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Hydrological Conditions for Atlantic Salmon Rivers in the Maritime Provinces in 1995[2]

by

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ABSTRACT

The objective of the present paper is to provide information on hydrological conditions for selected Atlantic salmon (*Salmo salar*) rivers within the Maritime Provinces during 1995. Long-term hydrological data are presented as well. High and low flow characteristics for each river, were calculated based on historical annual flow and low flow series. Stream water temperatures were obtained at a few river systems and temperature characteristics such as high stream water temperature events were presented.

In general, early winter provided above normal discharges with many rivers experiencing excessive monthly flow condition. February showed low flows for rivers in Cape Breton and Prince Edward Island. The spring breakup of 1995 was generally characterized as mild with practically no flooding in any of the Maritime Provinces.

Low flow conditions during the summer of 1995 varied with regions. For instance, New Brunswick was most affected with a 15-year low flow in the Miramichi River and a 25-year low flow at Upsalquitch River. Many of Nova Scotia's rivers experienced deficient flows during April and May 1995 and also low flow conditions of between 3 and 5-year during the summer.

River water temperature variations in 1995 are characterized by five major events between late June and mid-August. In early July, many rivers in the Maritime Provinces reached their peak summer temperatures; Southwest Margaree River (25.2 °C), Restigouche River (27.6 °C), and Morell River at Martinvale's Culvert (26.2 °C). Rivers in the interior of New Brunswick experienced their highest recorded temperatures in early August; Little Southwest Miramichi River (30.0 °C), Nashwaak (28.4 °C), Tobique (27.1 °C), North Branch Southwest Miramichi River at Juniper (26.6 °C;), and Dungarvon Rivers (25.9 °C). The Northwest Miramichi River below Big Hole Pool showed a maximum temperature of 28.2 °C during this period while the Southwest Miramichi River reached 26.4 °C (Millerton) and 25.5 °C (Enclosure).

RÉSUMÉ

Le présent article a pour objet de fournir de l'information sur les conditions hydrologiques qui ont prévalu dans quelques rivières à saumon de l'Atlantique (*Salmo salar*) dans les provinces Maritimes en 1995. Les caractéristiques de débits de crue et d'étiage ont été calculées pour chaque rivière en utilisant des données historiques de débits maximum et minimum annuels. La température de l'eau a été obtenue pour quelques rivières, et les caractéristiques de température, tel que les événements de température élevées, ont été présentées.

En général, le débit des rivières était supérieur à la normal pendant le début de la saison hivernal. En février, une période de débits faibles a été mesurée à l'Ile-du-Prince-Edouard et au Cape Breton. La débâcle en 1995 était très douce avec pratiquement aucune condition de crues dans toutes les provinces Maritimes. Plusieurs rivières en Nouvelle-Écosse ont mesurées un débit déficitaire durant le mois d'avril et mai 1995.

Les conditions de débits faibles durant l'été 1995 étaient variées. Par exemple, au Nouveau-Brunswick des conditions d'étiage d'une récurrence de 15 années furent mesurées sur la rivière Southwest Miramichi tandis que la rivière Upsalquitch était dans un état d'étiage d'environ 25 années de récurrence. Le débit des rivières en Nouvelle-Écosse étaient inférieures à la moyenne durant l'été, avec des conditions d'étiage variant entre 3 à 5 années.

Les variations dans la température de l'eau en 1995 peuvent être caractérisées par cinq événement importante à partir de la fin juin jusqu'à la mi-août. Au début de juillet, plusieurs rivières dans les provinces Maritimes ont observées leur température maximum de la saison; la rivière Southwest Margaree (25.2 °C), la rivière Restigouche (27.6 °C), et la rivière Morell à Martinvale's Culvert (26.2 °C). Les rivières dans la région de la Miramichi rencontrèrent leur température maximum au début d'août avec une température maximum de 30.0 °C sur la rivière Little Southwest Miramichi. Les autres rivières inclurent la rivière Nashwaak (28.4 °C), Tobique (27.1 °C), Juniper (26.6 °C), et la rivière Dungarvon (25.9 °C). La rivière Northwest Miramichi en aval de Big Hole Pool démontra une température maximum de 28.2 °C durant cette période tandis que la rivière Southwest Miramichi mesura une température de 26.4 °C (Millerton) et de 25.5 °C (Enclosure).

INTRODUCTION

Hydrological conditions may have major influences on our fisheries and aquatic resources. Certain of these conditions such as streamflow availability and variability can affect stream biota at different life stages and also during different seasons of the year. Atlantic salmon, which spend most of their juvenile stage in streams and rivers, are particularly sensitive to high and low flow conditions. Extreme hydrological events such as floods have often been reported to have important impacts on fish (Elwood and Waters 1969; Erman et al. 1988). Similarly, low flows can affect fish movement and stream water temperature (Cunjak et al. 1993; Edwards et al. 1979). In order to increase our understanding of streamflow variability of particular Atlantic salmon rivers for the purpose of assessing Atlantic salmon stocks, we need to study the stream hydrology for these rivers and in particular the streamflow conditions in 1995.

A regional hydrological analysis was carried out using historical hydrometric data from gauged stream and rivers in the study region. These data were used to calculate high and low flow characteristics for different recurrence intervals (T-year events). Annual flood flows and low flows were fitted to a statistical distribution function in a frequency analysis to estimate the T-year events (Kite 1978). For instance, the 25-year (T = 25) low flow is a low flow which occurs on the average every 25 years so that 4 such events would have occurred in the last 100 years. For the flood frequency analysis, a three-parameter lognormal distribution function was used to estimate the high flow T-year event based on historical annual flood observations (Kite 1978). In contrast, the type III extermal distribution was used to estimate the low flow frequency events using daily minimum discharge on an annual basis.

Monthly flow characteristics were also obtained for 1995 and compared to long-term average flow conditions. The high and low flow months were presented for each river system as part of the index river network used by Environment Canada. Environment Canada Monthly Surface Water Quantity Conditions for Atlantic Canada (Environment Canada 1995) was the source of data for this analysis. For rivers not part of the index river network, data available in 1995 were obtained and used to study the discharge conditions during the year.

The objective of the present study is to provide regional hydrological information on important Atlantic salmon rivers within the Maritimes Region for aquatic and water resource management. The specific objectives are to: a) provide an overview of the monthly flow conditions where data were available; b) determine the high and low flow months within the year or season; c) determine the frequency of floods and low flows of particular events within the year; and d) provide data on high water temperature events for some salmon rivers in the studied region.

STUDY REGION

The study comprises eight Atlantic salmon rivers within the Maritime Provinces (Figure 1). These rivers included: Nashwaak River (01AL002, NB), Upsalquitch River (01BE001, NB), Southwest Miramichi River (01BO001, NB), Northeast Margaree River (01FB001, NS), Grand River (01FH001, NS), St. Marys River (01EO001, NS), LaHave River (01EF001, NS), and Morell River (01CD003, PEI). Of the eight rivers, five were part of the Environment Canada index river network (Environment Canada 1995). Two rivers are presently discontinued hydrometric stations, the Grand River (NS) as of April 1995 and Morell River (PEI) as of September 1992. No substitute river was available for Grand River, however, to study the streamflow condition in PEI during 1995, the Wilmot River was used as a replacement for the Morell River.

The drainage basin of the studied rivers ranged from 120 km^2 (Grand River) to 5050 km^2 (Southwest Miramichi River; Table 1). LaHave and St. Marys Rivers have the longest daily discharge time series with 79 years of record. The mean annual flow (MAF), which is a function of drainage area, varies between 3.60 m^3/s for Morell River and 116 m^3/s for the Southwest Miramichi River. To compare discharge between basins of different sizes, the mean annual runoff was used. This represents the mean annual flow (MAF) expressed in unit discharge in mm (discharge per drainage area). The region has a wide range of runoff characteristics depending on parameters such as the amount of rainfall, soil type, etc. Northern New Brunswick showed the lowest runoff with only 568 mm for Upsalquitch River compared to more than double this value for Northeast Margaree River at 1485 mm. The precipitation varies from 1080 mm to 1420 mm (Table 1). The coefficient of variation (CV) of monthly flow characteristics show a more stable flow regime in Grand River (0.49) and Morell River (0.52) than rivers such as the Upsalquitch River (1.06).

Hydrological Conditions During 1995

In general above zero air temperatures in January 1995 resulted in excessive monthly flow conditions as result of melting in most rivers in the Maritime Provinces. Deficient flow conditions were shown in February on PEI (Wilmot R.)

and Cape Breton Island(Northeast Margaree R.). A flow within the 75% quartile identifies an excessive monthly flow condition while a flow within the 25% quartile denotes a deficient flow (Environment Canada 1995). As a result of the excessive flow in the beginning of the year, some rivers experienced their annual flood (highest daily discharge of the year) in January (Wilmot, LaHave and Northeast Margaree). On a daily basis, the Northeast Margaree River experienced the lowest flow conditions in Nova Scotia this year with a 7-year low flow event during the winter of 1995.

The spring of 1995 was generally characterized as mild in terms of flooding with discharge at or below normal. Most rivers in Nova Scotia experienced a deficient monthly flow during the spring (April and May) with LaHave showing a record low flow monthly discharge in April.

Flows in June were below normal in New Brunswick rivers while most of mainland Nova Scotia rivers were excessive. Deficient flows were monitored in New Brunswick from July to October at Southwest Miramichi and Upsalquitch Rivers with a record low flow month for July at Southwest Miramichi River and for August and September at Upsalquitch River. The low flow situation in 1995 was approximately a 25-year event at Upsalquitch River and a 15-year event for the Southwest Miramichi River. Rivers in Nova Scotia also had deficient flows from August to October with St. Marys being the most affected with a deficiency for all three months (Environment Canada 1995). Discharge increased again during the fall with excessive flows monitored in November for some New Brunswick and Nova Scotia rivers.

HYDROLOGICAL CONDITIONS BY RIVERS

Nashwaak River (NB)

Discharge data during the winter showed that the Nashwaak River had above normal flow conditions (Table 2). Spring data showed that April and May experienced average monthly flow conditions in 1995 with discharge of 115 m^3/s and 75.3 m^3/s respectively (Environment Canada, unpublished data). The average flow conditions for April and May are 100 m^3/s and 83.8 m^3/s (Table 2). The summer flow condition at Nashwaak River was deficient from July to October with the minimum monthly flow in September at 4.20 m^3/s compared to the average of 15.8 m^3/s. Daily discharges showed spring floods were not severe in 1995 with a high flow peak of 236 m^3/s recorded on April 22. This discharge was below the 2-year flood event which was estimated at 321 m^3/s (Table 3). The low monthly flow conditions during the summer resulted in the lowest daily discharge since 1987. The daily summer low flow event this year was in the range of a 5-year event (Table 4) with a minimum daily discharge of 3.02 m^3/s which was recorded on August 14.

Upsalquitch River (NB)

During the winter of 1995 excessive flow conditions were observed for the Upsalquitch River in January with flow of 20.6 m^3/s compared to the average 14.0 m^3/s (Table 2). February and March showed normal discharge of 11 m^3/s and 12 m^3/s (Environment Canada 1995). April was also normal with flows of 66 m^3/s compared to the long-term average of 89 m^3/s (Table 2). The spring high flow in May resulted in higher than average discharge, although not excessive, with monthly flows of 217 m^3/s compared to the average of 158 m^3/s. The June flow conditions were average while deficient flow conditions were observed between July to October at Upsalquitch River. In fact, August and September were record low flow months with monthly discharge of 5.87 m^3/s and 4.28 m^3/s respectively (Environment Canada 1995). Such low flow conditions were not observed in over 65 of data records dating back to 1918. The previous record low flow for the month of August and September were observed in 1968 at 5.90 m^3/s and 4.50 m^3/s respectively (Environment Canada 1990). Discharge in November was slightly below normal at 23.7 m^3/s while December was again in a deficient situation.

Daily discharge data showed, the winter low flows were approximately 8 m^3/s for the months of January, February and March. The spring high flow was monitored at 328 m^3/s which represents a flow below the 2-year flood (Table 3). During the summer low flow period a new daily record low flow was reached for the month of September, on the 27th at 2.81 m^3/s . The previous record was reached in September 1953 at 3.30 m^3/s. The minimum daily discharge in September of 1995 also was the minimum daily flow for the year, and was also close to a 25-year low flow (2.78 m^3/s) at Upsalquitch River.

Southwest Miramichi River (NB)

The Southwest Miramichi River experienced close to normal flow conditions during the winter season, with February having a slightly lower discharge of 34.1 m^3/s compared to 51.2 m^3/s, the long-term average (Table 2). During the spring of 1995, the high flow month was May with a monthly discharge of 355 m^3/s compared to 300 m^3/s in April (Environment Canada 1995). These flow conditions were near normal for that time of year. In the summer season the monthly flow were deficient from June to October in 1995, with July having a record low monthly discharge at 25.9 m^3/s. The average flow condition during July is 60.1 m^3/s (Table 2). Excessive flows were monitored in November on the Southwest Miramichi

River with a monthly discharge of 196 m^3/s with deficient flows again in December at 52.3 m^3/s (Table 2).

Daily discharge data showed, a 2-year low flow was observed mid January (15) at 18.2 m^3/s and also on March 8 at 20.0 m^3/s (Table 4). The peak flow in the spring was recorded on April 22 at 669 m^3/s. This flow represents a discharge lower than the 2-year flood (Table 3). The spring floods were not severe this year on the Miramichi. The minimum daily occurred on August 23 at 12.2 m^3/s. This particular low flow represents approximately a 15-year low flow event (Table 4). The minimum daily discharge in September was also significantly low at 12.6 on September 07.

Morell River (PEI)

The Morell River's hydrometric station in PEI has been discontinued since September 1992. However, long-term characteristics for that particular system are presented in Table 2, with monthly flows ranging from 7.95 m^3/s in April to a low flow period in September of 1.44 m^3/s. In order to assess the PEI streamflow condition for 1995, data from the Wilmot River from Environment Canada (1995) were used. A correlation analysis was carried out between historical discharge to these two rivers and results showed that they were highly correlated at 0.86 ($p<0.0001$). In 1995, no excessive flows were monitored on the island based on monthly flow conditions, however deficient flows were monitored in February and December (Table 2). The high discharge month in PEI occurred in April, normal for that time of year. Summer conditions were also close to normal while discharges in the fall were below normal. Data showed that December experienced the lowest monthly flow condition in 1995, with a discharge less than half of average. Similarly, November showed below normal discharge for the time of year although not in a deficient situation. Daily discharges showed, the annual flood peak was recorded during January and was below the 2-year flood event.

LaHave River (NS)

The LaHave River showed excessive flow during January at 86.6 m^3/s compared to the January monthly average of 46.8 m^3/s (Table 2). January was also the month with highest monthly discharge (higher than spring flow months). The conditions during late winter were below normal with flow of 28.1 m^3/s and 38.9 m^3/s in February and March (Environment Canada 1995). April also experienced a record low monthly flow conditions with a deficient flow of 30.8 m^3/s. This showed that the spring flow conditions were very mild on LaHave River in 1995. In contrast, the June flows were excessive with a mean monthly discharge of 35.1 m^3/s. These high flows were largely due to two high flow peaks, one on June 9 and the other on June 16. Both of these peaks were in the range of 75 m^3/s on a daily basis.

For LaHave River, July and August showed normal conditions while September and October of this year showed deficient monthly flows. The September monthly discharge was 1.02 m^3/s while the October monthly discharge was 4.11 m^3/s. In November the monthly discharge was excessive with a discharge of 75.9 m^3/s compared to 42.0 m^3/s for average flow conditions (Table 2). December flows were deficient in 1995. This particular river system experienced much variability in monthly flows this year from deficient to excessive flow conditions.

Daily discharge data showed, the peak flow this year was reached on January 08 at 270 m^3/s. This discharge represents a flow close to a 5-year flood event (Table 3). The minimum daily discharge was observed on September 17 at 0.618 m^3/s, which is a discharge with approximately a 5 year recurrence interval (Table 4).

St. Marys River (NS)

St. Marys River monthly discharge conditions in 1995 were very similar to those of LaHave River with excessive flows in January (Environment Canada 1995). The discharge in January was monitored at 76.6 m^3/s compared to a long-term average of 51.3 m^3/s (Table 2). During February the discharge was below normal with discharge at approximately half of the average flow condition. In March flows were average, however, April which is usually the high flow monthly, showed a deficient discharge this year at 53.0 m^3/s. The June monthly discharge was excessive at 56.7 m^3/s compared to 23.9 m^3/s, the average discharge (Table 2). Peak flows of 172 m^3/s and 217 m^3/s were recorded on the 9th and 15th and were responsible for the higher than normal conditions in June. Monthly deficient flows were then recorded between August to October at St. Marys River, with September having the lowest monthly discharge at 3.25 m^3/s. The average monthly flow rate for that time of year is approximately 15 m^3/s (Table 2).

On a daily basis, a high flow of 302 m^3/s was recorded on January 08, while the annual flood peak was recorded on May 08 at 420 m^3/s. For St. Marys River, such a discharge represents approximately a 3-year flood event (Table 3). In 1995, the minimum daily discharge was reached on September 17 at 1.37 m^3/s and this flow is estimated to be in the range of a 3-year low flow event (Table 4).

Northeast Margaree River (NS)

Excessive flow conditions were measured for the Northeast Margaree River in January of 1995 with a monthly discharge of 31.4 m^3/s compared to the long-term average of 15.2 m^3/s (Table 2). Discharge in February was deficient at 3.32 m^3/s (Environment Canada 1995) compared to an average value of 11.3 m^3/s. Both high and low winter flows were experienced in the winter of 1995. The monthly discharge in February was the lowest monthly flow in 1995 for the Northeast

Margaree River. March and April discharges were close to average conditions while May experienced a deficient monthly flow at 22.4 m^3/s. The long-term average discharge for May is at 44.5 m^3/s. The summer and fall hydrological conditions were between average and deficient. In fact, both July and September recorded deficient monthly discharges at 4.81 m^3/s and 4.77 m^3/s respectively. Monthly discharge in October and November were average for the Northwest Margaree River while December flows were deficient.

In 1995, the maximum daily discharge for Northeast Margaree River was monitored on January 16 at 226 m^3/s, which represents a discharge in the range of a 5-year flood event (Table 3). Interestingly the spring peak flows were at approximately 53 m^3/s during April and May, while peaks in June were as high as 62 m^3/s (June 17). The winter low flow during mid-February resulted in a annual daily minimum discharge of 2.20 m^3/s. This event was estimated as a 7-year low flow for the Northeast Margaree River based on annual low flows (Table 4) and is one of the lowest winter flows on record. Low flow conditions are more frequent during summer months than during winter in this particular system (Environment Canada 1990). The summer low flow conditions were approximately 2.70 m^3/s (Aug. 12) and 2.67 m^3/s (Sep. 26), which still represents a low flow of a 3-year event.

Grand River (NS)

The Grand River hydrometric station was discontinued during April of this year. During the winter months, normal flow conditions were monitored in January and March while February showed below normal flows. During February of 1995 discharge was monitored at 2.17 m^3/s (Environment Canada, Unpublished data) compared to the long-term discharge at 4.20 m^3/s. During the winter, a peak flow of 8.83 m^3/s was reached in January and a low flow of 1.42 m^3/s late February and these flows were not considered extreme events (Table 3 and Table 4).

STREAM WATER TEMPERATURES

River water temperatures can play an important role in the distribution of fishes and it can also influence other parameters such as dissolved oxygen content. Because maximum and minimum water temperatures are important to fish populations, they were presented as well as daily mean temperature. The range in daily water temperature (maximum-minimum) was also presented during high water temperature events.

The critical temperature for salmonids does vary between species. For instance, Atlantic salmon are more tolerant to high water temperatures than brook trout. For the purpose of this paper, a high water temperature events was a temperature that reached approximately 22 °C to 23 °C.

River water temperatures were available for different locations within the Maritimes Region in 1995. Compared to previous year, the conditions this year could be characterized as having many high water temperature events. During any high water temperature event, it was observed that the Maritime Provinces were affected by similar climatic conditions so that the high air temperature event affected most of the rivers in the region. For instance, during the summer of 1995, approximately five such events were monitored at Catamaran Brook (Table 5). This brook is located in the central part of New Brunswick and forms part of the Miramichi River basin. The first event occurred over 2 days late in June with maximum temperatures of 33.7 °C on the 24th (day 175) and 32.1 °C on the 25th (day 176). Also provided in Table 5 is the time of recorded maximum air temperature. High air temperature events were also monitored in July (7th or day 188 and 25th or day 206) with maximum temperatures on these days of 29.3 °C and 30.8 °C, respectively. The most significant event recorded at Catamaran Brook during July 31 and August 1 (day 212 and 213) with temperatures that reached 35.3 °C at 5:00 pm on August 1, 1995 (Table 5). This day also represented the highest daily mean temperature of the summer at 26.3 °C. The last major high air temperature event of the summer occurred on August 11, with a maximum recorded temperature of 31.6 °C (Table 5).

Stream water temperature variations for Tobique, Nashwaak (at fish counting fence) and Restigouche Rivers (Figure 2) showed that from late June to early August, many high temperature peaks were present with the exception of a short period mid-July (18th; day 199) for which the mean daily temperature dropped to approximately 17 °C. Location for the sites on Tobique and Nashwaak Rivers are identified in Marshall and Jones (1996) while the site on the Restigouche River was identified in Locke et al. (1995). The Tobique site is the New Brunswick Department of Natural Resources and Energy (DNRE) 1/2 mile barrier pool. The maximum temperature was recorded on July 3 (day 184) at 27.6 °C on the Restigouche River at Morrissey Rock Trap (Table 6). For the Nashwaak and Tobique rivers, the maximum recorded temperatures were reached on August 1 (day 213) at 28.4 °C and 27.1 °C respectively. The range in temperature (maximum-minimum) was generally lower for Restigouche River (except on July 3 or day 184), than for Nashwaak and Tobique Rivers (Table 6).

River water temperatures were also available at six different locations within the Miramichi River basin (Figure 3; see Chaput et al. 1996 for site locations). Results were similar to those from the previous rivers with high water temperature events between late June and early August. There was also a decline in water temperatures in mid-July as observed previously. It was noted that Little Southwest Miramichi River water temperature peaks first with a mean daily temperature of 25.3 °C on July 8 (day 189; Table 6). Results from Little Southwest Miramichi River showed that, this year, the maximum temperature at 30.0 °C (Table 6) was slightly higher than last year at 28.0 °C (Caissie 1995).

Water temperature on the Northwest Miramichi River at the Barrier Fence, was generally lower with daily mean temperatures between 12 °C and 18 °C during most of the warm season (Figure 3). Other rivers such as North Branch Southwest Miramichi River at Juniper and Dungarvon River experienced intermediate temperatures. Water temperatures on the Northwest Miramichi River below Big Hole Pool were very similar to those of Little Southwest Miramichi River and the maximum recorded temperature was 28.2 °C on August 1 (day 213).

The range in daily water temperatures varied within the Miramichi River drainage depending on the location. For instance the larger rivers experienced less daily variations in water temperatures than smaller and more exposed rivers. Temperature ranges as low as 2 to 3 °C were observed on the Southwest Miramichi River at Millerton and at the Enclosure (Table 6). In contrast, Little Southwest Miramichi River experienced water temperatures in the range of 5 °C to as much as 11 °C during these high water temperature events (Table 6).

River water temperatures were also available for three locations within the Morell River basin, at Martinvale's Culvert (East Branch), at McKenna's Culvert (South Branch) and at St. Patrick's Pond (West Branch) (see Cairns et al. 1996 for site locations). High water temperature events observed in Prince Edward Island were similar to those observed in New Brunswick (Figure 4). Martinvale's Culvert was the location with the highest recorded water temperature at 26.2 °C on July 8 (day 189), and 27.2 °C on August 1 (day 213; Table 6). The mean daily values during the high water temperature event were 23 °C and 22 °C respectively. At McKenna's Culvert and St. Patrick's Pond, the mean daily temperatures during high water temperature events were between 19.5 °C and 22.3 °C while the maximum temperatures were in the range of 23 °C to 25 °C. Results also showed that the daily variation in water temperatures was less at McKenna's Culvert than at the other PEI sites with a temperature range of approximately 4 °C compared to 6 °C.

Water temperature variations for the Southwest Margaree River at the gauging station at Baily Bridge (for site location, see Marshall et al. 1996) showed that the maximum daily mean temperatures were recorded on July 08 at 23.5 °C (Figure 5). The maximum water temperature was also recorded during that day at 25.2 °C (Table 6).

To compare water temperature data in 1995 to previous years, the data from Catamaran Brook was used. Monthly water temperatures were calculated data (Table 7) showed that temperature in 1995 were higher or similar to those in 1994. Highest water temperatures were recorded in July at 16.24 °C, although that this temperature was slightly lower than July of 1994. The June, August and October temperatures were the highest recorded temperatures in the last four to five years. Water temperatures in September were lower than normal compared to data form 1992 to 1994 (Table 7). The mean daily fluctuation in water temperature in 1995 compared to 1994 and 1993 shows that more high temperature peaks occurred in 1995 than in previous years during the upper portion of the long-term time series (Figure 6). The peaks late June and early July were higher than normal while the peaks in August were similar to those of 1993 and 1994.

Summary

In summary, the streamflow conditions during 1995 were characterized by an above normal discharge during January due to above zero air temperatures. Below normal discharge were monitored during February in PEI and Cape Breton Island while most other regions were at normal conditions.

The spring runoff of 1995 (April and May) was characterized as low and the discharge from most of the rivers analyzed were below normal for that time of year. Some rivers in Nova Scotia exhibited deficient conditions in 1995 during the high flow season.

During the month of June, many rivers in New Brunswick experienced below normal discharge while most of mainland Nova Scotia rivers had excessive flows. The summer low flow period was variable in the region with discharge ranging from close to a 2-year to 3-year low flow in Nova Scotia to a 25-year low flow in northern New Brunswick. Monthly discharge data showed rivers also had low discharge for a long period in New Brunswick. This was especially true for rivers in the Miramichi River area which had a deficient flows for over 5 months from June to October. In northern New Brunswick, the months of August and September monitored especially low flow conditions with both months establishing a new record low monthly discharge in over 65 years of data (based on Upsalquitch River).

The low flows during 1995 combined with summer high air temperatures resulted in high river water temperatures. The occurrence of five different high water temperature events was monitored during the summer (June 25, July 8 and 25, August 1 and 11). During these events the maximum hourly recorded temperature was between 23.6 °C to 28.4 °C for Restigouche, Nashwaak and Tobique Rivers. The Miramichi River area showed different temperatures depending on the location of the monitoring site. For instance, North Branch Southwest Miramichi at Juniper, Dungarvon, and Southwest Miramichi (Millerton and Enclosure) Rivers showed maximum temperature in the range of 23 °C to 26.6 °C. It was observed that the daily fluctuations in temperatures were less for larger river systems (closer to estuary) such as the Southwest Miramichi River. In contrast, the site on Northwest Miramichi River at the Barrier Fence showed lower temperatures in general with maximum values of approximately 20 °C to 22 °C. The highest water temperatures were monitored on the Little Southwest Miramichi River at 30.0 °C on August 1.

In Prince Edward Island, water temperatures measured on the Morell River were similar to those at other locations and maximum recorded temperatures ranged from 22 °C to 25 °C for McKenna's Culvert and St.Patrick's Pond. Temperatures were slightly higher at Martinvale's Culvert with maximum temperatures between 24 °C and 27 °C. Water temperatures at Southwest Margaree River reached a maximum early in the season on July 08 at 25.2 °C.

Data from Catamaran Brook showed that in 1995, the water temperature were similar to 1994 and higher than previous 3 years (1991-93). June, August and October showed monthly water temperatures which were the highest of the time series while September showed the lowest water temperatures since 1992.

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Table 1. Characteristics of analyzed Atlantic salmon rivers in the Maritime Provinces.

River	Area[1] (km^2)	N (years)	MAF (m^3/s)	Runoff (mm)	CV	Prec. (mm)
Nashwaak River (NB)	1450	33	35.0	761	0.80	1210
Upsalquitch River (NB)	2270	65	40.8	568	1.06	1080
Southwest Miramichi R. (NB)	5050	47	116	725	0.82	1090
Morell River (PEI)	147	27	3.60	770	0.52	1100
LaHave River (NS)	1250	79	34.4	870	0.59	1420
St. Marys River (NS)	1350	79	43.0	1007	0.54	1350
Northeast Margaree R. (NS)	368	78	17.4	1485	0.61	1330
Grand River (NS)	120	74	4.39	1152	0.49	1390

[1] Area = Drainage area in km^2; N = Number of years of data; MAF = Mean Annual Flow in m^3/s; Runoff = Unit discharge (discharge per unit of area) in mm; CV = coefficient of variation; Prec. = precipitation in mm.

Table 2. Long-term monthly and 1995 average flow conditions for different Atlantic salmon rivers in the Maritime Provinces (Environment Canada 1990). (First row of data for each river represents the long-term flow condition while the second row represents the 1995 discharges expressed in m^3/s; number of years of record for long-term data is shown in Table 1).

River	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Nashwaak River (NB)	18.0	18.5	24.6	100	83.8	31.1	16.8	13.9	15.8	25.4	37.7	34.2
	45.1E	39.3	69.1	115	75.3	18.6	5.94D	4.29D	4.20D	13.4	-	-
Upsalquitch River (NB)	14.0	10.8	13.2	88.6	158	53.8	25.7	18.7	17.9	27.2	34.7	25.8
	20.6E	11.0	12.0	66.1	217	44.1	13.8D	5.87DR	4.28DR	6.65D	23.7	12.6D
SW Miramichi R. (NB)	56.6	51.2	67.6	308	320	111	60.1	56.0	55.8	89.9	114	101
	43.9	34.1	58.2	300	355	69.9D	25.9DR	16.7D	15.8D	39.3D	196E	52.3D
Morell River (PEI)	3.56	3.24	4.61	7.95	5.66	2.78	1.73	1.65	1.44	2.36	3.73	4.41
	-	-.D	-	-	-	-	-	-	-	-	-	-.D
LaHave River (NS)	46.8	38.9	52.4	73.4	38.9	20.9	11.7	9.25	9.19	20.3	42.0	50.6
	86.6E	28.1	38.9	30.8DR	26.9	35.1E	10.2	3.58	1.02D	4.11D	75.9E	29.9D
St. Marys River (NS)	51.3	40.8	53.7	91.8	58.1	23.9	14.7	15.5	16.4	34.2	57.9	59.3
	76.6E	19.6	48.4	53.0D	64.2	56.7E	17.6	3.43D	3.25D	8.04D	79.0	45.3
Northeast Margaree R. (NS)	15.2	11.3	12.2	26.6	44.5	15.9	6.84	7.70	9.44	16.0	22.7	19.2
	31.4E	3.32D	12.6	20.1	22.4D	14.9	4.81D	7.97	4.77D	12.2	21.4	9.95D
Grand River (NS)	5.73	4.20	4.97	8.35	6.31	2.73	1.76	1.62	2.00	3.26	5.59	6.08
	6.59	2.17	4.25	-	-	-	-	-	-	-	-	-

D = Deficient flow; E = Excessive flow; R = New record flow (see text for more details).

Table 3. Flood frequency analysis (using a 3-parameter lognormal distribution function) for different Atlantic salmon rivers in the Maritime Provinces and for different recurrence intervals (T) in years. All flood flows are expressed in m^3/s.

	Recurrence interval (T) in years					
River	2	5	10	20	50	100
Nashwaak River (NB)	321	478	580	676	799	890
Upsalquitch River (NB)	354	479	552	617	695	750
SW Miramichi R. (NB)	834	1164	1391	1613	1909	2137
Morell River (PEI)	21.4	31.7	39.4	47.3	58.3	67.2
LaHave River (NS)	195	284	363	454	596	721
St. Marys River (NS)	382	509	593	675	782	863
Northeast Margaree R. (NS)	166	225	266	306	359	400
Grand River (NS)	17.9	22.7	26.0	29.1	33.1	36.2

Table 4. Low flow frequency analysis (using a Extremal type III distribution function) for different Atlantic salmon rivers in the Maritime Provinces and for different recurrence intervals (T) in years. All discharge values of low flows are expressed in m^3/s.

	Recurrence interval (T) in years					
River	2	5	10	20	50	100
Nashwaak River (NB)	3.90	3.05	2.79	2.65	2.56	2.52
Upsalquitch River (NB)	5.52	3.99	3.32	2.85	2.42	2.20
Southwest Miramichi R. (NB)	19.8	15.1	12.9	11.2	9.70	8.84
Morell River (PEI)	0.710	.458	0.333	0.237	0.139	0.082
LaHave River (NS)	1.59	0.619	0.355	0.226	0.147	0.119
St. Marys River (NS)	1.64	0.682	0.407	0.267	0.177	0.144
Northeast Margaree R. (NS)	3.02	2.35	2.01	1.73	1.44	1.26
Grand River (NS)	0.237	0.091	0.047	0.023	0.008	0.002

Table 5. High air temperature event during the summer of 1995 at Catamaran Brook (located in central New Brunswick, a part of the Miramichi River Basin). All temperatures are expressed in °C.

Date of event	Daily Mean	Minimum	Maximum	Time of Maximum
June 24	25.3	17.4	33.7	3:00 pm
June 25	24.4	16.0	32.1	1:00 pm
July 07	23.3	15.3	29.3	4:00 pm
July 25	22.7	14.5	30.8	3:00 pm
July 30	21.5	15.5	29.4	6:00 pm
August 01	26.3	15.1	35.3	5:00 pm
August 11	23.3	12.5	31.6	5:00 pm

Table 6. High stream water temperature events at various locations within the Maritime Provinces during the summer of 1995. All temperatures are expressed in °C.

River	Date of event	Daily Mean	Minimum	Maximum	Range
Restigouche River at Morrissey Rock Trap (NB)					
	Jul 03	23.9	20.5	27.6	7.1
	Jul 07	23.8	22.6	25.1	2.5
	Jul 25	22.5	21.2	23.6	2.4
	Aug 01	22.7	20.8	24.7	3.9
	Aug 11	23.7	21.9	26.1	4.2
Nashwaak River at Fish Counting Fence (NB)					
	Jun 25	24.1	21.3	27.1	5.8
	Jul 08	23.4	20.6	26.8	6.2
	Jul 25	24.1	21.3	26.8	5.5
	Aug 01	24.6	21.0	28.4	7.4
	Aug 11	24.5	21.6	27.0	5.4
Tobique River at 1/2 Mile Barrier Pool (NB)					
	Jul 25	21.6	18.3	24.2	5.9
	Aug 01	23.2	19.4	27.1	7.7
	Aug 10	22.6	18.8	26.4	7.6
Juniper River (Miramichi River, NB)					
	Jul 25	21.8	19.0	24.7	5.7
	Aug 01	22.5	18.7	26.6	7.9
	Aug 11	21.9	17.7	26.0	8.3
Dungarvon River (Miramichi River, NB)					
	Jun 25	20.5	17.7	22.9	5.2
	Jul 07	21.5	17.9	25.5	7.6
	Jul 26	21.4	19.6	23.3	3.7
	Aug 01	21.5	17.7	25.9	8.2
	Aug 11	21.0	16.9	25.5	8.6

Table 6 (cont.). High stream water temperature events at various locations within the Maritime Provinces during the summer of 1995. All temperatures are expressed in °C.

River	Date of event	Daily Mean	Minimum	Maximum	Range
Little Southwest Miramichi River at Confluence of Catamaran Brook (NB)					
	Jun 25	24.0	21.5	26.6	5.1
	Jul 08	25.3	22.8	28.4	5.6
	Jul 26	24.5	22.6	27.2	4.6
	Aug 01	23.5	18.0	29.0	11.0
	Aug 11	25.0	20.8	30.0	9.2
Northwest Miramichi River at Barrier Fence (NB)					
	Jun 25	16.3	13.6	18.4	4.8
	Jul 08	18.2	15.3	21.0	5.7
	Jul 25	17.0	13.6	20.3	6.7
	Aug 01	18.6	14.5	22.8	8.3
	Aug 10	18.1	14.4	21.9	7.5
Northwest Miramichi River below Big Hole Pool (NB)					
	Aug 01	24.9	21.6	28.2	6.6
	Aug 10	25.4	22.6	27.3	4.7
Southwest Miramichi River at Millerton (NB)					
	Aug 03	24.8	24.1	25.1	1.0
	Aug 11	25.4	24.5	26.4	1.9
Southwest Miramichi River at Enclosure (NB)					
	Jun 25	21.9	19.3	23.5	4.2
	Jul 12	24.0	22.6	24.8	2.2
	Jul 28	24.1	22.4	25.4	3.0
	Aug 01	24.2	23.1	25.5	2.4
	Aug 11	24.5	23.5	25.4	1.9

Table 6 (cont.). High stream water temperature events at various locations within the Maritime Provinces during the summer of 1995. All temperatures are expressed in °C.

River	Date of event	Daily Mean	Minimum	Maximum	Range
Martinvale's Culvert (East Branch, Morell River, PEI)					
	Jun 25	21.3	18.3	25.0	6.7
	Jul 08	22.6	19.8	26.2	6.4
	Jul 27	22.6	21.4	24.4	3.0
	Aug 01	22.1	18.5	27.2	8.7
	Aug 11	21.4	17.7	26.0	8.3
McKenna's Culvert (South Branch, Morell River, PEI)					
	Jun 25	21.7	19.6	24.1	4.5
	Jul 08	22.3	20.1	24.8	4.7
	Jul 26	21.0	19.3	23.4	4.1
	Aug 01	21.3	19.4	23.4	4.0
	Aug 11	20.6	19.0	22.6	3.6
St. Patrick's Pond (West Branch, Morell River, PEI)					
	Jun 25	19.5	16.5	22.7	6.2
	Jul 08	21.1	18.1	24.4	6.3
	Jul 26	20.5	18.5	23.2	4.7
	Aug 01	20.2	17.3	24.3	7.0
	Aug 11	20.2	17.3	23.4	6.1
Southwest Margaree River at the Baily Bridge Gauging Station (NS)					
	Jul 08	23.5	22.0	25.2	3.2
	Jul 14	23.3	22.0	25.0	3.0
	Jul 27	23.2	22.7	24.2	1.5
	Aug 01	22.7	20.5	24.9	4.4
	Aug 11	23.1	21.6	25.0	3.4

Table 7. Monthly water temperatures at Catamaran Brook (located in central New Brunswick, a part of the Miramichi River Basin). All temperatures are expressed in °C.

Month	1991	1992	1993	1994	1995
May	7.76	8.11 *	5.80	4.98	5.89
June	12.45 *	11.55	10.52	12.41	13.52
July	14.66	12.15	13.39	16.58	16.24
August	15.07 *	12.86	14.79	15.22	15.26
September	n/a	11.56	10.69	10.26	9.88
October	n/a	5.58	4.49	5.55	7.18

Note : * indicates that these months had missing values, and therefore the average was calculated with a reduced sample. June 1991 (28 days), August 1991 (27 days), and May 1992 (19 days).

Figure 1. Location of hydrometric stations on studied Atlantic salmon rivers in the Maritimes region.

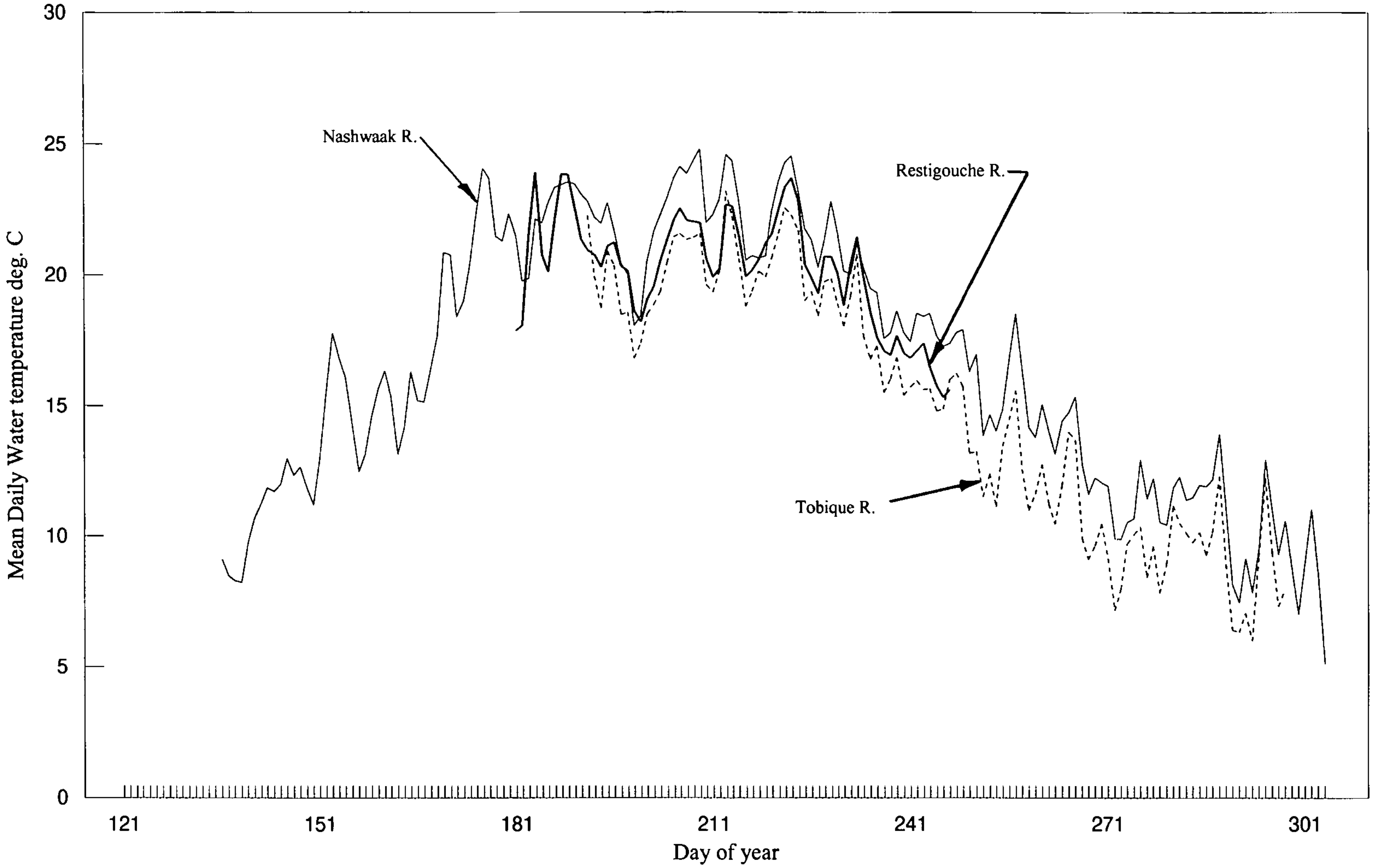

Figure 2. River water temperature for Tobique, Nashwaak and Restigouche Rivers during 1995
(Day 121 = May 1 and day 301 = Oct 28)

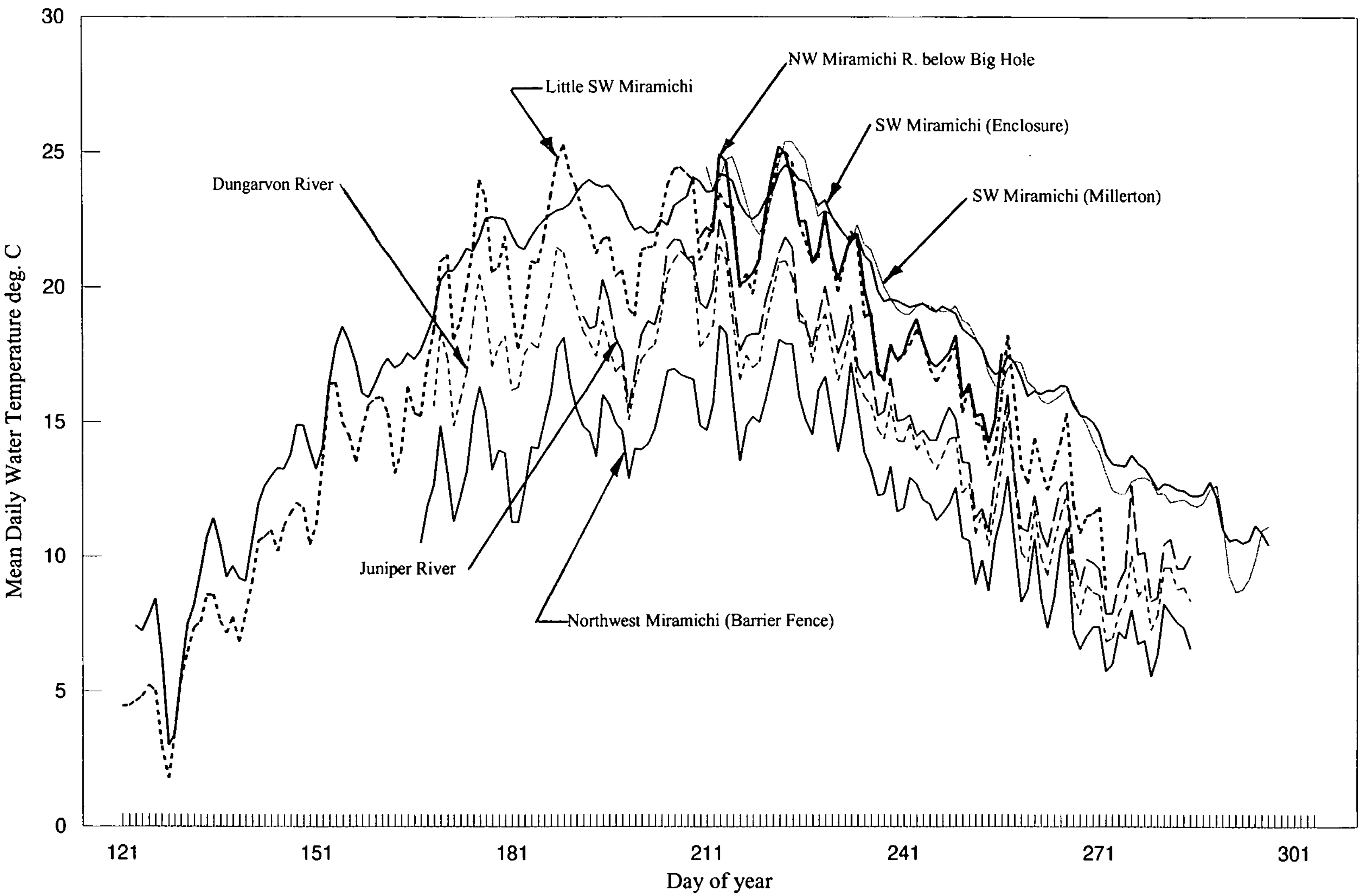

Figure 3. River water temperature variations at different locations within the Miramichi River basin during 1995 (Day 121 =May 1 and day 301 =Oct 28)

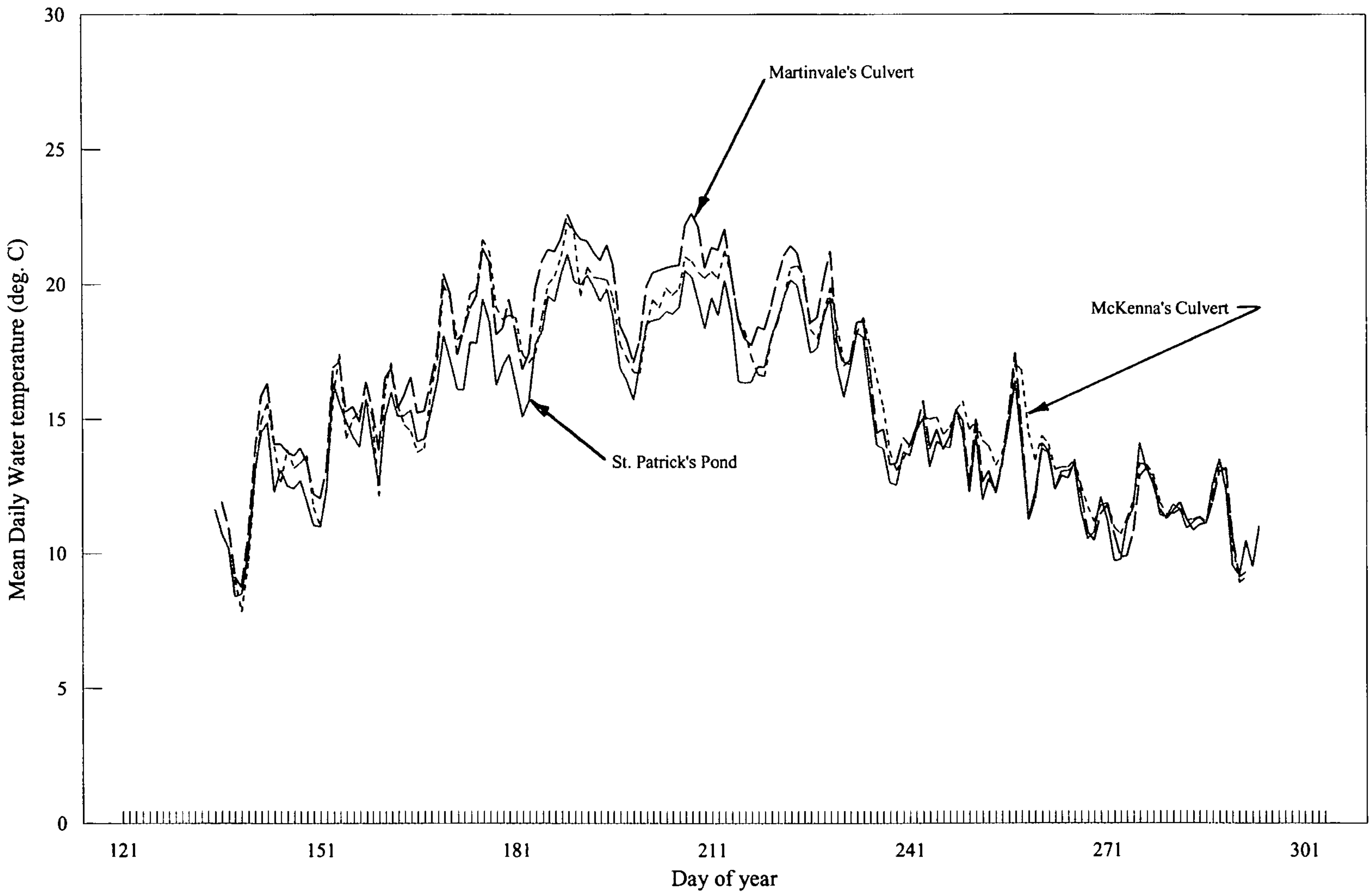

Figure 4. River water temperature variations within the Morell River basin (PEI) during 1995.
(Day 121 = May 1and day 301 = Oct 28)

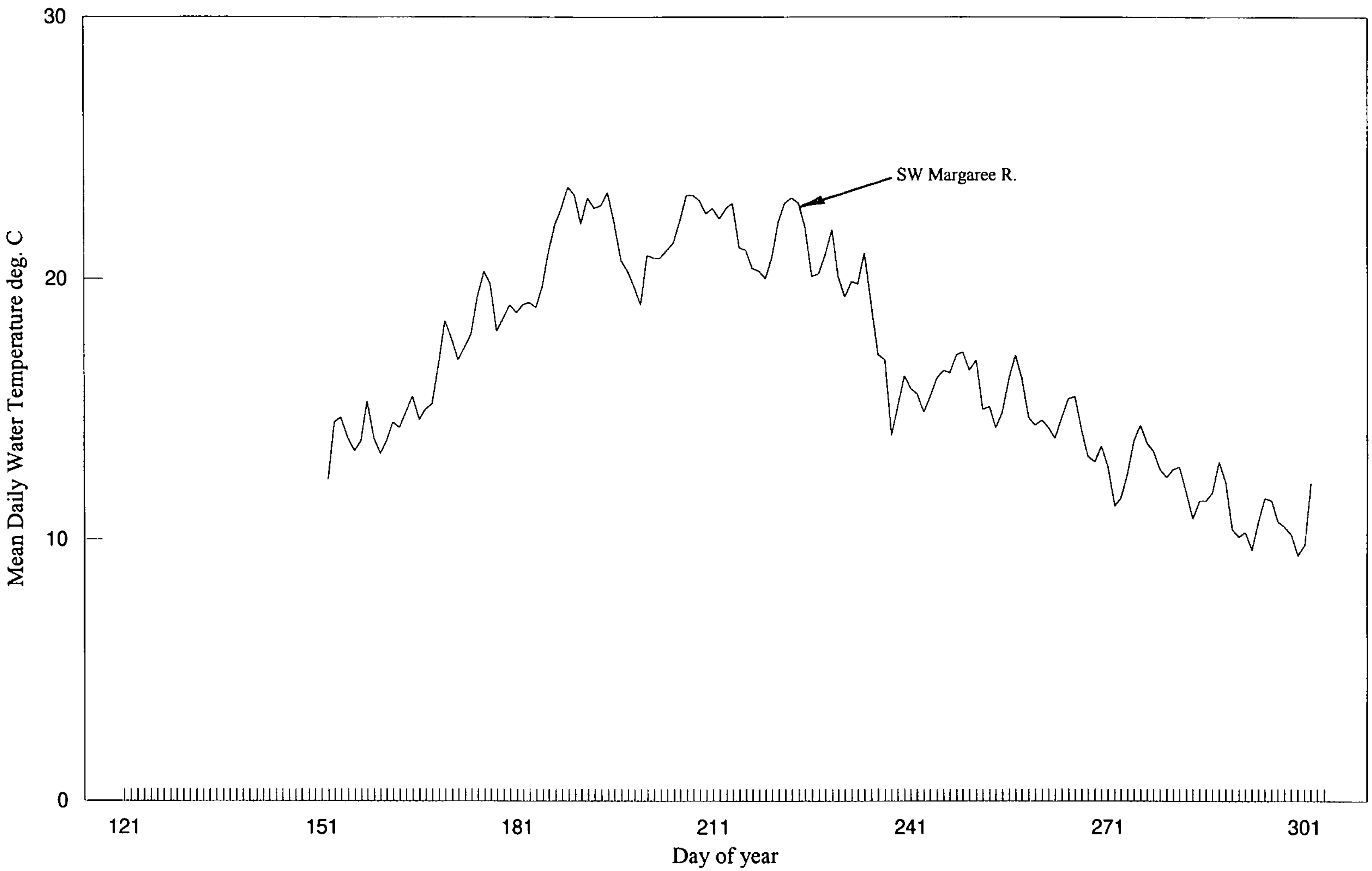

Figure 5. River water temperature variation for Southwest Margaree River at gauging station during 1995
(Day 121 = May and day 301 = Oct 28)

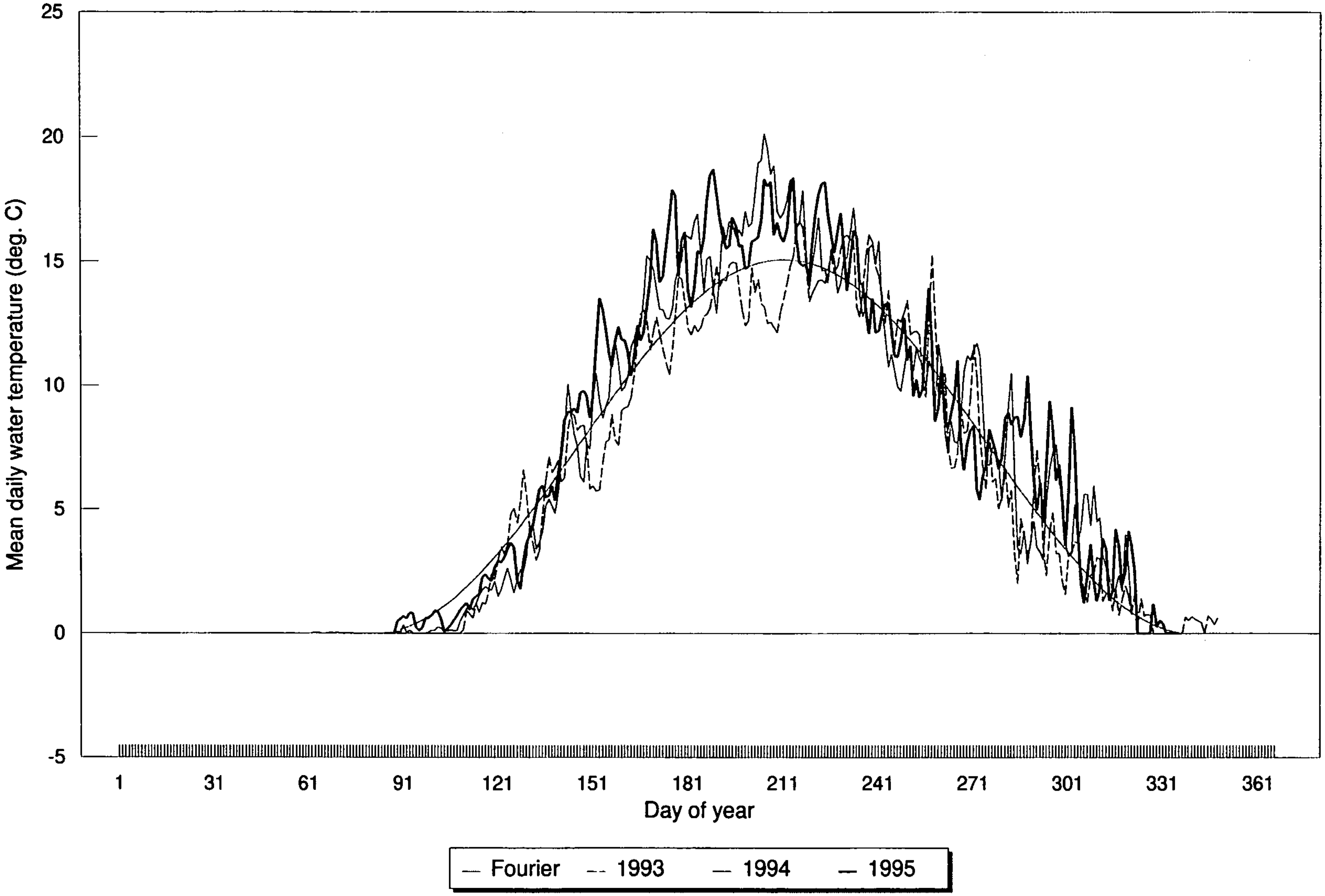

Figure 6. Stream water temperature at Catamaran Brook (Middle Reach) from 1993 to 1995; Fourier series represents long-term temperatures.