Fecundity and Sexual Maturity in Select Nova Scotia Trout Populations

Photo: J. MacMillan / A. McNeill

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Abstract

Fecundity, sexual maturity and general reproductive life history traits of native brook trout *Salvelinus fontinalis* and introduced brown trout *Salmo trutta*, in lotic and lentic habitats of Nova Scotia, were examined. Age at first maturity of brook trout was 1+ years and older and for brown trout was 2+ years and older. Fecundity of brook trout and brown trout was slightly higher than that expressed in literature. Expected number of eggs for a 250mm mature trout was 558 for lake-dwelling brook trout, 586 for stream-dwelling brook trout and 466 for stream-dwelling brown trout. Maturity was positively correlated with trout length, however lake-dwelling brook trout exhibited greater variation in length at maturity than stream-dwelling brook trout and brown trout. For brook trout, the length at which the probability of maturity was 50% was 196 mm in lake and 188 mm in stream habitats. Brown trout matured at a larger size than did brook trout and length at 50% maturity was 236mm. Implications of these data are discussed with a focus on trout management.

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TABLE OF CONTENTS

INTRODUCTION

The Nova Scotia Department of Fisheries and Aquaculture has collected extensive population parameter information for many brook trout and brown trout populations, estimating growth, age structure, mortality, life history/strategy and population size (e.g. Alexander and Merrill 1976, MacMillan and LaBlanc 2002, MacMillan and Crandlemere 2004, MacMillan and Crandlemere 2005). In addition to the descriptive nature of these data, their application to trout production models may provide valuable insight for effective trout management within the province. There are however some key parameters which remain to be estimated, including those important to estimates of reproductive potential, namely fecundity and length/age at maturity.

Fish production can be influenced by surficial lithology and is related to a watershed’s thermal characteristics, conductivity, and primary productivity. Stream conductivity has been used as a proxy for productivity and has been shown to correlate with trout growth and production (McFadden and Cooper 1965) and presumably length at maturity (Meyer et al. 2003). In Nova Scotia, cool water streams tend to be streams with relatively higher conductivity, higher alkalinity and consequently higher salmonid production, than those where stream temperatures are warmer (MacMillan et al. *in press*).

Several major geological groupings exist in Nova Scotia, however from a fisheries standpoint, two ecotypes based on surface geology are evident, from which the division of lake or streams could be respectively compared. Perhaps the most predominant are the high dissolved organic (TOC > 7 mg/L) ‘brown water” systems of the southern upland. These systems, mainly underlain by granite, greywacke and slates, generally have low pH (4.5-6.5), low conductivity (10 to 40 µS/cm) (Environment Canada, *unpublished data*) and are highly susceptible to acidification (Kerekes et al. 1982, DFO 2000, Clair 2002). Conversely, the relatively clear water, low dissolved organic (TOC < 7 mg/L) systems of the north (Northumberland rivers and Western Cape Breton Island) tend to have higher pH (6.5 – 8), higher conductivity (40-1500 µS/cm) (Environment Canada, *unpublished data)* and are more able to buffer acidification (MacMillan et al. *in press*).

It has been hypothesized that variation in life-history strategies among populations of salmonids is a result of environmental conditions (Hutchings 1996, Meyer 2003). By assuming that trout populations throughout each ecotype face similar general environmental conditions, estimates of population parameters may prove more ecologically realistic when extrapolated only to other populations within the same ecotype.

For the scope of this study, we examined two key habitat types, and the two most recreationally important, reproductively viable trout species in the province. The primary goal of this study was to describe typical fecundity of brook trout (*Salvelinus fontinalis*, Mitchell) in both low-productivity, high dissolved organic lakes, and in high productivity, low dissolved organic rivers. Also, data were collected to describe fecundity for brown trout (*Salmo trutta*, L.) for high productivity, low dissolved carbon rivers. Additionally, we aim to describe fecundity-related trends such as the size of mature eggs and rates of atresia.

Secondly, we collected data to estimate length at maturity for the above species in each ecotype. While maturation has been described as population-specific with high inter-population variability (Meyer et al. 2003), a general estimate of maturity may provide a valuable starting point from which further research may be conducted.

STUDY AREA

Lake Habitats

Brook trout from lake habitats were sampled from two lakes in the South-Western portion of the Tangier-Grand Lake Wilderness Area (TGLWA), a provincially designated protected area within Halifax county (Figure 1). This area is relatively remote with no road access to the two lakes sampled. Both Arnold Lake and Northeast Lake are highly organic-stained systems and fit well with the related ecotype previously discussed.

In these lakes, we found few competitor species, with only American eel (*Anguilla rostrata*, Lesueur) and banded killifish (*Fundulus diaphanus,* Lesueur) sampled.

Arnold Lake is a small lake of approximately 11.8 ha while Northeast Lake is considerably larger at approximately 63 ha. The bathymetry of these lakes is largely unknown, however observations suggest that a large proportion of the lakes is <2m depth, though depressions of 7.5m and 6.2m were identified in Arnold Lake and Northeast Lakes, respectively. Oxygen/temperature profiles on July 30th, 2007 identified thermoclines in both lakes and the hypolimnetic water was deemed suitable brook trout habitat (temperature <20ºC and DO >60% Saturation). Secchi disk readings showed water clarity to be 1.95m and 1.5m. Conductivity in these lakes is low (< 33 µS/cm), pH is low (≤ 5.2) and total organic carbon is high (> 6 mg/L), resulting in a dark brown stain (TCU>60) (Table 1).

River / Stream Habitat

The conglomerate of lotic habitats sampled in this study consisted of several rivers, representing two geographically distinct areas of the province (Figure 1), yet are of similar morphology, habitat type and general water chemistry. In general, these systems have low dissolved organic carbon (<7 mg/L), moderate to high alkalinity (5 mg/L – 57 mg/L) and circumneutral pH (6.5<pH<8.4) (Table 1).

Elderkin brook, a tributary of the Cornwallis River, is the most southerly system in this study. A first order stream, this system runs approximately 2.5kms from its headwaters to a point where it mixes with the tidal portion of the Cornwallis. Brook trout and brown trout were sampled in Elderkin brook.

River Phillip, Waughs River, River John, West River (Pictou), West River (Antigonish) and the Mabou River are all rivers of moderate size (~24 kms < length <~50 kms). All systems flow into the Northumberland Strait from the Northern Mainland with the exception of the Mabou River, which is located on Cape Breton Island. Brook trout and brown trout were sampled on all systems with the exception of River Phillip, where only brown trout were sampled.

Saint Francis Harbour River is a small river (~17kms) located south of Mulgrave, NS. This river is potentially the outlier of the group as its waters are more heavily stained by tanic acids, pH was low (5.9) and conductivity was low (37 µS/cm), (Table 1). Only brown trout were sampled in Saint Francis Harbour River.

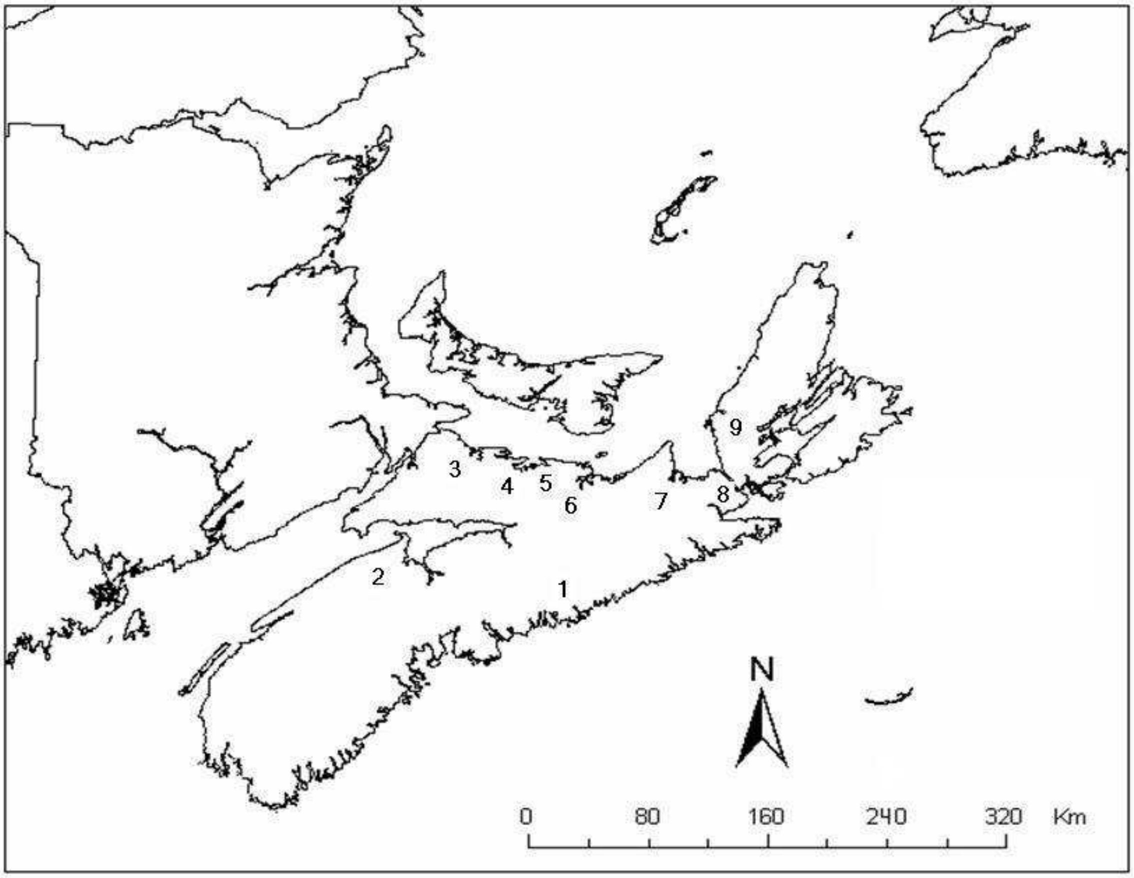

Figure 1 - Map of Maritime Canada indicating sites from which trout were collected. Sites are as follows; 1 = North East Lake and Arnolds Lake, 2 = Elderkin brook, 3 = River Phillip, 4 = Waughs River, 5 = River John, 6 = West River (Pictou), 7 = West River (Antigonish), 8 = Saint Francis Harbour River and 9 = Mabou River.

METHODS

Fish Sampling

To obtain fecundity samples, trout were captured during September, October and November 2007 (pre-spawn) using several methods. In lake habitats, trout were sampled via four 2.4m x 15.2m monofilament gill nets (mesh sizes 2.5cm, 3.8cm and 5.1cm) as well as via angling. All trout captured in the nets were retained for the samples. Trout captured by angling had sex determined and females were examined for obvious signs of maturity (distended body cavity). Those deemed gravid were retained for fecundity sampling.

To sample stream/river habitats, four separate methods were used. Angling and electrofishing dominated sampling and was used at all sites with the exception of River Phillip, Mabou River and Saint Francis Harbour River. The two remaining methods involved gill netting fish. Passive net sets were set in a pool habitat on the West River Antigonish on one occasion. Active gill netting (pool sweeps) was conducted as the only sampling method in the Mabou River, River Phillip, the West River (Pictou) and Saint Francis Harbour River. Active gill netting consisted of researchers stretching a barrier net across the bottom of a pool, and then sweeping a gill net (mesh size 7.6cm) from the top of the pool towards the downstream barrier net. Two divers ensured the lead line of the net remained in contact with the streambed. Corralled trout where then removed.

Fish Processing

With the exception of trout from NorthEast Lake and Boot Lake, all trout were processed in the laboratory within 1 day of sampling. NorthEast and Boot Lake fish were processed in the field as the remoteness of the sites made transportation/preservation difficult.

For each trout, fork length was measured to the nearest millimetre, the whole body was weighed to the nearest gram and scales were removed for later age determination. Fish were then dissected to determine sex and examine their stage of maturity using the criteria described in Vladykov (1956). If a female was mature (ova filled with yolk, ova diameter >1mm), the ovaries were removed, weighed to the nearest gram and preserved in a 5% buffered formalin solution (Vladykov 1956).

As some trout were processed in the field, fresh ovary weight was not measured. As a means of estimating the fresh ovary weight of these fish, a subsample of 31 ovaries which were weighed when fresh were then re-weighed following at least 1 month in the formalin solution. A correction factor was then devised by dividing preserved ovary weight/fresh ovary weight, and was applied to the preserved ovary weights of those fish processed in the field.

Egg Enumeration

Dependant on the size of the fish, the number of eggs was evaluated by one of two methods. For fish with a fork length less than 270mm (i.e. Figure 2), ova were counted using a dissecting microscope with 6.4x magnification. For trout greater than (or equalling) 270mm, the number of eggs was estimated gravimetrically. Gravimetric measurements were made by first weighing both entire ovaries (dried with paper towel). A representative 1g subsample of eggs (+ovary flesh), taken from the center portion of one ovary was then weighed and eggs counted. The number of eggs/g was extrapolated to the whole ovaries weight. As a means of quality control, a subsample of 6 ovaries examined using the gravimetric method were re-counted by eye as described above (Table 2).

Atretic eggs were included in the total count, however the number of atretic eggs were recorded. In both methods, 10 randomly selected eggs (not including atretic eggs) were measured to the nearest 0.1mm.

Age and Length at Maturity

All ages were determined using scales. Two readers evaluated each set of scales. For each set of scales (fish) on which they disagreed, the scales were re-evaluated and a consensus was made.

Length at maturity was calculated for all female data. Logistic modelling fit to the binomial maturity data to fork length data. To test if the logistic model would sufficiently describe the data, we first examined the parameter estimates and standard errors of a simple logistic regression model with binomial errors. If fork length had a significant ($P<0.05$), and positive effect of the probability of being mature, we continued with the logistic model. Logistic modelling was preformed using RGUI 2.6.0 statistical software.

During sampling, all young-of-year (YOY) fish were examined for signs of maturity (Males – kype formation, color change, Female - distended abdomen). These fish were generally less than 10cm, fork length. There was no evidence of maturity at this age and all fish were released. Therefore, 25 data points were entered to represent immature YOY trout with fork length less than 8.5 cm.

Water Chemisty Sampling

Water chemistry data were obtained in two ways. Water samples collected by the NSDFA in Arnold and Northeast Lakes were processed by the Capital District Health Authority – Environmental Services division. Additionally, data were extracted from the Environment Canada online water chemistry database, Envirodat (http://map.ns.ec.gc.ca/envirodat/).

RESULTS

Sample Characteristics

A total of 62 brook trout were sampled from lakes, of which 27 were mature females, 8 were immature females, 23 were mature males and 4 were immature males. Fork length ranged from 185 mm to 322 mm with a mean of 244 mm and a standard deviation of 34 mm.

A total of 63 brook trout were sampled from streams and rivers, of which, 26 were mature females, 20 were immature females, 4 were mature males and 13 were immature males. Fork length ranged from 111 mm to 311 mm with a mean of 172 mm and a standard deviation of 55 mm.

A total of 59 brown trout were sampled from streams and rivers, of which, 23 were mature females, 13 were immature females, 13 were mature males and 10 were immature males. Fork length ranged from 205 mm to 530 mm with a mean of 318 mm and a standard deviation of 98 mm.

Fecundity

Brook Trout – Lakes

The number of eggs produced by a female lake-dwelling brook trout correlated with fork length (R^2=0.49) in an exponential form. Using this regression equation, $y = 0.067x^{1.63}$, a 200mm brook trout would produce ~380 eggs and a 300 mm brook trout would produce ~730 eggs (Figure 3).

The mean number of eggs per mm of fork length was 2.35 (1.56, SD), (Table 3). Egg number per body length was positively correlated with fork length indicating that larger fish contained more eggs per mm fork length than smaller trout (Figure 4). The mean number of eggs per gram body weight was 2.95 (0.69, SD) (Table 3). The number of eggs per gram of body weight was negatively correlated (R^2 = 0.48) with total body weight indicating that heavier fish had fewer eggs per gram of body weight (Figure 5).

Brook Trout – Rivers / Streams

The number of eggs produced by a female stream-dwelling brook trout was highly correlated (R^2 = 0.93) with fork length in an exponential form. Using this regression equation, $y = 0.003x^{2.20}$, a 200mm brook trout would produce ~346 eggs and a 300mm brook trout would produce ~844 egg (Figure 3).

The mean number of eggs per mm of fork length was 1.70 (0.89,SD) (Table 3). Eggs per mm of fork length was highly correlated (R^2=0.79) with fork length, with a linear regression indicating that larger fish contained more eggs per mm fork length than smaller trout (Figure 4). The mean number of eggs per gram body weight was 4.65 (1.09, SD) (Table 3). The number of eggs per gram of body weight was negatively correlated with total body weight (R^2 = 0.37) indicating that heavier fish had fewer eggs per gram of body weight (Figure 5).

Brown Trout – Rivers / Streams

The number by eggs produced by a female stream-dwelling brown trout was highly exponentially correlated with fork length, providing the most typical fecundity curve of all species/ecotypes ($y= 0.00003x^{2.99}$, R^2 = 0.88). Using this regression equation, a 200mm brown trout would produce ~228 eggs and a 300mm brown trout would produce ~765 eggs (Figure 3).

The mean number of eggs per mm of fork length was 3.44 (2.63, SD) (Table 3). This was highly correlated (R^2=0.88) with fork length, with a linear regression indicating that larger trout contained more eggs per mm fork length than smaller trout (Figure 4). The mean number of eggs per gram of body weight was 2.66 (0.63, SD) (Table 3). The number of eggs per gram of body weight was not correlated to the weight of the individual brown trout (Figure 5).

Size of Mature Eggs

The size of mature eggs observed in trout of all species was largely dependant on the fork length of the fish. Regression analysis show correlation between fork length and mean egg diameter for lake-dwelling brook trout (R^2= 0.41), stream-dwelling brook trout (R^2= 0.18) and stream-dwelling brown trout (R^2= 0.52) (Figure 6).

Mean egg diameter in mm was 3.4 (0.55, SD) for lake dwelling trout, 4.0 (0.25, SD) for stream dwelling trout, and 5.2 (0.45, SD) for stream dwelling brown trout. Variation in egg diameter within individual fish was generally low compared to the variation between fish of similar size (Table 3).

Rates of Atresia

No clear trend in the mean proportion of atresia and fork length was evident for any of the three species/ecotype data sets (Figure 7). The mean rate of atresia was 0.02 (0.03, SD) for lake dwelling brook trout, 0.01 (0.02) for stream dwelling brook trout, and

0.03 (0.04, SD) for stream-dwelling brown trout (Table 3). The maximum observed rate of atresia was of 0.11 and the vast majority were under 0.04 (Figure 7).

Age and Length at Maturity

Length at age data indicated differences in growth rates between habitat types. Mean length at age (yrs) was 201mm at 1+ and 242 mm at 2+ for lake-dwelling brook trout and was 154 mm at 1+ and 216 mm at 2+ for stream-dwelling brook trout. The difference in growth was believed to influence the size structure of the sample from each habitat type and resulted in a higher proportion of small (<194mm fl) individuals sampled from stream habitats for fecundity analysis. Three-year-old brook trout were larger in stream habitat and this result may be related to the presence of fast growing anadromous trout in the sample. Only one brook trout aged 4+ was sampled from stream habitat (Table 4).

One-year-old brown trout were not sampled in this study because of the absence of characteristic indicative of sexual maturation. Length at age data indicated brown trout growth rates were similar to growth of brook trout in stream habitat (Table 4).

The fitting of logistic models indicated that only the stream-dwelling brown trout data was suitable as-is for logistic modelling with fork length being an acceptable predictor of maturity (P=0.013). During sampling, young-of-year (YOY) brook trout had been sampled and immediately released to reduce our impact on local populations. As all YOY appeared immature, it was not thought important to retain these fish. However, as sample size for both female data sets of lake-dwelling and stream-dwelling brook trout, it was deemed statistically and biologically acceptable to add 25 points of YOY data, indicating immaturity for fl<85mm, to each brook trout data set. This increased the power of fork length as an indicator of maturity from P=0.089 to P=0.003 for lake-dwelling brook trout and from P=0.673 to P=0.000 for stream-dwelling brook trout (Figures 8 and 9). To remain consistent, and to provide a better fit for the model, the brown trout data set also had 25 immature YOY data points added. This increased the power of fork length as a predictor of maturity to P=0.000 (Figure 10).

Approximately 10% of lake-dwelling female brook trout were sexually mature at fl= 135mm, 50% at 196mm and 90% at 255mm (Table 3). For stream-dwelling brook trout, 50% were mature at fl=188mm and 90% were mature at 341mm (no 10% estimate was made as the model predicts YOY as being mature). Finally, brown trout matured at slightly longer fork lengths with 10% being mature at 139mm, 50% were mature at 236mm and 90% were mature at 332mm (Figure 11).

DISCUSSION

Fecundity

Estimated fecundity for Nova Scotia lake-dwelling brook trout was in general slightly greater than that of Quebec brook trout expressed by Vladykov (1956), especially for fish with fork lengths <300mm. Above 300mm fork length, Vladykov's estimates were larger, however few large fish (N= 2, >300mm fl) in our sample likely contributed to an underestimate of the exponent variable in the regression of fecundity on fork length, thus underestimating the number of eggs for larger fish. Also, we estimated both lake-dwelling and stream-dwelling brook trout to be marginally more fecund than those described by Van Zyll de Jong et al. (1999). Lakes sampled by Van Zyll de Jong et al. (1999) were similar in conductivity but were on average much larger.

Our estimates of fecundity for stream-dwelling brown trout were slightly higher then those estimated by Taube (1976) for the Platte River, Michigan, USA, even though they expressed fecundity in a linear manor. Indicies of productivity for the Platte River, were not described.

Pearson correlation coefficients for fecundity curves (No. eggs vs. fork length), was smallest for lake-dwelling brook trout, indicating a higher degree of between-individual variability. The reasons for this variability are unknown and may warrant further investigation. The use of this fecundity data may only prove useful as a general estimate and refinements on a lake-by-lake basis may be required for incorporation into production models. Conversely, fecundity for stream-dwelling brook trout and brown trout showed little between-individual variability, and consequently, between-river variability. Therefore, there is little evidence to suggest that these fecundity data should not be used for rivers of similar ecotypes.

The discrepancies observed between lake-dwelling brook trout and stream-dwelling brook trout, where lake fish have fewer eggs/mm fl and more eggs/g body wt., is presumably a function of the size distribution of each data set, where the lake-dwelling trout sample contained fewer small trout. As length-weight relationships are exponential, weight would increase disproportionately with length, thus leading to the divergence of values. However, for brook trout of equal size, there is no obvious difference in the number (and corresponding weight) of eggs produced. This differs from findings of McFadden et al. (1962) where brown trout from low fertility waters matured later and produced a smaller weight of total eggs produced than those from more fertile waters.

In a study of Ontario lake trout (*Salvelinus namaycush*, Walbaum), those from lakes of low conductivity matured later, attained maturity at similar or smaller body size and were less fecund than those from higher conductivity lakes (Trippel 1993). Vladykov also found that the fecundity of lake-dwelling brook trout was greater in fish from lakes with high prey resources (Vladykov 1956). Therefore, the use of ecotypes as the predominant division between fecundity data, as opposed to system-specific data, may be vulnerable to error as a result of differences in specific growth affected by density-dependence and prey-resources. However, because of the large amount of work, and the removal of reproductively mature trout when assessing fecundity, these ecotype-specific estimates minimize error when inferring fecundity.

It has been proposed that the growth and density of lentic brook trout may be negatively correlated with the complexity of fish communities (Norman et al. 1994). As lake-dwelling brook trout sampled from Arnold and Northeast lakes come from fish communities low in diversity when compared with other dystrophic, tanic-stained Nova Scotia lakes, trout production is these systems is likely unique. The effect of this on fecundity and age of maturity is unknown and may affect the transferability of these data to systems with comparable geophsicochemical attributes but more complex fish communities.

Size of Mature Eggs

Egg diameter for brook trout in either ecotype was not significantly different that those described by Vladykov (1956), though he generally assumed that egg diameter was more closely related to stage of maturity than length of fish. Our observed egg diameter in brown trout did not substantially differ from that described by Taube (1976). For the purpose of future implications of fecundity and associated parameters, size of eggs should not be considered a factor controlling reproductive success and consequently trout production.

Rates of Atresia

Rates of atresia were generally low, however this was expected as fish in the later stage of maturity generally have a lower proportion of atretic eggs (Vladykov 1956). Atresia is not likely a factor worth considering in future estimations of fecundity or egg deposition/trout production.

Length at Maturity

Length at maturity was similar for lake-dwelling brook trout and stream-dwelling brook trout, with 50% maturity (ML50) for each group occurring at approximately 190mm. For many fast-growing populations, brook trout may reach this length by the end of their second growing season (1+). For trout, maturation is likely more strongly dependant on the attainment of a physiological critical size rather then age (Meyer et al. 2003). Therefore, when modelling trout production/ populations in similar Nova Scotia ecotypes, maturity may be safely estimated by assessing growth rates and extrapolating length-at-age information to this length-at-maturity relationship. By doing so, the effect of density-dependant growth, in addition to environmental constraints on growth, is included in the length at maturity estimates.

Additionally, from population-specific growth rates and based on length at maturity, age at maturity can be calculated so as to provide additional information of fishing mortality induced reductions in reproductive potential.

However, the "critical size" proposed by Meyer et al. 2003 is largely unknown, though our models suggest maturation based on fork lengths directly related to the growth of fish in our samples. That is, brook trout which exhibited slower growth (streams) began to mature at smaller sizes than lake-dwelling trout, but at what length lake-dwelling brook trout would mature given slower growth is unknown. Further investigation of fast growing lake populations may provide valuable information on early maturation. Because smaller sized (100mm to 190mm) brook trout were not sampled from lakes, the onset of maturation may have been overestimated.

Length at maturity modelling suggests that brown trout mature at a later age (>1+, i.e.) than brook trout (both ecotypes), as confirmed by age analysis. This is consistent with observations made in Sweden where introduced brook trout did not live as long as brown trout, exhibiting faster growth, earlier maturation, higher fecundity and a resultant higher instantaneous mortality rate (Ohlund 2002). In Nova Scotia where brook trout are native and brown trout introduced, our data suggests that brook trout may have a reproductive strategy of producing more eggs and at an earlier age. This reproductive strategy for brook trout may offset growth lost to competition, and mortality associated from direct predation, by brown trout.

Length at maturity for stream-dwelling brook trout exhibited a much more gradual transition to maturity than that of lake-dwelling brook trout or brown trout. This represented a severe overlap in sizes of mature and immature fish. Part of this variation may be explained by the pooled-nature of our data, with large systems such as the West River Antigonish being compared with smaller systems such as Elderkin brook. Stream size and gradient have been proposed to explain variation in length-at-maturity between populations of cutthroat trout in Idaho (Meyer et al 2003). Further investigation into factors controlling maturation in stream-dwelling brook trout may refine our maturity model. Also, a data set that includes smaller trout from lake habitats would strengthen the maturity model for lake-dwelling brook trout.

MANAGEMENT IMPLICATIONS

A sound understanding of fecundity and length at maturity for trout is required to understand population dynamics, and consequently to regulate angling in a safe and sustainable manor. Population models require a significant amount of population-specific information, however by extrapolating these findings to other similar ecotypes, modelling becomes a more viable option on many systems, reducing both the time spent in the field and the need to remove mature trout. These estimates of length and age at maturity may underestimate the contribution of small trout, however as a precautious and conservative estimate, these data indicate lengths/ages at which a significant proportion of spawning occurs.

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Table 1 – Water chemistry summary for select Nova Scotia systems. Represented is the mean value (or only value if N=1) and one standard deviation in parentheses (), where N ≥ 3. Only River John is not represented. Source indicates agency which collected samples. NSDFA = Nova Scotia Department of Fisheries and Aquaculture, EC = Environment Canada, TGLWA = Tangier Grand Lake Wilderness Area, SFHR = Saint Francis Harbour River, TCU=True Color Units, RCU = Relative Color Units. * Additional measurements of conductivity included. A – May be influenced by seawater, B – Main branch Cornwallis used as proxy for Elderkin Brook, which is a tributary of the Cornwallis River, C – James River is a major tributary of the West River, Antigonish, D – Goose Harbour Lake is the headwater lake to the Saint Francis Harbour River.

System	Site	Source	N	Year	Specific Cond.	pH	TOC	Alkalinity	Total Phosphorous	Dissolved Calcium	Color
					µS/cm	pH units	mg/L	As $CaCO_3$	mg/L	mg/L	TCU
TGLWA	Arnold Lake	NSDFA	3*	2007	28 (2)	5.2 (0)	6.7 (0.4)	<3.0	0.005 (0.001)	<0.5	62.5 (4.3)
TGLWA	Northeast Lake	NSDFA	3*	2007	31 (2)	4.9 (0)	9.0 (0.6)	<3.0	0.009 (0.004)	<0.5	86.3 (6.8)
Elderkin [B]	Cornwallis R. @ HWY #306	EC	5	1974-1975	405 (176)	7.5 (0.4)	6.7 (2.9)	51.4 (15.8)	0.061 (0.061)	63.0 (37.6)	n/a
Elderkin [B]	Cornwallis R. @ Lovett Bridge	EC	4	1982-1990	228 (42)	7.4 (0.5)	3.6 (3.1)	42.8 (6.3)	0.049 * 1 sample only	26.5 (4.7)	n/a
River Philip	@ Hwy #204 Bridge	EC	21	1971-1980	231 (109)	6.8 (0.3)	4.1 (2.3)	9.4 (3.0)	0.021 (0.009)	11.8 (5.8)	17 (11) *RCU
River Philip	@ Trans Canada Hwy Bridge	EC	19	1974-1977	62 (21)	6.9 (0.5)	4.5 (2.1)	8.4 (2.8)	0.015 (0.007)	3.7 (0.7)	17 (13)
Waughs R.	@ Falls	EC	1	1979	87	7.3	n/a	20.9	n/a	8.1	n/a
West R. Pictou	Durham	EC	1	1974	63	6.5	3.8	7.8	n/a	3.5	10 *RCU
West R. Antigonish	James R. @ Reservoir [C]	EC		1987	37 (1)	6.5 (0.3)	7.4 (2.6) *DOC only	4.1 (2.3)	n/a	2.2 (0.3)	50 (17) *RCU
West R. Antigonish	@ Hwy #4 Bridge	EC	1	1990	660	7.2	2.3 *DOC	20.2	0.005	31.0	10 *RCU
West R. Antigonish	James R. [C]	EC	1	2006	38	6.79	9.6	<20	0.023	2.1	92 *RCU
West R. Antigonish	Unknown	EC	2	2006	249	7.5	3.8	20.4	0.010	n/a	23
SFHR	Goose Hbr. L.[D]	EC	1	1979	37	5.9	n/a	0.5	0.007	1.2	n/a
Mabou R.	SW Mabou R.	EC	1	1979	1280 [A]	8.4	n/a	56.7	n/a	89.0	n/a

Table 2 – Results of quality assurance testing, where egg counts estimated gravimetrically were verified by microscope/eye counts. Percent error derived by the quotient of (recount / gravimetric count)/100.

Fish Reference #	Fish FL (mm)	Gravimetric Estimate	Re-count (by eye)	% Error
52	311	880	791	11.3%
96	310	560	548	2.2%
104	322	1598	1543	3.6%
111	330	791	742	6.6%
157	287	714	623	14.6%
177	305	1364	1276	6.9%
Mean Error Rate				**7.5%**
Standard Deviation				**4.7%**

Table 3 – Summary of results fro sample, fecundity and sexual maturity parameters of lake-dwelling brook trout, stream-dwelling brook trout and stream-dwelling brown trout populations.

	Brook Trout (Lakes)	Brook Trout (Streams)	Brown Trout (Streams)
Sample Characteristics (Fork Length) (mm)	N = 27 Mean FL = 244 SD FL= 34 Range FL = (185, 322)	N = 16 Mean = 172 SD = 55 Range = (111, 311)	N = 24 Mean = 318 SD = 98 Range = (205, 530)
Number of Eggs per Individual	Min. = 276 Max. = 1543 Mean = 546 SD = 231 N = 27	Min. = 94 Max. = 791 Mean = 295 SD = 215 N = 16	Min. = 235 Max. = 5712 Mean = 1360 SD = 1503 N = 24
Number of Eggs per mm Fork Length	Mean = 2.35 SD = 1.56 N = 26	Mean = 1.70 SD = 0.89 N = 17	Mean = 3.44 SD = 2.63 N = 20
Number of Eggs per gram Body Weight	Mean = 2.95 SD = 0.69 N = 26	Mean = 4.65 SD = 1.09 N = 17	Mean = 2.66 SD = 0.63 N = 23
Size of Eggs (mm)	Mean = 3.41 SD = 0.55 N = 26	Mean = 4.00 SD = 0.25 N = 17	Mean = 5.18 SD = 0.45 N = 23
Egg Size Variation within Individuals	Mean SD = 0.24 N = 26	Mean SD = 0.19 N = 17	Mean SD = 0.23 N = 23
Rates of Atresia	Mean = 0.02 SD = 0.03 N = 17	Mean = 0.01 SD = 0.02 N = 13	Mean = 0.03 SD = 0.04 N = 12
Length at 10% Maturity	135 mm	N/A	139 mm
Length at 50% Maturity	196 mm	188 mm	236 mm
Length at 90% Maturity	255 mm	341 mm	332 mm

Table 4 – Summary of age, length at age and expected fecundity at age/length for lake-dwelling brook trout, stream-dwelling brook trout and stream-dwelling brown trout samples. Exp. Fecundity = Expected fecundity for mean length at age.

Age	Parameters	Brook Trout (Lakes)	Brook Trout (Streams)	Brown Trout (Streams)
1	Mean	201	154	
	Range	(194 – 207)	(111 – 223)	n/a
	Sample Size	N=3	N=16	
	Exp. Fecundity	381 eggs	195 eggs	
2	Mean	242	216	211
	Range	(195 – 267)	(159 – 298)	N=17
	Sample Size	N=15	N=19	(174 – 267)
	Exp. Fecundity	515 eggs	411 eggs	268 eggs
3	Mean	285	310	304
	Range	(271 – 310)	(295 – 322)	N=13
	Sample Size	N=5	N=5	(232 – 376)
	Exp. Fecundity	673 eggs	909 eggs	797 eggs
4	Mean		360	386
	Range	n/a	(-)	N=3
	Sample Size		N=1	(282 – 460)
	Exp. Fecundity		1262 eggs	1626 eggs)
5	Mean			518
	Range	n/a	n/a	N=3
	Sample Size			(511 - 530)
	Exp. Fecundity			3918 eggs

Figure 2. Lake-dwelling brook trout with mature ova sampled on October 3/2007 from NorthEast Lake, TGLWA. This female was 228mm and contained 443 eggs.

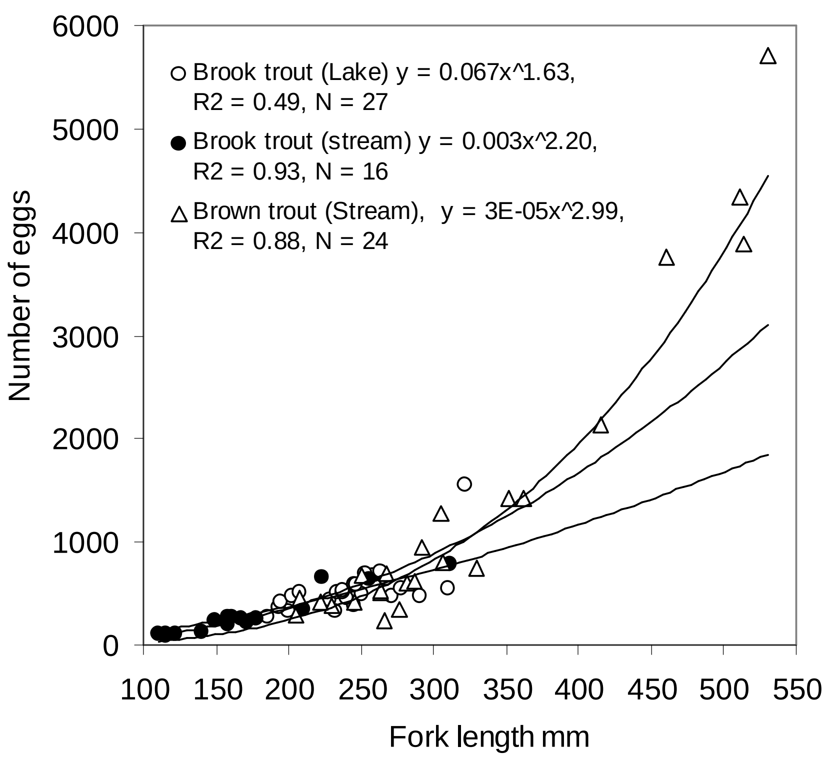

Figure 3. Fecundity and size relationship for lake-dwelling brook trout, stream-dwelling brook trout and stream-dwelling brown trout. Equations of regression lines are, from top to bottom; stream-dwelling brown trout, stream-dwelling brook trout and lake-dwelling brook trout.

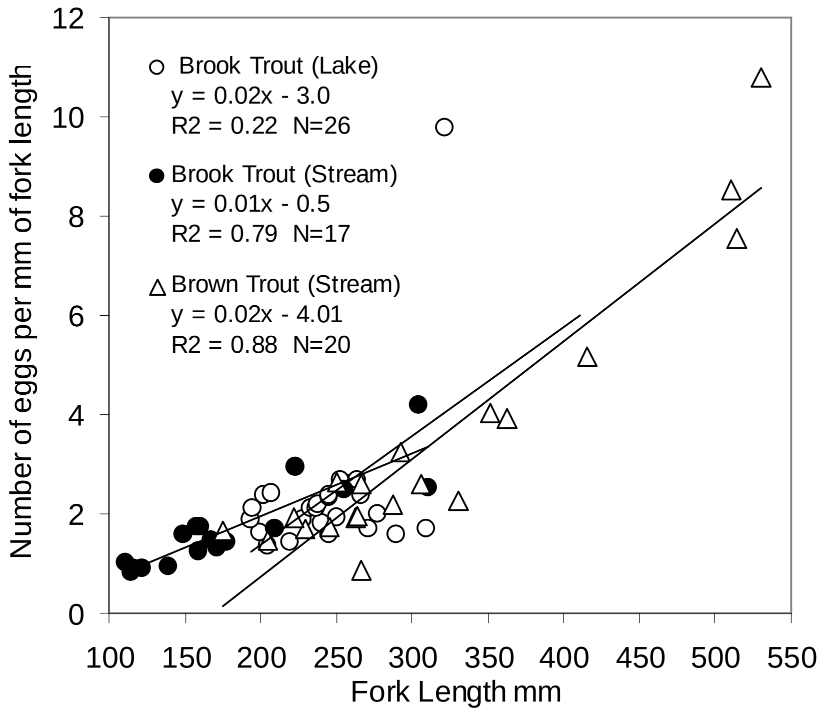

Figure 4 – Number of eggs per mm fork length and fork length relationship. Equations of the least-squares regression lines are, from top to bottom; lake-dwelling brook trout, stream-dwelling brown trout and stream-dwelling brook trout.

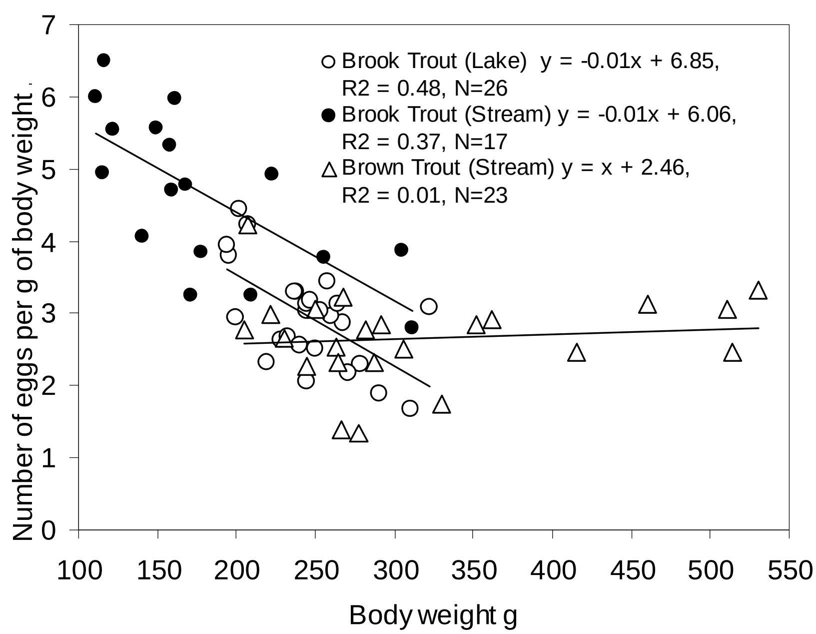

Figure 5 - The number of eggs per gram of body weight and body weight relationship. Equations of the least-squares regression lines are, from top to bottom; lake-dwelling brook trout, stream-dwelling brook trout and stream-dwelling brown trout.

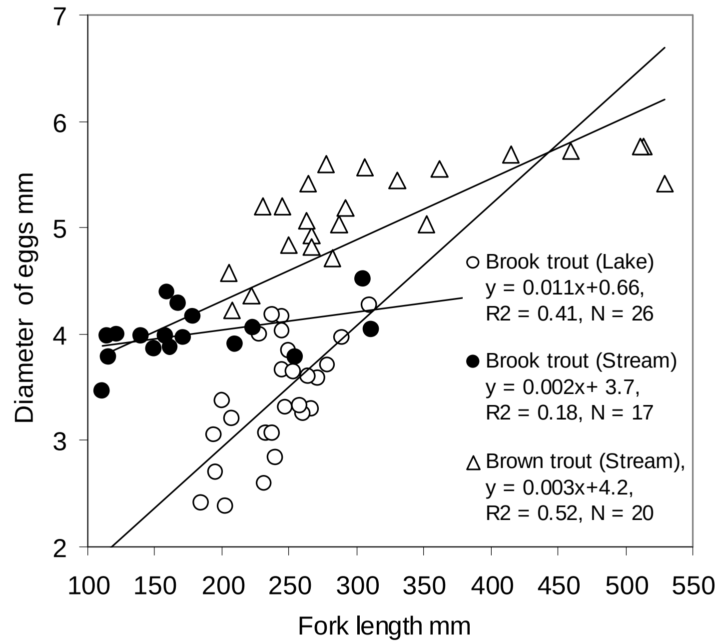

Figure 6. Mean egg diameter (mm) and fork length (mm) relationship for lake-dwelling brook trout, stream-dwelling brook trout and stream-dwelling brown trout. Equations of regression lines are, from top to bottom; lake-dwelling brook trout, stream-dwelling brook trout and stream-dwelling brown trout.

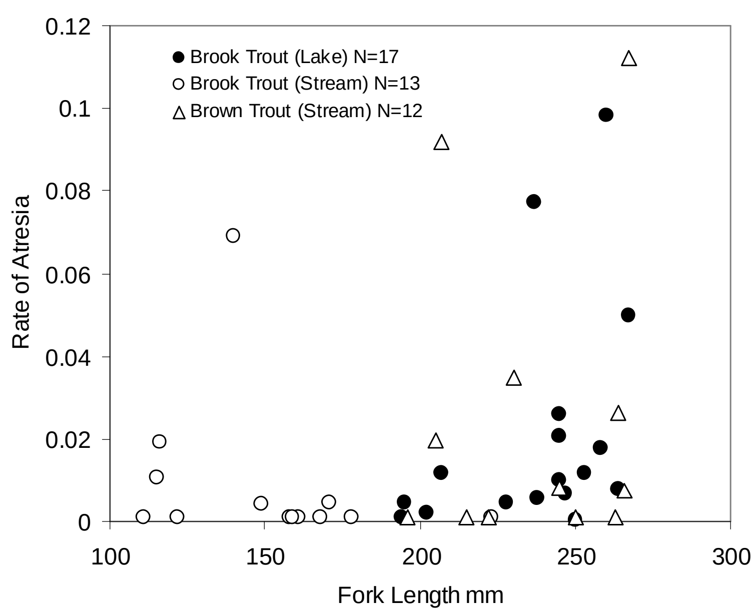

Figure 7 - Rate of atresia versus fork length (mm) of lake-dwelling brook trout, stream-dwelling brook trout and stream-dwelling brown trout.

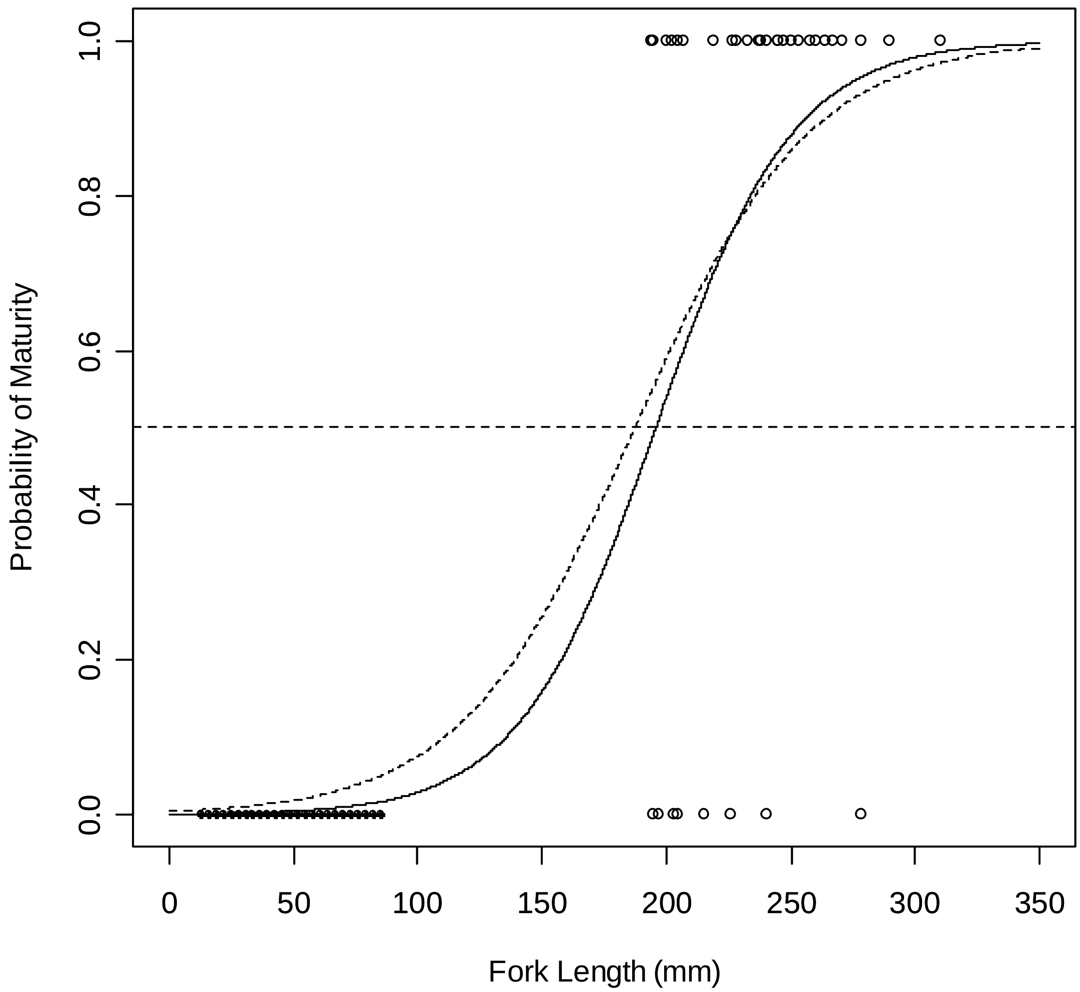

Figure 8. Probability of female maturity based on fork length for lake-dwelling brook trout. The horizontal dotted line at 0.5 indicates the 50% maturity level. The dotted line indicates maturity data (N=35) without the addition of 25 YOY data, and the solid line indicates the same maturity data with the 25 YOY data included (N=60).

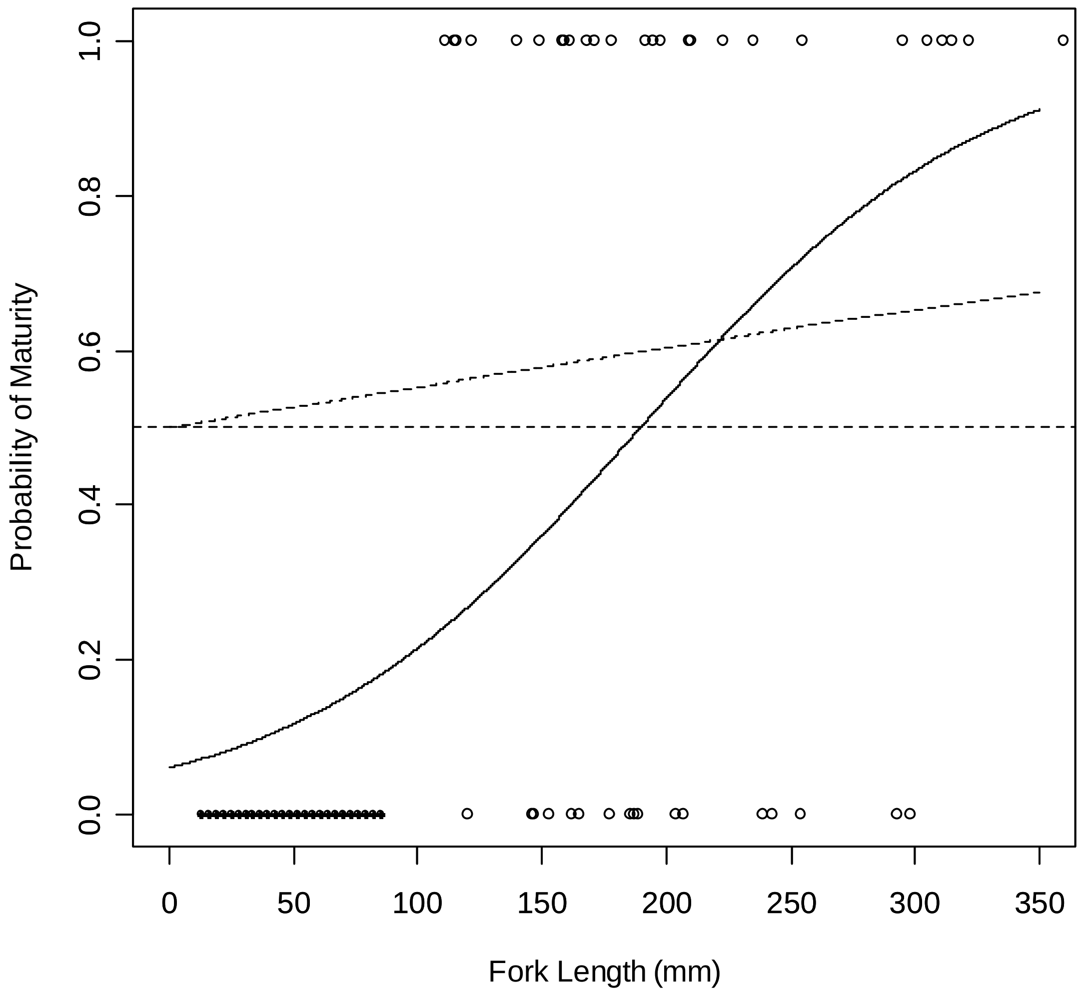

Figure 9. Probability of female maturity based on fork length for stream-dwelling brook trout. The horizontal dotted line at 0.5 indicates the 50% maturity level. The sloped dotted line indicates maturity data (N=46) without the addition of 25 YOY data, and the solid line indicates the same maturity data with the 25 YOY data included (N=71).

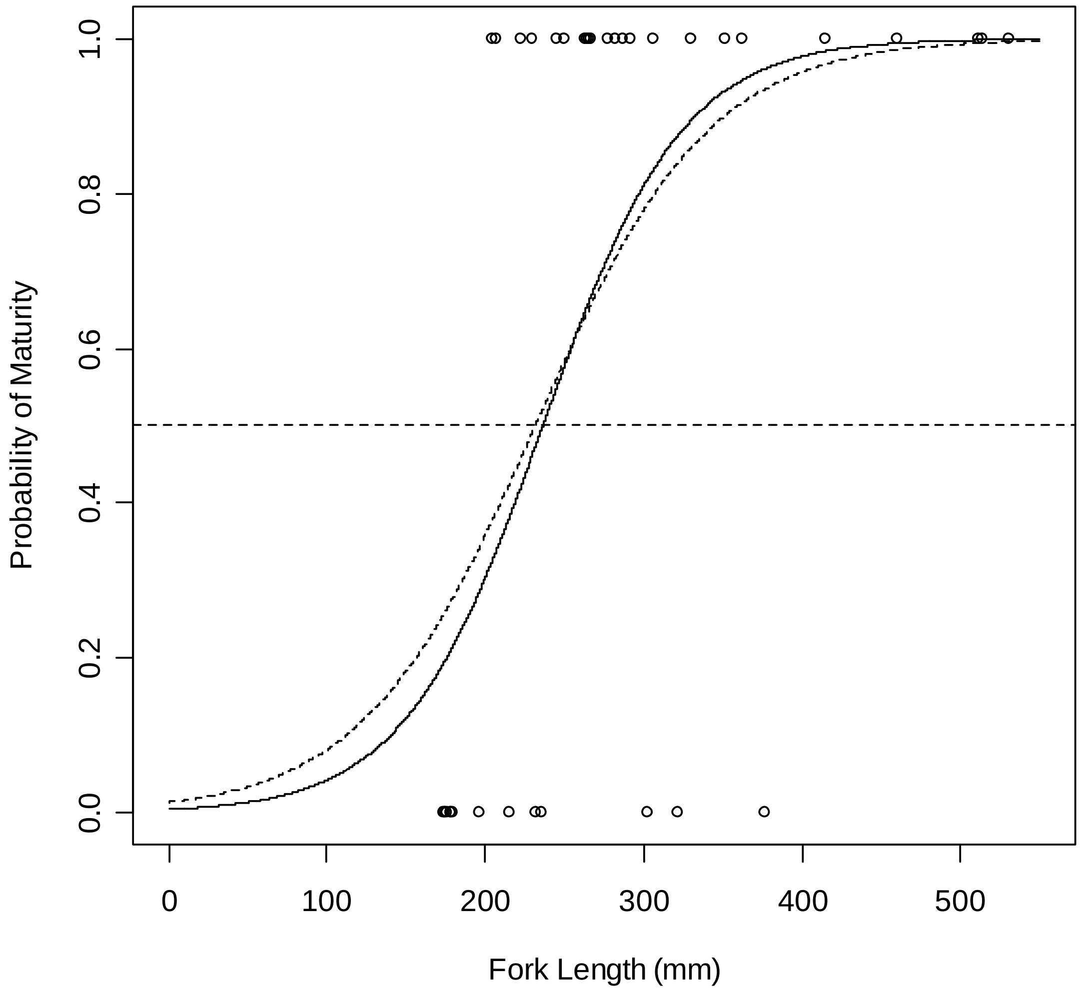

Figure 10. Probability of female maturity based on fork length for stream-dwelling brown trout. The horizontal dotted line at 0.5 indicates the 50% maturity level. The dotted line indicates maturity data (N=36) without the addition of 25 YOY data, and the solid line indicates the same maturity data with the 25 YOY data included (N=61).

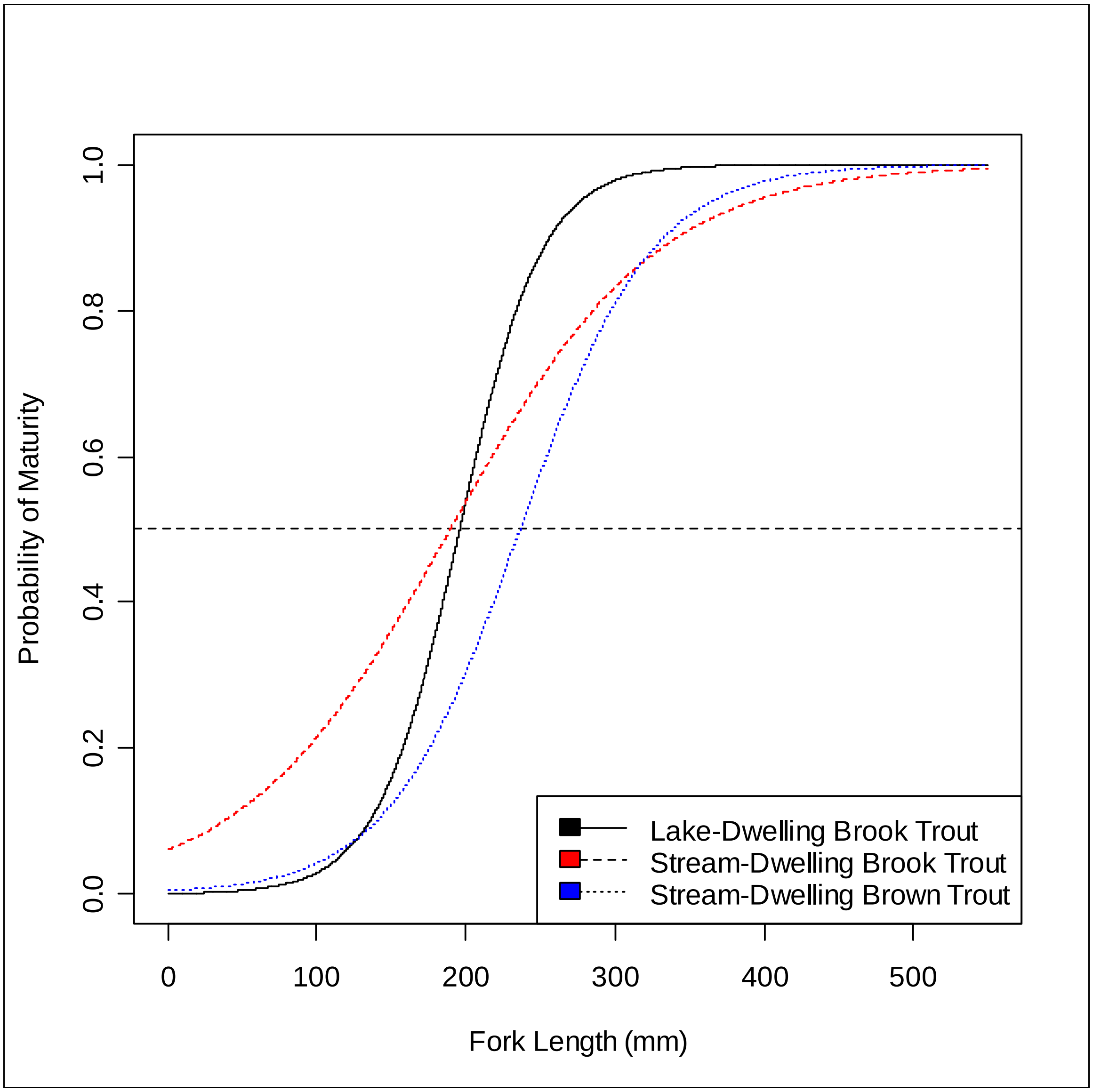

Figure 11 . Probability of female maturity based on fork length. Sample sizes for all models (including additional YOY data –described above) were 60, 71 and 61 for lake-dwelling brook trout, stream-dwelling brook trout and stream-dwelling brown trout. The dotted horizontal line indicates a 50% probability of maturity (ML50).