FINAL REPORT

Climate Change Impacts and Adaptation Program
Project A505

CLIMATE CHANGE IMPACTS ON RUN-TIMING OF ATLANTIC SALMON IN EASTERN CANADA AND ADAPTATION OF INSEASON MODELS AND MANAGEMENT TO IMPROVE RESOURCE ACCESS OPPORTUNITIES

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EXECUTIVE SUMMARY

BACKGROUND

Atlantic salmon, *Salmo salar*, inhabit cool temperate streams on Canada's eastern shore. In the Miramichi River (46.95° N, 65.60° W), New Brunswick, Atlantic salmon are located towards the southern limit but within the most productive area of its distribution. In fact, the Miramichi River has the largest Atlantic salmon population in eastern Canada. These stocks represent a valuable resource, supporting a lucrative recreational fishery and a sustenance aboriginal fishery. However, in recent years, the Atlantic salmon resource has declined and fisheries opportunities and benefits have been affected.

Due to their ecological and economic significance, Atlantic salmon stocks have been extensively researched and managed. Atlantic salmon return to rivers of eastern Canada from early May until November with structuring according to sea-age, spawning history, and geography. In some rivers, runs are characteristically "early", with peak numbers returning in summer (i.e. June and July), or "late", with peak numbers returning in autumn (i.e. September and October). The Miramichi River has both early and late run components.

The distribution and productivity of Atlantic salmon are intrinsically linked to environmental conditions in both freshwater and oceanic environments. Water temperature effects growth and development, and ultimately, survival of salmon. Migratory behaviour, including timing of salmon return to rivers and within river movement can be affected by sea-surface water temperature and river water temperature. River flow can affect fish movement, impeding upstream and downstream migration during low flow conditions. Atlantic salmon returning to the Miramichi River over-winter in the North Atlantic Ocean, near the northern Newfoundland and southern Labrador shelves. Environmental conditions in this area are expected to influence both the number of salmon returning and the timing of their return to the river.

In the 20th century, changes in climate, namely increases in global temperatures and altered wind, rain, snow, and storm regimes, have affected physical and biological systems in many parts of the world. Increases in air temperature and changes in precipitation have contributed to severe low water conditions in some streams and rivers in New Brunswick, resulting in fish kills and more frequent closures of rivers to recreational fishers. In the Miramichi River, for example, minimum water flows in the Miramichi River have significantly declined over the last three decades. Summer river flow is expected to decrease significantly in this century due to increases in air temperature (4 to 5 °C) and changes in precipitation patterns. Consequently, the time of return of Atlantic salmon to rivers may be modified and accessibility to headwater spawning areas reduced. These variations in environmental conditions and run-timing, affect the inseason models used for forecasting abundance of Atlantic salmon, the availability of salmon to aboriginal and recreational fisheries, and the fisheries management occurring within the river systems.

OBJECTIVES

The specific objectives of the study were:

1. To consider current and alternative inseason models of Atlantic salmon abundance based on daily counts of salmon at monitoring facilities and how environmental conditions modify the accuracy and precision of the inseason forecasts,

2. To quantify the association between environmental conditions and timing of arrival of fish to the estuary and the availability and exploitation of Atlantic salmon in the fisheries,

3. To quantify the frequency, duration and temporal trends of recreational and aboriginal Atlantic salmon fisheries closures resulting from environmental stresses (low water, warm water conditions) over the recent two decades and to quantify the consequences (days lost, revenue lost) to the recreational fisheries industry of within season closures to fisheries due to environmental stresses, and

4. To define and evaluate alternative management strategies to protect salmon under environmentally stressful conditions and to compensate for lost opportunities of aboriginal and recreational fisheries due to increased frequency of low water and warm water conditions expected under climate change scenarios.

The results of the detailed studies are summarized below.

METHODOLOGY AND TIMELINES

Progress relative to the four study objectives were planned during the two years structured according to the following schedule:

	Research activities	Contributors	Year 1				Year 2			
1.	**Inseason models**									
	Compilation of databases	DFO, DNRE, UdeM								
	Analyses	DFO, UdeM								
2.	**Availability to fisheries**									
	Compile tag database	DFO, MSA								
	Creel data compilation	MSA, DNRE, DFO								
	Geographic analysis	UdeM, DFO, MSA								
3.	**Social and economic effects of fisheries closures**									
	Management actions archive	DFO								
	Survey impacts on industry	MWMC, MSA, UdeM								
4.	**Adaptation strategies development**									
	Workshop I and draft	All partners								
	Final Workshop	All partners								

RESULTS AND CONCLUSIONS OF RESEARCH ACTIVITIES

1 - Inseason Models to Account for Effects of Environmental Factors on Run-Timing of Atlantic Salmon (Chapter 1)

Atlantic salmon populations in the Miramichi River are currently managed according to annual salmon management plans. Based on pre-season forecasts of the number of grilse and salmon expected to return to the Miramichi River, these plans establish acceptable rates of in-river exploitation while ensuring conservation requirements are met. Pre-season forecasts are generated from end of season returns in the previous year and, as a result, are frequently unable to predict the occurrence of an unusually early or late run, or an unusually small or large return. An alternative or complimentary approach to the use of pre-season forecasts is the application of in-season models which attempt to forecast the end of season returns of grilse and salmon to a particular river. However, in-season models estimates are made during the course of the run, and as a result respond to variability in the timing and number of grilse and salmon returning. In-season approaches range from simplistic qualitative approaches to more complex models, such as probability density functions and Bayesian probability models. Simplistic in-season models are less computationally intensive than other approaches and are, therefore, easily applied. In-season models can incorporate variations in environmental conditions which affect run timing, and therefore the models used for forecasting abundance of Atlantic salmon and the fisheries management occurring within the river systems.

The objective was to consider qualitative, proportional, and linear regression in-season models of Atlantic salmon abundance based on daily counts of salmon at monitoring facilities and how environmental conditions modify the accuracy and precision of the in-season forecasts.

The Miramichi River (46° 95' N; 65° 60' W) is the 2nd largest river system in New Brunswick draining an area of 14,000 km^2 with a maximum axial length of 250 km. Daily counts of returning grilse and salmon were compiled from four counting facilities in the Miramichi River: three were headwater sites and one was an estuary monitoring site. Each year at these facilities, approximately 6000 Atlantic salmon were counted from late May to early November. Mean monthly ice area (1000 km^2) on the northern Newfoundland and southern Labrador shelves and monthly thermal habitat data (index of ocean suitability for salmon growth and survival in the northwest Atlantic were examined as marine modifiers of abundance and run-timing. Daily discharge data (m^3/s) from two hydrometric stations water temperatures during ice free conditions simulated from air temperatures at meteorological stations were sued as fresh water environmental variables.

The qualitative, proportional and linear regression approaches to in-season forecasting are based on the relationship between cumulative counts to date and the end of season counts. Environmental variables such as discharge, sea ice, and thermal habitat were incorporated into these models to advance the possible forecast date with minimal loss in precision, while maintaining a standard error of the regression estimate within the acceptable margin.

Cumulative sea ice coverage area south of 55ºN on the Newfoundland shelf between December and June in the north Atlantic has varied between just over 500 thousand to over 1.6 million km^2. Area of sea ice coverage was low in the last eight years with ice coverage most important in February and March. The thermal habitat index of March to May has been warmer in the last eight years. Fresh water conditions in terms of the mean daily water temperature (ºC) and mean daily discharge ($m^3\ s^{-1}$) also show important annual variations.

Below average grilse and salmon runs were observed from 2001 to 2003 at two of the headwater monitoring facilities but the grilse and salmon runs at the estuary monitoring site were larger than the historical average Early runs of both grilse and salmon have been observed in some years and locations in the last 3 years. At all monitoring facilities, accurate predictions of salmon run size were less consistent than for grilse and resulted in later in-season forecast dates than grilse runs. Accuracy of forecast, generally, improved the later in the season the estimate was made.

The grilse forecast date for the Northwest Miramichi was advanced by 7 days by the addition of monthly thermal habitat indices in winter and June water temperature and substantially improved the description of the variation. At the Southwest Miramichi estuary monitoring facility, the addition of July water temperature to the in-season model advanced the usable forecast date by 14 days for grilse, while the February sea ice index advanced the usable forecast date by 7 days for salmon. Water temperature in June and average flow conditions in May explained a significant amount of the run-timing variability of both grilse and salmon for the Northwest headwater site. At the upper headwater facility in the Southwest Miramichi, water temperature and discharge were important explanatory variables of salmon run-timing variability.

Increases in air temperature, and changes in precipitation and streamflow regimes are expected to have significant implications for Atlantic salmon populations in the Miramichi River. Linear regression models have been applied with some success to a number of Atlantic salmon populations (for ex. Saint John River NB, LaHave River NS, Conne River and Campbellton River NFLD/LAB). The inclusion of the marine environmental variables (extent of sea ice and thermal habitat index) in the inseason forecast advanced the ability to suitably forecast end of year abundance for grilse from the Northwest headwater site and salmon for the Southwest estuary trapnet. The marine variables also reduced the annual variation in the forecast of end of year abundance of grilse and salmon. For the thermal habitat index, the associations with run-timing and abundance were positive indicating that warmer oceanic conditions produced increased and earlier runs of fish. The freshwater variables (discharge and temperature) advanced the run timing of the fish to the headwater facilities but had contradictory effects on abundance depending upon the site. Run characteristics to the Dungarvon Barrier were particularly sensitive to the discharge and temperature conditions; this site is also characterized by early run-timing to the facility.

Despite the large variation associated with salmon abundance and run-timing and the difficulty of summarizing an environmental index with which to examine the sensitivity of the former with the latter, there is evidence of environmentally modified migrations of Atlantic salmon. Marine factors generally modify the time of return to the river whereas fresh water conditions modify the rate of ascension to the headwaters. Low sea ice conditions are associated with earlier return to the coast but if water levels are low and water temperatures warm, then migrations upstream may be delayed.

2 - Environmental Determinants of Availability of Atlantic Salmon to Recreational Fisheries of the Miramichi River (Chapter 2)

In the Maritime provinces, Atlantic salmon is a highly prized aboriginal fishery and recreational fishery resource. The Miramichi River contains the largest, naturally reproducing population of Atlantic salmon in eastern Canada. Recreational fisheries use in eastern Canada is highest on the Miramichi River with an average annual effort of 109,000 days of angler activity on the river. The most recent survey of total angling activity in New Brunswick is for 1997 with an estimated total effort by anglers of 145,000 days of activity, of which 76% of the total salmon angling effort (111,000 days) occurred in the Miramichi River alone. Management of the fisheries occurs under a precautionary approach. Aboriginal fisheries are managed by quota, gear and season restrictions. Recreational fisheries are also managed by individual quota, maximum size limits, gear and season restrictions. In addition, sections of the river may be closed to all fisheries depending upon the water levels, water temperatures and relative risks of illegal fishing activities.

The availability of fish to the fisheries depends in part on the timing of arrival of fish to the estuary and migration rates in river, which are dependent on environmental conditions. Climate change may adversely affect Atlantic salmon by modifying their time of return to rivers, as well as accessibility to headwater spawning areas.

The following study analysed an extensive tag and return database to assess: 1) the effect of environmental conditions (discharge) on the movement of fish through the estuary; 2) the effect of environmental conditions on the movement of fish up river and availability of fish to angling fisheries; and 3) the effect of environmental conditions and the movement of fish to headwater sites.

Conditions which could potentially affect migration of Atlantic salmon were indexed using the daily discharge values. A threshold discharge value was calculated as the minimum daily discharge for the May to October period averaged for 1961 to 2003 (equivalent to a 1 in 2 year recurrence event). Daily discharge values less than the threshold value were categorized as extreme low flow conditions. Daily discharge values of twice the threshold were categorized as low flow conditions. Annual conditions were described as the number of days with low discharge and extreme low discharge, by month and season (summer = June to August, fall = September and October).

Individually numbered external tags were placed on Atlantic salmon adults returning to the Miramichi River intermittently since 1969 and annually from 1985 to the present. Tagged fish were recovered in various fisheries and facilities: aboriginal fisheries (usually gillnet fisheries in tidal waters or in fresh water of the Northwest Miramichi), recreational fisheries (in fresh water), and at counting fences and protection barriers in the Miramichi River. The recapture databases were used to address three specific questions associated with movements of Atlantic salmon and environmental conditions:

1. the database of recaptures at the trapnets themselves was used to assess the impacts of discharge conditions on the movement of salmon within and through the estuary;

2. the database of recaptures in the recreational fishery was used to assess the impacts of discharge conditions on the availability of salmon to the recreational fishery; and

3. the database of recaptures at the headwater counting facilities was used to assess the temporal composition of fish accessing the headwater sites and the variations of this and the time to ascend to the headwater sites relative to environmental conditions.

A - Environmental characteristics

The daily discharge is most frequently lowest in August and September and severe low discharge conditions are most frequent in August through October. Three of the four years with the most severe low water conditions were recorded in the last ten years in the Southwest and Northwest Miramichi rivers (Figures 1, 2). In six of the last ten years (1994 to 2003), low discharges in the Southwest Miramichi were observed during more than 80 days in June to October, the worst ten year period of the 1962 to 2003 series. In both the Southwest Miramichi and Northwest Miramichi, low water conditions were recorded in over half the fall period (30 days or more) in 8 of the last 10 years, a proportion unobserved in any other ten year period. Extreme low water conditions were recorded in more than half the days of the fall in the Southwest Miramichi in four years of the time series, three of the four occurred in the last decade (1968, 1994, 1995 and 2001). In the Southwest Miramichi, 2 of the 3 years with frequent extreme low flow events in the summer and fall were observed in the last ten years. For the Northwest Miramichi, 2 of the 3 years with frequent extreme low flow events also occurred in the last ten years.

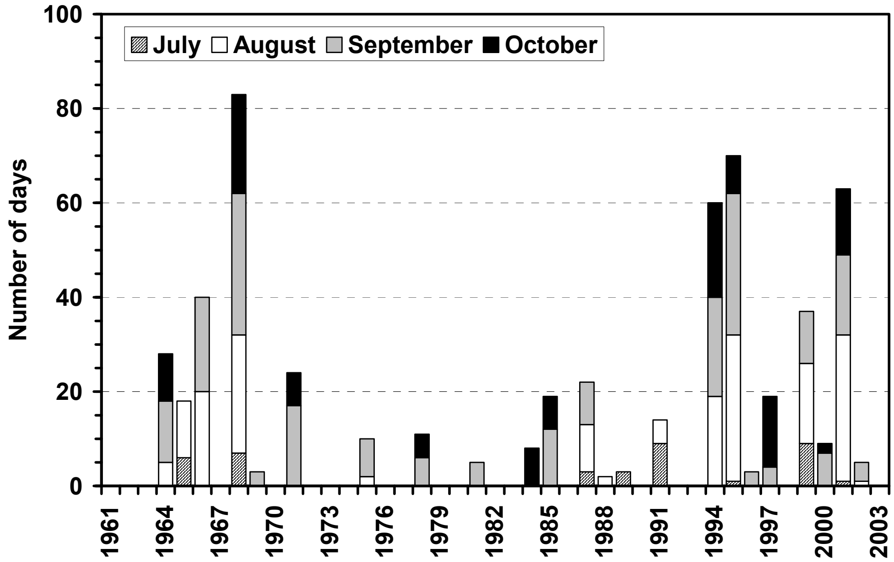


Figure 1. The number of days, by month, with extreme low discharge conditions in the Southwest Miramichi, 1962 to 2003.

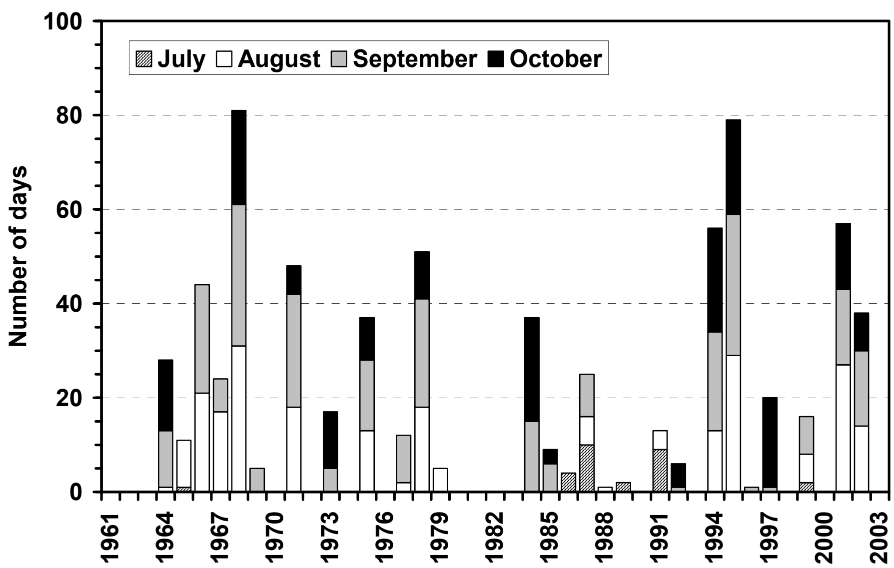


Figure 2. The number of days, by month, with extreme low discharge conditions in the Northwest Miramichi, 1962 to 2003.

B - Fish tagging and recoveries at estuary trapnets

Over all years, about 11% of the fish tagged in the estuary trapnets are seen again (recaptured) in the estuary in the same year. The variability in the annual recapture rates in each of the branches represent variations in the amount of gear available for capturing fish as well as the effects of environmental conditions on individual trapnet efficiencies. Salmon tagged in one branch of the Miramichi may be recovered at trapnets in either branch. Proportionally more salmon move out of the Northwest Miramichi than from the Southwest Miramichi. The time of recovery of tagged fish at the trapnets is constrained by the season of operation and the spawning time. Most of the fish seen again are observed within a short period of time post-tagging but some fish are seen again at the same or other trapnet several months post-tagging. It is assumed that these fish did not migrate into freshwater portions of the river but stayed within the estuary or returned to the bay. Between 12% and 16% of fish which switched branches were recovered within two days of tagging and more than 50% of the fish were seen again in 8 to 11 days post-tagging. This contrasts with fish which remained in the same branch for which 50% of the fish were seen again within 3 to 4 days post-tagging. The year 2001 stands out in both branches as there were higher percentages of fish seen again at the same trap and also switching between branches than in other years. The percentage of tagged fish seen again increases from June to October as does the proportion of fish which switch branches, consistent with lower water levels in the fall months relative to summer.

Fish movements through the estuary are hypothesized to be affected by conditions in river. The following hypotheses were examined:

- low discharge results in higher recovery rates of tagged fish at the trapnet where they were marked;
- low discharge results in a higher proportion of recovered fish occurring late; and
- low discharge results in longer times at large to recovery.

For the Southwest Miramichi trapnet, there was one significant correlation between the proportion of tags seen again and the annual discharge conditions as defined by the number of days with low water conditions. Generally, there was an increasing proportion of tags seen again with increasing severity of low water conditions.

Long absence recoveries are defined as those recoveries which occur in the upper quartile of times at large for all years and months combined. In the Southwest Miramichi, there was a significant positive correlation between the proportion of tag recoveries of long duration and the number of days of low discharge, during the month of tagging and to the end of the migration period for September fish. No statistically significant correlations were noted in the Northwest Miramichi but there was a strong positive associations noted for the September tag group. There were significant statistical differences in the mean date of fall recaptures of July-August and September tagged salmon from the Northwest Miramichi and significant differences for the September tag group from the Southwest Miramichi. For both these tagging groups, there were significant positive associations between the mean date of capture and the number of days with low discharge, suggesting that fish movements through the estuary in the fall are affected by low water conditions. The mean dates of recapture of Southwest Miramichi tagged fish were earliest in 1998, as was the case for the Northwest Miramichi.

C - Fish tagging and recoveries in recreational fisheries

The availability of salmon to the recreational fishery was examined using the database of fish tagged in the estuary and recaptured in the recreational fishery. Two potential effects of water conditions on fish availability were examined:

1) upstream migration of fish is delayed by low water (distance to recapture in freshwater should be short when water is low); and

2) fish don't take when the water is warm (i.e. days to recapture should be high when water is low, temperature is high).

Tagged fish were recaptured in the angling fisheries shortly after tagging. Salmon tagged in May to August (summer) were more quickly recaptured in the Northwest Miramichi than in the Southwest; this pattern was consistent for fish tagged in the main stem of the Miramichi, in the Northwest Miramichi and in the Southwest Miramichi. Salmon tagged in September and October were recaptured after generally equivalent times at large in the Northwest and Southwest Miramichi. Days to recapture were fewer in the fall than in the summer: median dates of less than 10 days for fall tagged fish from the Miramichi compared with 15 to 19 days for salmon tagged in the summer. Over half of the salmon tagged at the main stem Miramichi trapnet and recaptured in any given year were angled within 20 days of tagging. For the Southwest Miramichi tagged salmon; with 31% to 68% of the tag recoveries in the angling fishery occurring within 20 days post-tagging. The most downstream angling pools in the Miramichi River are located at the head of tide of both the Northwest and Southwest Miramichi branches. There are a number of important angling pools in the Miramichi distributed from the head of tide to over 170 km upstream. Most (>50%) of the recaptures of salmon tagged at the main stem trapnet in the Miramichi River were recovered from the head of tide pools to just over 30 km upstream in freshwater with the greatest distance to recapture at 190 km upstream in fresh water. There was no statistically significant difference in the cumulative distances to recapture for salmon tagged from the main stem trapnet in summer and salmon tagged in the fall.

For the Southwest Miramichi, 30% of the angling recaptures were recorded from four pools located within 40 km upstream of the trapnets with most (>50%) of the recaptures of salmon recovered from the head of tide pools to just over 30 km upstream in freshwater The median distance to recapture of fall tagged salmon was 39 km compared to 49 km for recaptures of salmon tagged in summer. No single pool from the Northwest Miramichi accounted for more than 6% of the recoveries in the angling fishery.

The median time to recapture in the angling fishery was generally not linearly associated with the number of days of either low discharge or extreme low discharge conditions in the Southwest Miramichi. Based on the four observations in which there were five or more tags recovered in the angling fishery of the Northwest Miramichi, the median time (days) to recapture of salmon tagged in September and October was strongly positively correlated with the number of days of extreme low discharge suggesting that salmon from this group are held back by the low water conditions. The median distance to recapture was negatively associated with the number of days of low and extreme low discharge, suggesting that the extent of penetration upstream is negatively affected by low water conditions. The cumulative distributions of tags placed were compared to the cumulative distributions of tags recaptured in the angling fishery by date of tagging, separately for summer tagged fish (June to August) and fall tagged fish (Sept. and October). The availability of fish to angling was expected to be affected by low water conditions. Differences in the distributions of recoveries relative to distributions of tagging were observed in one of the two years for the summer and in four of the five years for the fall when an effect was anticipated. In none of the years and seasons when no effect was expected were the distributions estimated to have differed.

D - Headwater counting fence recoveries

Salmon are captured, sampled and released into holding pools or are allowed to migrate upstream at six counting fences in the Miramichi River. The six facilities are located between 29 km and 180 km in stream distance from the head of tide at elevations above sea level ranging between 75 m and 320 m. A total of 730 tag recoveries were analysed.

The movements of salmon through the facilities are characterized by a gradation of summer (prior to September 1) to fall (after August 31) movement dominance. There was a dominant summer movement of salmon at two facilities, an important summer and large fall movement at another, predominantly fall movements at two sites, and exclusively fall movements at the small tributary in the lower portion of the Northwest Miramichi. There is a positive association between the proportion of the run which ascends to the counting facility early and the elevation of the facility, with fewer fish ascending the higher elevation sites in the fall

The fish which migrate to the facilities in the fall are a mixture of early and late running salmon at the estuary. There is a strong linear positive association between the elevation of the facility and the proportion of the fish which were tagged early in the estuary.

There are important annual variations in the proportion of the tagged salmon at the facility which were tagged in the early season in the estuary. Water conditions in terms of average discharge, or number of days with low or extreme low discharge, are poorly associated with the annual variations in either the proportion of the tagged fish which are from the early run or the rapidity of upstream migration of the early run salmon. Factors other than discharge appear to be conditioning the movement of salmon through the estuary to the upstream tributary facilities.

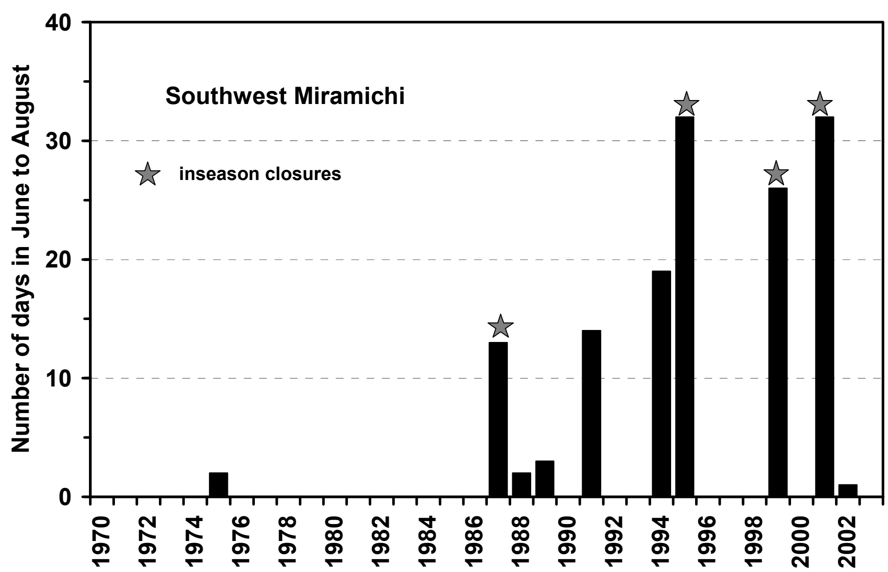
3 - Social and Economic Effects of Fisheries Closures (Chapter 3)

The Miramichi River is located at 47ºN, drains a total watershed area of about 14,000 km², and has over 2,300 km of stream providing opportunities for fishing. Aboriginal fisheries for salmon in the Miramichi are regulated by quota, gear and season, and most take place within the estuary portion of the watershed. The aboriginal fishery opens in mid-May to early June and closes after October 15 or when the quota is harvested.

The Miramichi River provides about 1,400 km of salmon angling water distributed over 700+ angling pools. The angling potential in terms of km of river and days of access is in the order of 200,000 km-days. The general angling season extends from April 15 to October 15. A small portion of the river is closed to angling after August 31 with larger closures occurring on September 15 in the upper portions of the watershed with the lower portions of river closing on October 15. In a limited number of years, season extensions for up to one week were introduced in a limited portion of the lower section of the Southwest Miramichi River.

Modifications to fisheries management plans are made via Variation Orders which define geographically and temporally the aspects of the regulations being modified. Variation orders, which identify fisheries closures resulting from low and warm water conditions for example, are legal documents of public record.

Since 1962, there have been four inseason closures of angling fisheries. The closures have corresponded to the years where discharge conditions were extremely low. There was no closure in place in 1991 or 1994 when environmental conditions in terms of the number of days with extreme low discharge were as important as in 1987.



The intervention in 1995 was an all-day closure which resulted in a loss of 13% of the total of 200,000 km-days of angling potential on the Miramichi River. The inseason closure was exacerbated by an aboriginal fishing dispute in the Northwest Miramichi which resulted in the effective prevention of upstream migration of Atlantic salmon in the Northwest branch of the Northwest Miramichi after July5 until September 20. In 1999, angling was prohibited after 10:00

AM from July 31 to August 10 in the entire watershed. This partial day closure resulted in a loss of 6% of the angling potential on the Miramichi River. The inseason closure of 2001 was an all day closure in specific areas of the river from August 10 to 31 which also resulted in a loss of 6% of the total angling potential on the Miramichi River. The cancellation of fishing parties in 1995 and 2001 to the Crown Reserve Waters of the Northwest Miramichi were estimated to have produced revenue losses of $41,000 and $8,000, respectively.

A survey questionnaire was developed in June 2002 through discussions with the Miramichi Watershed Management Committee Inc. (MWMC), Province of New Brunswick Dept. of Natural Resources and Energy, U. de Moncton (UdeM) and DFO (Chapter 3: Appendix 3). During July and August, a student from the UdeM and a second student from the MWMC interviewed retailers, outfitters and anglers from public pools on the Miramichi relative to the impact of inseason closures due to warm and low water on the fishing activities and on Atlantic salmon. The results and conclusions are detailed in Chapter 3.

The results of the survey were fairly consistent across the outfitters, retailers and anglers in most aspects related to the knowledge about inseason closures, the justification for the closures and the effectiveness or ineffectiveness of the measures. The most consistent criticism across all respondents was the lack of protection of fish from illegal activities when the rivers are closed to angling and anglers are not on the river. There was also some debate that the measures were not very effective at reducing mortality of salmon due to angling because it was considered that salmon did not rise to a fly when the water was warm therefore few fish were being angled under those conditions. When asked whether the uncertainty associated with inseason closures in response to environmental conditions could be reduced by starting the year with a pre-determined closure period in summer pending climatic conditions, the majority of the respondents were opposed to that. They preferred having the river open and only closing based on need. A large number of respondents felt that forestry practices such as clear-cutting and small buffer strips along streams aggravated the low water and warm water events and that there was a need to change these practices. Almost everyone interviewed had heard of climate change predominantly from radio, television and newspapers. It is interesting that few indicated that they had obtained information about climate change from government publications or environmental groups. The majority of individuals were also aware of some of the anticipated consequences of climate change such as warmer winters and summers, variable weather, etc. but a large proportion of the public water anglers were unsure what effect climate change would have on Atlantic salmon and the fishing potential in the Miramichi.

In terms of economic impacts, the fishery closures in 1999 and 2001 were important for retailers and for some outfitters. Although difficult to quantify or not willing to say, the economic losses were in the tens of thousands of dollars for each business group and combined would have exceeded the 100 thousand dollar value. As with any estimate of revenue or losses, the numbers are not exact but suggest a reasonable ball-park value associated with the business activities. For a rural area like the Miramichi whose economy is resource and tourism based, the losses to the communities are not negligible.

4 - Adaptive Management Strategies to Protect Salmon under Environmentally Stressful Conditions

In recent years, inseason management measures have been introduced to reduce the impact of recreational fishing on Atlantic salmon during periods of warm water and low water levels. The survey of the public and businesses provided indications of the types of activities which were favoured to deal with stressful conditions for Atlantic salmon (see Chapter 3). It became quite clear that the recreational fishery users felt that the recreational fishery was not the only activity which should be targeted. Indeed, there were strong opinions that numerous land use activities, particularly loss of riparian buffer strips due to forestry activities and land development were contributing and exacerbating the hydrological conditions leading to stress and mortality of Atlantic salmon. Most people preferred inseason closures when required based on environmental conditions but that other activities, including canoeing, tubing and swimming in salmon holding pools, should also be regulated under these conditions.

The decision to intervene in season should be based on a sense of being able to clearly show benefit and the intervention must be timely. Inseason intervention in angling fisheries in response to exceptional environmental conditions has been used in numerous jurisdictions within Canada and the U.S.A.

The water temperatures in portions of the Miramichi River can approach the upper lethal temperatures (25 to 28ºC) for Atlantic salmon and water temperatures in excess of 25ºC for several hours were recorded at a major salmon holding pool in the Southwest Miramichi. There is overwhelming evidence that incidental mortality from catch and release angling increases with water temperatures above 20ºC (Figure 2). Indeed, mortality associated with any additional stress resulting from displacement of salmon from cool water seeps, burst swimming, and general unease would be expected to increase with increasing temperatures.

The inseason closures which occurred in 1999 and 2001 were initiated in response to observed salmon mortalities, warm weather conditions and low water levels. The interventions of those years were less effective than they might have been if the response to the warm water events had been more immediate. The deficiencies in the approach include the absence of pre-agreed conditions for initiating a review, too slow a response time, an absence of characterization of the conditions throughout the Miramichi watershed, and the absence of evidence that the interventions were effective in reducing mortality of salmon (i.e. that the fisheries under these environmental conditions produced excessive mortality of salmon beyond that which would have occurred in the absence of fisheries).

Effective inseason management requires the ability to respond quickly to environmental stresses. Since 1999, a hydro-met station has been operating on the Southwest Miramichi from which hourly measurements of water and air temperature, precipitation and water levels are collected. There must be pre-agreed triggers for initiating a review and facilitating the decisions. Criteria for initiating review of possible closures and re-openings of salmon fisheries in the Miramichi remain to be defined. Possible intervention scenarios were examined and their performance was evaluated relative to three criteria: potentially positive effect on the resource; impact on the fisheries, and frequency of interventions.

There were strong opinions expressed at the public discussions regarding inseason management measures for the salmon fisheries of the Miramichi with many opposing such measures. Opponents argued there were no benefits for the fish and only negative consequences for the users. Temperature by itself may not be a sufficient indicator. Further studies initiated in 2002 and 2003 suggest that low discharge may have been a determining factor of salmon mortality in 2002 and a subsequent study in 2003 suggested that low dissolved oxygen levels, particularly when discharge is low and at dawn, may be exacerbating the cumulative stress on salmon.

The benefits to the resource of inseason intervention depend upon the additional and excessive mortality of salmon under warm and low water conditions associated with the fishing activity. Temperature stress by itself may also lead to mortality independent of fishing. The evidence that catch and release mortality increases at high temperatures is unequivocal. The number of fish which may be saved from incidental mortality from catch and release depends upon the number of fish which would have been caught during the interventions. The absence of detailed catch and effort data precludes any firm conclusions on that question. The large and diverse physical characteristics of the Miramichi River provide an additional challenge to managers. Due to the basin-wide variations in water temperatures and water levels, global interventions may restrict fisheries where such intervention are not warranted.

Since 1999, the federal and provincial governments have actively participated in consultations with the Miramichi Watershed Management Committee Inc. on the issues of inseason management and management strategies for protecting both the resource and the fisheries activities. A few adaptive approaches have been discussed and the MWMC is presently proposing additional options for coping with increasingly stressful summer conditions including the restoration of historical cold-water pools, mid-day closures rather than full day closures, and artificial oxygenation of pools during low and warm water events. Supplemental fish activity associated with rising temperatures and stress can be exacerbated by other non-catch activities such as wading by anglers, casting of flies, boating, and swimming; the latter two factors were considered significant in the subsequent high numbers of fish dying in August 2001. The regulation of recreational water users has not been considered to date.

A study has been proposed to assess the feasibility of artificially oxygenating key holding pools during particularly stressful conditions. The study design was to artificially oxygenate a holding pool and observe the response of adult salmon to this source of higher oxygenated water. An independent project by the Miramichi Salmon Association and the Miramichi Watershed Management Committee is the restoration of Doak Brook and the recovery of a cool water holding area at the mouth of the brook. This is one example of projects designed to respond to changes in river characteristics and increasing environmental stress.