00 | 4.36 |

*Table 4. Average back-calculated total length of brook trout, Salvelinus fontinalis from Ten Mile Lake, Newfoundland and Labrador, sampled in 2009.*

Total length (mm) at age

| Growth Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 2002 | 137.13 | - | - | - | - | - | - |
| 2003 | 143.96 | 173.56 | 207.33 | - | - | - | - |
| 2004 | 132.81 | 189.44 | 222.07 | 234.57 | - | - | - |
| 2005 | 123.85 | 176.84 | 225.83 | 252.62 | 256.66 | - | - |
| 2006 | 116.62 | 157.75 | 208.20 | 253.70 | 277.79 | 277.67 | - |
| 2007 | 119.56 | 141.98 | 185.27 | 234.76 | 282.58 | 277.67 | - |
| 2008 | 114.28 | 154.47 | 161.01 | 206.82 | 261.99 | 299.61 | 296.47 |

*Table 5. Results from two-way ANOVA's (α=0.05) comparing back-calculated length for brook trout, Salvelinus fontinalis. with the year and the fish's age at the time the growth occurred. Lakes were sampled in the vicinity of Ten Mile Lake and are known by local anglers as popular fishing destinations. (\* indicates the results from the interaction term). (df = degrees of freedom; F value = calculated F statistic; P = probability).*

| Waterbody | variable | df | F | Sig |
|---|---|---|---|---|
| **Angle** | age | 6 | 106.185 | $P < 0.001$ |
| **Angle** | growth year | 6 | 0.215 | $P = 0.972$ |
| **Angle** | *Age/ growth year | 19 | 0.897 | $P = 0.587$ |
| **Big Northeast** | age | 8 | 17.046 | $P < 0.001$ |
| **Big Northeast** | growth year | 8 | 2.162 | $P = 0.030$ |
| **Big Northeast** | *Age/ growth year | 24 | 1.463 | $P = 0.076$ |
| **Coles** | age | 8 | 13.081 | $P < 0.001$ |
| **Coles** | growth year | 8 | 1.720 | $P = 0.101$ |
| **Coles** | *Age/ growth year | 21 | 1.095 | $P = 0.364$ |
| **East Castor** | age | 7 | 63.381 | $P < 0.001$ |
| **East Castor** | growth year | 8 | 1.284 | $P = 0.249$ |
| **East Castor** | *Age/ growth year | 31 | 2.086 | $P = 0.001$ |
| **Forked Feeder** | age | 6 | 16.187 | $P < 0.001$ |

| Waterbody | variable | df | F | Sig |
|---|---|---|---|---|
| **Forked Feeder** | growth year | 6 | 1.046 | $P = 0.402$ |
| **Forked Feeder** | *Age/ growth year | 13 | 0.651 | $P = 0.804$ |
| **Joe Farrell's** | age | 5 | 11.484 | $P < 0.001$ |
| **Joe Farrell's** | growth year | 6 | 5.144 | $P < 0.001$ |
| **Joe Farrell's** | *Age/ growth year | 20 | 1.993 | $P = 0.008$ |

*Table 6. Parameters from the seven plotted brook trout, Salvelinus fontinalis, von Bertalanffy growth equations for seven lakes sampled on the Northern Peninsula of Newfoundland during the spring of 2009 and 2010.(K = growth rate; K_CI = 95% growth rate confidence interval; $L_\infty$ (L infinity) = maximum theoretical length that a fish can achieve; $L_\infty CI$ = 95% confidence interval for $L_\infty$ ; $T_0$ = y-intercept for the growth equation).*

| Waterbody | K | K_CI | $L_\infty$ | $L_\infty CI$ | $T_0$ |
|---|---|---|---|---|---|
| Angle Pond | 0.2836 | ±0.0015 | 460 | ±1.000 | -0.2244 |
| Big Northeast Pond | 0.2947 | ±0.0015 | 381 | ±0.888 | 0.0797 |
| Coles Pond | 0.4299 | ±0.0026 | 374 | ±0.759 | 0.0253 |
| East Castor Pond | 0.3942 | ±0.0014 | 349 | ±0.410 | -0.0683 |
| Forked Feeder Pond | 0.4317 | ±0.0034 | 476 | ±1.12 | 0.1218 |
| Joe Farrells Pond | 0.5108 | ±0.0033 | 283 | ±.524 | -0.1500 |
| Ten Mile Lake | 0.1367 | ±0.0011 | 621 | ±2.94 | -0.2151 |

*Table 7. Least square regression estimates of brook trout, Salvelinus fontinalis instantaneous mortality and annual survival for seven lakes sampled on the Northern Peninsula of Newfoundland and Labrador during the spring of 2009 and 2010. ( Z = instantaneous mortality; P = Significance value; $r^2$ = squared product moment correlation coefficient; (±) = Chapman-Robson Estimate of annual survival and 95% confidence limits; t = Abrosov's index) (α = 0.05).*

| Waterbody | Z | Annual Survival | P | $r^2$ | Chapman-Robson | t |
|---|---|---|---|---|---|---|
| Angle Pond | -0.4493 | 64% | P = 0.037 | 0.811 | 57.4% (± 8.1) | 1.014 |
| Big Northeast Pond | -0.6468 | 52% | P <0 .001 | 0.966 | 50.3% (±7.0) | 0.818 |
| Coles Pond | -0.4907 | 61% | P = 0.015 | 0.807 | 57.0% (±6.0) | 1.201 |
| East Castor Pond | -0.5573 | 57% | P =0 .011 | 0.836 | 58.4% (±3.7) | 0.943 |
| Forked Feeder Pond | -0.7783 | 54% | P = 0.007 | 0.937 | 50.0% (±12.8) | 0.531 |
| Joe Farrells Pond | -0.8538 | 42% | P = 0.010 | 0.980 | 40.2% (±8.8) | 0.351 |
| Ten Mile Lake | -0.1620 | 85% | P = 0.320 | 0.320 | 64.5% (± 6.3%) | 1.356 |

*Table 8. Water Chemistry parameters measured from seven lakes located on the Northern Penninsula. Parameters were measured using a YSI meter, multi-parameter sond (YIS enviromental inc.). (Date = month/day/year; N = Number of sampling events; Temp. = Temperature in °C; SPC = specific conductivity in μs/cm; TDS = Total Dissolved Solids (Specific Cond (μS/cm)\*0.00064); DO = dissolved oxygen in mg/L; pH = acidity).*

| Waterbody | Date | N | Temp. | SPC | TDS | DO | pH |
|---|---|---|---|---|---|---|---|
| Ten Mile Lake | 06/05/2009 | 922 | 6.031 (0.104) | 142.00 (1.000) | 0.091 | 12.162 (0.150) | 5.732 (0.101) |
| Forked Feeder Pond | 06/07/2009 | 1231 | 11.464 (0.449) | 240.00 (18.00) | 0.154 | 8.556 (2.854) | 5.731 (0.268) |
| Big Northeast Pond | 06/09/2009 | 532 | 10.549 (0.360) | 50.00 (2.00) | 0.032 | 10.881 (0.600) | 5.292 (0.073) |
| Angle Pond | 05/09/2010 | 996 | 7.722 (0.094) | 275.00 (26.00) | 0.0176 | 9.802 (2.253) | 7.823 (0.435) |
| East Castor Pond | 05/11/2010 | 1543 | 4.329 (0.153) | 141.00 (15.00) | 0.090 | 9.592 (2.251) | 7.216 (0.234) |
| Coles Pond | 05/14/2010 | 1447 | 4.792 (0.152) | 110.00 (26.00) | 0.070 | 9.710 (2.253) | 7.085 (0.435) |
| Joe Farrells Pond | 05/15/2010 | 399 | 6.384 (0.102) | 181.00 (4.00) | 0.116 | 10.615 (1.087) | 7.312 (0.098) |
| Average (all ponds) | --- | 7070 | 6.953 (2.696) | 166.00 (69.00) | 0.106 | 9.955 (2.194) | 6.683 (0.883) |
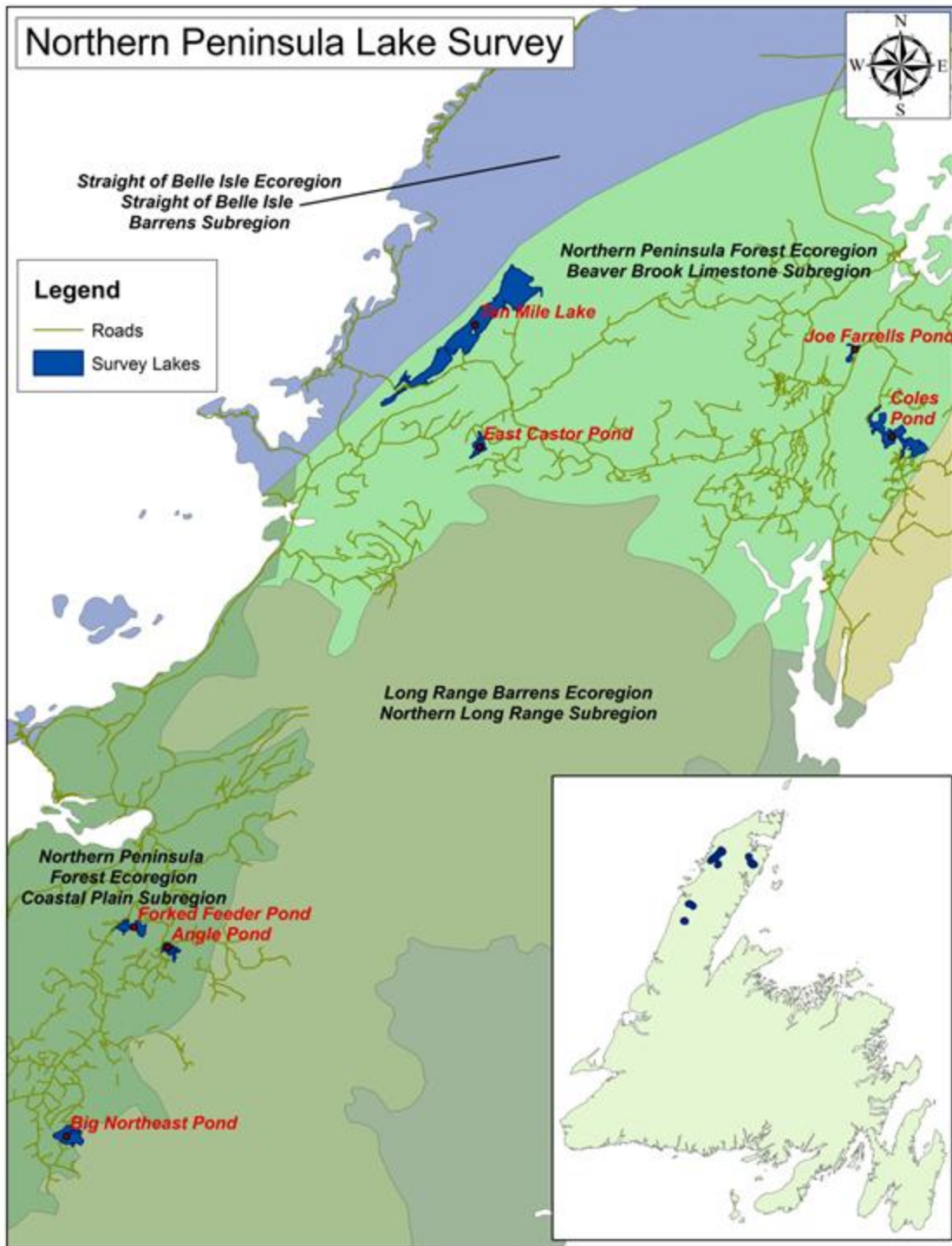
*Figure 1. Locations of the seven lakes that were sampled in the Northern Peninsula Forest Eco-region (Meades and Moores 1994), located on the Northern Peninsula during the spring of 2009 and 2010.*
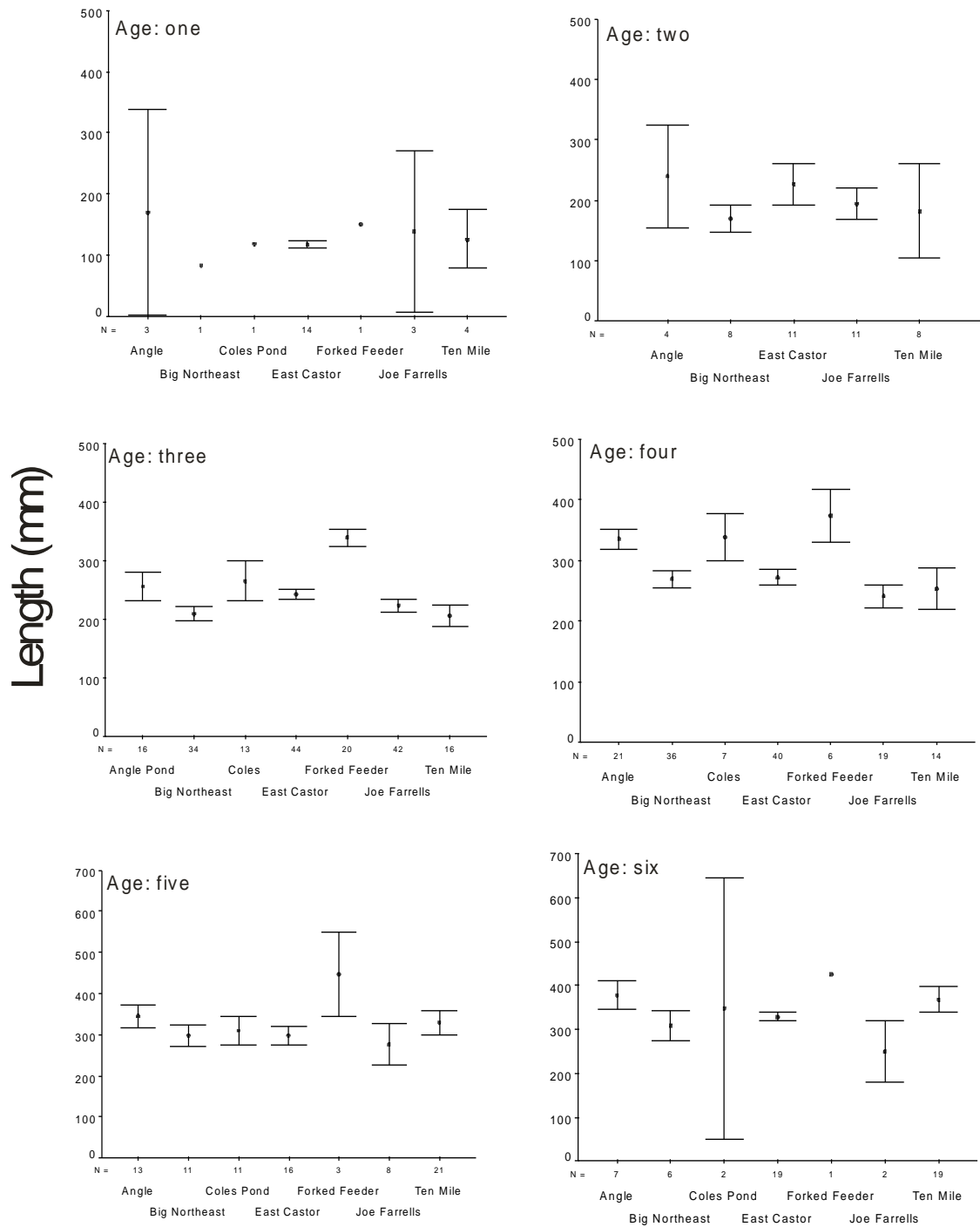
Figure 2. The mean length of brook trout, *Salvelinus fontinalis*, at a given age, sampled from seven locations on the Northern Peninsula of Newfoundland and Labrador during the spring of 2009 and 2010. Bars represent the 95% confidence limits. Sample size (N) is presented below the x-axis.
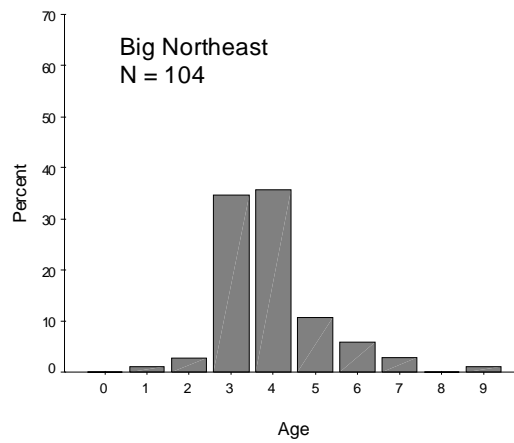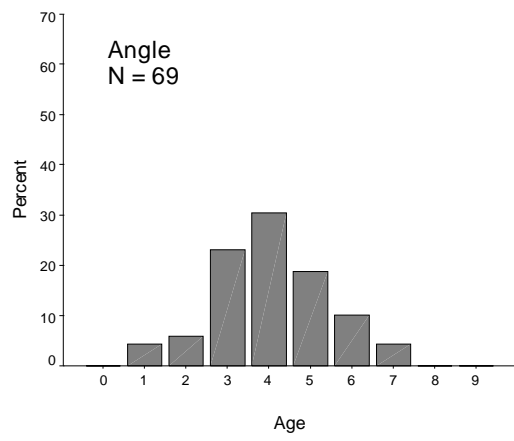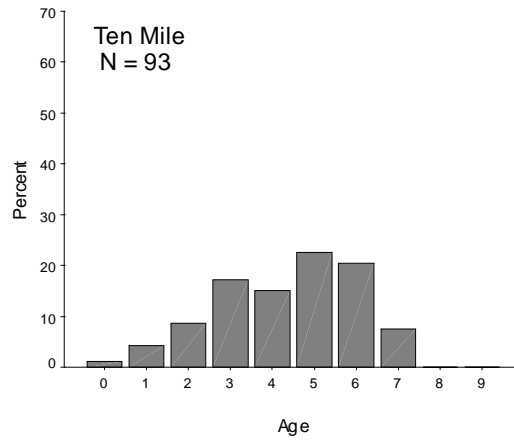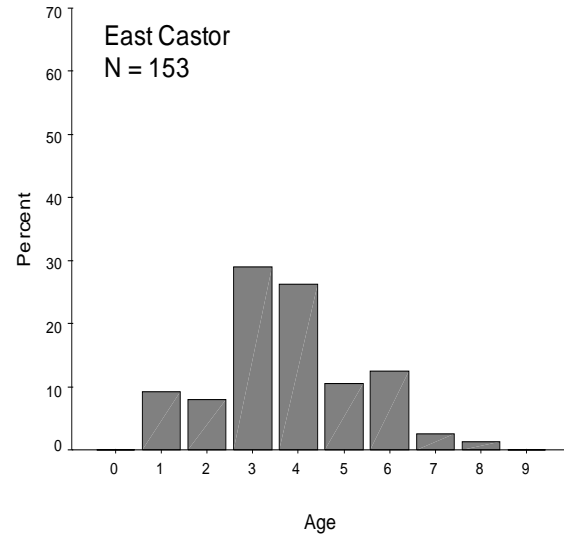
*Figure 3A. Age percentage distributions for Brook trout, Salvelinus fontinalis, in all ponds sampled on the Northern Peninsula of Newfoundland and Labrador. (N = Actual number of brook trout sampled from an individual population).*
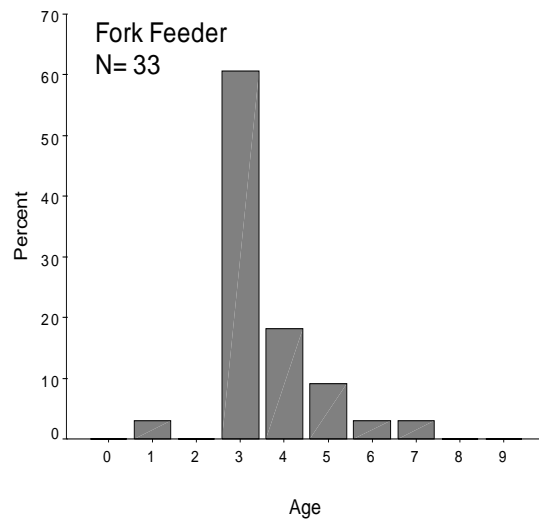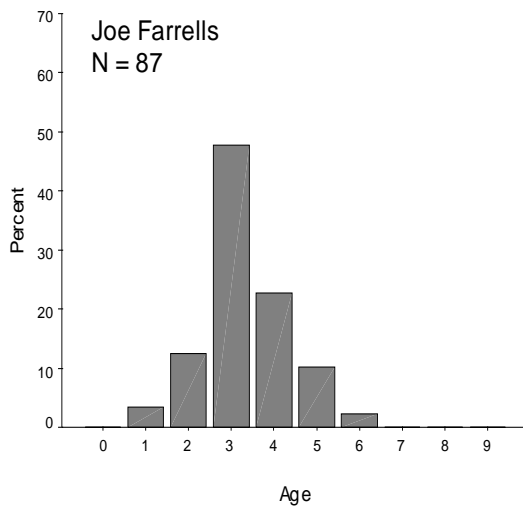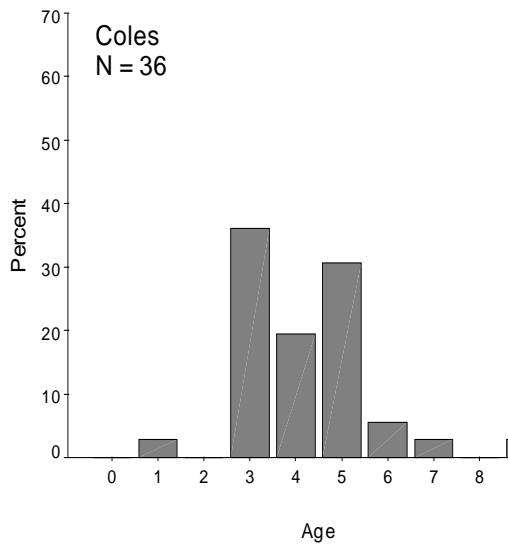
*Figure 3B. Age percentage distributions for Brook trout, Salvelinus fontinalis, in all ponds sampled from the Northern Peninsula of Newfoundland and Labrador. (N = Actual number of brook trout used in the distribution).*
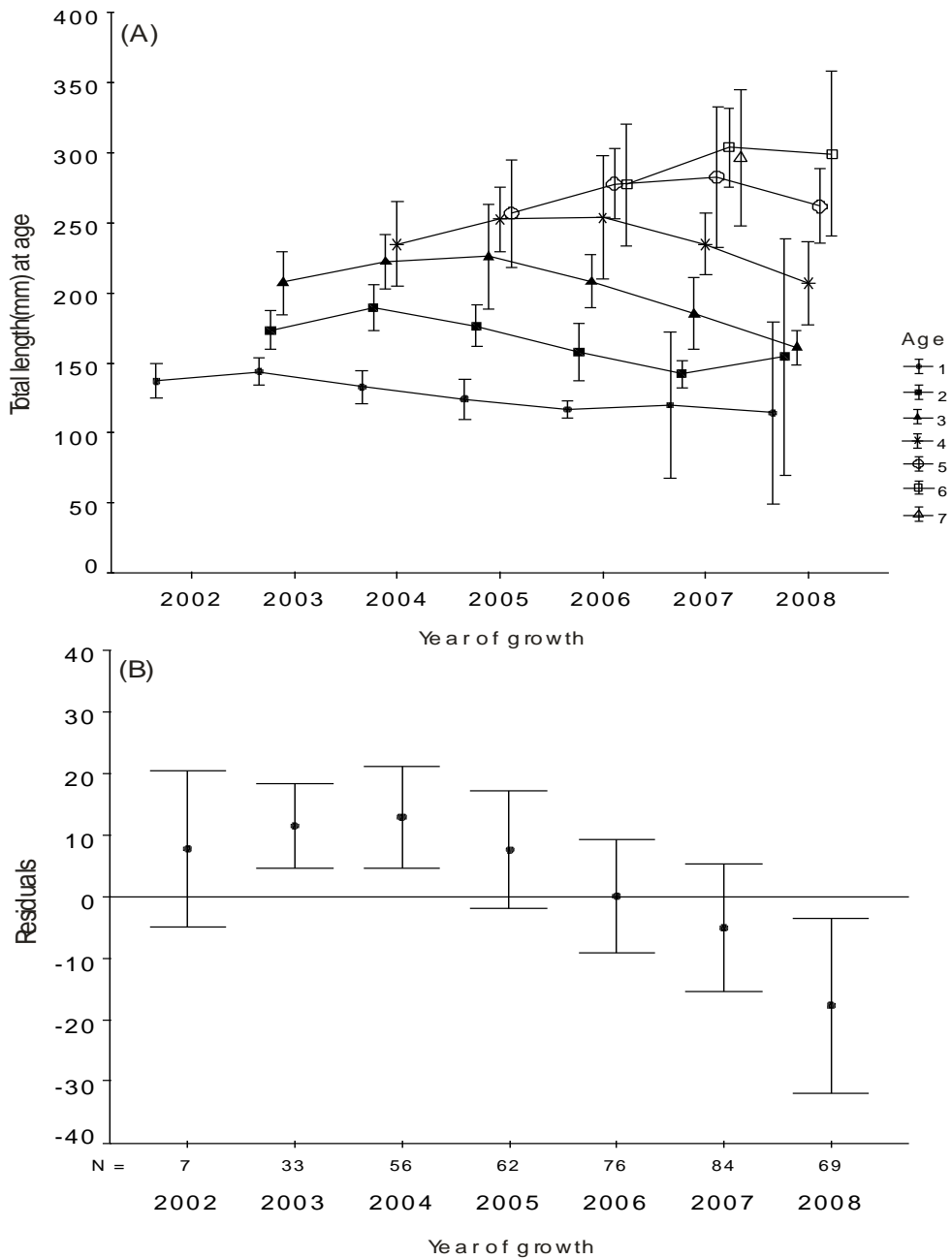
*Figure 4. Error bars comparing average back-calculated total length (TL mm) of brook trout, Salvelinus fontinalis, collected from Ten Mile Lake, Newfoundland and Labrador in 2009. Growth is separated based on brook trout age and year of growth (A). Error bars displaying an index of yearly growth, the effect of age removed (all fish combined) (B). Error Bars represent the 95% confidence interval around the mean estimate (N =number of back calculated fish lengths).*
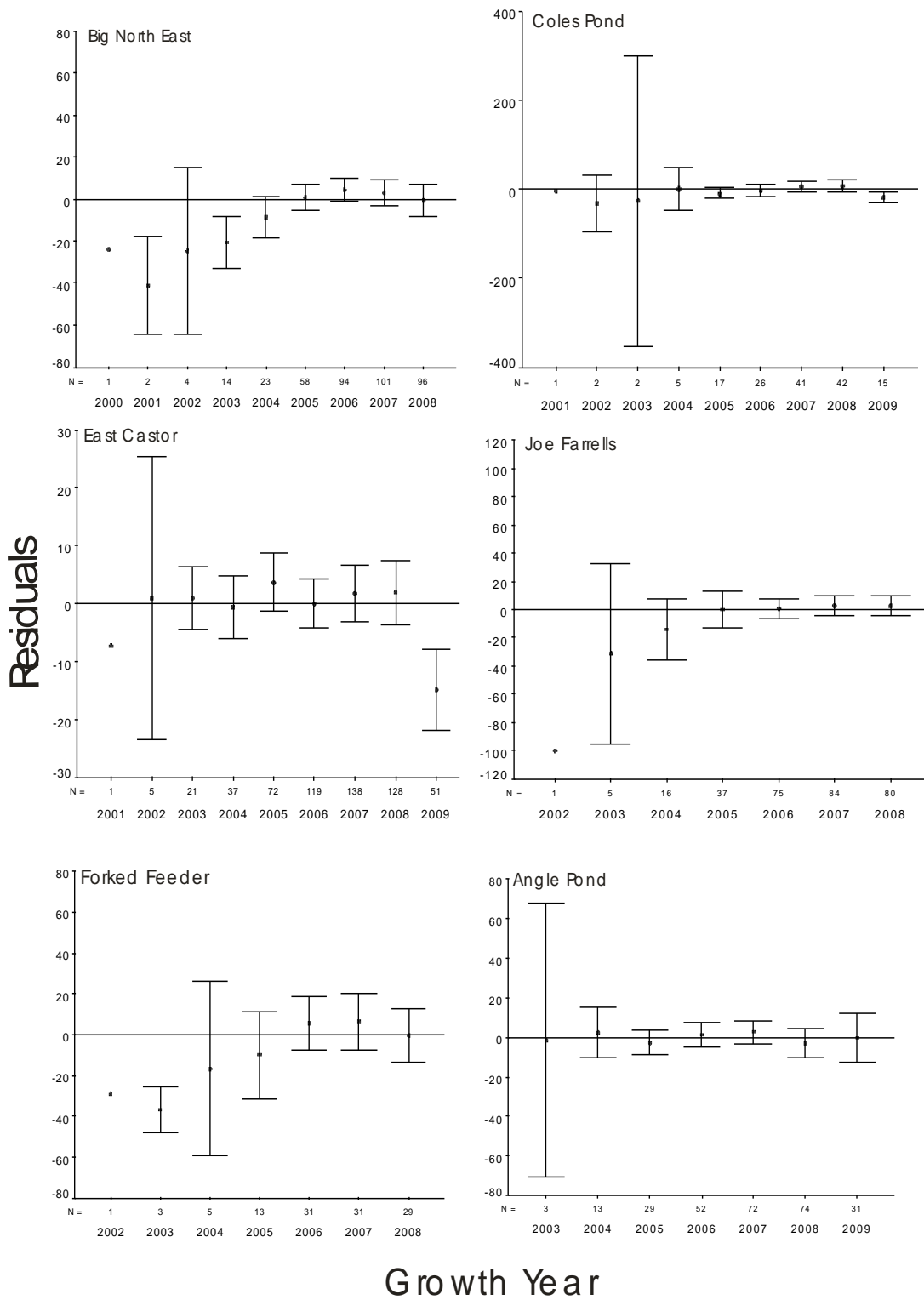
*Figure 5. Error bars displaying an index of yearly growth for brook trout, Salvelinus fontinalis, populations from the six lakes that neighbour Ten Mile Lake, Newfoundland and Labrador with the effect of age removed (all fish combined). Error Bars represent the 95% confidence interval around the mean estimate. (N =number of back calculated fish lengths).*