THE MORPHOLOIGCAL VARIATION OF FISH IN NOVA SCOTIA STREAMS

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Abstract: This research is a small component of a long-term ecological study examining the effects of river restoration on fish population and health. The research assesses the natural variation of morphological features (length, weight and age) as well as population structure of brook trout (*Salvelinus fontinalis*), brown trout (*Salmo trutta*) and Atlantic salmon (*Salmo salar*). Eight streams in Antigonish County, Nova Scotia, Canada were designated study sites and were all sampled equally from 2011 through 2015. Four of the eight sites will be designated treatment sites in the coming five years (2016-2020). This report aims to quantify the natural variation in order to create a baseline for comparison to restored treatments sites once completed. As expected, there were significant differences found when comparing all variables. Data analysis revealed that brook trout and brown trout have numbers that are consistent with past studies when looking at the number of fry in comparison to other age classes. Atlantic salmon had the lowest number of individuals in the fry age class. Population data showed variation between years, site and species. Brook trout populations varied and show signs of decline in most sites. Brown trout did not appear in all eight sites but, where found, were in high abundance and typically stable. Salmon showed a higher range of variability in population numbers throughout the sites and years. They were only found consistently in three of the eight sites. Further research using this data is necessary to find all patterns of variability. Site pairing for control and treatment sites need to be reassessed.

Introduction: Brook trout (*Salvelinus fontinalis*), brown trout (*Salmo trutta*) and Atlantic salmon (*Salmo salar*) are some of the most popular species targeted for recreational fishing in Nova Scotia (DAF, 2005). Ensuring a stable and healthy population of these species is of benefit to the province economically (DAF, 2005). In Nova Scotia, rivers and streams populated by these species have been degraded due to an influx in development province wide. In Antigonish

County, rivers and streams have been victim to historical damage and degradation that continues into the present. Channels have been straightened for logging purposes as well as degraded by agriculture activity, road development, urban development and forestry (DAF, 2005). Degradation to rivers is a threat to biodiversity and is especially concerning for the stability of trout and salmon populations (Wohl, 2005). An inflow of sediment from road development, alteration of hydrology and the removal of riparian vegetation is decreasing habitat complexity and disrupting the specific conditions preferred by the focal species (Bernhardt, 2007). Degraded streams can be characterized by wide and eroded banks, influx of fine sediment, uniform depth, increased velocity and temperature as well as minimal sinuosity (McInnis et al, 2008). Habitat heterogeneity is important for fish populations as different species and individuals utilize different spatial areas in the stream for foraging and protection from predation (Heggenes et al, 1999). Habitat complexity also allows for different species to coexist with reduced interspecies competition (Heggenes et al, 1999).

In areas of serious degradation, river restoration approaches have been used to improve conditions. River restoration is meant to use natural material to mimic and induce conditions that would occur in healthy streams (McInnis, 2008). It is a form of ecosystem management that works to enhance aquatic habitats to restore natural ecosystem functions therefore restoring fish populations (DFO, 2006). These methods of ecological engineering are implemented to allow streams to revert to more natural conditions, and are significantly important for conservation efforts (Wohl, 2005). A study by McInnis et al, in 2008, discussed the benefits of restoration on a stream in Antigonish County in regards to Atlantic salmon populations, but expressed the need for a study examining the long term effects. The understanding of the importance of river restoration is becoming known throughout North America, and as such, is becoming a necessary cost for local governments (Bernhardt et al, 2005). The province of Nova Scotia is interested in the effects of in-stream restoration on fish population and health, and whether or not these efforts are successful. As such, this research is part of a larger, ten year ecological study examining the effects of river restoration processes on three species of economic importance to the province; brook trout, brown trout and Atlantic salmon. This long term study is ongoing and currently at its halfway point. For the past five years, data has been collected by conducting habitat assessments and fish population assessments on eight sites in Antigonish County. This is done to create a comprehensive, detailed picture of the current conditions of both the habitats and fish populations. In the next five years, restoration will be done on four of the eight sites. The purpose of this study is to create a broad understanding of the effects on habitat, fish health and population structure caused by river restoration efforts. Additionally, the study will be able to give a broad understanding of population structure over a long period of time to accurately estimate the stability of the populations of important sport fish. Based on angler surveys, brook trout populations are declining but results could be a consequence of decreased angler participation (DAF, 2005). Additionally, Atlantic salmon in Nova Scotia are currently listed as threatened with some regional populations listed as endangered (DFO, 2012). Because a long term comprehensive scientific study has not been done for populations in this area, the additional results could prove beneficial to the province for management purposes.

The focus of this component of the study is to look at the natural variability of fish morphological features (length, weight, age) and the variability of population structure. As data has been collected for five consecutive years, we are able to create a comprehensive base-line of natural variance for all variables for comparison post-restoration. To understand if river restoration is in anyway beneficial to fish, it is first crucial to understand how they naturally vary in their current environment. Population structure of these fish is of significant concern as stable numbers are needed to maintain a sustainable recreational fishery (DAF, 2005). Brook trout, brown trout and Atlantic salmon have various life histories, but one commonality is the importance of lotic habitat. Healthy stream habitat is crucial for the developing years of these salmonid species. The variance in growth and population of fish is typically due to the limiting factors levied by their environment (Milner et al, 2003). Genetics and environmental conditions both play a role in determining the morphological features of fish in a population and the level of variation (Pakkasmaa, 2000). Variation in population and age class structures at specific sites could be influenced by fluctuations in prey and predator density between years and sites, as well as level of competition (Parrish et al, 1998). This can also vary due to changing habitat conditions and weather patterns.

Materials are Methods:

Study Area

The eight sites studied are all located in Antigonish County, Nova Scotia, Canada (Figure 1). North (C1), Ogden (T1), South (C2), Pomquet (T2), Meadow Green (C3), Heatherton (T3), New France (C4) and Fraser's Grant (T4) are the designated study rivers. All streams are either 2nd or 3rd order streams. The sites were chosen based on characteristics that made them representative of typical streams in northern Nova Scotia. The final eight study sites were narrowed down from a large list of potential sites and were eventually chosen based on a number of different factors determined from initial assessments. Access to ocean waters was considered, making sure there were no considerable barriers to fish passage that would affect the population numbers. The level of accessibility for crew members to assess the area was also considered. The level of degradation as well as the sites ability to be restored was a deciding factor. Preferred sites were in natural conditions with no record of previous restoration. Pairing capabilities were considered when choosing the sites. Sites with similar attributes were sought in order to designate as control and treatment combinations. . Sites were located in close proximity, with approximately 40 kilometers the greatest distance between locations. All sites were assumed to be subject to same climatic conditions and weather patterns. Up to this point in the study, the sites have been treated equally

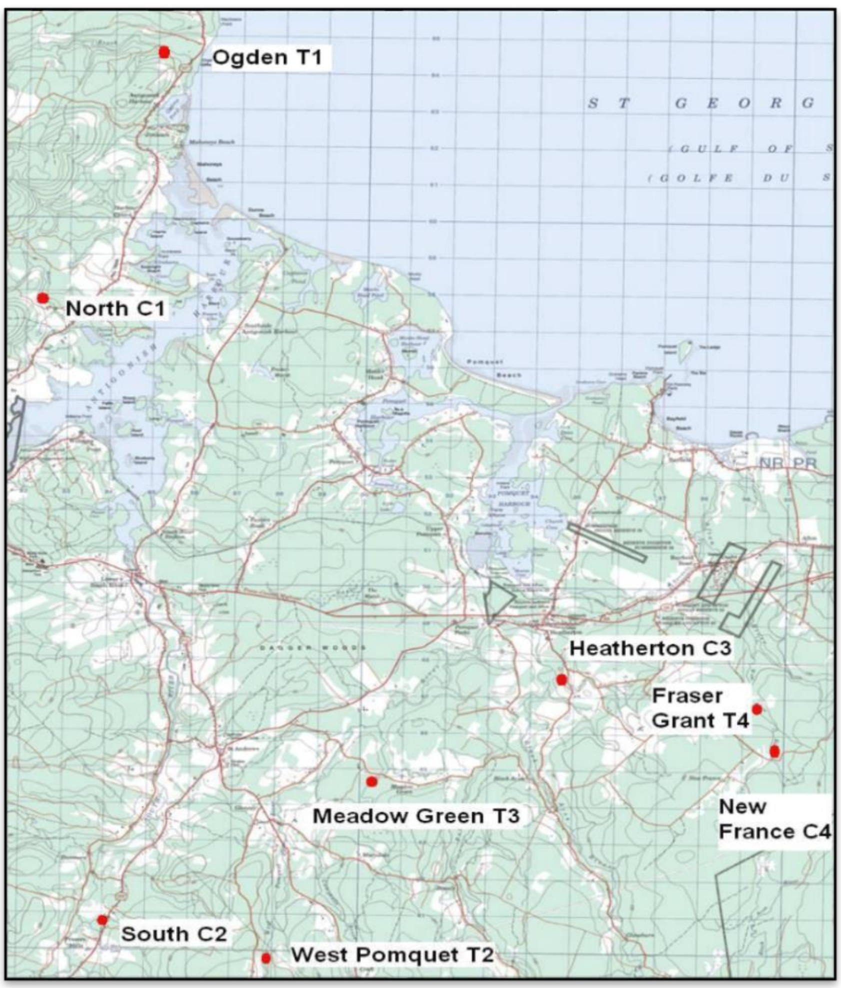

Figure 1: The eight study sites in Antigonish County, Nova Scotia, Canada. Each are labelled with treatment (T) or control(C) designations and pairings.

Habitat Assessments

During each summer over the past five years, all eight sites were visited once and habitat conditions were assessed. At a period of low flow, a comprehensive pre-restoration habitat assessment was done on a quantified 100 meter section of each stream. The section was marked to ensure the same area was visited each year. To assess the area, data loggers were deployed to monitor air temperature and quality from June 1st to November 1st. Water chemistry parameters were also measured including pH, DO and conductivity. Temperature was measured both upstream and downstream. A deployed temperature logger was installed to continuously collect water temperature data from June 1st to November 1st for three years. Stream morphology was systematically detailed. Substrate conditions, sediment size, distribution and embeddedness were visually assessed using $50cm^2$ quadrats. To assess the quality of the habitat in relation to focus species preference, habitat types were measured looking at pools, riffles and bars. Channel data was also recorded measuring bank width, wetted width and depth, sinuosity and slope. Stream data was collected such as velocity and transit time.

Fish Population Assessment

In the period between July and August of every year, a single day assessment was done to gain an estimate of the population of fish at each site. To do so, a triple-pass deduction electrofishing method was used. A 100 meter section was barricaded off using nets to create a closed system. Data was collected for all species caught, not just the species of focus. Fish were anesthetized while being processed and then released back into the environment. For every fish caught, a fork length measurement was taken to the nearest millimeter, which included fish that were not species of focus. For some focal fish, weights to the nearest gram were taken and some scale samples were collected as aging structures. Scales samples were taken from the fish below the dorsal fin above the lateral line. Fish were aged by standard ageing methods using scale samples. Scales were mounted on a slide and covered with a coverslip. The scales were analyzed under a microscope at 10x magnification. Annual growth zones were counted starting from the annulus and counting toward the edge of the scale to determine age.

Data Analysis

The data analysis was completed using the data collected over five years for all eight sites. The data that this report analyzes is mainly the information collected during the fish population assessment. Although all fish species caught were measured and recorded, this report only focuses on brook trout (*S. fontinalis*), *Atlantic* salmon (*S. salar*) and brown trout (*S. trutta*). As mentioned previously, every fish had a fork length measurement, but not all were weighed or age structures taken. Through exponential regression, an equation was developed to calculate a weight estimation for every fish based on the relationship between length and the actual weight measurements. This was done for each site, species and year. Age structures (scales) were taken from some fish, but not all. An ordinal logistic regression was used to give a calculated estimated age value to every fish based on the length-age relationship. From here, a more detailed data analysis could be done as all fish caught were assigned appropriate age, lengths and weights. To quantify variability, all factors needed to be considered. We wanted to know if there were significant differences between and within species, years and site. To detect these differences, a univariate analysis of variance test was used (ANOVA). Post-Hoc tests were run as well to view homogenous subsets of individual variables. All differences were considered significant where $P<0.05$.

Results

It was expected that there would be variance between all factors, especially when considering morphological features. As fish are from three different species and have various life histories, there was an understanding that genetics along with habitat conditions would play a role in variance to some extent. The main purpose of the study was to quantify this variance and report any patterns or trends that may be occurring.

Age

As mentioned previously, an ordinal logistic regression was used to calculate and estimated age for every fish caught throughout the study. These ages were used in the ANOVA analysis which reported significant differences between species. The expected results were shown within the brook trout and brown trout populations in regards to age class distribution. Figure 2 displays a large number of fry compared to the other classes. This was not the case for the salmon population. The number of fry was lower than the number of 2+ fish, showing an unusual trend. Since Figure 2 displayed age classes combined for all sites for all years, it was necessary to break down the age classes even further to analyze by site and by year for salmon specifically (Figure 3). The most significant data to analyze is from South, Heatherton and Meadow Green, as salmon only appear in the other sites sporadically and there was not sufficient data to see all trends. Both South and Meadow Green show variability in age classes throughout the years. Heatherton seems to show stable numbers as the median age is consistently 2+ for five years. There is a decrease in median age in 2011 and in 2014 at the South river site. During these years, median age was only 1+. The Meadow Green site showed a drop in median age to 1+ as well in 2013, but it returned to 2+ the following two years. Figure 4 shows the combined count of all fish and their corresponding ages, organized by site. These results were interesting as most show the expected pattern of a significantly higher number of fry than the other age classes. This pattern did not appear in Ogden and Pomquet. The number of fry is not significantly lower than the number of 2+ fish, but is does vary from the typical trend. In Pomquet, there is a higher number of fry, but not significantly. ANOVA revealed that between sites, brook and brown trout were significantly older than salmon. When disregarding site and species, and specifically looking at age classes by year (Figure 5), the typical pattern is shown overall for all fish and all sites each year, although some years show a stronger difference between fry and other age classes than others.

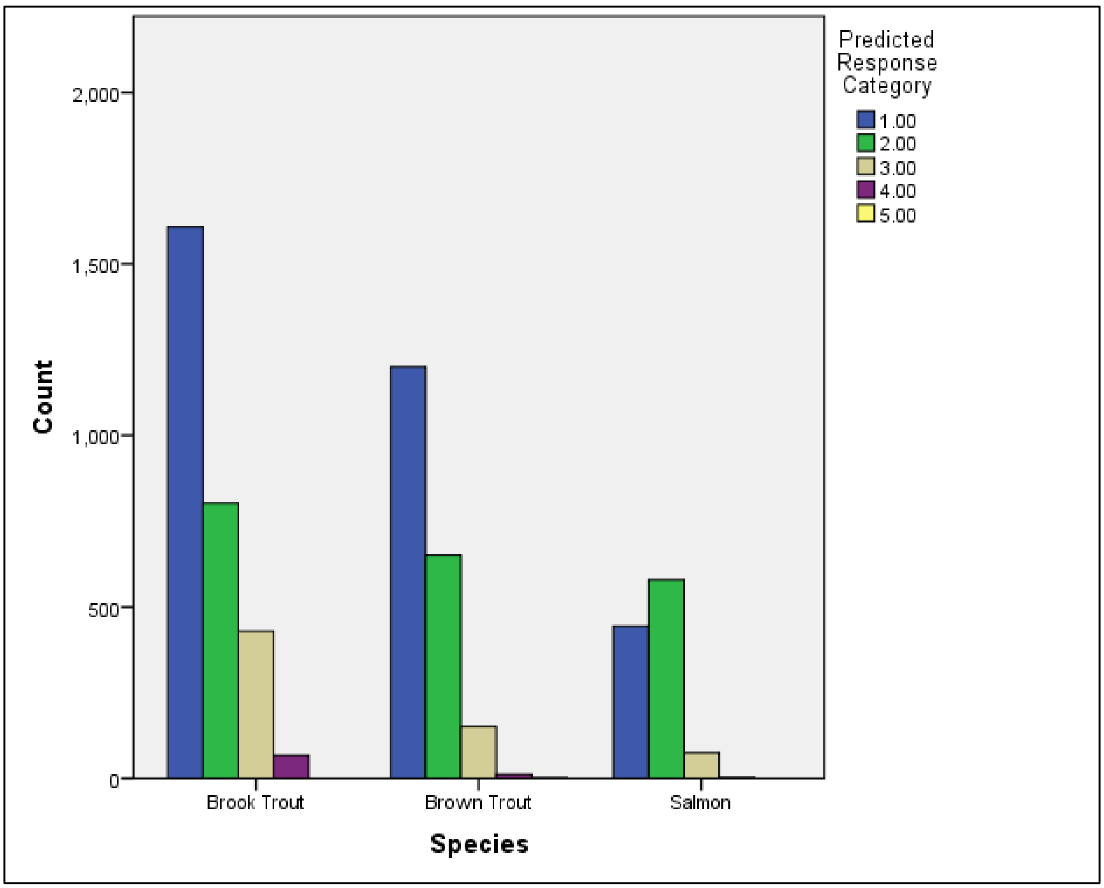

Figure 2: Total number of fish in each age class by species combined for all five years and all eight sites. Predicted responses, determined by ordinal linear regression, represent age classes in years beginning with 1.00 representing fry.

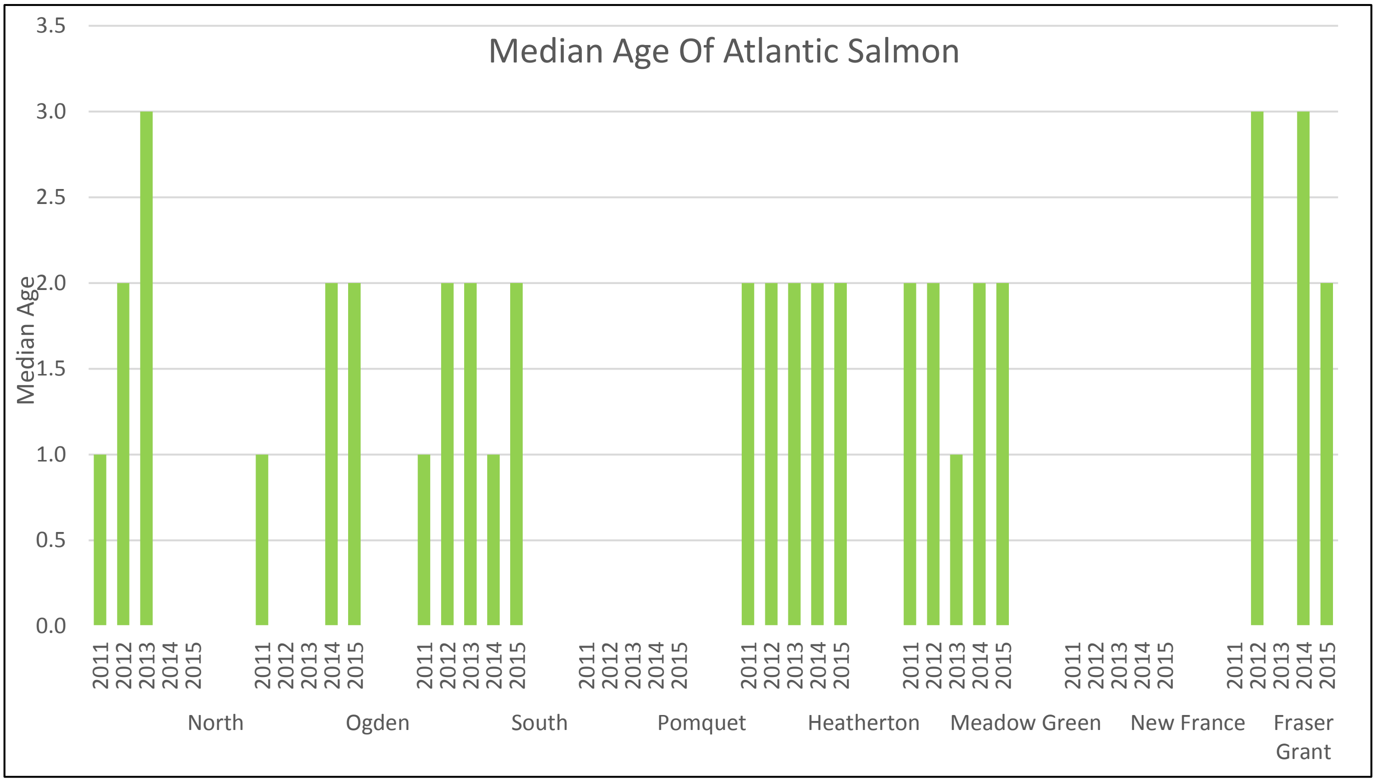

Figure 3: Observed median age of Atlantic salmon for each year at each site.

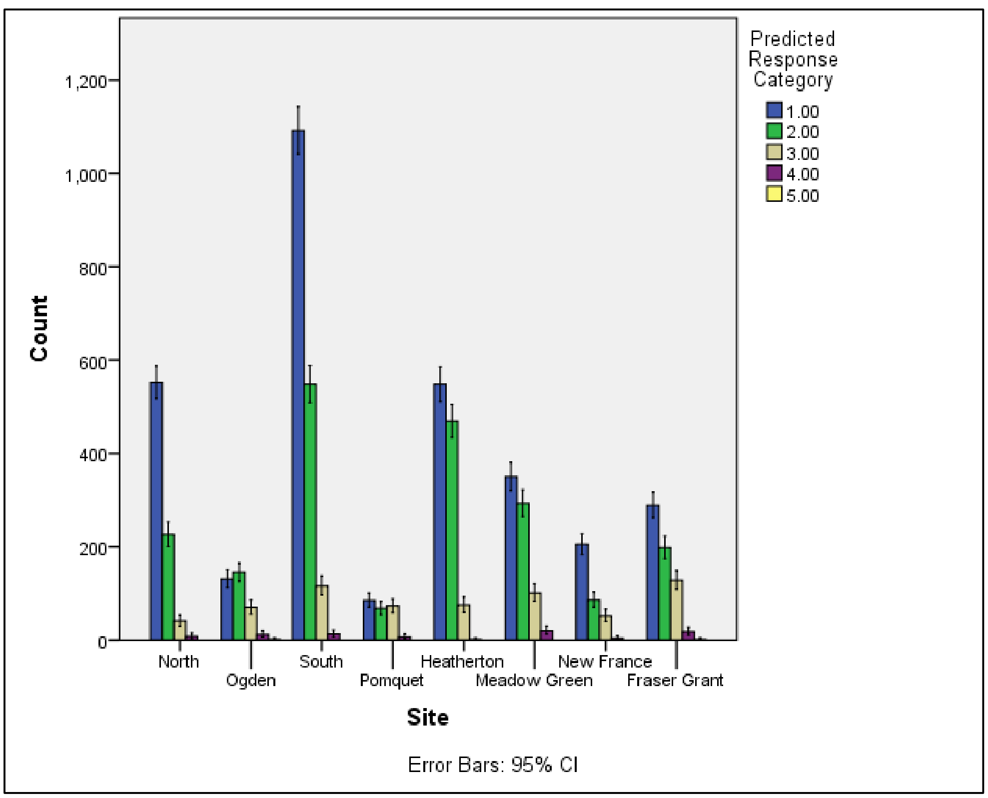

Figure 4: Total number of fish in each age class by site. This data combines all species and all years. Predicted responses, determined by ordinal linear regression, represent age classes in years beginning with 1.00 representing fry.

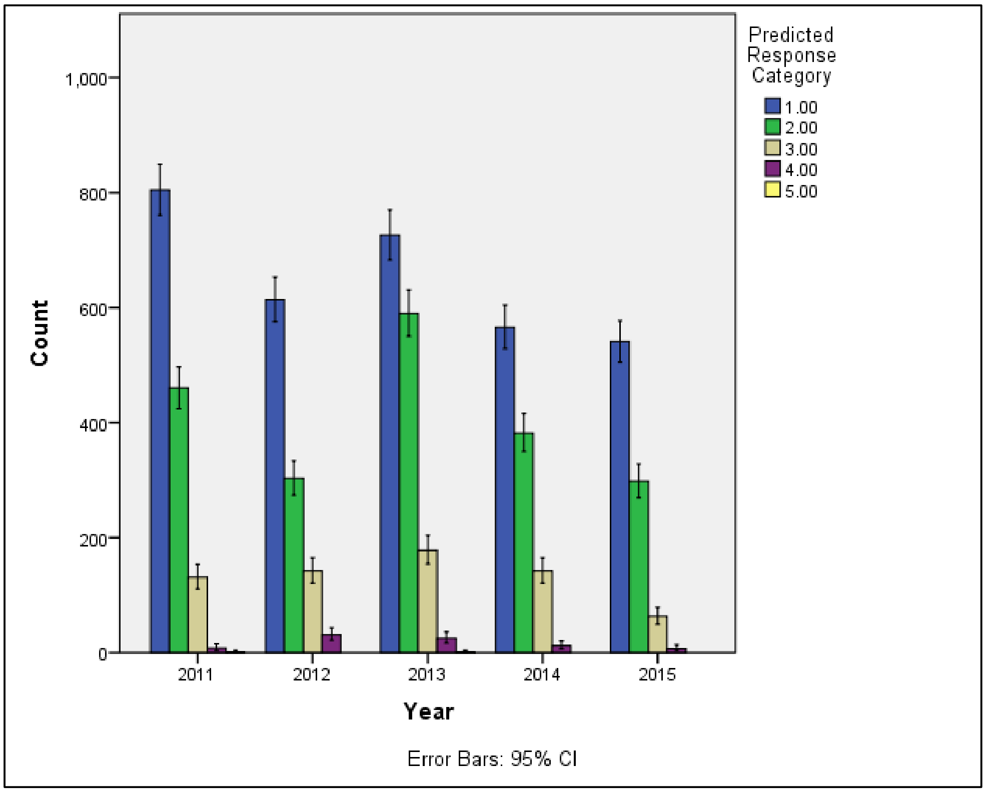

Figure 5: Total count of fish in each age class by year. Includes all species at all sites. Predicted responses, determined by ordinal linear regression, represent age classes in years beginning with 1.00 representing fry.

Population

Population varied expectedly between all factors. Figure 6 illustrates total fish count of all focal species, estimated for $100m^2$ (study area size). This figure specifically looks at years and site regardless of species. It is evident that South is the most populated site with an average of 104 fish over five years per $100m^2$ and an average total capture of 412 (Figure 7). The next most abundant site would be Heatherton with an average of 51 fish caught over five years per $100m^2$. South is paired as a control with Pomquet, which would potentially be a treatment site. Pomquet shows significantly less fish and only contains one species, whereas South was shown to contain all species throughout the data collection period. In Pomquet, the average density of fish caught per $100m^2$ only 19 fish, deeming it the least dense site. Figure 7 illustrates the raw population data by species, site and year. Both graphs illustrate relatively the same trends in terms of overall fish density at each site. By analyzing overall trends in Figure 7, it is evident that there is an overall decline in brook trout density in most sites. Fraser's Grant and New France showed some variability in numbers, but the rest of the sites show a decline in brook trout abundance. When comparing this trend to Figure 6, it does not seem to show many sites with considerable and constant decline. Pomquet, a site containing only brook trout, shows decline in both figures which indicates that the brook trout populations may be the only species with considerable and consistent population decline. Figure 7 indicates that brown trout are only consistently found in South, Heatherton and Meadow Green sites. While the numbers show that abundance is variable, there is a relatively high density of individuals and the figure indicates that populations at these sites seem stable. They sporadically appear in the other sites, in small numbers and rarely return year after year. Salmon are also only consistently found in the same three sites as brown trout. They appear in North in 2011 and 2012 and 48 were caught Ogden in 2013. The density of salmon at South, Heatherton and Meadow green was not as high as that of the brown trout, although 198 salmon were caught in 2013 in Meadow Green. The graph illustrates that salmon populations are variable in the three sites, but don't show any evidence of decline throughout the five years.

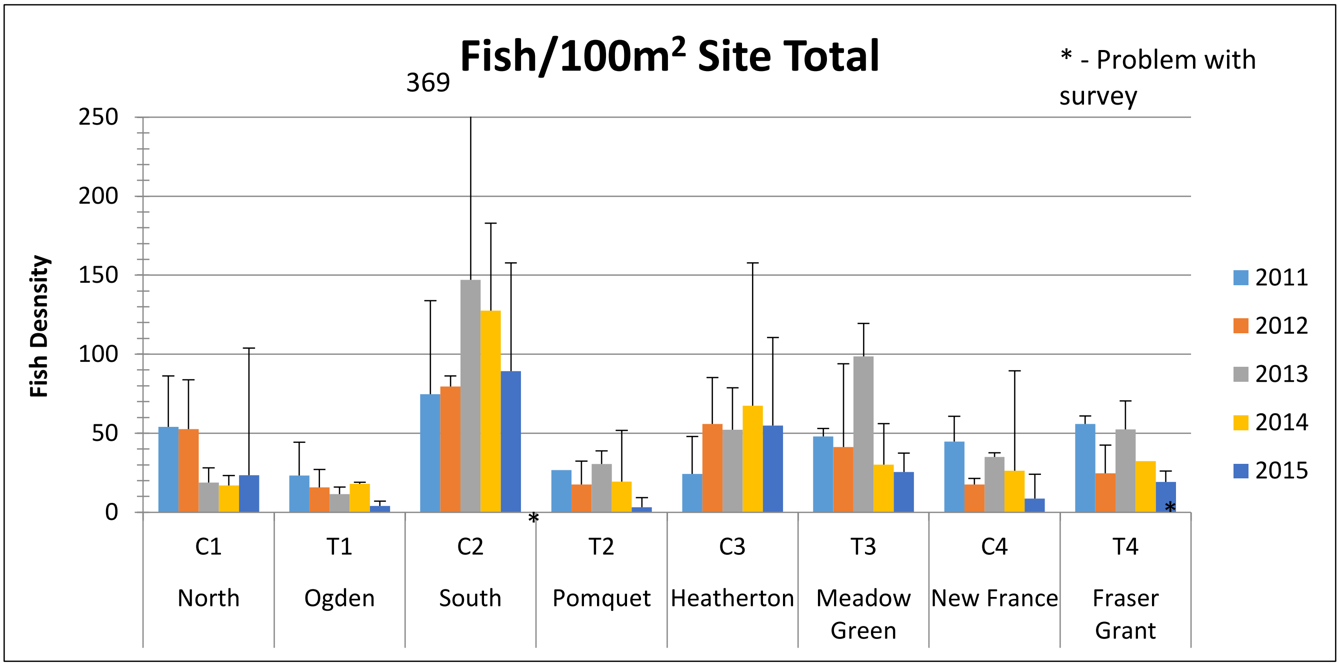

Figure 6: Total density of fish of all species by year and by site estimated for $100m^2$. Sample area size at each site was approximately $100m^2$.

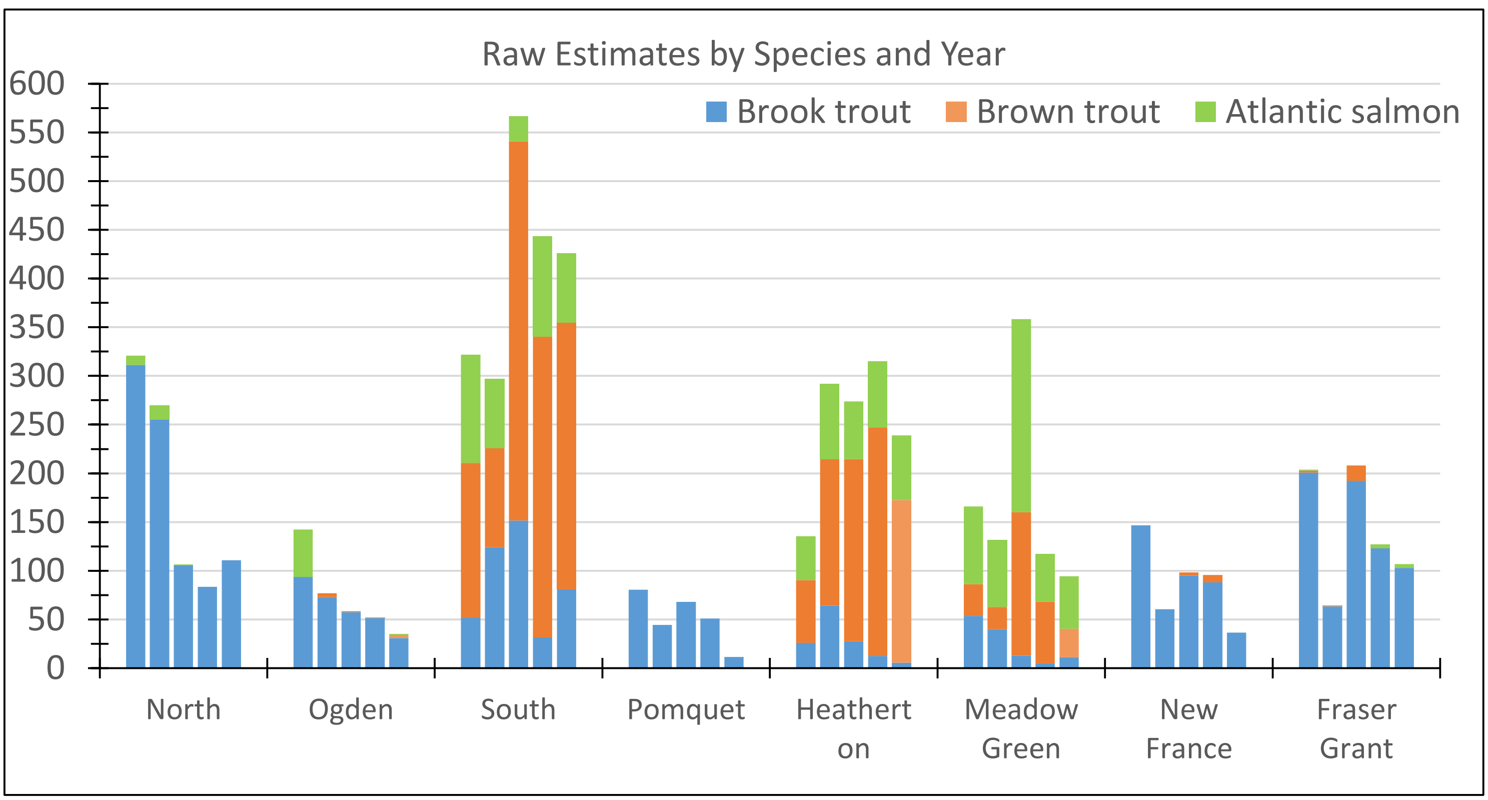

Figure 7: Total number of fish caught from each species for each site and year.

<u>Biomass</u>

Biomass, reported in grams, was calculated using the weight values estimated by the exponential regression based on the length-weight correlation. Figure 8 shows the total biomass for each species by site and year. The trends illustrated by the biomass data are in agreeance when considering a brook trout population decline. There is more variation of biomass by species with some years yielding larger total fish biomass than others, such as in Fraser's Grant and Meadow Green, but at all sites there is an overall decline in biomass of brook trout. Brown trout and salmon biomass seems consistent with population density at the sites where they are consistently found. ANOVA revealed that there is are significant difference between all species combinations and between most sites.

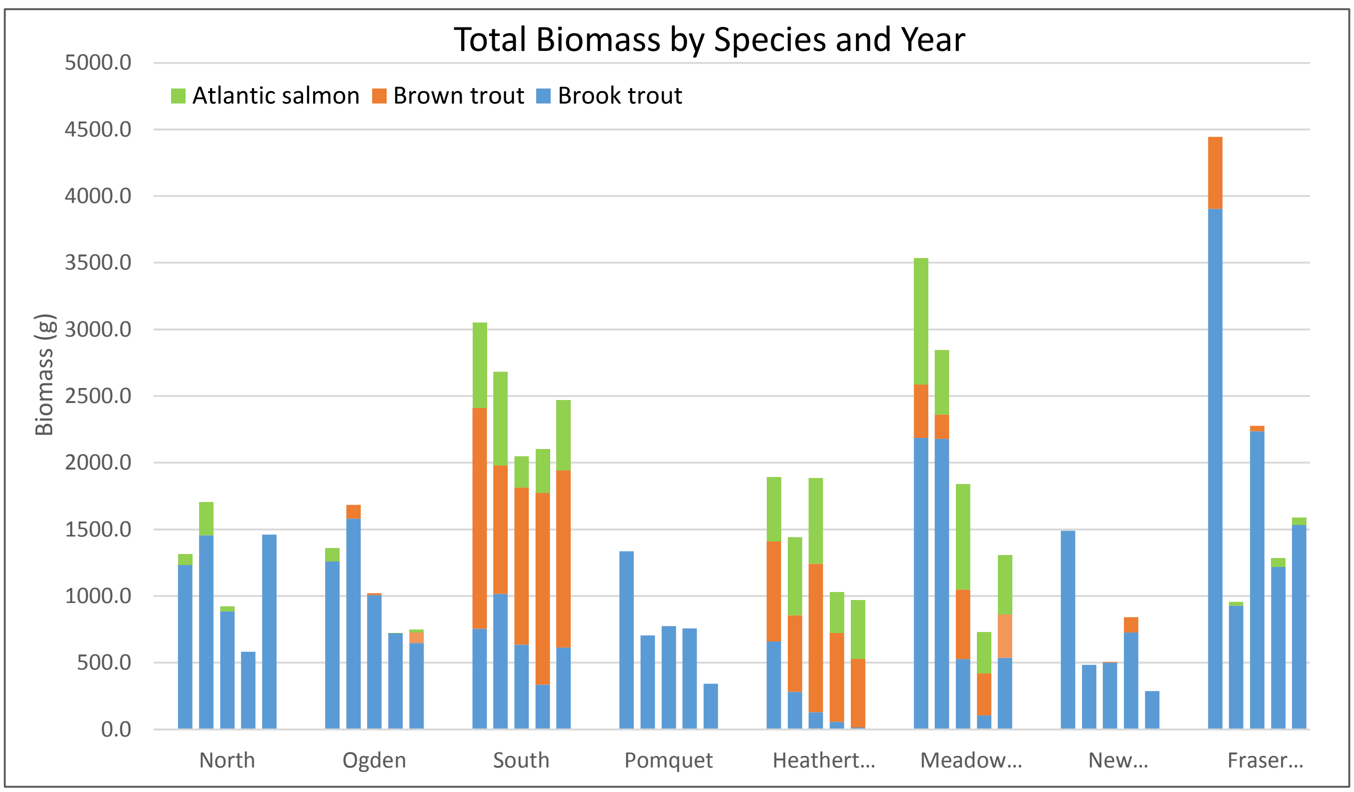

Figure 8: Total biomass by species for each site and year. Biomass was calculated using raw data.

Discussion

Variation in morphological features of fish is dependent on many factors such as the specific parameters set by their habitat, genetics and local adaptations (Milner et al, 2003). Population structures are based on habitat conditions and limitations, the ability to spawn and produce viable young and immigration and emigration of individuals (Milner et al, 2003). Without comparing fish data to the corresponding habitat data for this project, it is difficult to determine the specific causes of trends of variation among focal species. This subset of the overall study aims at quantifying the given data to clearly lay out the natural variation of fish in their current conditions. Some general trends are evident with the given data. While all species are of the salmonid family, they have different life histories and habitat specificities. Variation between populations was expected, as the populations are typically regulated by specific environmental conditions and the corresponding limitations, leading to a high level of variance (Milner et al, 2003). A study by Milner et al, (2003) suggested that environmental conditions are independent of density and determine the abundance. A specific habitat can only support a certain number of organisms before reaching the carrying capacity. In degraded streams, where suitable habitat is limited, this carrying capacity is potentially lower than what it could be, resulting in reduced opportunity for population growth (Hilderbrand, 2002). Population of salmonids in streams is in part, dependent on whether or not a stream hosts the preferred conditions.

With the data presented, it is interesting to look at the variation in population (Figure 7) and compare it to the age class distribution by site (Figure 4). When considering sites with decline in populations of brook trout, and few numbers of brown or salmon, such as Ogden and Pomquet, their corresponding age class distributions are not of the expected pattern. New France and Frasers Grant have a higher number of 1+ fish than other age classes, but not near the numbers of

North and South. Typically, a classic distribution results in a higher number of fry than other age classes as there is expected mortality and survivorship of remaining individuals increases with age class and growth (Hart, 2002). Salmonids eggs need specific conditions with particular sediment composition, water quality and flow as well as temperature (Malcom et al, 2003). It is the alteration of these factors that lead to an expected high mortality of eggs (Dahlberg, 1979). During the fry life stage, interspecies competition is at its strongest and it is suggested that this leads to density dependent mortality (Milner et al, 2003). Also, high rates of predation on fry corresponds with the expected high mortality rate (Mather, 1998). Typical age class distribution accounts for this expected high mortality rates in eggs and fry (Dahlberg, 1979). Figure 2 illustrates that brook trout and brown trout display this typical age class distribution when broken down by species. Pomquet interestingly, has only brook trout, and still displays the abnormal distribution of age classes. It is evident that fry density of each species is variable between sites.

When looking at salmon specifically, Figure 2 illustrates that, throughout all sites and years, there is consistently a low density of fry. It was first thought that this could be due to a bad year in terms of weather patterns, causing the decrease. Figure 3 indicates that this is not the case, as median salmon age is shown by year and by site. Since salmon only appear consistently throughout the study period at three sites (South, Heatherton and Meadow Green), these show the strongest trends. The figure indicates that Heatherton had a consistent median age of 2+ fish throughout the five years, indicating that random climatic events may not have influenced the atypical distribution at the other sites, assuming the proximity of the sites would result in the similar conditions. Instead, the variation in age distribution seems to be site specific and year specific. South River displays a median age of 1+ in 2011 and 2014 and Meadow Green has a median age of 1+ in 2013. The presence of a 2+ median age is indicative of survivorship, therefore leading to a more stable population and as such, a 1+ median age would be indicative of a decreased survival rate. When looking at the consistency of the Meadow Green site median age of salmon and the population density at the same site in Figure 7, it can be suggested that the Atlantic salmon population at this site is variable yet stable. ANOVA results showed that brown trout and brook trout were significantly older than salmon between sites, showing that not all sites display age distributions such as Heatherton. This again shows that the variation is site specific as the variability is noticed at these sites in different years.

Some studies suggest that density dependent mortality is a factor when considering age distribution (Milner et al, 2003). This may have been the case historically with the Atlantic salmon population, as they would spawn in higher densities, resulting in higher fecundity and fry (DFO, 2012). As mentioned previously, competition for resources is typically increased during this life stage and as a result, mortality increases with increased density (Milner et al, 2003). This is likely not the case presently as Atlantic salmon populations have shown decline in Nova Scotia, including the study area, over the past two decades (DFO, 2012). It is likely that density dependent mortality is not the reason for the decreased number of fry. Without comparing to the corresponding habitat data, it cannot be known if environmental parameters are causing this decline, although it is a possibility. From the data presented in Figure 4, the decrease in fry density and variance of survivorship is site specific, consequently it is likely that habitat is playing a role. Milner et al (2003) suggests, that while it is typical to see variance in population and age structure in streams of close proximity, short sample sections may not be representing actual age class structure. The study poses the idea that limited study areas offers a bias as some stream sections may be more favorable than others for certain age classes (Milner et al, 2003). This is a possibility as the sections were only 100 meters of the stream and the same sections were visited each year, but specific habitat qualities were considered when choosing the sections. The abundance and distribution of salmon is important to consider as the growth and development in lotic habitats is a determining factor of success at sea (Milner et al, 2003). Salmon life histories may appear more variable as they are anadromous and migrate great distances before returning to streams to spawn (McCormick, 1998). The effects of climate change and other habitat conditions at sea may also play a role in the variation of stream salmon (Otero et al, 2012).

Brook trout density show decline over five years in most sites, specifically North, Ogden and Meadow Green. Brook trout are very sensitive to temperature change and have a maximum tolerance of about 20ºC (McCormick, 1972). In Nova Scotia, degradation of rivers coupled with climate change has resulted in the increase of temperature of many streams (MacMillan, 2008). We do not know whether or not this is what is causing the decline in population over these five years without looking at habitat data, but it is a possibility as these streams are degraded. North and Ogden are on the same system, and are located in an area that is less impacted by current development and degradation. Historically, the area was heavily forested and resulted in the removal of riparian zones along these streams, but currently, riparian vegetation has not been removed for approximately 80 – 100 years. Yet, brook trout total count in 2011 at North was 311 and decreased throughout the five years with a total count of 111 in 2015. Similar decreases were reported at Ogden with a 2011 count of 94 and a final 2015 count of 31. The reason for steady decline at these site specifically is not known. While these two sites show steady decline over five years, populations at other sites fluctuate, but are suggesting population density decline as well. Pomquet in particular has a very low density of brook trout over five years. The biomass at Pomquet (Figure 8), is comparable to other sites, indicating that the few individuals in that population are larger fish. The overall biomass trends agree with the population trends, showing a considerable decline of brook trout throughout all sites. The threats that could be impacting the population structure could include both habitat and angler pressure. Brook trout are the most fished species in Nova Scotia, and this pressure could be a contributing factor, although further research is needed to confirm this (MacMillan and Madden, 2007).

Brown trout seem to show some variation in population structure and biomass, but do not suggest a population decline. Brown trout typically are less sensitive to habitat changes than brook trout and salmon, leading to success at some sites (DAF, 2007). Although brown trout only appear consistently at South, Meadow Green and Heatherton, their population structure and biomass indicates that their abundance is stable. Their corresponding age class distribution displays a typical ratio of fry to other age classes, which would indicate stable numbers at some sites. It is not known why brown trout and salmon sporadically appear in small numbers in some sites in some years but it will hopefully become evident once habitat data in analyzed. Again, due to a small section being sampled, more fish could be present up or downstream and are not present at the time of survey. What the consistent occurrence of both species at South, Meadow Green and Heatherton indicate is that, at these sites, populations appear to be stable.

Conclusions

The sites chosen were to be representative of northern Nova Scotia streams, and therefore, represent current conditions and natural variations of fish, that could be applied to other rivers in the area. This baseline of variation is an important data set to consider when analyzing the effectiveness of a restoration project. To fully understand the range of variation in all morphological features and population structures, a full analysis of the corresponding habitat data in needed. From this paper, the natural variation among the focal species in pre-restoration conditions is outlined. Population decline in brook trout is evident from both population density data as well as biomass data. Salmon and brown trout populations are variable and only appear consistently in three sites. Salmon have an atypical age class distribution, indicative of current or future population decline or a large range natural variability. Variation of population and age distribution seems to be site specific. Current pairings may not be sufficient as there are large variations in population structures and species occurrences between some sites, especially South river and Pomquet. Going forward, it is recommended that pairing of treatment and control sites be revisited.

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