Proceedings of Wild Trout 1X Symposium 2007: 186-193.

Angler effort and harvest of sea-run brook trout from a specially regulated estuary, Nova Scotia, Canada.

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ABSTRACT

Special Trout Management Areas (STMAs) were established to enhance wild, sea-run brook trout *Salvelinus fontinalis* fisheries in Nova Scotia. In 2001, the West River of Antigonish was designated a STMA. New regulations included a delayed opening to 15 May, lure- or fly-only and a reduced daily limit of one trout with a minimum total length of 35 cm. The STMA boundaries extend into the Antigonish Harbour estuary, shared by the West and South rivers. The South River side of the estuary is under general regulations (five trout daily limit, bait permitted, 15 April opening date). During Recreational Fisheries Advisory Council meetings, anglers expressed concerns that increased effort and harvest in the South River was negatively impacting the West River.

Ten years of creel data collected prior to establishing the STMA were compared with data from 2006 and 2007. Angler effort and trout harvest increased dramatically on the South River side of the estuary. Trout longer than 35 cm increased from 23% pre-STMA to 64% in 2006 and 53% in 2007. The percentage of 4 and 5-year-old trout was 10% in previous surveys and 51% in 2006 and 2007. Although the impact of exploitation outside the STMA estuarine border is unknown, size and age changes suggest the West River STMA improved the sea-run brook trout fishery.

INTRODUCTION

In Nova Scotia approximately 51,000 licensed anglers participated in a sport fishery that generated approximately CAN $53 million to the provincial economy. In terms of annual catch per year by Nova Scotia anglers, brook trout *Salvelinus fontinalis*, are the most popular, followed by introduced smallmouth bass *Micropterus dolomieu* and native anadromous rainbow smelt *Osmerus mordax* (Fisheries and Oceans 2007). Anadromy in brook trout is common and many anglers pursue sea trout because of their large size (Scott and Scott 1988). Wild, sea-run brook trout populations have been deteriorating throughout their range from habitat loss and over exploitation. This decline is especially apparent in the southern half of their North American distribution, which includes Nova Scotia (Ryther 1997).

Interest in changing regulations was fueled by growing public support and publications suggesting that a collapse of many recreational fisheries was related to overfishing (Post et al. 2002). The response of fishery management agencies has often been the use of special regulations on certain rivers and lakes even when baseline data were minimal or absent (ASF 1999). Nova Scotia Recreational Fisheries Advisory Councils provide anglers the opportunity to offer input into fisheries management decisions regarding regulatory change. Legislative changes enabled the province of Nova Scotia to implement unique regulations on a river specific manner in 2001. The criteria used to select Special Trout Management Areas (STMA) for sea-run brook trout were similar to those outlined for exceptional trout waters by Born et al. (1990). Criteria for riverine STMAs include a high carrying capacity, potential for trophy wild trout, and public access. New regulatory approaches in STMAs justify the need for assessment. Population modeling studies have demonstrated positive impacts of size limits on trout fisheries (Clark et al. 1981, Power and Power 1996, Post et al. 2003); however, relatively few studies

have been conducted on severe regulatory changes on heavily exploited anadromous brook trout populations.

Nova Scotia sea-run trout fisheries are characterized by heavy angler pressure, high rates of retention, and the use of bait (LeBlanc 2000). Angling in April and May typically takes place in both tidal areas and lower reaches of rivers making large numbers of migrating brook trout susceptible to heavy angling pressures. With support from the public Recreational Fisheries Advisory Councils, the West River of Antigonish was approved as a Special Trout Management Area in 2001. New regulations were developed based on previous spring creel surveys, which revealed that very few sea run trout lived beyond 3 years of age or had a fork length longer than 35 cm. The new regulations for the West River sea-run trout fishery included a delayed opening to 15 May, gear restriction to lure- or fly-only (no bait), and a reduced daily bag limit of one fish with a minimum total length of 35 cm. The West River STMA includes the main branch of the river system and a portion of the Antigonish Harbour estuary that is shared by both the West and South rivers of Antigonish (Figure 1). The portion of the Antigonish Harbour that is located on the South River side is under general fishery regulations (five trout bag limit, bait permitted, and an open date of 15 April). The Wallace River, located approximately 120 km NW of the West River of Antigonish, was considered as a STMA for sea-run brook trout but has remained under general fishing regulations.

Objectives of the regulations used in Special Trout Management Areas were to improve the size and number of trout caught and to reduce the time required to catch a trout. The purpose of this study is to assess the impact of regulatory change on the stated objectives.

STUDY SITE

The West (N45°37′14.4″ W61°58′50.5″) and South (N45°36′01.0″ W61°54′51.3″) rivers of Antigonish and Wallace River (N45°48′44.4″ W63°30′58.3″) are located on the northern shore of mainland Nova Scotia and flow into the Northumberland Strait. The approximate main river length of the West River is 30.6 km, that of the South River is 31.7 km, and the Wallace River is 30.1 km. These systems are known as productive habitats for brook trout and the geological makeup of their drainage areas includes limestone and gypsum, both of which provide a natural buffering capacity against acid precipitation. The West River has a pH range of 7.5 to 8.0 while the South and Wallace rivers have a pH range of 6.3 to 6.8 and 6.4 to 7.5, respectively.

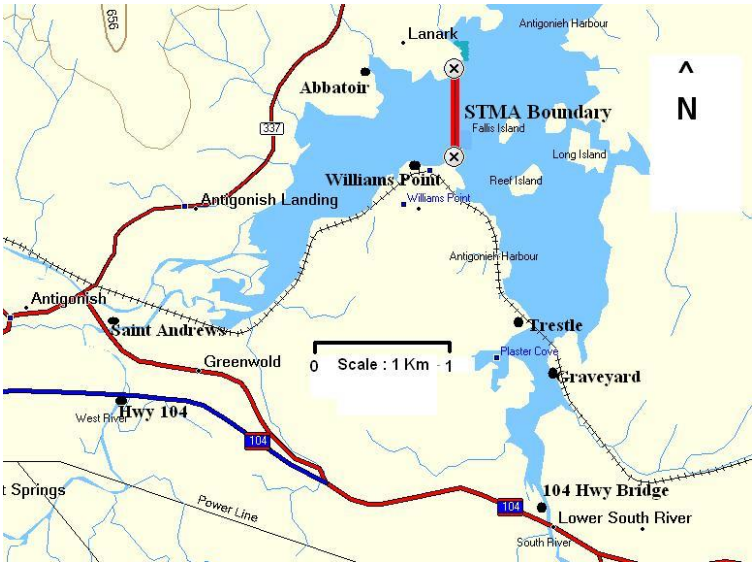

Figure 1. Creel survey sites and West River Special Trout Management Area estuarine boundary.

Land clearing associated with forestry, agriculture, and other development has impacted these habitats. Few lakes and impoundments are present on the Wallace and West rivers of Antigonish. Although warm water and low flow conditions reduce salmonid habitat in summer, warming is much less relative to many riverine habitats located in more southern regions of the province (MacMillan et al. 2006). Salmonids inhabiting these systems include; native Atlantic salmon *Salmo salar*, brook trout, introduced brown trout *Salmo trutta*, and rainbow trout *Oncorhynchus mykiss*. Brown trout have established self-sustaining pulations in many rivers whereas the ral sites or direct stock enhancement

strategies. Counts of upstream migrating anadromous brook trout from a South River fish counting fence were 351 in 1981 and 1,024 in 1982 (Miles 1985).

METHODS

The creel survey sites were selected based on their angling popularity and were located in tidal areas or just above the head of tide on the West and South rivers of Antigonish and Wallace River. Creel survey data for the first week of the angling season between 15 April and 22 April were used to estimate changes in trout catch per hour between 1991 and 2000 and 5 and 6 years after regulatory changes in 2006 and 2007. As a result of a delayed opening of the fishery to 15 May, creel data from West River sites and sites on the West River side of the Antigonish Harbour were available only prior to 2001 (Figure 1). Sites on the South River side of the estuary and on the Wallace River remained under general fishing regulations and had a consistent 15 April opening of the angling season throughout the 17-year study period. The South River shares the same estuary (i.e., Antigonish Harbour) with the West River and sea-run trout are known to migrate throughout their native estuaries. Catches in the South River side of the Antigonish estuary were probably influenced by regulations implemented in 2001 on the West River and estuary. The Wallace River creel survey sites were assessed from 1991 to 2000 and 2007 and included as a control site in this study.

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

During week-long creel surveys in 1991-1999, a maximum of 6 of the first 7 d of the angling season were sampled. Hourly survey start times were randomly selected between 0600 and 2000 hours. Results of these surveys indicated that angler activity and catches were variable and trout catch per hour was highly dependent on weather conditions, and an increase in duration of sampling and sampling methodology was required to assess the spring sea-run fishery on an annual basis. Ice cover on estuaries is common during the opening week of the angling season, when effort is heavy and water temperature often remains below 6 ^{o}C. The optimum range for brook trout activity is 10-17^{o} C as summarized by Power (1980). The mean catch per hour, pooled size and age structure data of 1991-1999 and 2000 were compared with that from 2006 and 2007.

The expanded sampling methodology for creel surveys in 2000, 2006, and 2007 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 two angler interviews. Mean catch per hour for each system and year was determined. Daily mean activity was calculated from the two angler counts on each system.

The number of days sampled was determined using the following equation: $N = (1/CV^2) * (1/A + 1/3.4) * (0.5 + 1/m)$, where N= number of days needed to sample with a precision of 0.20, CV= coefficient of variance (precision, 0.20), A = mean estimated number of interviews per day, and m = number of counts (circuits) per day (i.e. 2).

From 15 April to 15 May, the number of sample days was 14 in 2000, 6 in 2006, and 11 in 2007 in South River; and was 14 in 2000 in West River. Limited resources available in 2006 resulted in fewer days sampled compared to other years. Previous surveys have indicated that the high activity on opening day of the angling season was unique from other days. Opening day was, therefore, selected as a sampling day and was treated separately from other days in the survey.

The circuit start time was randomly selected from 10 possibilities for month-long surveys. One circuit required about 2 to 3 h to complete; therefore, a sampling day required approximately 5 to 6 h. The second circuit was started approximately 2 to 3 h after the start of the first circuit. One clerk was required to interview or count anglers. Creel clerks attempted to interview as many anglers as possible and budget time to complete circuits in about 3 h. When angling activity was high (i.e. opening day of season), anglers were subsampled to complete the circuit in approximately 3 h.

Effort, total angler hours spent on each system, was estimated from activity strata from the following equation; $E = TA_1+TA_2$, where E = effort (number of hours angled), T = duration of the fishing day (hours), and A = mean activity: 1-opening day, 2-other days. The total number of brook trout caught from each system was estimated using the following equation: C = E * CPUE, where C = total number of fish caught, E = effort, and CPUE = mean catch per unit effort. The weight of the harvested brook trout was estimated by applying the weight- length equation for anadromous brook trout, Weight in grams = 0.0028 * (FL cm ^ 3.39), in the following equation: Weight in kilograms C = C * (0.0028* (mm FL cm of C) ^ 3.39) / 1000 g).

Standard deviation, standard error, and coefficient of variance were determined for catch per unit effort, activity, and harvest. Coefficient of variance was determined for effort and catch calculated using the following equation: CV = SE (x) / x, $CV(E) = CV^2(A)$, $CV(C) = CV^2(A) + CV^2(CPUE)$, where CV= coefficient of variance, SE = standard error, x = mean, E = effort, A = activity, and CPUE = catch per unit effort.

The catch per angler hour during the first week of the angling season for the periods 1991-2000 and 2006-2007 was used to detect differences before and after the regulatory change in West River STMA using t-test. Catch per angler hour, effort and harvest for the first month of the angling season was compared among those for 2000, 2006 and 2007. The mean length of the catch and relative density index of large fish in the population, as defined by the proportion of the fish >35 cm FL, was calculated from pooled 1991-2000 survey data as well as from the 2006 and 2007 data from each system. The mean length of the catch was compared using ANOVA. The relative density index of large fish was compared among years and between systems using a z-test.

RESULTS

During the first week of the angling season between 1991 and 2007, the mean number of brook trout caught per hour on West and South rivers of Antigonish and the Wallace River was 0.10 (0.16, SD) and ranged from 0.00 to 0.80. Water temperatures during this period were between 1.0 and 10.0 ^{o}C. Two creel survey sites, Williams Point, Abattoir and West River Highway 104, were impacted by new regulations in the West River STMA. Prior to West River's delayed opening in 2001, the mean trout catch per hour during the first week of the angling season was 0.05 (0.07, SD) in West River (Table 1). Sites located in the South River side of the estuary, outside the border of the West River STMA, included the Highway Bridge, Railway Trestle and Cove site. The Cove site was a creel survey site assessed during 2006 and 2007 and was located approximately 500 m east of the Railway Trestle site. Angler access to the Cove site was made easier because of recent road construction and the close proximity to the Railway Trestle site indicated that fish could easily swim between the sites. Although the mean number of trout caught in South River sites increased from 0.14 (0.25, SD) prior to 2001 to 0.27 (0.08, SD) during 2006-2007, this difference was not significant (T-test, P>0.05). The mean number of trout caught from Wallace River control site was 0.6 (0.05, SD) prior to 2001 and 0.02 in 2007.

Table 1. Annual catch data from the first week of the angler season on South and West Rivers of Antigonish and Wallace River, 15 April - 22 Aprill, 1991 - 2007.

System	Year	Angler hours	Anglers interviews	Brook trout	Trout caught per hour mean
West*	1991-2000	240	90	20	0.05 (0.07, SD)
South	1991-2000	567	207	72	0.14 (0.25, SD)
	2006-2007	179	56	49	0.27 (0.08, SD)
Wallace	1991-2000	1215	417	74	0.06 (0.05, SD)
	2007	99	43	2	0.02

*West River sites were under a delayed opening to 15 May after 2000.

From 1991 to 1999, creel surveys were conducted during the first week of the season. In 2000, 2006, and 2007, however, these were expanded to include the first month of the season. Changes in catch per unit effort, activity, and harvest before and after 2001 were used to determine the impact of the West River STMA on the sea-run brook trout fishery. In 2000, prior to the West River STMA, approximately 1,556 h (0.3, CV) were spent angling in various West River sites during the first month of the angling season. The angling effort recorded during 2000 on West River and some of the Antigonish Harbour sites was displaced as a result of the delayed opening. Effort increased dramatically in South River sites; from 2,053 angling hours (0.2, CV) prior to implementation of West River STMA to 6436 angling hours (0.3, CV) in 2006 and 6831 angling hours (0.2, CV) in 2007. In South River sites the trout catch per hour was 0.16 (0.6, CV) in 2000, 0.19 (0.4, CV) in 2006 and 0.18 (0.3, CV) in 2007, while the harvest, in terms of number of trout caught, was 275 (0.7, CV) in 2000, 1008 (0.5, CV) in 2006 and 887 (0.4, CV) in 2007. Increased harvest was mainly attributed to an increased angler effort rather than a change in rate of catch. In South River, total weight of the catch was 61 kg in 2000, 677 kg in 2006 and 507 kg in 2007. The largest change was the estimated weight of the total catch and this was related to a significant increase in the mean size of the catch after the regulation changes (ANOVA, $P<0.05$). The mean size of the catch was 27.8 cm (7.4, SD) in 2000, 38.5 cm (7.1, SD) in 2006 and 36.7 cm (6.8, SD) in 2007. In West River, the total number of trout caught was 138 (0.5, CV) and had a weight of 31 kg. The levels of angler effort and harvest from South River sites in 2006 and 2007 were greater than the combined estimates of effort and harvest from West and South rivers in 2000 (Table 2).

Table 2. Angler catch per hour, activity per hour, effort, and catch on South and West Rivers of Antigonish, Nova Scotia, 15 April - 15 May, 2000, 2006, and 2007.

Brook trout		Trout caught per hour					Anglers counted per day						Effort		Harvest		
							Opening day	other days					Angler hours		Fish		Wt
System	Year	Days	mn	SD	SE	CV	mn	Days	mn	SD	SE	CV	N	CV	N	CV	Kg
West *	2000	10	0.10	0.14	0.04	0.4	11	13	2.6	2.6	0.7	0.3	1565	0.3	138	0.5	31
South	2000	12	0.16	0.34	0.10	0.6	4	13	3.7	3.0	0.8	0.2	2053	0.2	275	0.7	61
	2006	6	0.19	0.18	0.07	0.4	37	6	10.3	7.9	3.2	0.3	6436	0.3	1008	0.5	677
	2007	11	0.18	0.18	0.05	0.3	55	11	9.1	6.5	2.0	0.2	6831	0.2	887	0.4	507

*West River sites were under a delayed opening to 15 May after 2000.

The increase in size of the catch was demonstrated by changes in the relative proportion of large fish (FL > 35cm) in the catch (Figure 2). A significant change was detected after 2001 when the relative proportion of large trout increased from 0.23 in 1991 - 2000 to 0.64 in 2006 and 0.53 in 2007 (z-test, $P < 0.05$). A significant increase in the proportion of 4-year-old and 5-year-old trout in the catch was detected after the 2001 West River STMA (z-test, $P < 0.05$). The proportion of 4-year-old trout in the catch was 0.10 in 1991- 2000, 0.35 in 2006 and 0.41 in 2007. The proportion of 5-year-old trout in the catch was zero in 1991- 2000, 0.16 in 2006 and 0.10 in 2007.

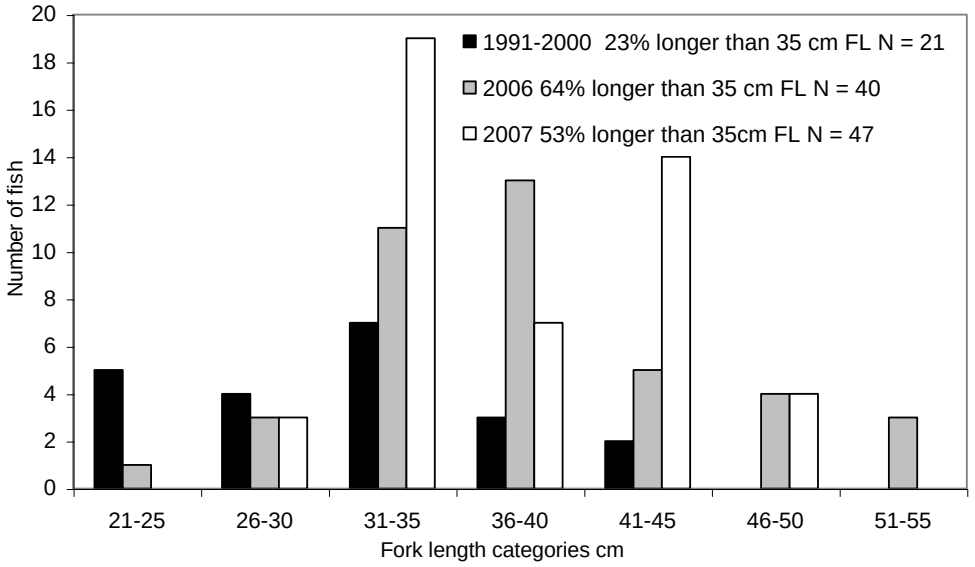

Figure 2. Size structure of the sea run brook trout in the catch of anglers during the spring of 1991-2000, 2006, 2007, South and West Rivers of Antigonish, Nova Scotia. Length data for South and West River was combined for period between 1991-2000.

DISCUSSION

Angling tends to select larger individuals in the population and can reduce the size of the catch (Jensen 1971). Catch and release, slot limits, and minimum length limits on heavily exploited populations can improve the catches in trout fisheries (Clark et al. 1981, Power and Power 1996). Potential gains from such regulatory changes can, however, be lost as a result of a change in angler behavior (Post et al. 2003). Although only small increases in catch per hour were detected, angler effort on South River was three times greater in 2006 and 2007 compared to 2000 when the entire estuary was open under general angling regulations. This change in angler effort was potentially due to a delay in the season, which displaced anglers from West River sites and a change in the sea run trout population. Anglers were attracted to sites where large fish were captured using terminal gear on the South River side of the estuary. Post et al. (2003) modeled responses of bull trout fisheries under regulatory changes and different levels of angler effort. High angler effort limited the potential gains from regulations as hooking mortality on released fish and illegal harvest can be significant. Bull trout are more susceptible to over-exploitation as they are longer lived and are late maturing (~6 years) compared to other salmonids (Post et al. 2003). Nova Scotia brook trout are fast growing and short-lived species that mature at two years of age. West River regulations were designed to protect first and second-time spawning brook trout and are potentially effective in improving the fishery under increased angler effort. However, heavy angler effort outside the estuarine border of the management area could reduce recruitment to the fishery if a large number of West River sea run are harvested from South River sites.

The number of sea-run brook trout harvested in South River increased more than three times in 2006 and 2007 compared to that in 2000. The creel surveys included only the popular angling sites and do not represent the total harvest of sea trout during the first month of the season. The number of brook trout harvested during the first month of the angling season in South River was close to that (1,024 trout) counted migrating upstream in a 1982 trapping study on South River (Miles 1985). Although tagging studies have demonstrated that sea trout may swim throughout estuaries, the origin of the South River

catch remains uncertain. Increased recruitment of trout to the fishery may also relate to additional enforcement presence on the West and South rivers.

One of the objectives of Special Trout Management Areas was to increase the number of larger (>35 cm) FL and older (>3 years) brook trout in the catch. Although anecdotal accounts indicate that the change in the catch from angling in West River STMA has been positive, proper assessment is difficult because this fishery is diffuse in freshwater regions. Previous trapping studies of sea-run populations in South River (Miles 1985) and in other Nova Scotia rivers indicated that 4-year-old brook trout were scarce and 5-year-old brook trout were absent. Results of trapping studies in Moser River, located in Eastern Nova Scotia, indicated that the maximum age of captured sea-run brook trout was 6 years in 1939-1940 (Wilder 1952) and 4 years in 2006. The size structure of captured trout changed from 23% >30cm FL to 3% > 30cm FL over that same time period (MacMillan and Madden 2007). The difference in age and size structure of trout in Moser River was potentially related to flow rates, climate changes, increased acidity, loss of buffering capacity, and to a lesser extent, exploitation. The West River of Antigonish is alkaline, cool, and productive compared to many rivers in Southern and Eastern Nova Scotia.

The potential role of the environment on catches in South River must be considered. Natural variability in environmental conditions can cause dramatic fluctuations in lotic trout populations (Platts and Nelson 1988). Brook trout can quickly repopulate habitat after catastrophic flooding events (Roghair et al. 2002). Over a 70-year period (1934 – 2004), a variety of regulatory changes were implemented to improve angler catch of rainbow trout in Great Smoky Mountains National Park (Kulp and Moore 2005). Conclusions indicated that abiotic factors such as drought and floods controlled fluctuations in abundance and catch to a much larger degree than diverse regulations. The sea trout catch in Wallace River in 2007, selected as a control in our study, did not demonstrate an improvement in the fishery during the first week of the angling season when angling effort was high. The lack of change in the Wallace River fishery indicated that the catch of South River anglers may relate more to regulation changes than a change in recruitment associated with past environmental conditions, however, the relatively short term duration of our study warrants additional monitoring.

Size, age, and number of sea trout caught in the spring of 2006 and 2007 suggest that West River STMA improved the sea-run brook trout fishery. Concern remains as to the impact of high angler effort and harvest of South River anglers on the West River sea trout population. Initiatives are planned to determine the contribution of West River sea-run trout to the catch of South River anglers.

ACKNOWLEDGEMENTS

We thank Darryl Murrant, John A. MacGillivary, Stephen Thibobeau, Jillian Tozer, and Jason LeBlanc for their participated in the data collection component of this study. Murray Hill, Director, and Don MacLean, Assistant Director, Inland Fisheries Division, Nova Scotia Department Fisheries and Aquaculture provided resources for this study. Al McNeill NSDAF and Peter Amiro and Shane O'Neil, DFO provided editorial and scientific advice on earlier drafts of this manuscript.

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