Biological characteristics of sea-run salmonids from a spring angler creel survey on five Northumberland Strait river systems in Nova Scotia, and management implications.

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Abstract

Creel surveys are a common method used to assess biological characteristics of angler catches which can act as a basis for fisheries management decisions. A total of 533 angler interviews were conducted during a roving creel survey on five Northumberland Strait river systems to assess the spring fishery for anadromous brook trout, brown trout, Atlantic salmon, and rainbow trout from 15 April to 15 May, 2000. Mean angler catch per hour for all systems was 0.08 brook trout, 0.07 brown trout, and 0.02 Atlantic salmon. An estimated 11,537 angler hours were spent to catch 1093 brook trout, 820 brown trout, and 236 Atlantic salmon. Approximately 85% of anglers used bait during the first month of the season. Mean fork length of brook trout caught was 29cm compared to the mean length of brown trout caught which was 32cm. Creel data from previous angler surveys from 1991 to 1999 was used to assess age at length and annual mortality rate of brook trout and brown trout. The age structure of brook trout ranged from two to four years and indicated that most first time sea-run migrants were three years old. Annual mortality rates for three-year-old brook trout ranged from 60% to 93%. The age structure of brown trout ranged from two to seven years, and indicated that most first time sea-run migrants were three and four years old. Annual mortality rates for four-year-old brown trout ranged from 80% to 100% and 75% to 100% for five-year-old brown trout. The percentage of brook trout and brown trout longer than 35cm was lower on most systems in 2000 compared to 1991-1999 survey data. The estimated number of Atlantic salmon kelts that will return to freshwater as multi spawners, using an 89% kelt mortality rate, was 26 fish from a total of 236 Atlantic salmon released during the spring trout fishery. Additional hook and release mortality rates of 5% and 10% resulted in a reduction of one fish and two fish from the estimated 26 multi-spawner Atlantic salmon returning the following year. Additional study is needed to gain a better understanding of the importance of exploitation on anadromous populations, and to assess long-term changes. Small catch rates, high annual mortality rates, and decreasing number of large fish suggest that regulations to reduce trout harvest could benefit anadromous populations and the sport fishery.

Introduction

In order to effectively manage a fishery, a variety of assessment tools are required to gather data. Creel surveys are used to determine biological parameters of fish populations from angler interviews, and are used to assess the health and status of exploited fisheries (Lester et al. 1991). The Northumberland Strait Angler Survey was conducted to assess the spring fishery for anadromous (sea-run) salmonids on five river systems that flow into the north shore of Nova Scotia. The spring fishery is primarily directed at the lower tidal regions of systems, where the salmonid catch was assumed to be anadromous. Anglers, who participate in the popular spring fishery predominately use bait, retain trout, and release Atlantic salmon (LeBlanc 2000).

Four salmonid species have been caught in this region: brook trout, *Salvelinus fontinalis*, brown trout, *Salmo trutta*; Atlantic salmon, *Salmo salar*, and rainbow trout, *Oncorhynchus mykiss* (LeBlanc 2000). Of the four anadromous species, brook trout and Atlantic salmon are native to Nova Scotia. Brown trout originate from Europe and were introduced to Nova Scotia in 1923, having established self-sustaining populations in many rivers across the province (Scott and Scott 1988). Rainbow trout originate from the West Coast of North America and were introduced in 1899 (Gilhen 1984). Since the introduction to Nova Scotia, rainbow trout have only been found to successfully reproduce in a few stream systems, and for the most part, the majority of the rainbow trout fisheries are thought to be dependent on aquaculture escapement or stock enhancement initiatives.

Generally, these species spend their juvenile stage (2-4 years) in freshwater, then a fraction of the population will migrate to sea in spring. The fraction that leaves freshwater can vary among populations and species. Migration to salt water is thought to be undertaken to satisfy a need for more food and space. Anadromous populations tend to grow faster than freshwater populations and are highly prized by sport fishers (Ryther 1997). Anadromous brook trout will move downstream in spring and spend one to three months in tidal (estuarine) waters before returning in May through August. The timing of upstream migration may be related to the onset of sexual maturity and associated loss of osmoregulation ability in salt water, or environmental stressors such as warm water temperatures in estuaries and in downstream reaches of rivers. Studies of anadromous populations have been undertaken in Nova Scotia (Miles 1985, Wilder 1952, White 1940, White 1941) and in other regions (Dupuis et al. 1991, Thompson 1991, Montgomery et al. 1990, Castonguay et al. 1982, Smith and Saunders 1958). Brown trout have are believed to follow a similar migratory pattern as brook trout; however, few studies have been undertaken on brown trout biology or exploitation in Atlantic Canada (Scott and Scott 1988).

Overall, a decline in anadromous brook trout is occurring throughout their range. The decline is especially apparent in the southern half of their distribution that includes the Gulf of Saint Lawrence to Connecticut. Rivers in Connecticut and Massachusetts once supported healthy populations of anadromous “salter” brook trout, but now many populations have been lost or are at very low levels of abundance. The downward trend in anadromous brook trout populations has also occurred in New Hampshire and Maine (Ryther 1997).

In the Maritime provinces, both anecdotal accounts and catch statistics reflect the status of salmonid fisheries. In New Brunswick, declines seem to be more apparent in the southern region of the province, where angler accessibility and development are much greater compared to the northern regions (Ryther 1997). In Prince Edward Island, angler catch rate of brook trout has dropped 33% from a rate of 3.5 per day in 1973 to 2.3 per day in 1994 (Cairns 1996). Reductions in angler catch rates for brook trout have been reported by Johnston et al. (1993) from an angler creel survey on the West River, Prince Edward Island. In New Scotia, previous spring angler surveys indicated that the small catch rates could reflect small populations of anadromous brown trout and brook trout (LeBlanc 2000). Provincial catch statistics have shown that the number of brook trout caught by anglers has declined by about 60% from mid-1980s to the mid-1990s in Nova Scotia. Since 1995, regulation changes that included a reduction in the angler bag limit from 10 trout per day to five trout per day, and a catch and release season in September, have been implemented to reduce over fishing (MacLean, personal communication).

Many Atlantic salmon populations are in a state of diminishing returns with many populations not meeting the number of adults required to replenish an available riverine habitat with juveniles (Department of Fisheries and Oceans Canada 2001). Upon entering salt water, salmon can migrate hundreds of kilometers to waters off Greenland and Newfoundland for one to three years before returning to freshwater to spawn (Saunders 1981, Dadswell 1999). Increased mortality during the marine phase of the life cycle appears to be the main cause for declines and extirpation of many populations (Department of Fisheries and Oceans 2001). Marine mortality rates tend to be higher in the southern range of their distribution (Department of Fisheries and Oceans 2000). As with anadromous brook trout, the southern range of the Atlantic salmon has been contracting northward.

Causes for most declines in anadromous runs are thought to be the result of over exploitation, habitat loss, and competition from other species. In many areas, stocking and regulation changes have been used in attempts to protect and enhance anadromous populations and sport fisheries (Ryther 1997). The Nova Scotia Department of Agriculture and Fisheries have initiated some changes for the 2001 angling season to protect anadromous brook trout and brown trout populations on several river systems. The Northumberland Strait Creel will provide baseline data on anadromous fisheries to assess future changes in anadromous salmonid populations.

Methods

The purpose of this angler survey was to collect angler effort, harvest, catch rate, and biological data for the first month of the spring angling season on five river systems. Anadromous salmonids can migrate to neighboring estuaries; therefore, rivers in close proximity were grouped and assessed as one system. Two sampling routes were selected based on their proximity to Fraser's Mills Salmonid Hatchery and the Inland Fisheries Division in Pictou. The Pictou circuit included River John, Waugh's and French River systems, and Wallace River. The Fraser's Mills circuit included South and West River systems, and Barney's River (Figure 1). The systems included in this survey were impacted by land clearing associated with forestry, agricultural, and other development. Relatively few lakes and impoundments were present within the drainage areas and water acidity remained at levels which were close to neutral. Warm water temperature and low flow rates occurred in summer; however, these factors were considered to impact salmonid habitats less than in more southern regions of Nova Scotia.

Data collected during the angler interview included the name of the angler, date and time of an interview, site of an interview, species caught, fork length of fish caught, hours angled, and gear type used. Number of anglers, water temperature, air temperature, and weather conditions were recorded from sites each sampling day. Anglers that were interviewed a second time in one day were surveyed regarding the time fished since the first interview (Appendix 1).

The sampling methodology followed a two-stage design, where a fishing day was the primary sampling unit, as described in Lester et al. (1991). Mean catch per hour and mean activity (anglers counted) were assessed from two sampling circuits for each day sampled. Mean catch per hour of each species was determined for each angler and then for each day sampled for each system. Daily mean catch per hour was based on samples of more than one angler interview. Mean catch per hour for each system was determined from the daily mean angler catch per hour.

Daily mean activity was calculated from the two angler counts on each system. Cars that were located in between survey sites and in close proximity to the survey river were counted. As a part of the activity assessment for each site, all anglers and cars were counted. The ratio of anglers to cars was used to predict angler counts when only cars were counted.

The number of days sampled was determined from the following equation in Lester et al. (1991):

$$N = (1/CV^2) * (1/A + 1/3.2) * (g + 1/m)$$

where N = number of days needed to sample with a precision of 0.20
CV = coefficient of variance (precision, 0.20)
A = mean number of interviews per day (i.e., 3.4, estimate from previous surveys)
g = relative population variance (among day population variance/ within day population variance; i.e., 0.5, coefficient from Lester et al.1991)
and m = number of counts (circuits) per day (i.e., 2)

The number of sample days in the survey was fifteen from 15 April to 15 May. Previous surveys have indicated that the high activity on opening day of the angling season was unique from other days; therefore, opening day was selected as a sampling day and was treated separately from other days in the survey. Sampling days were also stratified based on weekdays and weekend days or holidays. Proportionally more days were sampled on weekends and holidays because mean activity and standard deviation were higher compared to weekdays. A total of seven days was sampled on the weekend and holidays and a total of eight weekdays was sampled.

The circuit start time was randomly selected from ten possibilities (Table 1). The direction or route for each sampling circuit for each day was randomly selected. One circuit required about three hours to complete; therefore, a sampling day required approximately six hours. The second circuit was started approximately three hours after the start of the first circuit. One clerk was required to creel anglers. Creel clerks attempted to interview as many anglers as possible, and budget time in order to complete circuits in about three hours. When angling activity was high (i.e., opening day of season), anglers were sub-sampled in order to complete the circuit in approximately three hours.

Effort, total angler hours spent on each system, was estimated from activity strata from the following equation in Lester et al. (1991):

where $$E = TA_1+TA_2+TA_3$$

E = effort (number of hours angled)
T = duration of the fishing day (hrs)
and A = mean activity: 1-opening day, 2-weekday, 3-weekend & holiday

Total number caught for each species from each system was estimated using the following equation in Lester et al. (1991):

$$C = E * CPUE$$

where C = total number of fish caught
E = effort
and $CPUE$ = mean catch per unit effort

Standard deviation, standard error, and coefficient of variance were determined for catch per unit effort and activity. Coefficient of variance was determined for effort and catch calculated using the following equation in Lester et al. (1991):

$$CV = SE\ (x)\ /\ x$$
$$CV\ (E) = \sqrt{CV^2(A)}$$
$$CV\ (C) = \sqrt{CV^2(A) + CV^2(CPUE)}$$

where CV = coefficient of variance
SE = standard error
x = mean
E = effort
A = activity
and $CPUE$ = catch per unit effort

Historical data collected from the first week of the angling season during 1991-1999 was used to assess trout length at age. Scale samples were collected from the catch and used to age trout. Annual mortality rates were calculated from age data from each system for each year, and from all years for each system. Annual mortality rates were calculated using the following equation in Ricker (1975):

$$M = 1 - (N_{t+1} / N_t)$$

where M = annual mortality rate
and N_t = number of trout in year class t

As an index of the number of larger and older fish in each system, the percentage of the fish longer than 35cm in fork length was calculated from 1991-1999 survey data, as well as, from the 2000 survey for each system.

The effect of the spring fishery on returns of multi-spawner Atlantic salmon was estimated using three hook and release mortality rates of 5%, 10%, and 20%. A mean natural mortality rate for kelts was 89% and was estimated from the mean percentage of repeat Atlantic salmon spawners (11%) in Fleming (1998). The number of multi-spawner Atlantic salmon returns from the estimated number of Atlantic salmon released was estimated from the following formula:

$$R = (Nr * (1-Mh)) * (1-M)$$

where R = number of returning salmon
Nr = number released
Mh = hook and release mortality rate
and M = natural annual mortality rate

Results

A total of 533 angler interviews gave a mean angler catch per hour of 0.08 brook trout, 0.07 brown trout, and 0.02 Atlantic Salmon. An estimated total of 11,537 hours was spent angling to catch 1093 brook trout, 820 brown trout, and 236 Atlantic salmon from all systems during the first month of the angling season (Table 2).

The number of brook trout caught per hour over the sampling period ranged from zero in River John to 0.17 (±0.09,SE) from South and West River systems. The number of brook trout caught per hour was 0.10 (±0.09,SE) from Barney's River and 0.09 (±0.07,SE) from Wallace River. The zero catch rate from River John does not reflect the catch rate of a single angler interviewed on 5 May, who had captured one brook trout. Daily mean catch rates were based on more than one interview per day per system. The number of brown trout caught per hour ranged from 0.01 (±0.01,SE) on South and West River systems to 0.14 (±0.07,SE) on Barney's River. The number of brown trout caught per hour was 0.07 (±0.03,SE) on River John, 0.06 (±0.03,SE) on Waugh's and French River systems, and 0.05 (±0.03,SE) on Wallace River. The number of Atlantic salmon caught per hour ranged from 0.01 (±0.01,SE) on both Barney's River and Waugh's and French River systems to 0.06 (±0.03,SE) on River John. The number of Atlantic salmon caught per hour was 0.02 (±0.01,SE) on South and West River systems and 0.02 (±0.02,SE) on Wallace River. One rainbow trout was caught on Wallace River was not included in the analysis of catch rate or harvest.

Mean activity (anglers counted) on opening day was higher than other counts in the survey on all five systems and ranged from 15 on South and West River systems to 61 on Barney's River. Opening day mean activity was 20 on Wallace River, 27 on River John, and 49 on Waugh's and French River systems. Mean activity counts on weekdays ranged from 0.9 (±0.4,SE) on River John to 4.7 (±1.5,SE) on South and West River systems. Mean activity counts on weekdays were 1.0 (±0.6,SE) on Waugh's and French River systems, 2.6 (±1.1,SE) on Wallace River and 3.8 (±1.0,SE) on Barney's River. Mean activity counts on weekends and holidays ranged from 3.3 (±1.3,SE) on Wallace River to 9.0 (±1.2,SE) on South and West River systems. Mean activity counts on weekends and holidays were 3.7 (±1.0,SE) on River John, 6.0 (±5.3,SE) on Waugh's and French River systems, and 8.3 (±2.2,SE) on Barney's River.

Total angler effort (hours angled) during the first month of the season ranged from 1,328 (±643,SE) on River John to 3,415 (±1,268,SE) on Barney's River. Total angler effort was 1,595 (±922,SE) on Wallace River, 2,091 (±2,256,SE) on Waugh's and French River systems, and 3,108 (±1,057,SE) on South and West River systems.

The number of brook trout harvested (catch) during the first month of the season ranged from zero from River John to 539 (±425,SE) on South and West River systems. The number of brook trout harvested was 63 (±100,SE) on Waugh's and French River systems, 138 (±177,SE) on Wallace River, and 353 (±419,SE) on Barney's River. The number of brown trout harvested ranged from 39 (±37,SE) on South and West River systems to 493 (±442,SE) on Barney's River. The number of brown trout harvested was 79 (±88,SE) on Wallace River, 94 (±91,SE) on River John, and 115 (±181,SE) on Waugh's and French River systems. The number of Atlantic salmon released during the first month of the season ranged from 24 (±29,SE) on Barney's River to 77 (±75,SE) on River John. The number of Atlantic salmon released was 31 (±47,SE) on Waugh's and French River systems, 35 (±47,SE) on Wallace River, and 69 (±59,SE) on South and West River systems (Table 2).

The majority of anglers used bait to angle during the first month of the system. Of the 533 anglers interviewed; 85% of the anglers used only bait; 9% used combinations of bait, fly, and lure; 5% used only lures; and 2% used only fly (Table 3).

Daily mean angler catch per hour for brook trout and brown trout indicated that most of the catch was in April. All of the Atlantic salmon catch was recorded before April 25, with the exception of Barney's River, where one salmon was caught on 14 May. Mean activity declined over the sampling period in all systems, with the exception from South and West River systems. Water temperatures warmed over the sampling period and ranged from 3^{o}C to 9^{o}C on 15 April and ranged from 8^{o}C to 13^{o}C on 13-14 May (Table 4).

Mean fork length of brook trout caught ranged from 26.9cm (±2.0,SE) from Wallace River to 30.7cm (±2.4,SE) from Barney's River. Mean fork length of brook trout caught was 27.8cm (± 2.7,SE) from South and West River systems and 29.7cm (±1.2,SE) from Waugh's and French River systems. The single brook trout creeled from River John was 29.8cm in fork length. Mean fork length of brown trout caught ranged from 31.6cm (±1.9,SE) from Waugh's and French River systems to 33.0cm (±2.5,SE) from Barney's River. Mean fork length of brown trout caught was 32.6cm (± 2.2,SE) from River John and 32.4cm (±1.6,SE) from Wallace River. The single rainbow trout measured from Wallace River was 27.5cm in fork length (Table 5).

Creel data from previous angler surveys during the first week of the angling season from 1991 to 1999 was used to assess age at length and annual mortality rate of brook trout and brown trout. The age of brook trout caught ranged from two to four years, with the majority from the three-year age class. The mean length at age of brook trout ranged from 26.5cm to 32.1cm at age three years, and ranged from 27cm to 36.5cm at age four years (Table 6). Annual mortality rates for three-year-old brook trout were 60% on Barney's River, 80% on Wallace River, and 93% on South and West River systems. No five-year-old brook trout were sampled during the creel. Annual mortality rate was 100% for the four-year-old age class (Table 6). The age of the catch of brown trout ranged from two to seven years, with the majority from the three and four year age classes. The mean length at age of brown trout ranged from 28.4cm to 32.5cm at age three years, 31.6cm to 36.7cm at age four years, 29.2cm to 42.1cm at age five years, 41cm to 56cm at age six years, and 49.0cm to 54.4cm at age seven years (Table 6). Annual mortality rates for four and five-year-old brown trout were 84% and 89% on Barney's River, 80% and 83% on River John, 94% and 100% on Wallace River, and 91% and 75% on Waugh's and French River systems. No five-year-old brown trout were sampled from South and West River systems; annual mortality rate was 100% for the four-year-old year class (Table 6).

From 1991 to 1999 survey data, the percentage of brook trout longer than 35cm in fork length was 17% from Barney's River, and 26% from South and West River systems, and 8% from Wallace River. From 2000 survey data, the percentage of brook trout longer than 35cm in fork length was 17% from Barney's River, zero from Waugh's and French River systems, 16% from South and West River systems, and zero from Wallace River. From 1991 to 1999 survey data, the percentage of brown trout longer than 35cm in fork length was 32% from Barney's River, 33% from Waugh's and French River systems, 13% from River John, and 18% from Wallace River. From 2000 survey data, the percentage of brown trout longer than 35cm in fork length was 31% from Barney's River, 8% from Waugh's and French River systems, 29% from River John, and zero from Wallace River.

The estimated number of Atlantic salmon kelts that will return to freshwater as multi- spawners, using an 89% kelt mortality rate, was 26 fish from a total of 236 Atlantic salmon released during the spring trout fishery. Additional hook and release mortality rates of 5%, 10%, and 20% resulted in a reduction of one fish, two fish, and five fish, respectively, from 26 multi-spawner Atlantic salmon returning the following year (Table 7).

Discussion

Angler catch rates have been used as an index of fish population densities and to compare different populations (Hoenig et al. 1987). In our study, the catch rate was 0.08 brook trout per hour and was 0.07 brown trout per hour. This result was similar to the brook trout catch of 0.09 per hour in April and May from tidal areas on the West River, Prince Edward Island (Johnston et al. 1993). The Nova Scotia Angler Logbook Program provides catch rate information for water bodies across the province throughout the angling season, and most of the data originates from freshwater areas. In 1999, the provincial catch rate from the Logbook Program was 1.0 brook trout per hour and was 0.33 brown trout per hour (Brandt 2000). Cool temperatures in spring may influence activity and catch of anadromous salmonids and reduce comparability with surveys conducted at different seasons; however, the large difference between catch per hour from the two surveys potentially indicates that densities of anadromous populations are small compared to many freshwater populations.

Angler catch rates on most systems were low and indicate that most of the salmonid catches occurred in April. Changes in a catch rate could be the result of the removal of a significant portion of the anadromous population, or may reflect salmonid migration upstream or downstream from the area of angling pressure. Atlantic salmon were released after capture and the timing of the Atlantic salmon catch was probably indicative of the timing of post-spawn (kelt) migration out of freshwater to the sea, rather than a reduction in the population associated with angling. Despite low catch rates, high angling pressure over the first month of the season produced sizable catches of brook trout and brown trout. The importance of the numbers harvested was unclear when this data was considered alone; however, combined with other population parameters and additional study, the numbers caught could indicate a significant impact to the number in these anadromous populations. The Northumberland Creel was conducted over the first month of the angling season, and thus provided a partial picture of the number of anadromous fish caught by anglers. Miles (1985) reported that many of the tagged fish caught by anglers were caught after the first month of the season and were reported from freshwater sites upstream from the head of tide tagging location on South River of Antigonish, Nova Scotia. Regulatory measures to protect anadromous populations should be directed at reducing harvest throughout the angling season.

Fish growth can be influenced by environment and population density. Over-exploitation can reduce fish density and result in an increase in food availability and rates of growth (Van Den Avyle 1993). Differences in growth have been observed between anadromous and freshwater resident populations of brook trout. Anadromous brook trout from the Moser River, Nova Scotia, were 20cm at age two years, 25cm at age three years, and 27cm at age four years compared to freshwater populations which were 16cm at age two years, 18cm at age three years, and 22cm at age four years (Wilder 1952). Length at age of Northumberland Strait anadromous populations was slightly larger than those reported from the Moser River and was 30cm at age three years and 33cm at age four years. Studies conducted on the West River and Morell River, Prince Edward Island, indicated anadromous growth rates were similar to that of Nova Scotia anadromous brook trout populations (Dupuis et al. 1991). Nova Scotia brown trout grew faster and were longer-lived than brook trout; however, age at length data indicated that brown trout growth was similar to brook trout growth for the ages of three years and four years.

Angling tends to remove the larger and older individuals in a population (Jensen 1971). High annual mortality and the age structure of anadromous populations indicate that angling in tidal and freshwater areas could have an impact on reducing the size and number in the anadromous population. The age of the catch indicates that most brook trout become anadromous at age three years, and most brown trout become anadromous at age three and four years. The age structure of the populations and annual mortality rates indicated that very few brook trout survived to be four years of age and older, and very few brown trout survived to be six years of age and older in Nova Scotia anadromous populations. The absence of anadromous brook trout older than four years of age was in agreement with the results of a study on anadromous brook trout from the South River of Antigonish, Nova Scotia (Miles 1985). Brook trout as old as six years have been captured in anadromous brook trout populations from Moser River in Nova Scotia (Wilder 1952), and from rivers in Prince Edward Island (Johnston et al. 1993, Dupuis et al. 1991, Thompson 1991) and from rivers in Newfoundland (van Zull de Jong 1999). Under low levels of exploitation, brown trout have the potential to reach a large size and old age (Scott and Scott 1988); a sea run brown trout caught in Newfoundland weighed 13 Kg and was 13 years of age (Williamson 1963). White (1940) estimated anadromous brook trout mortality from angling to be 23% for brook trout longer than 29cm on Moser River, Nova Scotia. Thompson (1991) reported that 25% of anadromous brook trout longer than 25cm was captured by anglers on the Montague River, Prince Edward Island. White (1940) and Thompson (1991) did not attempt to assess the degree of non-reporting of tagged fish caught by anglers or tag loss that could have resulted in an underestimate of angling mortality. The oldest brown trout, seven years old, was three years older than the oldest brook trout. The increased longevity of brown trout could be related to a natural ability that reduces their susceptibility to angling or other factors that cause mortality.

Comparing 1991-1999 length frequency data to 2000 length frequency data indicates that the percentage of brook trout and brown trout longer than 35cm declined on most systems. Changes in the number of larger fish could reflect natural variability or a trend related to over-exploitation (Van Den Avyle 1993). Annual mortality rates provide an indication as to the importance of angling to the population; however, natural mortality caused by predators or environmental conditions can significantly contribute to annual mortality in anadromous populations (Alexander 1979). Common predators of salmonids include cormorants, *Phalacrocorax spp*. (Greenstreet et al. 1993), mink, *Mustella spp.* Alexander 1979), and otters, *Lutra lutra* (White 1939a), seals, *Phoca spp.* (Rae 1973), mergansers, *Mergus merganser americanus* (White, 1939b), heron, *Ardea spp.* (Alexander 1979), belted kingfishers, *Megaceryle alcyon* (White 1936), Osprey, *Pandion haliaetus* (Blair 1956), Atlantic salmon (White 1939b), American eels, *Anquilla rostrata* (White 1939b), brook trout (White 1939b), brown trout (Alexander 1979), and striped bass, *Morone saxatilis* (Ryther 1997). Future trout tagging studies on some Northumberland Strait systems could provide useful data to differentiate mortality from exploitation and natural sources.

Understanding of the genetic influences on growth and anadromy is limited. Anadromy in salmonids is known to be at least partly heritable. Offspring of anadromous parents will tend to exhibit anadromy; however, conclusive evidence is difficult to obtain in nature (Castric, personal communication). Many trout remain in freshwater streams throughout their lives instead of migrating to lakes or estuaries where the potential for growth is greater (Scott and Scott 1988). A migratory life strategy could expose individuals to more perils that cause mortality. Fast growers in the relatively short river systems in Nova Scotia may become anadromous to satisfy a need for more food and space and may be more susceptible to angling before they are able to reproduce and contribute to recruitment of future generations; While the slower growing freshwater resident trout may remain in freshwater streams and successfully contribute their genes to future generations. The decline of anadromous populations in some regions may reflect selection of a life strategy that is superior to one that exposes the fish to heavy exploitation pressure and mortality. Restrictive angling regulations designed to allow first or second time anadromous spawners to reproduce and stock enhancement with offspring from anadromous parents could be methods of maintaining the level of fast growers and/or anadromy in a population.

Salmonid movements have been associated with changes in temperature, photoperiod, and flow rate (Smith and Saunders 1958). In a study on the South River of Antigonish, Nova Scotia, the majority of upstream brook trout migration occurred in June and early July, and timing of upstream migration was correlated with increasing water temperature and changes in flow rates (Miles 1985). Warm conditions in estuaries and the lower reaches of rivers could facilitate upstream migration to cool waters in spring or early summer, or delay upstream migration until late summer or fall after water temperatures cool. Salmonids are known as cold water species, and brook trout are one of the most sensitive to warm temperatures, and will migrate to cooler areas when water temperatures warm above 20^{o}C (Fry 1951, Coutant 1977, Gibson 1966, Elson 1942). Many rivers in Nova Scotia have been impacted by past and present land clearing activities and development that have been believed to contribute to low flows and warm water conditions in summer. Water temperature data on the main branch of the LaHave River exceeded a 20^{o}C daily mean for over a 100-day period in 1999. Other temperature data indicated that stressful warm water conditions existed for prolonged periods on the main branch of many Nova Scotia rivers (MacMillan et al 2005). Brook trout populations must use cool water refugia located in small tributaries, estuaries, or deep areas of pools and lakes for extended periods in summer. Warm water impacts could restrict habitat for brook trout production to a very small percentage of the river system; this may cause overcrowding in some areas (MacMillan and Crandlemere 2005). Overcrowded populations are more susceptible to disease and parasite transmission, predation, and exploitation (Coutant 1987). Brook trout production and recruitment of anadromous stocks may be directly related to the amount of cold water habitat in summer, as food and space are often important regulators of salmonid populations (Chapman 1966). Climate warming could significantly reduce available habitats for, and production of, cold water species from present levels (MacMillan et al. 2005, Schindler 2000, Meisner 1990).

The work of community groups toward enhancement of cold water refugia habitat has probably increased recruitment to the fishery and the number of fish that can survive in these areas.

Thermal restriction of brook trout habitats in summer could result in voids in available habitats that brown trout may occupy. Brown trout, like brook trout, prefer slow flowing sections of streams, but are more tolerant of warm water conditions than brook trout (Scott and Scott 1988). In some areas where sympatric populations exist, the habitat tolerance, predatory, and longevity characteristics of brown trout could provide them with a competitive advantage over brook trout (Brynildson et al. 1963, DeWald and Wilzbach1992, Staley 1966, Dumont and Mongueau 1990, Waters 1983, Alexander 1979). Competition for habitat could occur in the upper reaches of stream systems where physical habitats and thermal requirements suite both species. Although a loss in brook trout production may have occurred as a result of increased competition, the increased tolerance of brown trout to survive in marginal habitats has probably resulted in a net gain to the Nova Scotia salmonid sport fishery. Marshall and MacCrimmon (1970) suggested that the presence of self-sustaining brown trout populations in some heavily exploited Ontario brook trout streams could result in an increase in angling harvest and improved sport fishery. The one rainbow trout caught was probably related to the apparent lack of successful reproducing populations in the Northumberland Strait rivers. Poor reproductive success could limit the ability of introduced species to become important competitors with native species (Whoriskey 2001).

Other potential impacts to salmonids, and aquatic systems in general, include acid precipitation, sedimentation, and migratory barriers. Air pollution originating mainly from Northeastern United States has been a major contributor to acid problems in many Nova Scotia rivers (Esterby et al. 1989). Atlantic salmon are one of the more sensitive salmonids to acidic conditions (Mayhew 1989, Lacriox 1985). Acidity, although not considered a major concern in Northumberland Strait River systems, has resulted in severe reductions of the potential reproduction and juvenile habitat in some river systems in Southwestern Nova Scotia (Amiro et al. 2000, Lacroix et al. 1995). Soil erosion from poor agricultural, forestry, and other land use practices has resulted in sedimentation of pools and gravel substrate (Department of Fisheries and Oceans 2000a). The loss of pools has resulted in a loss of holding areas for larger individuals in the salmonid populations. Salmonids spawn in gravel substrate and sedimentation of these areas results in a loss of potential reproductive capacity of habitat (Saunders and Smith 1965). Barriers to upstream movement may result from poorly constructed impoundments and road crossings. Important spawning and rearing habitats could be present in the upper reaches of river systems and barriers to these locations can reduce the overall habitat available to migratory salmonid populations (Orth and White 1993).

Declines in Atlantic salmon populations are believed to be associated with changes in the marine environment that have resulted in an increased mortality between the smolt and adult stage (Department of Fisheries and Oceans 2000). Concerns have been expressed regarding the potential impact of the spring trout fishery on the number of multi-spawner Atlantic salmon returns. The estimated number of Atlantic salmon kelts that will return to freshwater as multi spawners, using an 89% kelt mortality rate, was 26 fish from a total of 236 Atlantic salmon released during the spring trout fishery. Additional hook and release mortality rates of 5% to 20% resulted in a reduction of one to five fish, from the estimated 26 multi-spawner Atlantic salmon returning the following year. An assessment on Atlantic salmon kelts indicated that mortality rates from fly hook and release angling were zero in Miramichi River, New Brunswick (Brobbel et al. 1996). Similar hook and release mortality results were reported in Atlantic salmon kelts in Margaree River, Nova Scotia (Forsythe, personal communication). Cool water temperatures during the timing of the spring kelt migration could be related to the low mortality rates associated with hook and release angling (Brobbel et al. 1996). A potential limitation in our methodology to calculate the effect of hook and release on Atlantic salmon returns was the use of an 89% kelt mortality rate from Fleming (1988) that could already include some mortality associated with hook and release angling. As well, the exact hook and release mortality in a Northumberland Strait spring trout fishery is not known due to the different gear types used and the possibility that some Atlantic salmon could be caught more than one time; however, the hook and release mortality range in our study suggest that the effect of the spring trout fishery on returns of multi-spawner Atlantic salmon is minimal.

Small catch rates, high annual mortality rates, and decreasing number of large fish suggest that regulations to reduce harvest could benefit anadromous populations and the Northumberland Strait sport fishery. Lester et al. (1999) modeled the effect of different regulatory changes on several exploited Newfoundland brook trout populations that had mean mortality rates of about 50% for year classes greater than one year of age, and concluded that regulations using high minimum length limits would have the most impact on protecting fish populations and enhancing the sport fishery. The Nova Scotia Department of Agriculture and Fisheries has initiated additional regulations on the West River of Antigonish to protect anadromous brook trout and brown trout populations and to enhance the sport fishery. Regulations include a delayed opening angling season date to 15 May; a minimum length limit of 35cm, to protect potential first and second time spawners; a daily bag limit of one trout, to reduce harvest; and a gear restriction to fly and single hook lure, to increase survival rates of released fish. Future angler creel surveys will be used to assess the impacts of regulation changes that may include a higher catch rate and an increase in the number of larger trout caught.

Recommendations for future study include a better estimate of activity by including a larger area surveyed on each system. An improved precision of estimates could be achieved through an increased frequency of sampling. Tagging studies combined with angler creels could provide better data on the number in the anadromous populations and the impact of angler harvest on population size. Future beneficial activities may include the continued work of community groups in enhancement of salmonid habitats, and stock enhancement strategies that use the offspring from anadromous brood stock.

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Table 1. Sampling time periods randomly selected during the day and sampling schedule for Pictou and Fraser's Mills, 15 April - 15 May, 2000.

Sample Period										
Number	1	2	3	4	5	6	7	8	9	10
Time	6am-12pm	7am-1pm	8am-2pm	9am-3pm	10am-4pm	11am-5pm	12pm-6pm	1pm-7pm	2pm-8pm	3pm-9pm

Pictou Shedule

Day	Date	Sample period		Route		Day	Date	Sample period		Route	
		Number	Slot	1 or 2	Start			Number	Slot	1 or 2	Start
Sat	15-Apr	2	7am-1pm	1	Wallace	Sun	30-Apr	9	2pm-8pm	1	Wallace
Sun	16-Apr	9	2pm-8pm	2	R John	Mon	01-May				
Mon	17-Apr	1	6am-12pm	2	R John	Tue	02-May				
Tue	18-Apr	2	7am-1pm	2	R John	Wed	03-May				
Wed	19-Apr					Thu	04-May	4	9am-3pm	2	R John
Thu	20-Apr					Fri	05-May	1	6am-12pm	2	R John
Fri	21-Apr	8	1pm-7pm	1	Wallace	Sat	06-May				
Sat	22-Apr					Sun	07-May	3	8am-2pm	2	R John
Sun	23-Apr					Mon	08-May				
Mon	24-Apr	7	12pm-6pm	1	Wallace	Tue	09-May	9	2pm-8pm	1	Wallace
Tue	25-Apr	2	7am-1pm	1	Wallace	Wed	10-May				
Wed	26-Apr	10	3pm-9pm	1	Wallace	Thu	11-May	5	10am-4pm	2	R John
Thu	27-Apr					Fri	12-May				
Fri	28-Apr					Sat	13-May	8	1pm-7pm	2	R John
Sat	29-Apr					Sun	14-May				

Fraser Mills Shedule

Day	Date	Sample period		Route		Day	Date	Sample period		Route	
		Number	Slot	1 or 2	Start			Number	Slot	1 or 2	Start
Sat	15-Apr	1	6am-12pm	1	South R	Sun	30-Apr				
Sun	16-Apr	2	7am-1pm	2	Barney's	Mon	01-May	8	1pm-7pm	2	Barney's
Mon	17-Apr	1	6am-12pm	1	South R	Tue	02-May				
Tue	18-Apr					Wed	03-May				
Wed	19-Apr	3	8am-2pm	2	Barney's	Thu	04-May	2	7am-1pm	2	Barney's
Thu	20-Apr					Fri	05-May				
Fri	21-Apr	3	8am-2pm	1	South R	Sat	06-May	10	3pm-9pm	2	Barney's
Sat	22-Apr					Sun	07-May				
Sun	23-Apr	5	10am-4pm	2	Barney's	Mon	08-May				
Mon	24-Apr					Tue	09-May	1	6am-12pm	1	South R
Tue	25-Apr	5	10am-4pm	2	Barney's	Wed	10-May				
Wed	26-Apr					Thu	11-May				
Thu	27-Apr	7	12pm-6pm	1	South R	Fri	12-May	2	7am-1pm	1	South R
Fri	28-Apr					Sat	13-May				
Sat	29-Apr	7	12pm-6pm	2	Barney's	Sun	14-May	7	12pm-6pm	1	South R

Table 2. Angler catch per hour, activity per hour, effort, and catch on five Northumberland Strait systems, 15 April - 15 May, 2000.

Brook trout	CPUE (fish caught per hour)					Activity (anglers counted per hour)											Effort		Harvest	
						Opening	Weekday					Weekend or holiday					Angler-hours		Fish	
System	N	mn	SD	SE	CV	day	N	mn	SD	SE	CV	N	mn	SD	SE	CV	N	CV	N	CV
Barney's River	14	0.10	0.32	0.09	0.8	61	7	3.8	2.6	1.0	0.3	6	8.3	5.4	2.2	0.3	3415	0.4	353	1.1
River John	10	0.00	0.00	0.00	0.0	27	8	0.9	1.0	0.4	0.4	6	3.7	2.6	1.0	0.3	1328	0.5	0	0
Waugh's and French	9	0.03	0.06	0.02	0.6	49	8	1.0	1.7	0.6	0.6	6	6.0	5.1	5.3	0.9	2091	1.1	63	1.6
South and West	12	0.17	0.30	0.09	0.5	15	7	4.7	3.9	1.5	0.3	6	9.0	3.0	1.2	0.1	3108	0.3	539	0.8
Wallace River	14	0.09	0.27	0.07	0.8	20	8	2.6	3.1	1.1	0.4	6	3.3	3.2	1.3	0.4	1595	0.6	138	1.3
All		0.08															11537		1093	
Brown trout	CPUE (fish caught per hour)					Activity (anglers counted per hour)											Effort		Harvest	
						Opening day	Weekday					Weekend or holiday					Angler-hours		Fish	
System	N	mn	SD	SE	CV	mn	N	mn	SD	SE	CV	N	mn	SD	SE	CV	N	CV	N	CV
Barney's River	14	0.14	0.23	0.06	0.4	61	7	3.8	2.6	1.0	0.3	6	8.3	5.4	2.2	0.3	3415	0.4	493	0.9
River John	10	0.07	0.11	0.03	0.5	27	8	0.9	1.0	0.4	0.4	6	3.7	2.6	1.0	0.3	1328	0.5	94	1.0
Waugh's and French	9	0.06	0.09	0.03	0.6	49	8	1.0	1.7	0.6	0.6	6	6.0	5.1	5.3	0.9	2091	1.1	115	1.6
South and West	12	0.01	0.03	0.01	0.7	15	7	4.7	3.9	1.5	0.3	6	9.0	3.0	1.2	0.1	3108	0.3	39	0.9
Wallace River	14	0.05	0.10	0.03	0.5	20	8	2.6	3.1	1.1	0.4	6	3.3	3.2	1.3	0.4	1595	0.6	79	1.1
All		0.07															11537		820	
Atlantic salmon	CPUE (fish caught per hour)					Activity (anglers counted per hour)											Effort		Released	
						Opening day	Weekday					Weekend or holiday					Angler-hours		Fish	
System	N	mn	SD	SE	CV	mn	N	mn	SD	SE	CV	N	mn	SD	SE	CV	N	CV	N	CV
Barney's River	14	0.01	0.02	0.01	0.9	61	7	3.8	2.6	1.0	0.3	6	8.3	5.4	2.2	0.3	3415	0.4	24	1.2
River John	10	0.06	0.09	0.03	0.5	27	8	0.9	1.0	0.4	0.4	6	3.7	2.6	1.0	0.3	1328	0.5	77	1.0
Waugh's and French	9	0.01	0.02	0.01	0.5	49	8	1.0	1.7	0.6	0.6	6	6.0	5.1	5.3	0.9	2091	1.1	31	1.5
South and West	12	0.02	0.05	0.01	0.6	15	7	4.7	3.9	1.5	0.3	6	9.0	3.0	1.2	0.1	3108	0.3	69	0.9
Wallace River	14	0.02	0.08	0.02	0.9	20	8	2.6	3.1	1.1	0.4	6	3.3	3.2	1.3	0.4	1595	0.6	35	1.4
All		0.02															11537		236	

N= number of days, mn = mean, SD = standard deviation, SE = starndard error, CV = coefficient of variance

Table 3. Gear types used by anglers, 15 April - 15 May, 2000.

Gear type	Angler interviews		Angler hours	
	Number	Percentage of total	Number	Percentage of total
Bait	441	85	1212	87
Bait and Fly	4	1	15	1
Bait and Lure	34	7	86	6
Bait Fly Lure	4	1	22	2
Fly	11	2	19	1
Lure	28	5	35	2

Table 4. Water temperaures recorded from each system, 15 April -15 May, 2000.

System	Date	Temperature °C	System	Date	Temperature °C
Barney's River	15-Apr	8	Waugh's and French	15-Apr	5
	19-Apr	6		16-Apr	6
	23-Apr	7		17-Apr	4
	25-Apr	8		18-Apr	4
	27-Apr	10		21-Apr	5
	29-Apr	8		24-Apr	10
	01-May	8		25-Apr	6
	04-May	9		26-Apr	9
	06-May	12		30-Apr	8
	09-May	8		04-May	10
	14-May	13		05-May	9
South and West	15-Apr	9		07-May	9
	16-Apr	9		11-May	7
	17-Apr	6		13-May	8
	19-Apr	8	Wallace	15-Apr	3
	21-Apr	6		16-Apr	6
	23-Apr	7		17-Apr	4
	25-Apr	9		18-Apr	5
	27-Apr	8		21-Apr	5
	29-Apr	10		24-Apr	10
	01-May	10		25-Apr	6
	04-May	10		26-Apr	8
	06-May	14		30-Apr	8
	09-May	8		04-May	10
	14-May	12		05-May	8
River John	15-Apr	5		07-May	10
	16-Apr	6		09-May	10
	17-Apr	4		11-May	8
	18-Apr	4		13-May	8
	21-Apr	6			
	24-Apr	11			
	25-Apr	6			
	26-Apr	10			
	30-Apr	8			
	04-May	9			
	05-May	9			
	07-May	9			
	09-May	9			
	11-May	8			
	13-May	8			

Table 5. Mean length of brook trout, brown trout, and rainbow trout caught by anglers, 15 April - 15 May, 2000.

Species	System	N	FL mn cm	SD	SE
Brook Trout	Barney's River	23	30.7	5.9	2.4
	River John	1	29.8	-	-
	Waugh's and French	3	29.7	1.6	1.2
	South and West	6	27.8	7.4	2.7
	Wallace River	12	26.9	3.9	2.0
	All		29.0		
Brown trout	Barney's River	93	33.0	6.1	2.5
	River John	14	32.6	4.7	2.2
	Waugh's and French	25	31.6	3.4	1.9
	Wallace River	12	32.4	2.5	1.6
	All		32.4		
Rainbow trout	Wallace River	1	27.5	-	-

N = number of fish, FL = fork length, mn = mean, cm = centimeter,
SD = Standard deviation, SE = standard error number

Table 6. Mean length at age and annual mortality rate of three and four-year-old brook trout and four and five-year-old brown trout, caught by anglers, by system, 15 - 22 April, 1991-1999.

Species	System	Age yrs	FL cm	N	Mortality annual %
Brook Trout					
	Barney's River	2	16.0	1	
		3	26.5	5	60
		4	36.5	2	100
	South and West	3	32.1	15	93
		4	27.0	1	100
	Wallace River	3	29.0	30	80
		4	33.0	6	100
Brown trout					
	Barney's River	3	31.3	67	
		4	34.4	55	84
		5	42.1	9	89
		6	56.0	1	
	River John	3	28.4	43	
		4	31.6	30	80
		5	36.5	6	83
		6	52.0	1	
		7	49.0	1	
	Waugh's and French	2	27.5	2	
		3	32.5	45	
		4	35.1	43	91
		5	41.7	4	75
		6	41.0	1	
		7	54.4	2	
	South and West	2	20.0	2	
		3	32.5	1	
		4	36.7	4	100
	Wallace River	3	31.1	12	
		4	32.9	16	94
		5	29.2	1	100

yrs = years, FL = fork length cm = centimeter, N = number of fish

Table 7. Estimated impact of the spring trout fishery to the number of multi-spawner Atlantic salmon returns under different mortality rates associated with hook and release angling, 15 April - 15 May, 2000 .

River	Released Fish Number	Natural mortality estimate 89% multi-spawners returning number	Release mortality estimate 5% multi-spawners returning number	Potential mortality estimate 10% multi-spawners returning number	Potential mortality estimate 20% multi-spawners returning number
Barney's river	24	3	3	2	2
River John	77	8	8	8	7
Waugh's and French	31	3	3	3	3
South and West	69	8	7	7	6
Wallace	35	4	4	3	3
All sites	236	26	25	23	21

Figure 1. Creel survey sampling sites designated as red pentagons, 15 April - 15 May, 2000.

Appendix 1. Creel survey forms used to assess Northumberland Strait river spring fishery, 15 April - 15 May, 2000.

Catch and sample form

Name of sampler ________________________ Date ______________________
Site name ______________________________ Time ______________________ am / pm
Name of Angler__________________________________
Gear bait___ lure ___________ fly____________________

Catch information

Hours angler(s) has fished so far (today) _______________________per angler.
Do not include travel time

Was the angler interviewed earlier today yes _____ no ______
How many of the fish recorded below were caught since then___________________

Species caught	Number (per angler) Kept	Released
A. Salmon	__________	____________
Brook trout	__________	____________
Brown trout	__________	____________
other ____________	__________	____________

Sampling information (see kept fish above)

No.	Species	Fork length (cm)	Other comments
1			
2			
3			
4			

other comments include tags, fin clips, parasites, abnormalities, predator marks, etc.

Sites and angler counts

Name of sampler ____________________________ Date __________________________
Weather conditions (fill out once during beginning of sampling period)
Air temp______% cloud_______snow/rain_______ windy calm_____ tide ______ other _________

Site	# cars	# anglers	time (am/pm)	water temp
Wallace River at Howards Pool Bridge	______	_______	__________	___________
Wallace River at Kerrs Bridge Pool	______	_______	__________	___________
Wallace River (Bland Brk) Redbanks	______	_______	__________	___________
cars between sites	______			
French River at Route 6	______	_______	__________	___________
French R bridge next to Mattatal Lake Brk bridge	______	_______	__________	___________
Waughs River at Route 6 bridge	______	_______	__________	___________
Waughs R at first bridge up from Route 6 bridge	______	_______	__________	___________
cars between sites	______			
Barneys River at Route 245 bridge	______	_______	__________	___________
other cars along Barneys R	______			
River John at Route 6 bridge	______	_______	__________	___________
River John railway bridge	______	_______	__________	___________
cars between sites	______			
West River Antigonish Hwy 104 Bridge	______	_______	__________	___________
Other cars along West River	______			
Antigonish Harbour (Williams Point)	______	_______	__________	___________
Antigonish Harbour (Abbitoir)	______	_______	__________	___________
cars between sites	______			
South River at Dunmore	______	_______	__________	___________
South River at St Andrews	______	_______	__________	___________
South River at Hwy 104	______	_______	__________	___________
South River at railway trustle	______	_______	__________	___________
cars between sites	______			