Examining the Occurrence of Wild Rainbow Trout in the Bras d'Or Lakes, Nova Scotia: Using Scale Pattern Analysis to Differentiate Hatchery and Wild Populations

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REGINALD J. MADDEN*, JOHN L. MACMILLAN
Nova Scotia Department of Fisheries and Aquaculture, Inland Fisheries Division, Fisheries Management Section, 91 Beeches Road, Pictou, Nova Scotia, Canada, B0K 1H0
* Corresponding author: maddenrj@gov.ns.ca
JOSEPH APALOO
St. Francis Xavier University, Department of Mathematics, Statistics and Computing Science, P.O. Box 5000, Antigonish, Nova Scotia, Canada, B2G 2W5

ABSTRACT
Rainbow trout *Oncorhynchus mykiss,* a known invasive species, are the second most popular sport fish in Nova Scotia. First introduced in 1899, the successful reproduction of rainbow trout was believed to be limited and angler catches were dependant on stocking. Wild juvenile rainbow trout electrofished from the Bras d'Or Lakes watershed were directly compared to unknown (angled) and known origin (hatchery) rainbow trout.

Rainbow trout reared under aquaculture conditions experience rapid growth resulting in morphological differences from wild juveniles. Mean length and weight at age 1+ of known origin wild and hatchery trout were 13.1 cm (29.5 g) and 27.6 cm (252.8 g), respectively. Scale analysis revealed hatchery samples had more circuli spaced farther apart. Significant variations were detected in the mean difference in distance (12.3 μm) of the first six circuli pairs of wild and hatchery rainbow trout (T-test, $P<0.05$). A Stepwise Logistic Regression Model was constructed to classify the unknown origin samples into either wild or hatchery. Approximately 70% of the known origin data were randomly selected to construct the logistic model. The remaining 30% were used for validation. The dependent variable was wild or hatchery and the predictor variables were weight, length and the six circuli pair distances. The significant predictor was the 6th circuli pair distance. The model classified 71% of the rainbow trout with unknown origin as hatchery and 29% as wild origin suggesting that rainbow trout reproducing in the wild contribute to a significant proportion of the angler catch.

Rainbow trout are successfully reproducing in Nova Scotia and this is the first research to confirm successful reproduction using scale analysis. All aquaculture operations are encouraged to use triploid rainbow trout to reduce impacts associated with successful reproduction on native populations of brook trout *Salvelinus fontinalis* and Atlantic salmon *Salmo salar*.

INTRODUCTION

The native range of the rainbow trout *Oncorhynchus mykiss* is the Eastern Pacific Ocean and freshwater lying west of the Rocky Mountains, extending from northwestern Mexico to the Kuskokwim River in Alaska (Scott and Crossman 1998). Rainbow trout were first introduced to Nova Scotia in 1899 (Scott and Crossman 1998). They are true spring spawners, preferring smaller tributaries of rivers but will also use suitable environments within lakes. They tend to inhabit open, fast flowing regions of streams similar to native Atlantic salmon *Salmo salar* parr (Cunjak and Green 1983) and are more tolerant of warm water compared to native brook trout *Salvelinus fontinalis* (Cunjak and Green 1986). In other areas of North America, rainbow trout exhibit invasive characteristics towards brook trout (Moore et al. 1983; Larson and Moore 1985; Larson et al. 1995) and other salmonids (McKenna and Johnson 2005; Boyer et al. 2008; Metcalf et al. 2008; Thibault et al. 2009). Rainbow trout are one of the most acid-sensitive salmonids (Chadwick and Bruce 1981) and acidic conditions in mainland Nova Scotia likely impede successful reproduction of rainbow trout and, therefore, their significance as an invasive species. Past electrofishing surveys in a number of tributaries of the Bras d'Or Lakes have detected the presence of juveniles and suggest that limited natural reproduction has occurred (Sabean 1983).

In Nova Scotia, rainbow trout have a long history of being grown commercially in aquaculture facilities and stocked from hatcheries to create sportfishing opportunities. The two main known contributors to wild rainbow trout populations in Nova Scotia are aquaculture escapement and hatchery stocking. Development of a reliable method to distinguish between hatchery and wild populations of rainbow trout will aid in future management decisions for this popular sport fish, and help to develop a greater understanding of their biological parameters. The contribution of wild origin rainbow trout to the angler creel provides insight as to their importance recreationally and as competitors with wild native stocks.

Rainbow trout are the second most popular sport fish in Nova Scotia (Fisheries and Oceans 2007). The most productive rainbow fisheries are located within the Bras d'Or Lakes and anglers have reported that catches of large ripe female rainbow trout are common in the Fall while angling historic Atlantic salmon rivers. Although rainbow trout are found in tidal waters, rivers and lakes throughout the province, little research has been conducted to examine their populations and how they adapt to Nova Scotias environment and impact native species. Although mixed-sex rainbow trout were stocked prior to 2007, a common inference, has been that rainbow trout have limited reproductive success in Nova Scotia. Wild rainbow trout referred to in this paper are the offspring of naturally spawning hatchery or aquaculture fish.

Scale patterns show the spacing and number of circuli on the scale, which are correlated with food consumption and growth (Bilton and Robins 1971). Rainbow trout within a hatchery environment experience feeding rates that are characteristically much greater than those experienced in the wild, especially in the first year of life. Scale pattern analysis has been successfully used to differentiate between hatchery and wild salmonids by analyzing the freshwater growth zone and the location of the first annulus. Quantitative scale pattern analysis techniques have been developed to differentiate between farmed and wild Atlantic salmon in the maritime provinces (Stokesbury et al. 2001) but currently, no quantitative scale analysis technique exists to estimate proportions within mixed populations of introduced wild and hatchery rainbow trout. Quantitative scale pattern analysis methods independent of age determination are essential to avoid inclusion of false annuli on hatchery rainbow trout scales (Bernard and Myers 1996; Davis and Light 1985) and other potential visual pattern identification errors. Relatively low agreement between fisheries biologists on visual determinations of freshwater age of rainbow trout (Davis and Light 1985) further suggests that quantitative techniques independent of freshwater age could improve the accuracy of population estimates. If successful, this quantitative scale pattern analysis method can, regardless of accurate annulus confirmation (aging), calculate (with degrees of precision) the proportion of wild and hatchery rainbow trout in a mixed population while greatly reducing potential inter-observer analysis error.

The purpose of this paper is threefold: (1) to confirm that rainbow trout are successfully reproducing in Nova Scotia, (2) to determine if scale pattern analysis can be used with a high degree of confidence, to differentiate between hatchery and wild rainbow trout and (3) to estimate the proportion of wild rainbow trout in the angler catch from the Bras d'Or Lakes watershed.

STUDY AREA

The study area focused on Nova Scotia's largest estuary, the Bras d'Or Lakes, Cape Breton Island, Nova Scotia, Canada (Figure 1). The Bras d'Or Lakes watershed has an area of 3,565 km^2 with 12 sub-watersheds and approximately 1,000 km of coastline (Krauel 1976; Parker et al 2007). The Bras d'Or Lakes fall within the boundaries of all four counties (Cape Breton, Inverness, Richmond, Victoria) and cover approximately one-third of Cape Breton Island. Fortytwo percent of all freshwater that flows into the Bras d'Or Lakes originates from six major rivers. The drainage basin area of each of these rivers is: Middle (325 km^2), Baddeck (295 km^2), Denys (215 km^2), Skye (120 km^2), Black (42 km^2), and Washabuck (23 km^2). Smaller systems account for the remaining 58% of flowage (Krauel 1976; Parker et al 2007).

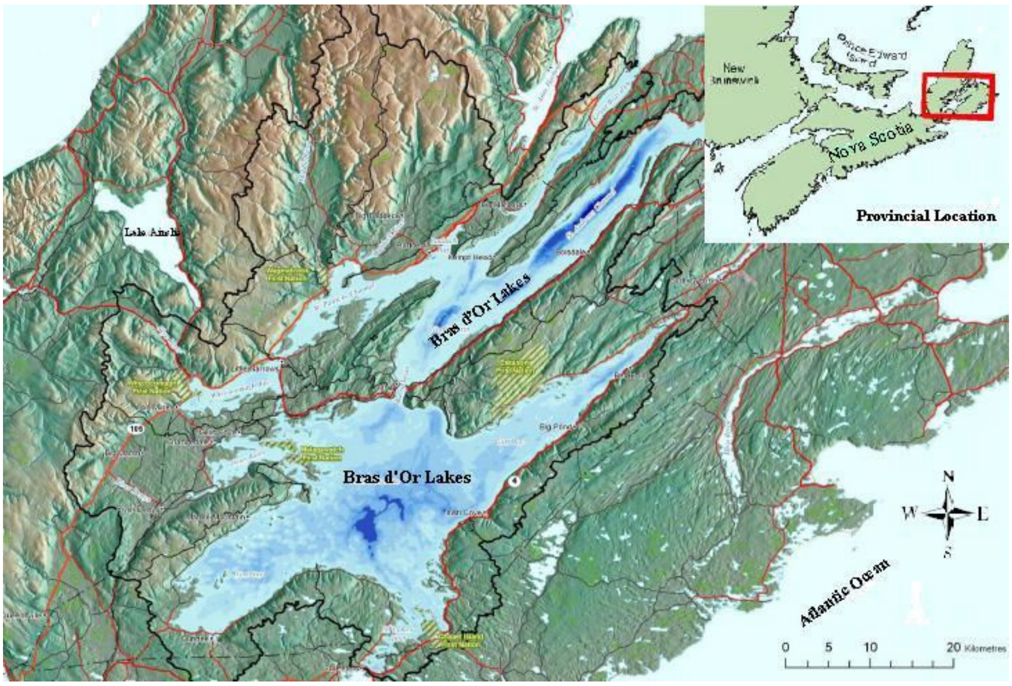

Figure 1. The study area: Bras d'Or Lakes, Nova Scotia, Canada. Map inlay depicts the provincial location of the study area.

METHODS

Three different samples of rainbow trout were collected during 2008 and 2009. Staff from the Nova Scotia Department of Fisheries and Aquaculture (NSDFA) – Inland Fisheries Division, electrofished seven lotic systems in the Bras d'Or Lakes watershed to assess the presence or absence of naturally reproducing rainbow trout; Skye River, Breac's Brook, McNabs Brook, Irish Cove Brook, MacRae Brook, North Branch Baddeck River, and New Glen Brook. Although River Denys, also part of the Bras d'Or Lakes watershed, was not specifically evaluated for rainbow trout, intensive trapping and electrofishing conducted simultaneous to this study did not reveal the presence of juvenile rainbow trout. Based on the timing of stocking occurrences and size and weight at age, juvenile samples electrofished from the Bras d'Or Lakes watershed were presumed the progeny of successful wild spawning. Rainbow trout collected from Fraser's Mills Hatchery were used for analysis and comparison to wild rainbow trout. Fraser's Mills Hatchery is operated by the NSDFA and is located in Antigonish County, Nova Scotia. Anglers provided the third sample of fish, angled throughout the Bras d'Or Lakes and its tributaries. The specific origin (hatchery or wild) of these samples was unknown.

A single pass technique with a Smith-Root backpack model LR-24 was used for electrofishing the lotic systems. Areas of assessment on each system were either chosen randomly or based on vicinity to road access in remote areas. During each electrofishing survey, large sections of river were continuously shocked, and, where available, researchers incorporated all habitat and river morphology (riffle, run, pool). Rainbow trout of a known age (7, 13 and 19 months) from Fraser's Mills Hatchery, grown for stocking in the Bras d'Or Lakes were used as the comparison sample. Fraser's Mills rainbow trout were all-female diploids raised from egg and purchased from Trout Lodge in Washington, USA. Hatchery samples were randomly selected during both 2008 and

2009 to reduce the influence of year to year variation in growth. The sample of unknown origin rainbow trout was captured throughout the Bras d'Or Lakes watershed by anglers using fly, lure and bait.

Electrofished and hatchery sampled fish were anesthetized with a clove oil solution and visually inspected for any marks or abnormalities. Scale samples were taken for analysis from above the lateral line on the left side of the body in the area midway between the dorsal and adipose fins. Fork length, to the nearest millimeter, and weight, to the nearest gram, were measured and recorded. The date and sampling location were also documented. All wild fish were lethally sampled while hatchery samples were released back into Fraser's Mills Hatchery. Samples provided by anglers were processed by anglers and later delivered to NSDFA staff. Data received from anglers included: site location, date, scale samples, length, and weight.

A total of 108 scale samples were analyzed. Known origin samples were comprised of 18 wild rainbow trout (11 fish 2008, 7 fish 2009) and 38 hatchery rainbow trout (11 fish 2008, 27 fish 2009). Fifty-two unknown origin samples were provided by anglers throughout 2008. Scales were mounted on microscope slides labeled with each specimen's corresponding length, weight and relevant capture data. Mounted slides were examined using a compound microscope to select the best quality (non-regenerated, unsoiled) and most representative scale from each fish. Scales were all aged separately by two readers and discrepancies were resolved by re-examining collectively. Based on the stocking date, length and weight, only one fish electrofished could have potentially been of hatchery origin and was, therefore, excluded from the study.

Scale examination revealed all known origin scale samples were less than 2 years of age. Variation in scale growth patterns between hatchery and electrofished samples was also observed and noted. Circuli spacing in hatchery samples appeared more consistent and uniform compared to wild scales. Scales from wild fish displayed fewer circuli spaced closer together in the first year of life (Figure 2).

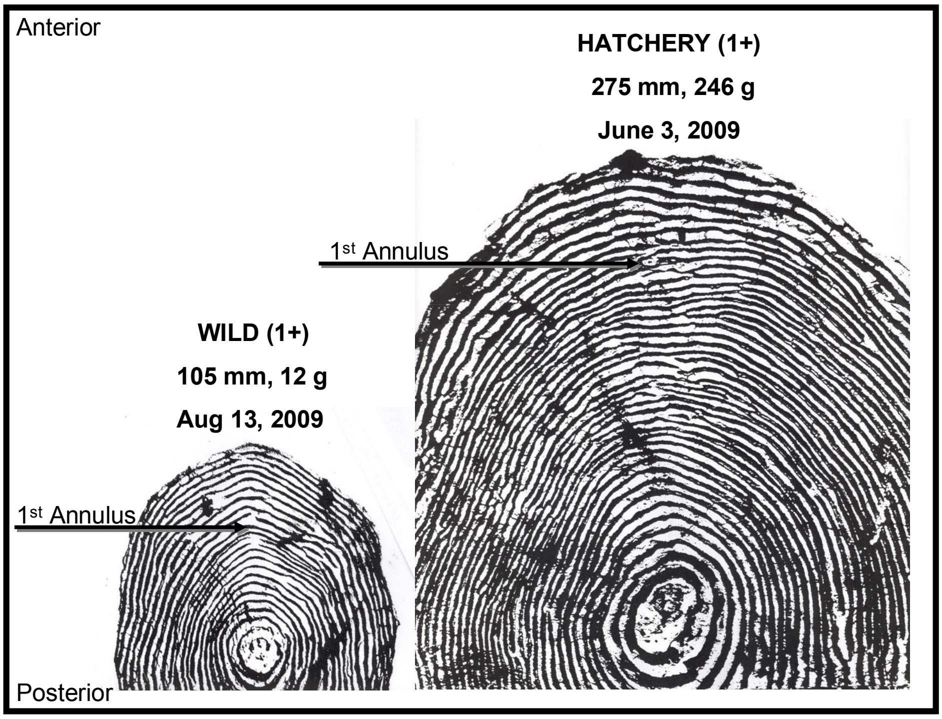

Figure 2. Scale samples from a known 1+ wild and 1+ hatchery rainbow trout depicting growth differences and 1st annulus (year 1 mark). Scales magnified 40x.

All selected scales were enlarged using a Canon Microfilm Scanner to 160x magnification (40x microfilm scanner, 4x Xerox machine). Each magnified scale was situated in a comparable position on the Canon Microfilm Scanner and printed on 8.5” x 14” paper. Each individual printed scale was given a unique number and the corresponding length, weight and relevant capture data was transferred to the paper copy. The distance between circuli was measured from the center of one circuli to the center of the next circuli, grouped into pairs and recorded to the nearest half millimeter. For example, a circuli pair was the distance between circuli 1-2, measured along the longest axis of the scale. The first circuli surrounding the focus was circuli 1, the first six circuli pairs were measured (Figure 3). All scale measurements were taken by the same person and were measured to the nearest half millimeter. Circuli distances were converted to micrometers (µm) to correspond to the actual distance on each scale using the known magnification.

Because of accelerated growth experienced in hatchery environments, it was hypothesized that the mean width of the first six circuli pairs would be greater in hatchery origin rainbow trout. Therefore, the mean, standard deviation and 95% confidence intervals of the distance between the first six circuli pairs of all wild, hatchery and unknown samples were calculated.

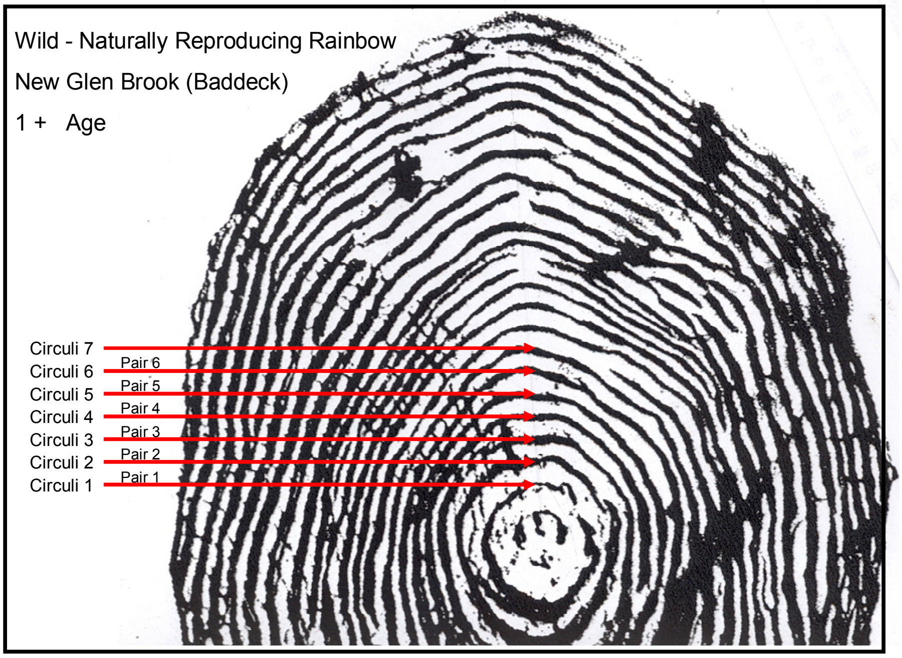

Figure 3. Wild rainbow trout scale depicting circuli pairs used for measurements.

The age of each fish was found for all samples of known origin (hatchery or wild). An exact age was already known for hatchery rainbow trout and the first annulus on wild origin rainbow trout was easily distinguished by the obvious growth patterns displayed on the scales. All wild origin rainbow trout were aged as 1+. During analysis of hatchery scales a false annulus was detected and assumed to have occurred when rainbow trout were introduced to a new environment such as being moved from inside the hatchery to larger, outdoor runs. Hatchery samples displayed many more circuli in the first year of life than the wild samples (Figure 2). Rainbow trout of unknown origin were aged but, due to the presence of false annuli, a definite age could not always be determined.

Circuli pair distances from the different origins were calculated. A Stepwise Logistic Regression was conducted, in Statistical Package for the Social Sciences (SPSS) Version 15, to obtain results on the classification of rainbow trout of unknown origin. The data set consisted of several variables measured for groups of scales from rainbow trout with known origin (hatchery or wild) and a third group with unknown origin. Approximately 70% of the data from the wild and hatchery trout were randomly selected and used to construct a logistic model. The remaining 30% of wild and hatchery data were used for model validation. The dependent variable was wild or hatchery and the predictor variables were weight, length and the six circuli distances. The logistic regression model was used to classify the data with unknown origin as hatchery raised or wild trout. All analyses were performed in SPSS version 15.

RESULTS

Wild juvenile rainbow trout were successfully electrofished in two Bras d'Or Lakes river systems. All wild rainbow trout captured were 1+ years of age. Mean length and weight of wild rainbow trout was 131 mm (2.57, SD) and 29.5 g (18.76, SD) respectively. Mean length and weight of 1+ years old hatchery rainbow trout was 276 mm (2.15, SD) and 252.8 g (58.58, SD) respectively. Hatchery rainbow trout exceeded wild rainbow trout by 145 mm in length and 223.3 g in weight. Hatchery reared samples taken at only 7 months of age, having a mean length and weight of 125 mm (0.74, SD) and 24.8 g (7.08, SD), respectively were similar to 1+ wild rainbow trout. The consistent and intensive feeding regimes of rainbow trout within Nova Scotia hatcheries create rapid growth and measurable differences in scale growth patterns during the first year of life (Figure 2). Length, weight at age and the fact that hatchery stocking occurred after samples were collected, demonstrate that juveniles electrofished from the Bras d'Or Lakes watershed during 2008 and 2009 were of wild origin. Quantitative scale pattern analysis and stepwise logistic regression model analysis further demonstrate that rainbow trout are successfully reproducing in Nova Scotia.

Growth was compared between known origin (wild and hatchery) and unknown origin (angled samples) fish by measuring the distance between circuli (Figure 3). The distance between all six circuli pairs was recorded for each individual fish and the mean distance of all six circuli pairs was calculated for all rainbow trout (Figure 4). The grand mean distance of all six circuli pairs, calculated for all wild, unknown, and hatchery samples was 25.75 µm, 35.03 µm and 38.06 µm, respectively. The grand mean distance of all six circuli pairs of hatchery origin trout is 12.31 µm greater than wild samples.

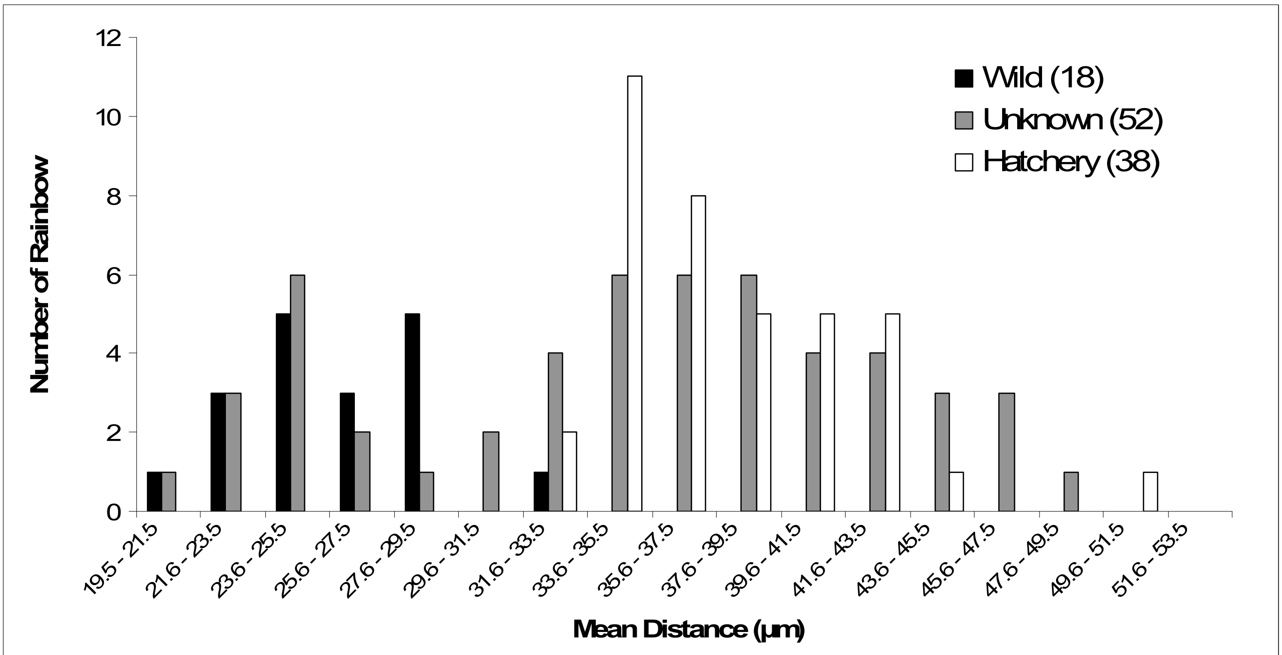

Figure 4. Length frequency distribution of the mean distance of six circuli pairs for each wild, unknown and hatchery rainbow trout.

The total length of six circuli pairs for each fish was determined by calculating the sum of the distance of all six circuli pairs. The mean total length of the six circuli pairs for wild, unknown and hatchery groups was 154.51 µm, 210.16 µm and 228.37 µm, respectively.

The mean distance of the individual circuli pairs (1 - 6) for all wild, unknown (angled) and hatchery samples was calculated. The mean distance of the 6th circuli pairs for all wild, unknown and hatchery samples was 17.53 µm, 28.37 µm and 30.51 µm, respectively (Figure 5).

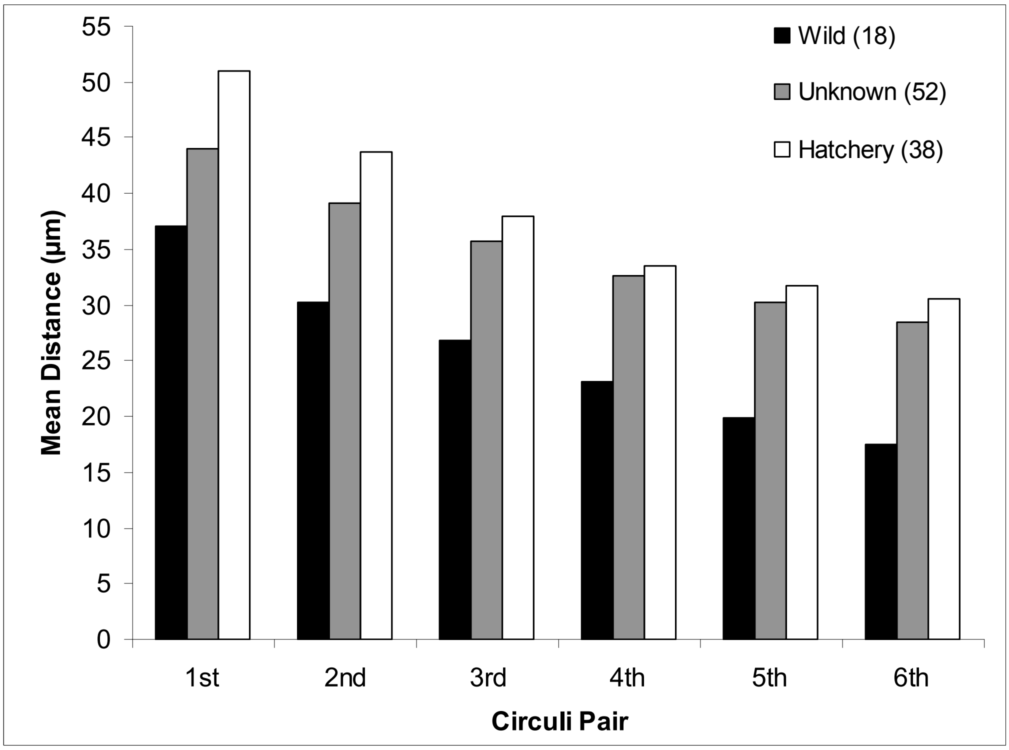

Figure 5. The mean distance of the individual circuli pairs for all wild, unknown and hatchery rainbow trout.

The mean of the circuli pair distances decreases outwards from the focus of the scale towards the anterior edge (Figure 5). Mean distances for the circuli pairs of hatchery rainbow trout were consistently larger than those from the wild. The means for rainbow trout of unknown origin are between those from the hatchery and wild samples (Table 1). Differences between the mean distances of circuli pairs were greater between unknown origin and wild origin fish compared to those between unknown origin and hatchery fish, suggesting that the unknown sample may contain a greater proportion of hatchery fish (Figure 5).

The 95% confidence intervals for the circuli pair distances for the hatchery and the wild rainbow trout do not overlap. Similarly, the 95% confidence intervals for the circuli pairs of trout with unknown origin do not overlap with those of wild origin. There are, however, partial overlaps with the confidence intervals for rainbow trout of unknown and hatchery origin. The only exception is the circuli pair 1 distance (Table 1).

Circuli pair distances in the hatchery raised trout are consistently above the upper quartiles of the wild trout (Figure 6). Thus, the values of circuli pair distances in the range of lower quartile to upper quartile of wild trout do not overlap with those of hatchery raised trout. The corresponding values for those with unknown origin overlap with those from the hatchery and from the wild except in the case of circuli pair 6 for trout with unknown origin and trout with wild origin.

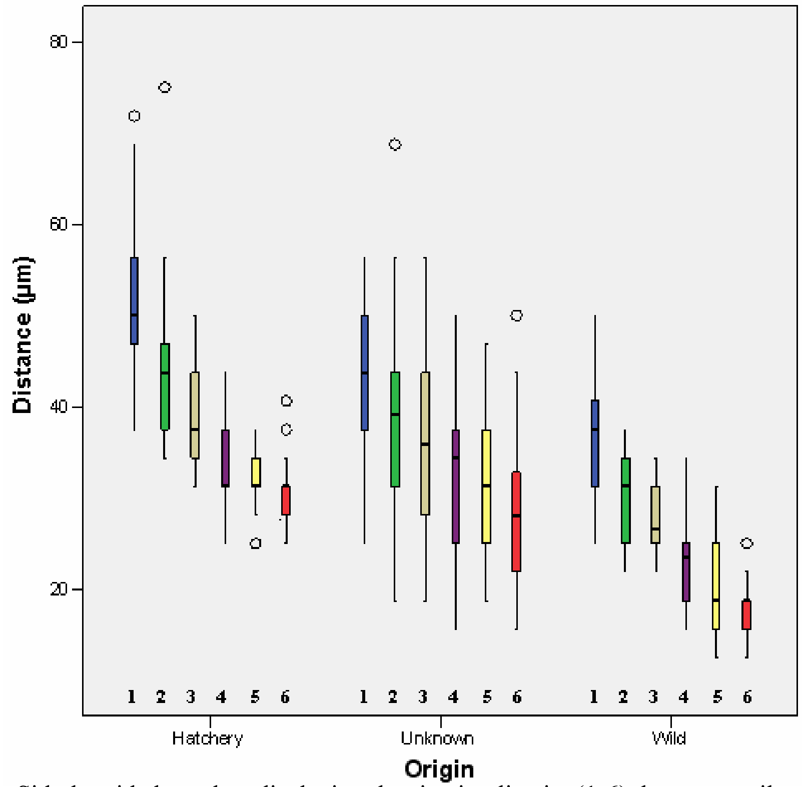

Figure 6. Side-by-side box plots displaying the six circuli pairs (1-6), lower quartile, median, upper quartile and outliers (o) of rainbow trout from different origins (hatchery, unknown and wild).

The sample sizes for the trout from hatchery, unknown and wild origins are 38, 52 and 18, respectively. Stepwise logistic regression analysis using origin (with values wild or hatchery) as the dependent variable and the six circuli pair distances, length and weight of the rainbow trout as predictor variables, showed that only circuli pair 6 distance is a significant predictor. A Hosmer-Lameshow statistic was also calculated indicating a good fit (Sig, 1.000). In the case of selected data with known hatchery or wild origin, the model classified 90.9% of the data from wild samples correctly and 100% of the data from hatchery samples, making the overall percentage correct for selected cases 96.9%. The model classified 100% of all remaining known origin samples used for model validation correctly into hatchery and wild origin.

Out of the 52 rainbow trout with unknown origin, the model predicted 71.15% (± 12.31, 95% c.i.) as hatchery originated. This makes the estimated proportion of wild rainbow trout in the angler catch from the Bras d'Or Lakes watershed 29%.

Table 1. The mean (X), standard deviation (SD) and 95% confidence intervals (CI) in µm of the width of the first six circuli pairs of all wild, hatchery and unknown samples of rainbow trout from the Bras d'Or Lakes, Nova Scotia.

	Wild			Hatchery			Unknown		
Circuli Pair	X	SD	CI	X	SD	CI	X	SD	CI
1	36.98	6.36	33.81, 40.14	50.99	8.45	48.21, 53.76	43.99	8.25	41.69, 46.29
2	30.21	5.14	27.65, 32.77	43.67	7.28	41.27, 46.06	39.12	10.23	36.27, 41.97
3	26.91	3.89	24.98, 28.84	37.99	5.22	36.28, 39.71	35.76	9.68	33.06, 38.45
4	23.09	5.27	20.47, 25.71	33.47	4.47	32.00, 34.94	32.57	9.02	30.06, 35.08
5	19.79	5.47	17.07, 22.51	31.74	3.29	30.66, 32.83	30.35	7.41	28.29, 32.41
6	17.53	3.73	15.68, 19.39	30.51	3.66	29.31, 31.71	28.37	8.39	26.03, 30.70

DISCUSSION

Rainbow trout are successfully reproducing in Nova Scotia and this is the first research to confirm successful reproduction using scale analysis. Quantitative differences in scale characteristics differentiating hatchery stocked and naturally reproducing (wild) rainbow trout suggest that wild rainbow trout represent a substantial proportion of the angled catch from the Bras d'Or Lakes.

Since juvenile rainbow trout grow very rapidly in hatchery conditions and other research (Davis and Light 1985; Stokesbury et al. 2001) illustrates differences in growth through scale analysis in early life stages, scale measurements within the first year of life were used in this study. The first annulus is commonly used in scale analysis to distinguish between hatchery and wild rainbow trout (Davis and Light 1985; Tattam et al. 2002). Misidentification of the first annulus may, however, lead to the inclusion of false annuli when analyzing rainbow trout scales for age and growth. The failure of some salmonids to form their first annulus also reduces the accuracy of this method (Lentsch and Griffith 1987). To eliminate the misidentification of annuli and create a less subjective technique to distinguish the origin of rainbow trout, therefore, the quantitative method used in this study was based on repeatable measurements of circuli spacing. The stepwise logistic regression model used was successful, with a high level of confidence, in accurately differentiating between wild and hatchery rainbow trout and, therefore, can be used as a management tool. All juvenile rainbow trout electrofished from the Bras d'Or Lakes watershed were classified as wild rainbow trout.

Rainbow trout were commercially produced at aquaculture facilities in the Bras d'Or Lakes from 1972 to 2002 and there are currently nine marine rainbow trout aquaculture sites in abeyance (personal communication, Cameron 2010). Large aquaculture escapement events added to the popularity of the fishery and likely contributed to the reproducing population. After these escapements, Hurley Fisheries Consulting (1989) reported runs of rainbow trout in Skye River and, to a lesser extent, in other rivers during the late 1980's.

Stocking of mixed-sex hatchery rainbow trout has occurred in Nova Scotia since the early 1900's. In 2007, however, diploid all-female rainbow trout became the standard for stocking. Hatchery rainbow trout stocked in the Bras d'Or Lakes have not been externally marked. Past stocking and escapement of viable rainbow trout have potentially bolstered spawning biomass. Previously, juvenile rainbow trout have been captured during electrofishing surveys in the Middle River (Robichaud-Leblanc and Amiro 2004), Skye River, Gillis Lake Brook, Blues Brook, and Breac's Brook (Sabean 1983) indicating that reproducing populations may exist. From a management perspective, the successful reproduction of rainbow trout presents several questions. What impacts will this known invasive species have on native fauna? What is the current contribution of wild rainbow trout in the Bras d'Or Lakes watershed? What management decisions need to be implemented to ensure the conservation and protection of native species? How can a sport fishery for rainbow trout be maintained without further impacting native fish species?

Brook trout are Nova Scotia's provincial fish and the most important freshwater species to the recreational fishery. Brook trout are one of the most temperature sensitive salmonids and tend to avoid temperatures greater than 20ºC (Lee and Rinne 1980; Biro 1998; MacMillan et al. 2005). Water bodies in Cape Breton, Nova Scotia offer more cool water refugia than southern sections (MacMillan et al. 2005) of the province and acidification is of little significance in the Bras d'Or drainage basin (Parker et al. 2007); both positive conditions for brook trout to thrive. It is also well documented, however, that brook trout do not successfully compete with other species (Fraser 1978; East and Magnan 1991; Flick and Webster 1992; MacMillan et al. 2005; Halfyard et al. 2008). Rainbow trout, on the other hand, have an optimal water temperature of approximately 19ºC (Cunjak and Green 1986), display a distinct survival advantage over other salmonids at water temperatures above 20ºC (Bear et al. 2007) and compete well with other salmonids (McMichael and Pearsons 1998). Watershed temperature increases associated with global warming, therefore, may create a more suitable environment for rainbow trout, consequently giving them an additional competitive advantage over brook trout. Rainbow trout have shown to be well suited to the Bras d'Or Lakes environment, displaying weight increases of approximately 400% in the first two months of a mark and recapture study (Sabean and Banks 1987).

Overall, although the successful reproduction of the invasive rainbow trout is a management concern in Nova Scotia, it is currently of relatively low priority as recent and past electrofishing surveys demonstrate that limited reproduction has occurred. Although 29% of the harvested (angled) sample was determined to be wild rainbow trout, research has shown that densities of juvenile rainbow trout are far below those of native brook trout and Atlantic salmon (Robichaud-Leblanc and Amiro 2004; MacMillan et al. 2008). Compared to other invasive species such as smallmouth bass and chain pickerel, rainbow trout are believed to have minor influences on native species. Smallmouth bass *Micropterus dolomieui* and chain pickerel *Esox niger* have already had detrimental effects on native fish species by establishing large populations and spreading through trout and salmon waters across the province. Smallmouth bass, well established in southern and central Nova Scotia, were first reported in northern Nova Scotia in 2000 (LeBlanc 2010) after an illegal introduction into Lake Ainslie, the province's largest (5600 ha) natural freshwater lake located just outside the Bras d'Or Lakes watershed (Figure 1). Following the illegal release of this invasive competitor, the catch per unit effort (CPUE) of smallmouth bass in Lake Ainslie increased from 0.3 bass/h in 2003 to 1.63 bass/h in 2008 while brook trout decreased from 1.5 trout/h to 0.11 trout/h during the same time period (LeBlanc 2010). This demonstrates the impacts that invasive species can have on native species, even over short periods of time in large and very productive watersheds.

Currently, triploid rainbow trout are used in Provincial stocking strategies for the Bra d'Or Lakes. The process of creating triploid salmonids is well developed and Dillon et al. (2000) estimate the cost to produce triploid rainbow trout is only 15 percent higher than diploids. Because triploid fish are sterile, they cannot contribute to existing rainbow populations and, therefore, may be a solution to considerably reducing impacts to native stocks while maintaining the sport fishery. Through analysis of creel survey results, Dillon et al. (2000) indicated that triploids provide an angling opportunity equal to that of fertile diploids. Triploid rainbow trout have displayed survival rates 40% - 90% greater than diploid rainbow trout (Teuscher et al. 2003). Compared with all-female and mixed-sex diploid rainbow trout, all-female triploids have higher growth rates (Sheehan et al. 1999). Because triploids put so much energy into growth, an additional beneficial result of using triploid rainbow trout is the possibility of creating a trophy fishery. The current world record for rainbow trout is 21.77 kg (48 lb) (International Game Fish Association 2010). This trophy was angled in Lake Diefenbaker, Saskatchewan, Canada and is widely believed to be a triploid. Stocking only triploid rainbow trout currently seems to be the best management option for the Bras d'Or Lakes watershed as it helps to conserve native species while maintaining this popular sport fishery and costs only marginally more to produce.

The quantitative scale pattern analysis technique used in this study is a non lethal, relatively inexpensive, repeatable, and, as shown in this research, accurate method to differentiate between wild and hatchery origin rainbow trout. The measurement of distance between the first six circuli pairs eliminates the need to correctly determine annuli and the errors commonly associated with that method. This quantitative scale pattern analysis method will be a valuable management tool for future evaluation of impacts of the use of triploids by hatcheries and aquaculture facilities on the angler catch.

Additional research will need to be conducted to fully assess wild rainbow trout contributions and impacts to the Bras d'Or Lakes watershed. Future studies to determine if juvenile densities are increasing and to assess the impacts of implementing a triploid stocking strategy should be undertaken. All aquaculture and hatchery facilities in Nova Scotia are encouraged to use triploid rainbow trout to reduce impacts associated with successful reproduction on native populations of brook trout and Atlantic salmon.

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