

SALMONIDS OF THE ST. MARY'S RIVER WATERSHED (I):
A SPATIAL AND TEMPORAL ANALYSIS OF SIZE AND GROWTH.

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Disclaimer: The data for this analysis was provided by DFO and NSDFA, but the analysis, results and interpretation are those of the author alone.

EXECUTIVE SUMMARY

Fish size-at-age and annual growth are useful indicators of environmental conditions. There is considerable variation in environmental conditions in a watershed in spatial and temporal dimensions, and the effects of this variation on size and growth, particularly of salmonids, are of interest to understand population stability over space and time. The purpose of the work described here was to identify areas in the watershed in which fish size-at-age or annual growth are unusual, and highlight these areas for future work. The St. Mary's River drains a large watershed in northeastern Nova Scotia and has an extensive electrofishing dataset. These data sets come from the Department of Fisheries and Oceans and Nova Scotia Department of Fisheries and Aquaculture and consisted of more than 100,000 records of individual fish from 33 systems (tributaries or mainstem locations) over 31 years. The data are recorded, and analyzed here, as both fork length and total length. Age classes were discriminated by Length Frequency Analysis for salmon and trout, but the non-salmonids not discriminated by age class but rather treated as an aggregate. Growth was calculated as the increase in mean size between successive age classes in successive years.

There is evidence of statistical differences in size-at-age of Atlantic salmon among branches, but it is questionable whether the small differences in absolute values of means are ecologically meaningful. Salmon size and growth appear larger in West Branch headwater and mainstem areas than among other areas of the watershed. All age classes of Atlantic salmon show a high degree of stability in body size among tributaries; none of the systems examined showed exceptionally large or small body size compared to others. This suggests that none of the locations are chronically producing small or large salmon, rather all are producing similar size juveniles, with some, but not consistent, small variation. This is also true for body size over time. There is little evidence, and none strong, of significant differences in juvenile Atlantic salmon body size over space or time in the St. Mary's River. Juvenile salmon annual growth was similar among all systems for age 1+ to 2+ and most systems for age 0+ to 1+. The upper areas of the West Branch appear to have larger growth increments for age 0+ to 1+ than mid-areas of the West Branch. Mean growth for juvenile salmon is ~50 mm/year for age 0+ to 1+ and ~27 mm/year for ages 1+ to 2+.

Similar to salmon, brook trout show a high degree of stability in body size over tributaries, branches and time. There is very little correspondence among those systems of small or large body size of trout, with those identified for salmon. Thus it appears there is a large degree of small "random" variation, but no particular systems are more (or less) conducive to salmonid growth. There is also very little evidence of trends in size over time for brook trout. Trout growth is based on few estimates but appears quite stable among years based on CV.

Of five non-salmonid species for which size could be analyzed, the common shiner, creek chub and white sucker indicated mean size in the East Branch was less than or equal to that of the West Branch. American eel and lake chub showed inconsistency of results between fork length and total length.

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1.0 INTRODUCTION

Size-at-age of individual species, and annual growth, are useful indicators of environmental conditions. These characteristics provide a measure of how the species is responding to environmental conditions of the habitat whether it be impaired or accelerated growth or size-at-age. Considerable environmental variation exists among locations in a watershed due to land use, water chemistry, and local site specific influences which may affect fish size and growth. Further, there is temporal variation at a given site as conditions fluctuate and change from year to year. The effects of this spatial and temporal variation are as interesting, if not more so, than the “average” condition as areas of large variation are less stable or predictable than those areas of lower variation. Thus, variation may be used to assess constancy of conditions for fish size and growth. Similarly, variation over time can be very instructive to identify locations of low constancy, and from there assess the reason for this. However, to conduct a comprehensive spatial and temporal analysis requires a large dataset of fish size among years. This requirement is met by a long-term Department of Fisheries and Oceans (DFO) electrofishing program in the St. Mary’s River, consistently sampling between 7 and 46 sites per year in 31 years between 1969 and 2010. Further, the Nova Scotia Department of Fisheries and Aquaculture (NSDFA) has also conducted limited electrofishing in the St. Mary’s River, contributing further data.

These data from DFO and NSDFA are used here to conduct spatial and temporal analysis of fish size-at-age and growth within the St. Mary’s River, with an emphasis of Atlantic salmon and brook trout. The purpose of this work is to identify areas in the watershed in which fish size or growth is unusual, and highlight these areas for further work. This work is part of a larger project which included a similar analysis of fish community structure (see SMRA Technical Report #14: *Fish Communities of the St. Mary’s River Watershed: An analysis of community diversity and structure*). Future analysis is to also include spatial and temporal variation of salmonid density, biomass and production.

2.0 STUDY AREA

The St. Mary’s River, Guysborough County, drains an area of approximately 1,350 km², flowing into a flooded-river-valley type estuary at Sherbrooke, Nova Scotia (45°08’00”N, 61°59’01”W). This river is a large system with a mean annual flow of 45.6 m³/s at Stillwater (Mitchell, 2009) and includes an estimated 118¹ tributaries ranging from 1st to 4th order and 132 lakes. Elevations within the watershed range from 0 m (sea level) to 260 m.

There are three major branches to the St. Mary’s River (Figure 1):

- (1) The East Branch extending from the headwaters of Moose River, Garden River and Eden Lake to Glenelg (27 km long; drainage area 389 km²). Communities along the East Branch include Garden of Eden, Willowdale, East River St. Mary’s, Newtown and Denver. This branch contains 27 streams and 43 lakes.
- (2) The North Branch (Lochaber, Lochiel and Wallace lakes; 27 km long; drainage area 82 km²). This branch contains 27 streams and 14 lakes.

¹ 11 of these tributaries are on the Main Branch, below the confluence of the East and West Branches at Glenelg, and so outside the scope of this report.

- (3) The West Branch extending from the headwaters near Trafalgar (Nelson and North Nelson Rivers) to Glenelg (56 km long; drainage area 470 km²). Communities along the West Branch include Cameron Settlement, Caledonia, Lower Caledonia and Smithfield. This branch contains 53 streams and 57 lakes.

Electrofishing has been conducted throughout the watershed in various years between 1969 and 2011 (See *Materials and Methods* for details). Only data to 2010 is included here as at the time of data analysis, the 2011 data not yet finalized.

3.0 MATERIALS & METHODS

3.1 DATA SOURCES:

Electrofishing data for this community composition analysis came from two sources. The Department of Fisheries and Oceans has data for up to 31 years between 1969 and 2010 on 27 “systems” (systems defined here as tributaries or river mainstem) of which 9 are on the East Branch, 2 on the North Branch, and 16 on the West Branch, (Table 1; Figure 1; Figure 2). The number of years sampled per system ranged between 1 and 31 years, with 16 systems sampled in 7 or fewer years, 11 sampled for 14 or more years and zero sampled between 7 and 14 years (Table 1). This dataset consisted of 115,007 records of individual fish. As the data were collected over a long period with varying levels of effort and purposes of data collection, various methods were used (e.g., number and timing of passes). Further electrofishing data for the St. Mary’s River was provided by the Nova Scotia Department of Fisheries and Aquaculture. These data consisted of two years of record, 2003 and 2005, for 15 systems – 14 on the West Branch and 1 on the East Branch (Table 1; Figure 1). The dataset included 668 records of individual fish.

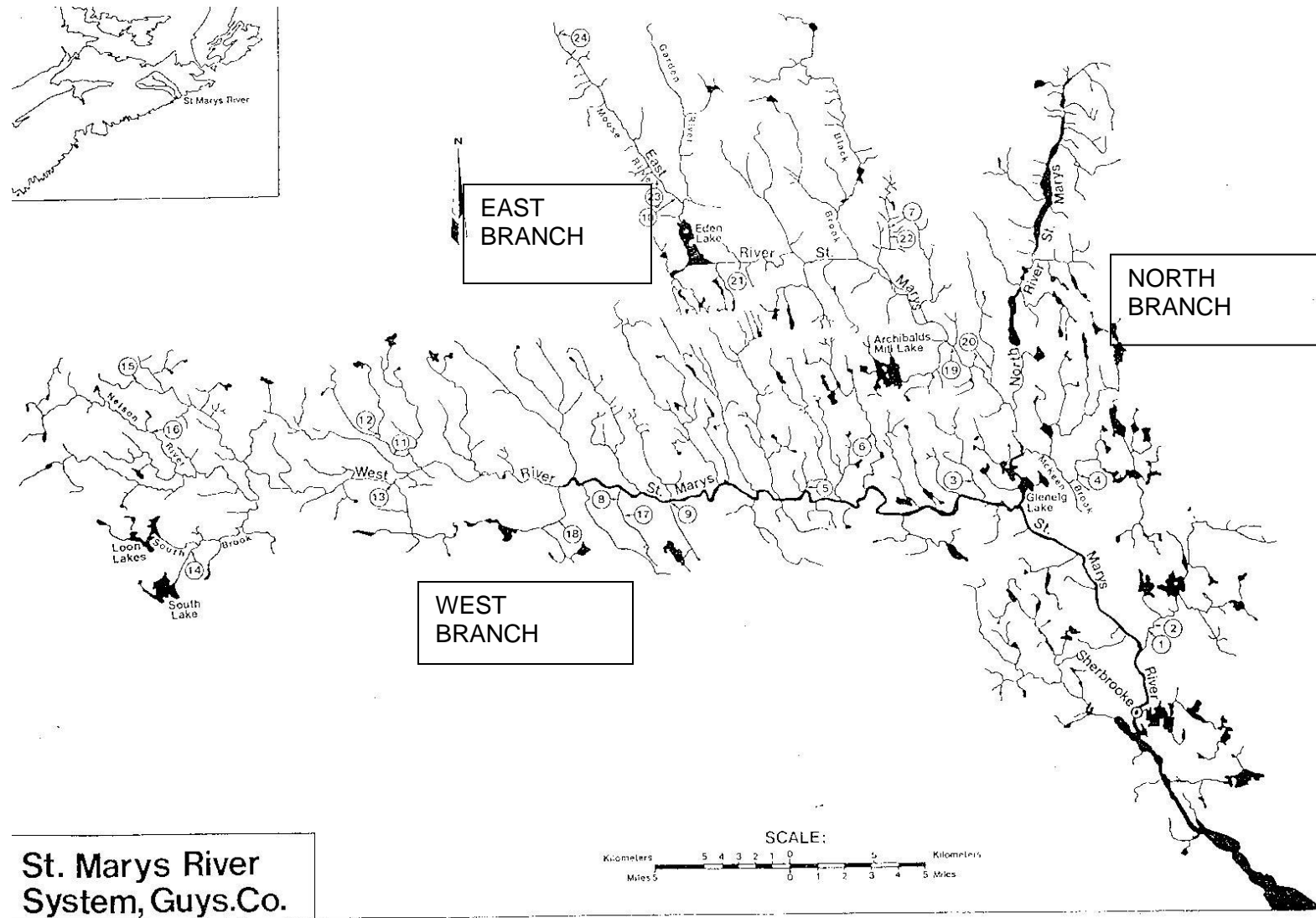


Figure 1: St. Mary's River watershed illustrating four "branches" of river. Circled numbers are electrofishing sites, but does not include all those used here. Numbered sites are cross-referenced to Table 1 for identification. (Figure from Mitchell, 2011a)

Table 1: Number of years and methods used for 33 systems (individual brooks or mainstem rivers) for St. Mary's River from DFO and NSDFA electrofishing database. NSDFA samples indicated in parentheses. Methods are Mark-Recapture (MR), Multiple Pass (MP) or One-Pass (OP). Numbered site locations shown in Figure 1 are identified here. Not all system sampled numbered in Figure but unnumbered sites may be interpolated as systems placed in order of downstream to upstream

System	Number of sites in system	Number of years sampled	Sampling method (DFO only)	DFO electrofishing site numbers from Figure 1
EAST BRANCH (n=9)				
East River St. Mary's mainstem	13	22	MR; MP; OP	19, 21
McKeen's Brook	3	26	MR; MP; OP	4
Big Meadow Brook	2	5	MR	20
Archibald's Mill Brook	(1)	(1)		
MacKay Brook	3	7	MR	7, 22
Black Brook	1	2	MP	
Campbell Brook	1	2	MP	
Garden River	2	6	MP	
Moose River	7	26	MR; MP; OP	10, 23, 24
NORTH BRANCH (n=3)				
North Branch mainstem	1	4	MP; OP	
Bogg's Brook	1	1	MP	
McNab's Brook	2	2	MR; MP	
WEST BRANCH (n=21)				
West River St. Mary's mainstem	17	31	MR; MP; OP	13
Archibald's Brook	9	14	MR; MP; OP	3
McLeod Lake Brook	(1)	(1)		
Glencross Brook	5 (1)	6 (1)	MR; MP; OP	6
Clark Brook	1 (1)	1 (1)	MP	
Indian Man Brook	1 (1)	20 (1)	MR; MP; OP	5
MacDonald Brook	2 (1)	2 (1)	MP; OP	
Sutherland's Brook	(1)	(1)		
MacDonald Mill Brook	(1)	(1)		
Barren Brook	3 (1)	14 (1)	MR; OP	
Kelly Brook	1 (1)	2 (1)	MR	9
Mitchell Brook	3 (1)	21 (1)	MR; OP	8, 17
Cross Brook	(1)	(1)		
Chisholm Brook	1 (1)	3 (1)	MR; OP	18
Bryden Brook	2	3	MR	11
Middle Bryden Brook	1	3	MR	12
Long John (Black) Brook	(1)	(1)		
Castley Brook	2	1	MR	15
South Brook	3	19	MR; MP; OP	14
Nelson River	3 (1)	17 (1)	MR; MP; OP	
North Nelson River	6	16	MR; MP	16

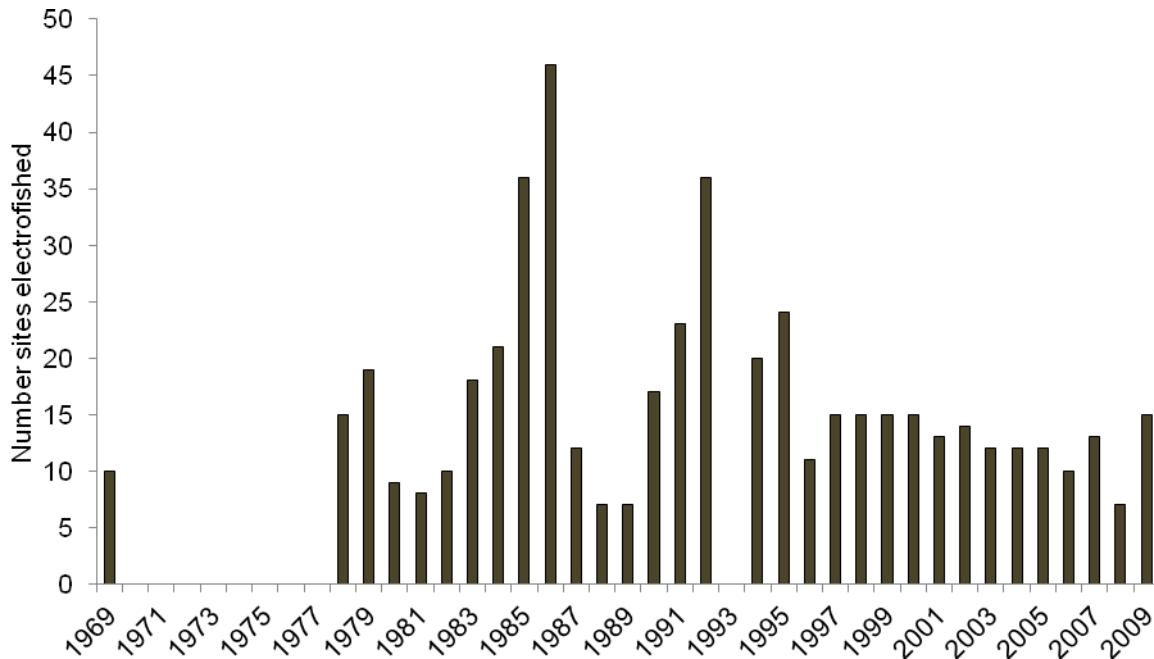


Figure 2: Number of sites electrofished each year in St. Mary's River watershed, 1969-2010 by DFO.

3.2 DATA ANALYSIS

Many of the systems sampled had multiple sites fished in various years (i.e., not the same site every year). For the sake of this analysis, these individual sites within a system were combined and the data treated as representing the system rather than a specific site. This ignores “within system” variation displayed by individual sites, but such an analysis would be confounded by time as sites changed among years and so any observed differences would not be unambiguously traceable to a spatial or temporal effect.

For both salmonids and non-salmonids, two measurements of body size have been recorded in the database - fork length and total length. These are analyzed separately here. For salmonids, body size statistics are calculated by age class (age 0+, age 1+, age $\geq 2+$) which in turn are determined from Length Frequency Analysis (LFA) of the data. Age classes were determined for each of the East and West Branches for individual years when $n > 100$ for that year. Fewer than 100 data points was deemed insufficient to determine reliable age classes from lengths. Brook trout had >100 measurements/year in 7 years on the East Branch (1985, 1986, 1990, 1991, 1992, 1994, 1995) and 6 years on the West Branch (1985, 1986, 1990, 1991, 1992, 1998). Atlantic salmon showed this condition in 19 years on the East Branch (1985-1987, 1990, 1994-1996, 1998-2007, 2009-2010), and 26 years on the West (1982, 1984-1992, 1994-1995, 1997-2010). Annual growth was calculated for each system for the salmonids as the increase in mean body size (total and fork length separately) from age class j to $j+1$ between years t and $t+1$.

In contrast to the salmonids, non-salmonids were not discriminated by age class, but rather body size statistics represent the aggregate of all ages in the sample.

4.0 RESULTS

4.1 ATLANTIC SALMON

Discrimination of age classes by LFA was conducted on Atlantic salmon for each branch and each year in which there were more than 100 measurements of length. Preliminary age classes based on LFA were discriminated as being similar for each branch as:

Age 0+ (<80 mm), age 1+ (80-140 mm), and \geq age 2+ (>140 mm)

However, comparison with DFO ageing data (3,526 records) suggested that the age 0+ age class was accurate but Age 1+ encompassed too great a range of body size. Based on DFO ageing data, Atlantic salmon age classes for the St. Mary's River (both branches) are:

Age 0+ (<80 mm), age 1+ (80-120 mm), and \geq age 2+ (>120 mm)

Two measurements were made of salmon body size: fork length (total of 6,695 records) and total length (total of 21,758 records). Due to the large sample sizes both measures are analyzed here, though fork length is generally the standard measure for salmonids as total length may be truncated by damage to the trailing edge of the caudal fin.

4.1.1 Among Branches

When all of the data are combined and analyzed at the level of the three individual branches (Figure 3), the very large sample sizes result in extremely tight confidence intervals which, in turn, result in statistically significant differences in sizes among branches which are unlikely to be of biological significance. For example, there is a statistically significant difference in fork length between East and West Branches for age 0+ salmon (based on 95% CI), but the difference in mean sizes is only 0.9 mm; unlikely to be of any ecological significance. There is no difference in fork length between branches for age 1+ or $\geq 2+$. In terms of total length, the age 0+ of the North Branch (mean=64.2 mm; \pm SD=8.06; n=69) are statistically larger than the East (mean =58.8 mm; \pm SD=6.73; n=3,073) which are greater than the West Branch (mean =55.8 mm; \pm SD=6.51; n=3,915). For age 1+ the North (mean=114.6 mm; \pm SD=3.75; n=59) is larger than the East (mean=104.8 mm; \pm SD=9.37; n=4,701) and West branches (mean=105.0 mm; \pm SD=8.48; n=5,521) which are equal to each other. For age $\geq 2+$, the size in the North Branch (mean=134.9 mm; \pm SD=10.65; n=131) and West Branch (mean=136.0 mm; \pm SD=32.67; n=2,220) are equal to each other, and both are larger than East Branch (mean=131.9 mm; \pm SD=11.5; n=2,069). In terms of absolute differences of mean values the maximum difference is 9.8 mm (age 1+ salmon).

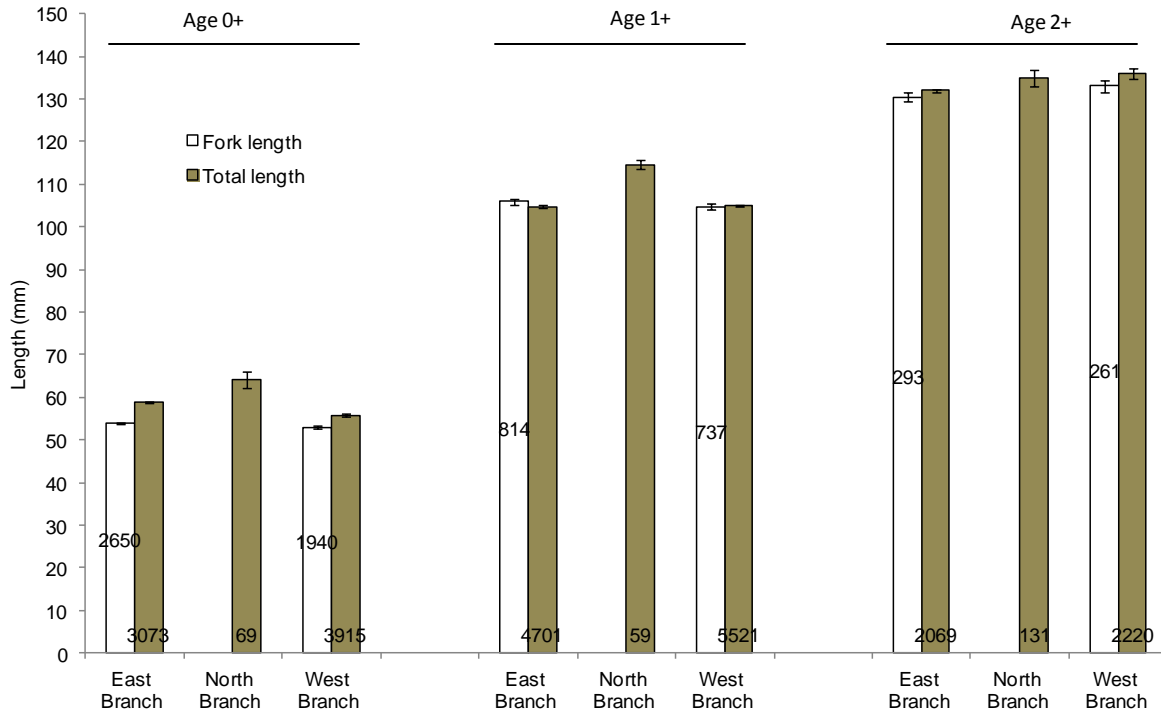


Figure 3: Mean Atlantic salmon fork and total lengths for each branch in St. Mary's River, 1969-2010 averaged over all sampled years. Error bars are 95% CI. Column values are sample size associated with estimate.

4.1.2 Within Branches

Age 0+ salmon body lengths among systems within branches are generally not highly variable (Figures 4 & 5). In the East Branch, mean fork length within two systems are within 3.1 mm of each other and in the West Branch within 9.3 mm across 10 systems. Mean fork length among systems ranged from 48.2 mm (Mitchell Brook) to 57.5 mm (Archibald's Brook). Coefficient of variation of means for the East Branch is 3.97% and for the West Branch 5.17%. Systems with the smallest fork lengths were Mitchell, MacDonald and Barren Brook, while largest lengths were found in Archibald's and McKeen's Brooks, and the North Nelson River. In terms of total length, the East Branch means are within 3.6 mm and West Branch within 12.3 mm, with CVs of 4.32% and 5.89%, respectively, and 6.78% for the North Branch. Mean total length among systems ranged from 52.2 mm (Middle Bryden Brook) to 70.3 mm (Bogg's Brook). Smallest mean total length was found in Middle Bryden, Barren and Clark Brooks, while largest were in Bogg's and Mitchell brooks, and the North Branch. In the West Branch, Mitchell Brook 0+ salmon appear smaller than most others based on fork length (n=51) but larger when examining total length (n=4). However, the small sample size of Mitchell Brook total lengths prevents a strong conclusion about size in this system. The North Branch appears to, in general, have larger size age 0+ salmon but, again, the small sample size (n=69) relative to the East and West Branches must be borne in mind.

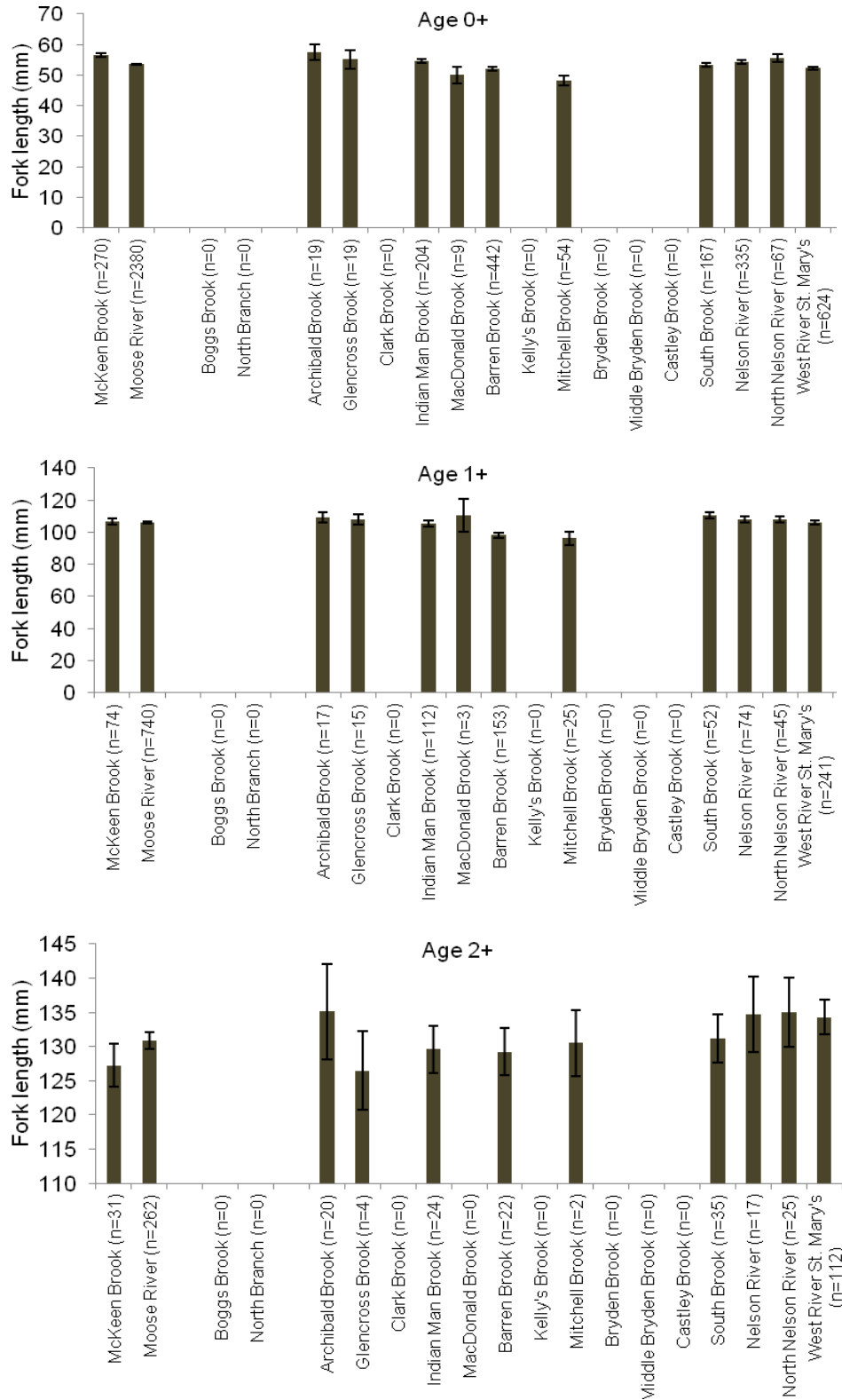


Figure 4: Mean fork lengths of Atlantic salmon in systems of branches of St. Mary's River, 1969-2010. Error bars are 95% CI.



Figure 5: Mean total lengths of Atlantic salmon in systems of branches of St. Mary's River, 1969-2010. Error bars are 95% CI.

Similar to age 0+, the age 1+ salmon show very similar body sizes among tributaries within a branch. That is, mean fork lengths are within 0.9 mm in the East Branch (2 systems; CV = 0.5%) and 14.5 mm in the West Branch (10 systems; CV=4.7%). Mean fork length among systems ranged from 96.2 mm (Mitchell Brook) to 110.7 mm (MacDonald Brook). Mitchell and Barren Brooks contain the smallest age 1+ salmon, and McDonald, South and Archibald's brooks the largest. Mean total lengths are within 1.7 mm (East Branch; CV=1.2%) and 2.5 mm in West Branch (2.6%). Mean total length among systems ranged from 99.8 mm (Barren Brook) to 117.0 mm (Bogg's Brook). Smallest mean total length was found in Barren, Archibald's and McKeen's Brooks, while largest were in Bogg's and Castley brooks, and the North Branch. Similar to age 0+, Mitchell Brook appears to have smaller salmon than others, but this is so only for fork length (n=25); when total length (n=117) is examined, Mitchell Brook is similar to other West Branch streams. Age 1+ salmon in Barren Brook appear to be significantly smaller than other systems for both fork length and total length. North Branch systems, again, appear to have larger age 1+ salmon than the East and West Branches, but sample size remains small.

Fork length of age $\geq 2+$ is of low variability among systems within a branch similar to the previous two age classes. Mean fork length among the two systems of the East Branch are within 3.6 mm of each other (CV=1.98%) and among 9 West Branch streams within 8.6 mm (CV = 2.4%). Mean fork length among systems ranged from 126.5 mm (Glencross Brook) to 135.1 mm (Archibald's Brook). Systems with smallest age $\geq 2+$ fork length are Glencross, Barren and McKeen's brooks, and largest age $\geq 2+$ in Archibald's Brook and the Nelson and North Nelson Rivers. Mean total lengths of the East Branch are within 0.15 mm of each other (CV=0.08%) and for the West Branch within 16 mm (CV=2.68%). Mean total length among systems ranged from 126.0 mm (Castley Brook) to 142.0 mm (Clark Brook). Smallest age $\geq 2+$ total lengths were found in Castley, Bryden and MacDonald brooks and largest in Clark and Mitchell Brooks, and North Branch. There is no strong evidence that body size of age $\geq 2+$ differs significantly among tributaries in the St. Mary's watershed. The North Branch does not show larger size than the other branches as previously noted for earlier age classes.

4.1.3 Size-over-time

Analysis of body size over time was conducted by (i) Coefficient of Variation to evaluate among-year variation, and (ii) linear regression to evaluate directed change (trends). Both fork length and total length were very similar over time within a system, as measured by CV (Table 2). Variation among years for any of the systems evaluated is low for both fork length and total length (i.e., <12%; Figure 6). Age 0+ showed the greatest variation and this was greatest (>10%) in Barren and Mitchell brooks (fork length) and Barren and Archibald's brooks (total length). Nelson River age 2+ salmon were the only other group showing CV greater than 10%. All other systems show CV among years <10% indicating little variation, or alternatively high stability, among years. Mean CV over time (\pm SD; sample size) across systems within a branch were:

Fork length:

Age 0+ = 8.6 mm (\pm 1.60; 11); Age 1+ = 6.8 mm (\pm 1.49; 11);

Age 2+ = 6.3 mm (\pm 2.06; 11)

Total length

Age 0+ = 8.7 mm (± 1.97 ; 14); Age 1+ = 6.0 mm (± 1.92 ; 14);
Age 2+ = 7.0 mm (± 1.26 ; 14)

Only one of 14 (7.1%) regressions of mean fork length on years, and 5 of 28 (17.8%) total length regressions, were statistically significant (Table 2). Of these, two showed negative slopes (decreases in size over time) and four positive slopes (increase in body size over time). Further, the significant regressions were not found among successive age classes within a system, but rather among five different systems. For several regressions, the fork length data were temporally separated into the periods of 1981-1989 and 2004-2010 with a gap in the middle. “Reduced” models were run for these using only the data from 2004-2010 to evaluate trends occurring in the recent period and these are termed “Reduced” in Table 2. None of these reduced models were statistically significant. All of this, taken together, suggests there is not strong evidence of directed change in size over time. There are some indications of increase or decrease in a small number of systems, but these are isolated, only apply to a single age class, and are inconsistent. Thus, I conclude that there is little evidence of directed change over time, despite the impressive data set used for the St. Mary’s River watershed.

4.1.4 Growth

Growth of salmon between age classes are summarized in Table 3 and Figure 7. There are very few detected differences in growth among tributaries. For growth between ages 0+ and 1+, Barren Brook appears to have less growth than the West River mainstem in terms of fork length and total length. Using the more complete total length dataset, the Nelson River, North Nelson, and West River mainstem appear to have greater growth than Moose River, Archibald’s Brook, Barren Brook, Indian Man Brook and South Brook. Overall mean growth between these age classes is 50.1 mm/year total length, ranging from 44.1 to 58.2 mm/year.

Age 1+ to 2+ growth showed no significant differences among tributaries for total length, and the only difference in fork lengths was that Indian Man Brook showed less growth than Moose River, Barren Brook, and West River mainstem. However, these are using small sample sizes relative to total length. Overall mean growth between these age classes is 27.3 mm/year total length, ranging from 22.7 to 33.0 mm/yr (excluding Bryden Brook as $n=1$ and the value appears suspiciously low).

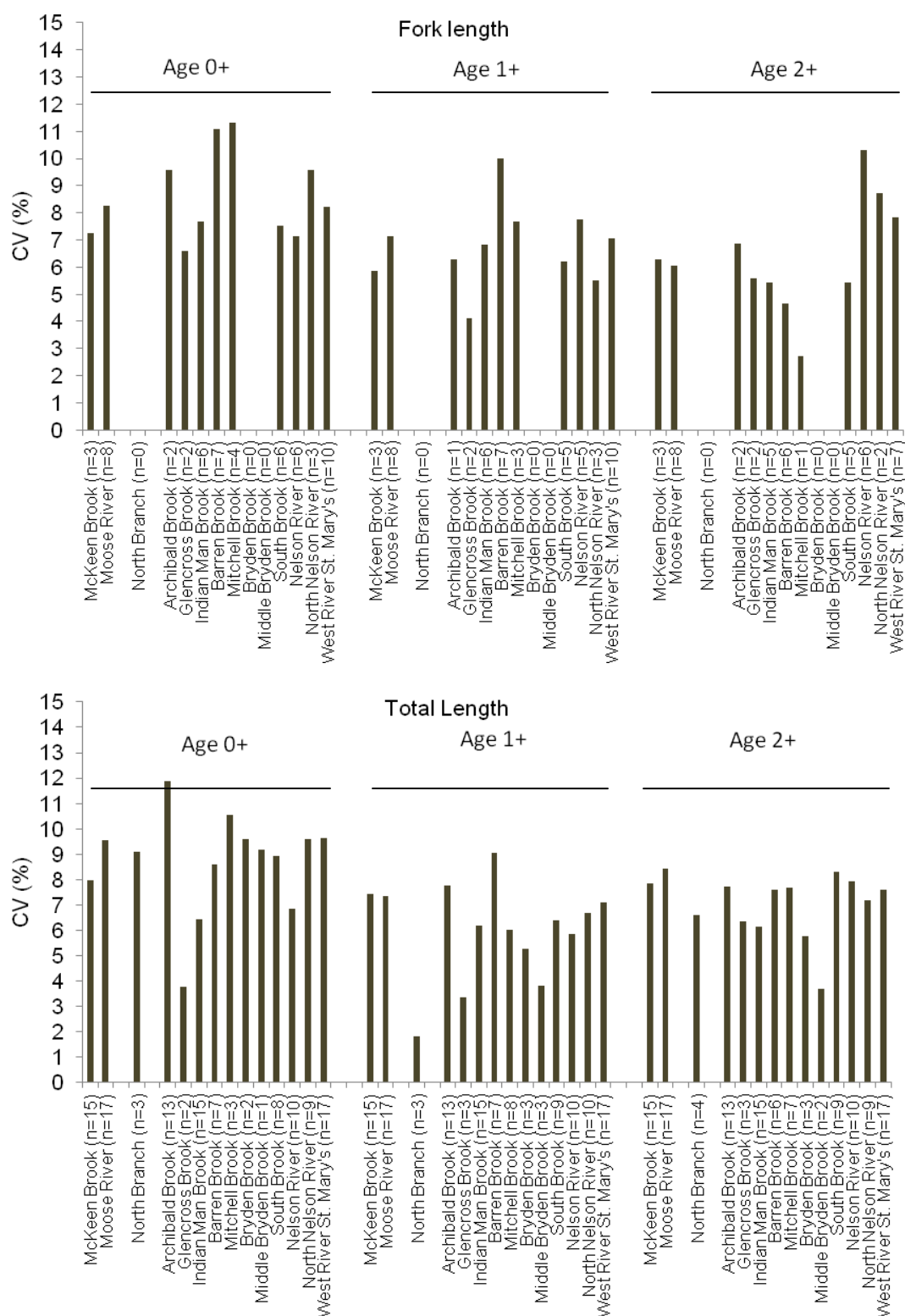


Figure 6: Variation among years in Atlantic salmon fork and total length, using Coefficient of Variation as the measure, for systems and age classes in the St. Mary's River. Values on x-axis represent number of years used in calculation.

Table 2: Results of CV and regression analysis of Atlantic salmon body size over time for individual systems. Only systems in which there are 7 or more years of data are used. Bold indicate regression is statistically significant. CV associated with individual systems represent variation over years for that system. CV associated with age class is variation across years and systems

		Regression equation	R ²	p-value	N (Years of record)
FORK LENGTH					
Age 0+	Mean CV =8.56% (SD = 1.60%); range 6.6% - 11.3%; n=11				
Moose River	CV = 8.25 %	Y = -0.1054 * X + 267.03	0.0414	0.628	8 (1985; 2004-2010)
Moose River (reduced)		Y = 1.0835 * X - 2119.4	0.3078	0.196	7 (2004-2010)
Barren Brook	CV = 11.08%	Y = 1.0634 * X - 2081.7	0.4317	0.108	7 (2004-2010)
West River mainstem	CV = 8.25%	Y = -0.0923 * X + 236.58	0.043	0.565	10 (1981, 1985; 1989; 2004-2010)
West River (reduced)		Y = 1.4483 * X - 2855.8	0.304	0.199	7 (2004-2010)
Age 1+	Mean CV =6.76% (SD = 1.49%); range 4.1% - 10.0%; n=11				
Moose River	CV = 8.6 %	Y = 0.0925 * X - 78.377	0.045	0.612	8 (1985; 2004-2010)
Moose River (reduced)		Y = 0.9958 * X - 1891.6	0.328	0.178	7 (2004-2010)
Barren Brook	CV = 6.8%	Y = 0.1502 * X - 202.84	0.01	0.831	7 (2004-2010)
West River mainstem	CV = 6.4%	Y = -0.0023 * X + 111.26	0.00004	0.985	10 (1981, 1985; 1989; 2004-2010)
West River (reduced)		Y = 1.115 * X - 2131.6	0.2897	0.212	7 (2004-2010)
Age 2+	Mean CV =6.35% (SD = 2.06%); range 2.7% - 10.3%; n=11				
Moose River	CV = 6.07 %	Y = 0.133 * X - 136.46	0.192	0.277	8 (1985; 2004-2010)
Moose River (reduced)		Y = 0.5351 * X - 943.45	0.218	0.290	7 (2004-2010)
West River mainstem	CV = 7.85%	Y = -0.2973 * X + 726.32	0.684	0.011	8 (1981, 1985; 1989; 2004-2006; 2008; 2010)
West River (reduced)		Y = 0.5718 * X - 1017.8	0.292	0.347	5 (2004-2006; 2008; 2010)

Table 2. (cont'd)

		Regression equation	R ²	p-value	N (Years of record)
TOTAL LENGTH					
Age 0+	Mean CV =8.68% (SD = 1.97%); range 3.7% - 11.9%; n=14				
McKeen's Brook	7.96 %	$Y = -0.181 * X + 419.99$	0.062	0.370	15 (1982; 1984; 1986-1987; 1990; 1992; 1994-1999; 2001-2003)
Moose River	9.57%	$Y = -0.0671 * X + 192.03$	0.012	0.675	17 (1984-1987; 1990-1992; 1994-2003)
Archibald's Brook	11.88%	$Y = -0.3273 * X + 710.53$	0.118	0.251	13 (1982; 1985-1986; 1988; 1990-1992; 1994-1995; 1997-2000)
Barren Brook	8.60%	$Y = -0.5149 * X + 1084.3$	0.085	0.524	7 (1997-2003)
Indian Man Brook	6.42%	$Y = 0.0147 * X - 29.041$	0.0005	0.938	15 (1984-1986; 1990-1992; 1994-2000; 2002-2003)
Nelson River	6.85%	$Y = -0.4239 * X + 900.32$	0.074	0.445	10 (1992; 1994-1996; 1998-2003)
North Nelson River	9.57%	$Y = -0.5559 * X + 1158.3$	0.566	0.019	9 (1982; 1986-1988; 1991-1992; 1995)
South Brook	8.92%	$Y = 0.5339 * X - 1005.9$	0.261	0.195	8 (1982; 1984; 1986-1988; 1991-1992; 1995)
West River mainstem	9.65%	$Y = -0.1742 * X + 399.34$	0.070	0.307	17 (1982; 1984-1988; 1991-1992; 1994-1995; 1997-2003)
Age 1+	Mean CV =6.01% (SD = 1.92%); range 1.8% - 9.0%; n=14				
McKeen's Brook	7.41 %	$Y = 0.3401 * X - 571.92$	0.234	0.670	15 (1982; 1984; 1986-1987; 1990; 1992; 1994; 1995-1999; 2001-2003)
Moose River	7.35%	$Y = 0.1544 * X - 201.45$	0.070	0.305	17 (1984-1987; 1990-1992; 1994-2003)
Archibald's Brook	7.77%	$Y = -0.35 * X + 799.97$	0.182	0.146	13 (1982; 1985-1986; 1988; 1990-1992; 1994-1995; 1997-2000)
Barren Brook	9.05%	$Y = -0.0373 * X + 174.7$	0.0006	0.959	7 (1997-2003)
Indian Man Brook	6.20%	$Y = 0.3562 * X - 606.18$	0.346	0.021	15 (1984-1986; 1990-1992; 1994-2000; 2002-2003)
Mitchell Brook	6.03%	$Y = 0.598 * X - 1081.8$	0.499	0.050	8 (1985-1986; 1990-1991; 1995; 1998-1999; 2001)
Nelson River	5.87%	$Y = 0.1343 * X - 158.78$	0.071	0.454	10 (1992; 1994-1996; 1998-2003)
North Nelson River	6.68%	$Y = -0.4316 * X + 964.45$	0.330	0.082	10 (1982; 1984-1988; 1991-1992; 1995)
South Brook	6.38%	$Y = 0.3304 * X - 548.81$	0.149	0.306	9 (1982; 1984-1988; 1991-1992; 1995)
West River mainstem	7.09%	$Y = 0.0047 * X - 97.123$	0.0002	0.958	17 (1982; 1984-1988; 1991-1992; 1994-1995; 1997-2003)

Table 2. (cont'd)

		Regression equation	R ²	p-value	N (Years of record)
TOTAL LENGTH (cont'd)					
Age 2+	Mean CV =7.06% (SD = 1.26%); range 3.7% - 8.4%; n=14				
McKeen's Brook	7.83 %	$Y = -0.0247 * X + 181.22$	0.002	0.886	15 (1982; 1986-1987; 1990; 1992; 1994-1999; 2001-2003)
Moose River	8.45%	$Y = 0.0319 * X + 68.583$	0.009	0.716	17 (1984-1987; 1990-1992; 1994-2003)
Archibald's Brook	7.72%	$Y = -0.1799 * X + 491.79$	0.041	0.507	13 (1982; 1985-1986; 1988; 1990-1992; 1994-1995; 1997-2000)
Indian Man Brook	6.16%	$Y = 0.1823 * X - 230.66$	0.039	0.479	15 (1984-1986; 1990-1992; 1994-2003)
Mitchell Brook	7.68%	$Y = -0.1957 * X + 528.09$	0.013	0.811	7 (1985-1986; 1990-1991; 1997-1998; 2001)
Nelson River	7.93%	$Y = 1.2053 * X - 2272.6$	0.510	0.020	10 (1992; 1994-1996; 1998-2003)
North Nelson River	7.19%	$Y = -0.4306 * X + 986.49$	0.123	0.355	9 (1982; 1985-1988; 1991-1992; 1994-1995)
South Brook	8.29%	$Y = -0.1928 * X + 516.36$	0.027	0.669	9 (1982; 1984-1988; 1991-1992; 1995)
West River mainstem	7.58%	$Y = 0.4863 * X - 837.23$	0.476	0.002	17 (1982; 1984-1988; 1991-1992; 1994-1995; 1997-2003)

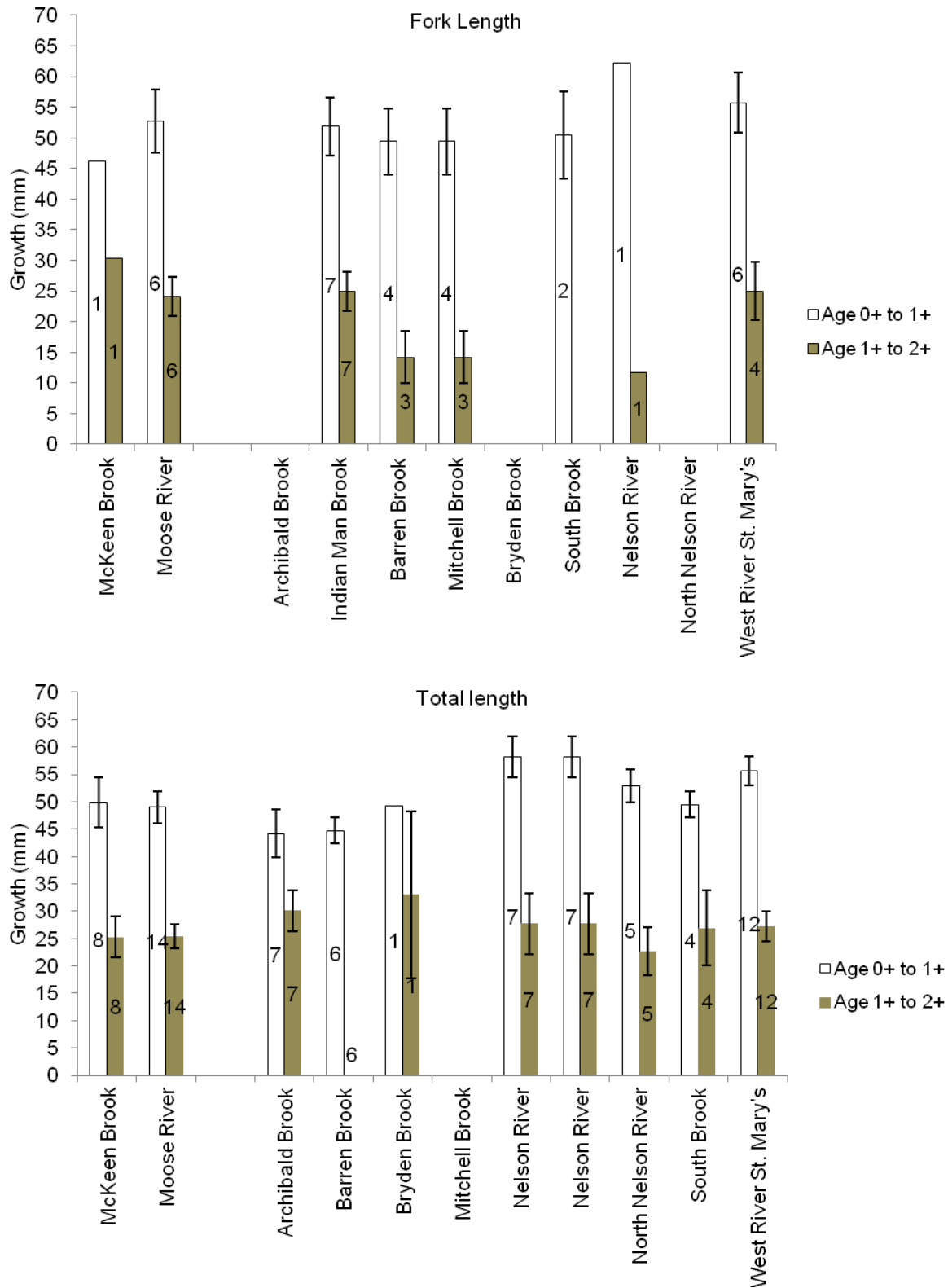


Figure 7: Mean annual growth of Atlantic salmon in St. Mary's River between age classes. Error bars are 95% CI. Values represent number of estimates of annual growth.

Table 3: Summary statistics of estimated annual growth (mm/year) of Atlantic salmon between age classes in the St. Mary's River.

	Mean	SD	n	Range
FORK LENGTH				
Age 0+ to 1+	51.9	6.35	30	46.1 – 62.2
Age 1+ to 2+	24.7	8.2	25	11.75-30.33
TOTAL LENGTH				
Age 0+ to 1+	50.13	6.34	75	44.1 – 58.2
Age 1+ to 2+	27.3	6.45	74	22.7 – 33.0

4.2 BROOK TROUT

Discrimination of age classes for brook trout by LFA yielded the following size (=age) classes:

East Branch: Age 0+ (<80 mm), age 1+ (80-125 mm), and \geq age 2+ (>125 mm)

West Branch: Age 0+ (<80 mm), age 1+ (80-140 mm), and \geq age 2+ (>140 mm)

There was no independent ageing of fish, as there was with salmon, and so validation from another method was not available. There are 3,786 total length measurements of brook trout and only 272 fork length measurements. Therefore, fork lengths are excluded from this analysis due to “small” sample size.

4.2.1 Among Branches

Age 0+ trout are of statistically similar size between the East and West Branches (Figure 8) with mean sizes being 60.9 mm in the East Branch (SD=10.1, n=323) and 61.4 mm in the West Branch (SD=8.4, n=712). For the older age classes of 1+ and $\geq 2+$, those trout in West Branch streams are larger than in the East Branch. Age 1+ trout in East Branch average 103.6 mm (SD=11.4, n=729) while West Branch streams average 112.8 mm (SD=14.8, n=808). Age $\geq 2+$ trout in East Branch average 160.6 mm (SD=31.7, n=654) while West Branch streams average 174.7 mm (SD=23.2, n=559).

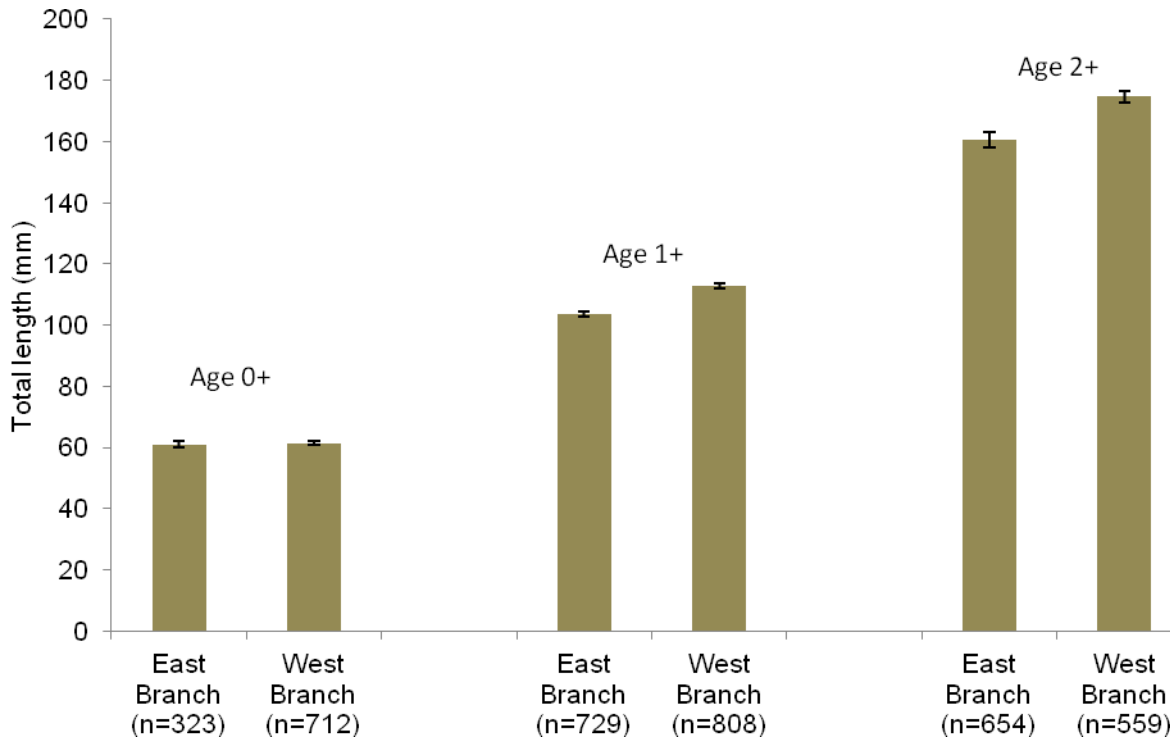


Figure 8: Mean size (total length) of brook trout in East and West Branches of St. Mary's River, 1969-2010. Error bars are 95% CI.

4.2.2 Within Branches

Mean size of age 0+ trout in different systems of the East Branch ranged from 60.6 to 65.6 mm (Figure 9) and in the West Branch from 53.7 to 68.4 mm. Coefficients of Variation for each branch were low (5.6% and 7.1%, respectively), suggesting little spatial variation among systems within a branch. Smallest age 0+ trout occurred in Barren, Kelly's, and Middle Bryden Brooks, and largest trout of this age class in Glencross and Chisholm brooks, and the Nelson River. Age 1+ trout ranged from 103.2-109.6 mm (East Branch, CV=4.2%) and 106.1-123.0 (West Branch, CV=4.4%) with the smallest trout in Glencross and Castley Brooks and Moose River. Largest age 1+ trout occurred in Barren, Chisholm, and Indian Man Brooks. Age $\geq 2+$ trout ranged from 160.3-163.3 mm (East Branch, CV=1.3%) and 163.8-191.3 mm (West Branch, CV = 5.2%). Smallest bodied age $\geq 2+$ trout were found in McKeen and Chisholm brooks and Moose River, while largest trout of this age class were in Barren and Bryden Brooks, and the West River mainstem.

Four streams are identified from above as having either largest or smallest trout body sizes for more than one age class:

- Moose River has small age 1+ and 2+ trout
- Chisholm Brook has large age 0+ and 1+ trout
- Barren Brook has small age 0+ but large age 1+ and 2+ trout
- Glencross Brook has large age 0+ but small age 1+ trout

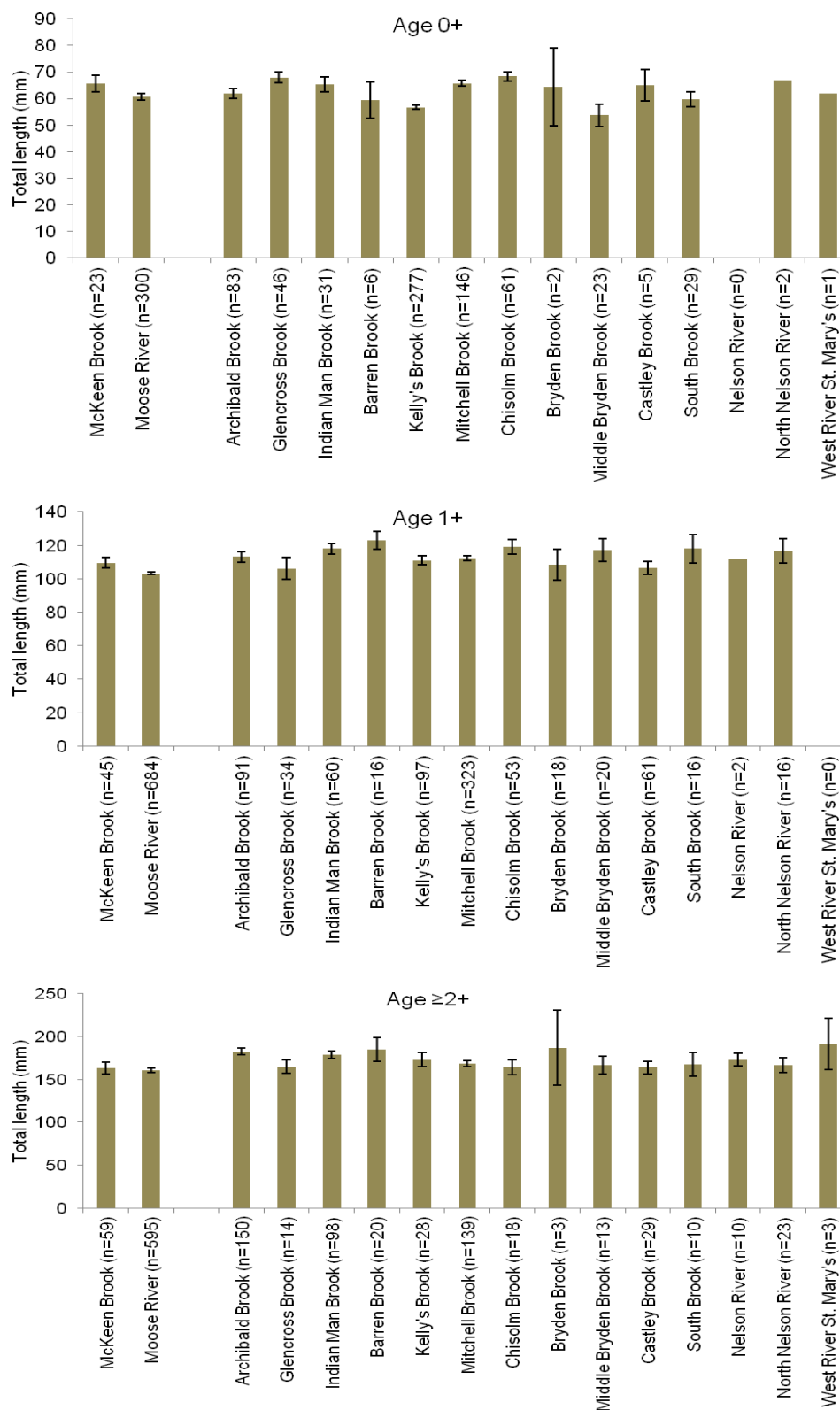


Figure 9: Mean total length of brook trout by system within each branch of St. Mary's River for three age classes. Error bars are 95% CI.

4.2.3 Size over time

Similar to Atlantic salmon, temporally the data were analyzed using two approaches, coefficient of variation and linear regression: For the CV analysis, data used were those confined to systems which had (a) more than 5 length measurements in a year, and (b) more than three years of sampling over the period 1969-2010. Variation among years for any of the systems evaluated is low (i.e., <12%; Figure 10) and lowest (<5%) for age 1+ trout. Age 0+ showed the greatest variation, and this was greatest (>10%) in McKeen's and Archibald's Brooks. All other systems show CV among years <10% indicating little variation, or alternatively high stability, among years. Interestingly, those systems with the most years of data (n>5 years) show low variation (<8.5%); these values are likely more representative than those based on smaller sample sizes.

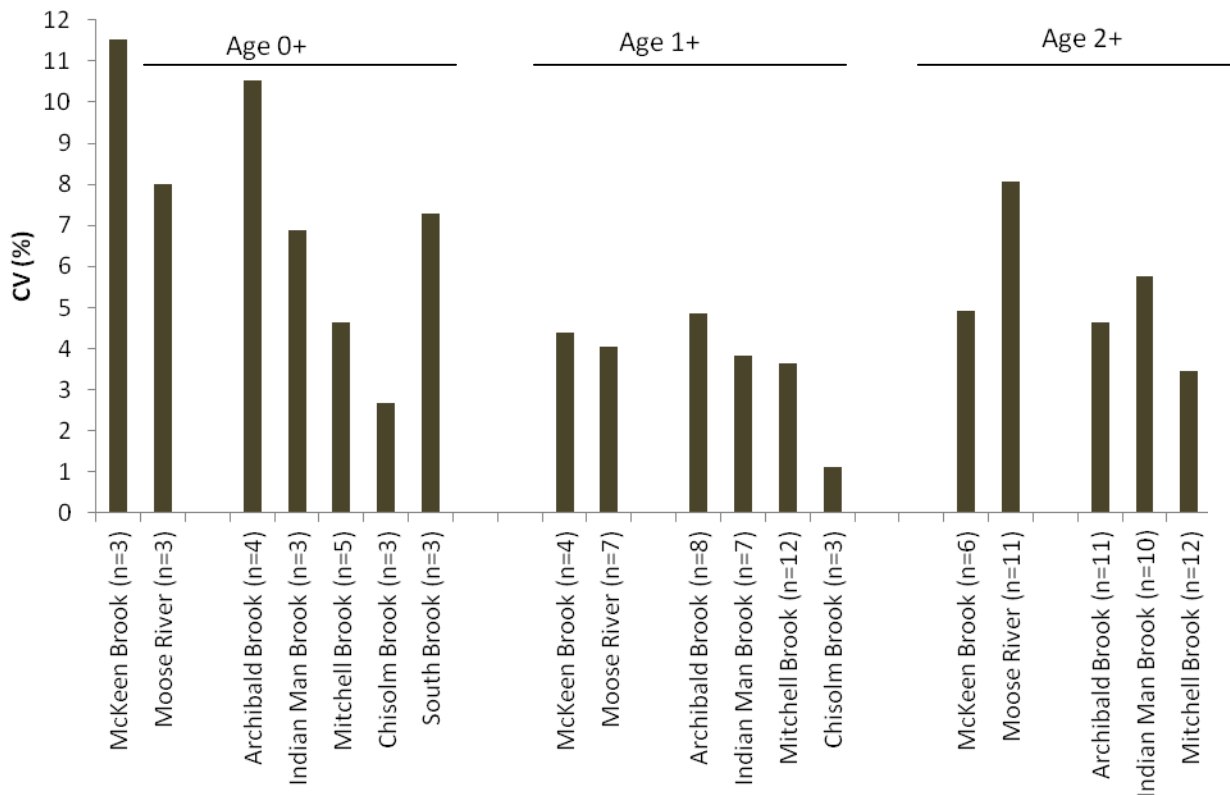


Figure 10: Variation among years in brook trout total length, using Coefficient of Variation as the measure, for systems and age classes in the St. Mary's River. Sample sizes on x-axis represent number of years with estimates of mean body size.

Linear regression analyses were conducted to examine data for directed change over time (trends). Only systems with five or more years of record, and at least five length measurements per year, were used (Table 4). There was only a single statistically significant regression from 10 regressions (10%), and this was Moose River for age $\geq 2+$ trout. Thus, while mean size of this

age class in this system may have increased over time, there is no evidence of trends over time for any of the other systems analyzed.

Table 4: Results of regression analysis of brook trout body size (total length, mm) over time for individual systems. Only systems in which there are 5 or more years of data are used. Bold indicate regression is statistically significant.

	Regression equation	R ²	p-value	N (Years of record)
Age 0+				
Mitchell Brook	$Y = 0.0705 * X - 75.437$	0.0224	0.811	5 (1986; 1991-1992; 2000-2001)
Age 1+				
Moose River	$Y = -0.0002 * X + 105.174$	0.000	0.999	7 (1985-1986; 1990-1992; 1994-1995)
Archibald's Brook	$Y = -0.3870 * X - 884.134$	0.168	0.313	8 (1985-1986; 1992; 1994; 1997-2000)
Indian Man Brook	$Y = 0.1329 * X - 146.110$	0.037	0.680	7 (1985-1986; 1995-1997; 2000; 2002)
Mitchell Brook	$Y = -0.1240 * X - 360.048$	0.031	0.579	12 (1985-1986; 1990-1992; 1995; 1997-2001; 2003)
Age ≥2+				
McKeen's Brook	$Y = 1.781 * X - 3381.50$	0.652	0.052	6 (1986; 1992; 1994; 1995-1996)
Moose River	$Y = 1.4319 * X - 2688.7$	0.426	0.029	11 (1985-1986; 1990-1992; 1194-1995; 1997; 2001-2003)
Archibald's Brook	$Y = 0.3171 * X - 450.280$	0.036	0.574	11 (1985-1986; 1990-1992; 1994-1995; 1997-2000)
Indian Man Brook	$Y = 1.0101 * X - 1836.5$	0.260	0.132	10 (1985; 1992; 1994-1998; 2000; 2002-2003)
Mitchell Brook	$Y = -0.2350 * X - 637.16$	0.046	0.502	12 (1985-1986; 1990-1992; 1995-2001)

4.2.4 Growth

There was little data from the 3,786 original length records which could be used to calculate growth. This analysis required that a minimum of 5 length measurements for an age class for a year, and a matching set of data for the successive age class in the following year (i.e., requiring $n > 5$ for age class i in year t , and for age class $i+1$ in year $t+1$). This was only met for six system and year pairs for ages 0+ to age 1+ and 22 systems/year pairs for ages 1+ to 2+. Growth for age 0+ to 1+ is similar among the four systems which have estimates of these (Figure 11). Growth for age 1+ to 2+ is greater in Archibald's Brook than Indian Man and Mitchell Brooks, and Moose River, but the latter three all show the same growth. In general, growth appears the same in the two branches, though the very small sample size precludes strong inference of this. Based on these, the mean growth for brook trout from age 0+ to 1+ in the St. Mary's system is 50.1 mm (SD=8.0 mm; $n=6$) and for age 1+ to 2+ is 60.1 mm (SD=10.6 mm; $n=22$). The associated CV with these estimates (15.9% and 17.6%, respectively) is low suggesting that growth among systems and years is quite stable.

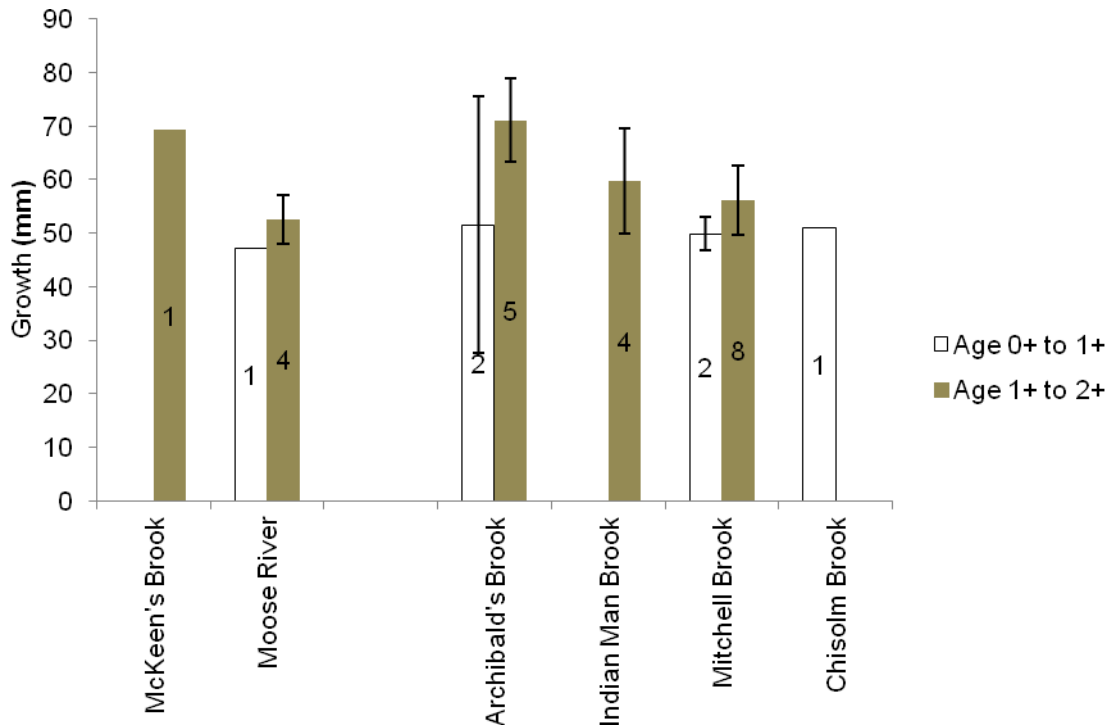


Figure 11: Mean growth of brook trout among systems of the two branches of St. Mary's River watershed. Error bars are 96% CI.

4.3 NON-SALMONIDS

In addition to Atlantic salmon and brook trout, data on body size has been collected for American eel ($n=1,987$), white sucker ($n=1,277$), lake chub ($n=567$), common shiner ($n=264$), and creek chub ($n=233$). As with salmon, two measurements of body size, fork length and total length, have been made for these species despite some species (e.g., eel) having no fork length possible due to the morphology of the caudal fin. Fork and total lengths are analyzed separately here.

Comparison of body size between branches showed similar results for fork length and total length for common shiner and white sucker (Figure 12), with body size of these species in the East Branch being smaller than in the West Branch (chi square analysis of medians, $p < 0.001$ for each of fork length and total length) (Table 5). Creek chub were of equal body size on each branch (chi square analysis of medians, $p > 0.50$ for each of fork length and total length). American eel and lake chub provided ambiguous results, indicating a difference between branches in one measurement but not the other. American eel showed difference in fork length ($p < 0.01$) but not total length ($p > 0.10$) and lake chub in total length ($p < 0.001$) but not fork length ($p > 0.90$).

Annual growth was not calculated for these species as that would require reliable estimates of age classes which were not possible here.

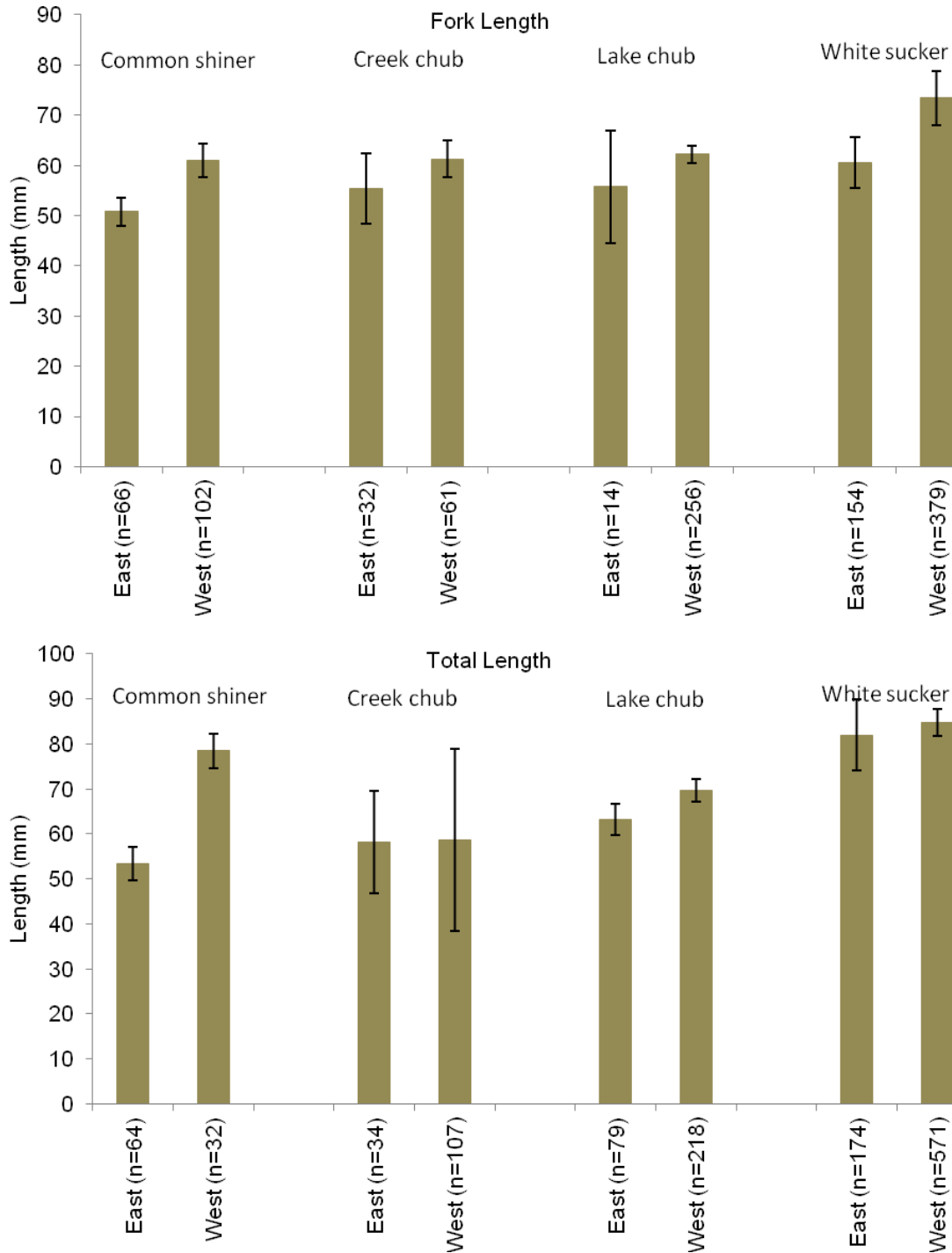


Figure 12: Mean fork and total length of cyprinids recorded in East and West Branches, St. Mary's River. Error bars are 95% CI. American eel not shown on this figure for clarity of these smaller bodies species.

Table 5: Summary statistics of body size for non salmonid fishes from DFO electrofishing database of St. Mary's River. Only species for which length measurements have been made are included.

		Min	Max	10th pctl	25th pctl	Median	75th pctl	90th pctl	n
COMMON SHINER									
WEST BRANCH	Fork length	19	100	38.2	48.5	62	74	82.9	102
	Total length	52	96	62.2	73.75	80	85	91.8	32
EAST BRANCH	Fork length	24	90	41	45	47	55	65	66
	Total length	25	121	33.3	47	53	58.25	67	64
CREEK CHUB									
WEST BRANCH	Fork length	35	118	45	52	58	69	80	61
	Total length	25	112	32.6	49.5	62	69.5	76	107
EAST BRANCH	Fork length	15	110	30.2	44.75	54.5	67	75	32
	Total length	33	100	38.6	43	62	68.75	75	34
LAKE CHUB									
WEST BRANCH	Fork length	22	101	44.5	55	63.5	71	78	256
	Total length	20	182	49.7	63	70	80	85	218
EAST BRANCH	Fork length	24	91	28.6	36	59	70	78.5	14
	Total length	28	120	47	52	62	72	83	79

Table 5 (Cont'd)

		Min	Max	10th pctl	25th pctl	Median	75th pctl	90th pctl	n
WHITE SUCKER									
WEST BRANCH	Fork length	22	885	34.8	44	67	88	113	379
	Total length	25	255	42	59	82	100	123	571
EAST BRANCH	Fork length	20	212	29	37	56	72	103.1	154
	Total length	20	380	42	51	73.5	89	122	174
AMERICAN EEL									
WEST BRANCH	Fork length	70	540	133	178.5	243	295	320	538
	Total length	55	590	135	175	235	290	325	313
EAST BRANCH	Fork length	75	560	125	168	225	280	318	659
	Total length	65	750	140	172.5	220	277.5	320	471

5.0 DISCUSSION

The large number of total length measurements for the salmonids in the DFO database was surprising as the standard length measurement for salmonids is fork length. Total length has the risk of biasing length estimates low if the trailing edge of the caudal fin is damaged, whereas the indented area of the fin (“the fork”) is protected and so more consistent. Further, the inclusion of fork lengths for species such as American eel, for which the caudal fin is confluent with the dorsal and anal fin and without a fork, is questionable. Where possible, separate analyses were conducted here on these two measurements.

There is evidence of statistical differences in size-at-age of Atlantic salmon among branches, but it is questionable whether the small differences in absolute values of means (<1.0 cm) are ecologically meaningful. Total length by age class shows an interesting pattern in which age 0+ in the East Branch are larger than the West, age 1+ are equal size in the two branches, and age 2+ are larger in the West than the East branches. This suggests to possibility of better growing conditions in the West Branch for the parr stages. The growth analysis suggests that growth is higher in the headwater tributaries (South Brook, Nelson River, North Nelson River) and West Branch mainstem. The more downstream locations on the West Branch show equivalent growth to the East Branch. These areas of greater growth share two attributes: (1) they are physically larger (wider, deeper, greater volume) than the smaller tributaries showing lower growth rates and smaller size, and (2) the headwater systems are not significantly impacted by land use, but rather the habitat remains in very good condition (see Mitchell, 2010, 2011b). In terms of salmon conservation, focus should be placed on preserving and maintaining these high quality habitats for salmon size and growth in the upper one half of the West Branch St. Mary’s River (*Recommendation #1*).

All age classes of Atlantic salmon show a high degree of stability in body size among tributaries within a branch, as indicated by low CV values. None of the systems examined showed exceptionally large or small body size compared to others. Further, there was inconsistency in identified systems with smallest or largest body sizes (*i*) between fork length and total length, and (*ii*) among age classes. This suggests that none of the locations are chronically producing small or large salmon, rather all are producing similar size juveniles, with some, but not consistent, small variation. This is also true for body size over time. The low CV values imply a high degree of stability for both fork and total lengths over time for all systems evaluated. There were few significant regressions of body size over time and these showed inconsistency with respect to direction of change (increasing or decreasing) and were not carried from one age class to the subsequent one within a system. Thus, there is little evidence, and none strong, of significant differences in juvenile Atlantic salmon body size over space or time in the St. Mary’s River.

Juvenile salmon annual growth was similar among all systems for age 1+ to 2+ and most systems for age 0+ to 1+. The upper areas of the West Branch (e.g., Nelson and North Nelson Rivers) appear to have larger growth increments for age 0+ to 1+ than mid-areas of the West Branch (Archibald’s, Barren, Indian Man Brooks). But this is ambiguous as South Brook (near the Nelson River) is more similar to the mid-branch systems. Mean growth for juvenile salmon is ~50 mm/year for age 0+ to 1+ and ~27 mm/year for ages 1+ to 2+. Gibson et al. (2009) estimate

that 91% of the smolts leaving the St. Mary's River are age 2+ and average 145 mm in length and 9% are age 3+ and average 164 mm. This implies that growth from age 1+ to smolt size (i.e., ~105 mm to 145 mm) is 40 mm and from age 2+ to smolt size (i.e. ~135 mm to 165 mm) is 30 mm.

Similar to salmon, brook trout show a high degree of stability in body size over tributaries, branches and time. Those tributaries identified as having the smallest (or largest) body sizes are not consistent among age classes. For example, Barren Brook has some of the smallest age 0+ trout but largest age 1+ and 2+ (and unfortunately there are no growth data for this brook to examine this pattern in greater detail). The data are not consistent in highlighting particular areas of small or large body size. Further, there is very little correspondence among those systems of small or large body size of trout, with those identified for salmon. That is, only one stream (Barren Brook, age 0+) is identified as having smallest or largest individuals in an age class for both salmon and trout. Thus it appears there is a large degree of small "random" variation, but no particular systems are more (or less) conducive to salmonid growth. There is also very little evidence of trends in size over time for brook trout (i.e., 1 in 10 regressions) and this only represents a single age class in one system. The low CV implies high stability of body size among years for each system. Mitchell (2011a) identified Glencross, Kelly, and Mitchell Brooks on the West Branch as being of particular low pH and this might be expected to reduce size-at-age or growth. There is no indication from this analysis that either salmon or trout are negatively affected in terms of size, in these "low pH" streams.

Brook trout growth is based on few estimates but appears quite stable among years based on CV. Age 0+ to 1+ growth is similar to that of salmon for that age class (i.e., ~50 mm/year) but growth from age 1+ to 2+ is double that of salmon (i.e., ~60 mm/year for trout).

Of five non-salmonid species for which size could be analyzed, the common shiner, creek chub and white sucker indicated mean size in the East Branch was less than or equal to that of the West Branch. American eel and lake chub showed inconsistency of results between fork length and total length. This may be interpreted as the lack of a "true" difference in body size as it is dependent upon which measure is used, and therefore likely not ecologically significant.

6.0 CONCLUSIONS

The DFO and NSDFA databases have provided a very large body of information to evaluate salmonid body size and growth within the St. Mary's River. Based on this very large number of records, there is little evidence of large differences in size and growth by Atlantic salmon or brook trout over space or over time in the St. Mary's. There is some indication that the upper reaches and tributaries of the West Branch have large size salmonid juveniles and better growing conditions. But, apart from this, the remainder of the watershed appears to have similar size and growth.

To have a complete and comprehensive understanding of "environmental conditions" and effects on the rearing salmonids, density, biomass and production should also be analyzed (see *Recommendation #2*) which was beyond the scope of this analysis due to the huge volume of

data contained within these databases. Based only on size-at-age and growth, however, none of the sampled areas appear limiting to salmonid rearing, nor has there been directed change (trends) over time.

7.0 RECOMMENDATIONS

The following recommendations are not presented in order of importance, but rather in order of appearance in the text.

Recommendation #1: The only location identified as having larger size-at-age or growth in the St. Mary's River was the upper areas of the West Branch,, St. Mary's River (e.g., Nelson and North nelson River, West Branch mainstem) In terms of salmon conservation, focus should be placed on protecting and maintaining these high quality habitats for salmon size and growth.

Recommendation # 2: This analysis did not include calculating spatial and temporal variation of salmonid density, biomass and production, which should be conducted to allow a comprehensive understanding of fish production and capacity within the St. Mary's River. It is recommended that such an analysis be conducted in the near future to assess locations in which salmonid production may be limiting and thus allow habitat restoration planning and activities.

8.0 LITERATURE CITED

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