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Hydrological conditions for Atlantic salmon rivers in the Maritime provinces in 1996

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 1996. 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, winter of 1996 provided above normal discharges with many rivers experiencing excessive monthly flow condition. February showed excessive flow for all rivers in the Maritime Provinces. The spring breakup of 1996 was generally characterized as normal with most studied rivers having floods close to or less than a 2-year flood event. A few rivers showed higher flows than the 2-year flood such as Upsalquitch River which reached a 5-year flood and Northeast Margaree River which was close to a 50-year flood.

Low flow conditions in 1996 were very similar throughout the area with discharges during the low flow period higher than the 2-year event. Such low flow conditions do not represent severe low flow conditions.

River water temperatures in 1996 were characterized by a few high temperature events between early June to early August.

The early August event was the most important event for most rivers in the Maritime Provinces. They reached their peak water temperatures near August 8 at Nashwaak River (24.2 °C), Mactaquac Fishway (22.6 °C), Kennebecasis River (21.1 °C), Tobique River Barrier Pool (21.6 °C), and Tobique River Fishway (24.7 °C).

In the Miramichi River basin, rivers also reached their peak water temperatures in early August at; below Big Hole Pool (26.8 °C), in Little Southwest Miramichi River (26.1 °C), in Dungarvon River (21.6 °C), in Northwest Miramichi River at the Barrier Fence (19.3 °C) and at Eel Ground (23.6 °C).

In Prince Edward Island, high stream water temperatures were measured at Indian Bridge (19.8 °C), Grants (22.1 °C), McKenna's Culvert (24.6 °C), St. Patrick's Pond (23.4 °C) and the highest recorded water temperature in PEI in 1996 came from Matinvale's Culvert (25.0 °C).

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 1996. 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 l'hiver 1996. En février, une période de débits forts été mesurée partout dans les provinces Maritimes. La débâcle en 1996 était normale avec des débits de crues de l'ordre de 2 années de récurrence pour plusieurs rivières. Quelques rivières démontrèrent un débit de crue plus fort tel que la rivière Upsalquitch avec un débit de 5 années de récurrence et la rivière Northeast Margaree avec une crue d'environ 50 ans.

Les conditions de débits faibles en 1996 étaient similaires sur toute la région et d'un débit supérieur à celui de 2 années de récurrence. Ces débits ne représentent pas une condition d'étiage sévère.

Les variations dans la température de l'eau en 1996 peuvent être caractérisées par quelques événements importantes à partir du début juin jusqu'au début août.

Au environ du 8 août, plusieurs rivières dans les provinces Maritimes ont observées leur température maximum de la saison; la rivière Nashwaak (24.2 °C), la passe à poissons de Mactaquac (22.6 °C), la rivière Kennebecasis (21.1 °C), la rivière Tobique au Barrier Pool (21.6 °C) et la passe à poissons de la rivière Tobique (24.7 °C).

Plusieurs endroits de la rivière Miramichi observèrent également une température maximale au début août; la rivière Northwest Miramichi en aval de Big Hole Pool (26.8 °C), la rivière Little Southwest Miramichi (26.1 °C), la rivière Dungarvon (21.6 °C), la rivière Northwest Miramichi à la Barrier Fence (19.3 °C) et à Eel Ground (23.6 °C).

A l'Ile-du-Prince-Edouard, des températures maximales de l'eau ont été mesurées sur la rivière Morell; à Indian Bridge (19.8 °C), à Grants (22.1 °C), à McKenna's Culvert (24.6 °C), à St. Patrick's Pond (23.4 °C) et la température de l'eau la plus élevée en 1996 a été mesurée à Matinvale's Culvert (25.0 °C).

INTRODUCTION

Hydrological conditions are important in the management of 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 can be affected by stream discharge such as high flows (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.

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: a) to provide an overview of the monthly flow conditions where data were available, b) to determine the high and low flow months within the year or season, c) to determine the frequency of floods and low flows of particular events within the year, and d) to provide data on high water temperature events for some salmon rivers in the studied region.

The 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 in 1996 and compared to long-term average flow conditions. The high and low flow months were presented for each river system. The data in 1996 were obtained for Environment Canada and used to study the hydrological conditions during the year.

STUDY REGION

The study comprises eight Atlantic salmon rivers within the Maritime Provinces (Figure 1). These rivers are: Nashwaak River (01AL002, NB), Saint John River (01AK004, NB), Upsalquitch River (01BE001, NB), Southwest Miramichi River (01BO001, NB), Wilmot River (01CD003, PEI), Northeast Margaree River (01FB001, NS), St. Marys River (01EO001, NS), and LaHave River (01EF001, NS).

The drainage basin of the studied rivers ranged from 45.4 km^2 (Wilmot River) to 39900 km^2 (Saint John River; Table 1). LaHave and St. Marys Rivers have the longest daily discharge time series with 80 years of record. The mean annual flow (MAF), which is a function of drainage area, varies between 0.947 m^3/s for Wilmot River to 810 m^3/s for Saint John 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 1010 mm to 1500 mm (Table 1). The coefficient of variation (CV) of monthly flow characteristics show more stable flow regime for rivers than others. For instance, Wilmot River has a more stable flow regime with a CV of 0.49 compared to Upsalquitch River with a CV of 1.06 (Table 1).

PRECIPITATION IN 1996

Data were gathered for different locations in the Maritime Provinces on total monthly precipitation in 1996. Long-term data (1953-1990) were also obtained from Environment Canada for comparative purposes as shown in Table 2. The highest monthly precipitation in 1996 was recorded in Kejimkujik in September with a total value of 324.0 mm. This value represents three times the long-term conditions for that particular month. In contrast, the lowest precipitation recorded in the region was at Saint John with a precipitation in August of only 4.6 mm. Charlottown also showed a low value in August with a total precipitation of 8.6 mm. Other conditions of interest, included the months of July and September in 1996, which consistently showed higher than normal precipitation throughout the Maritime Provinces.

HYDROLOGICAL CONDITIONS IN 1996

In general above freezing temperatures during the winter (Dec. to Mar.) of 1996 contributed, through snow melting to a series of high flow peaks from January to March. Those high flow peaks resulted in excessive monthly flow conditions in

most rivers in the Maritime Provinces. In the present study, a flow above the 75% quartile identifies an excessive monthly flow condition while a flow below the 25% quartile denotes a deficient flow (Environment Canada 1995).

Most New Brunswick rivers experienced excessive flows in winter with new record flows monitored on the Nashwaak and Saint John Rivers (Table 3). The record monthly flow for Nashwaak River was monitored at 60.6 m^3/s compared to a long-term average of 18.0 m^3/s for January. Similarly, a record flow of 833 m^3/s was measured on Saint John River compared to the monthly average of 359 m^3/s.

For rivers in PEI and NS, flow conditions in winter of 1996 were normal except for February which showed excessive flow conditions in all rivers (Table 3). It can be noted that the Northeast Margaree River also experienced high monthly flows in January.

The spring high flow months (e.g. April and May) showed normal conditions in 1996 for most Maritimes rivers except for a few rivers which showed deficient flow conditions, e.g. both the Wilmot and Northeast Margaree Rivers in May of 1996. It is believed that the high water conditions in the early winter were responsible for the late spring lower flow conditions as most of the snow had melted early.

The summer flows of 1996 can be characterized by higher than normal flow conditions. July experienced excessive flow in most Maritimes rivers except for Upsalquitch River in northern NB. Record high monthly flows were recorded in both the Nashwaak and Southwest Miramichi Rivers in July. Nashwaak River recorded a monthly flow of 65.0 m^3/s compared to a long-term average of 16.8 m^3/s and the Southwest Miramichi River experienced a high flow of 195 m^3/s compared to a normal monthly average of 60.1 m^3/s (Table 3).

In autumn, deficient flows were recorded in northern NB while some mainland NS rivers experienced record high flows. Upsalquitch River showed deficient flow in both September and October this year, with the lowest monthly flow in October at 8.06 m^3/s (Table 3). Flows were excessive in LaHave and St.Marys Rivers in September. LaHave River showed a new record high flow of 60.7 m^3/s for the month of September compared to a long-term average of 9.19 m^3/s. Similarly, St. Marys River experienced a new record monthly flow of 90.0 m^3/s for September compared to the normal monthly flow of 16.4 m^3/s.

Figure 2 shows the deviation from the normal discharge conditions expressed in percentage in the Maritime provinces. As shown previously, above normal flow

conditions were present with deviation ranging from 100% to 200% above normal in winter of 1996 (Figure 2a and 2b). Above normal discharge conditions were also present in July and in September for Nova Scotia (Figure 2b). In contrast, NB rivers showed below normal water conditions in autumn of 1996 (Figure 2a).

Mean annual flow can be used to compare between year and show which were high and/or low water years. In 1996, higher annual discharges were recorded than in previous years espesically in NB (Figure 3a). The years 1979 and 1990 were also high water years throughout the Maritime provinces. This year in NS, the annual discharge was characterized as close to average flow conditions (Figure 3b). It was also be observed that in NS, the annual flow variability was less over the past few years while in NB it was higher (Figure 3a and 3b).

On a daily basis, stream hydrograph for many rivers showed a marked variability in 1996 (Figure 4 & 5). As observed for monthly flows, winter high flow peaks were present this year and the low water period occurred late summer.

The maximum daily discharge for Nashwaak River was observed on January 28 at 314 m^3/s (Figure 2a). This flow represents a discharge in the range of a 2-year flood (Table 4) which is unusual for January. Saint John River experienced its high flow period on April 25 (Figure 4b, day 116) with a maximum daily discharge of 6130 m^3/s, again, an event in the range of a 2-year flood. Upsalquitch River reached a discharge of 443 m^3/s on April 28, which was the only significant peak in 1996 for that river. This high flow represents a discharge slightly below a 5-year flood (Table 4). Similar to the Nashwaak River, the Southwest Miramichi River showed many significant peaks during the year including one in winter (Figure 4d). The maximum discharge in 1996 occurred during the spring snowmelt on April 25, with a flow of 825 m^3/s. This flow represents a discharge in the range of a 2-year flood event.

In PEI the maximum daily discharge was realized March 21 (day 81) on Wilmot River (Figure 5a). The peak discharge was measured at 15.1 m^3/s and represents a 5-year flood event (Table 4). Secondary peaks in winter were also high for Wilmot River in 1996 with peaks over 5 m^3/s. In Nova Scotia, LaHave River showed a maximum daily flows on February 26 at 206 m^3/s (Figure 5b). Such flow conditions represents a 2-year flood event. A flow of 468 m^3/s was measured on St. Marys River on February 18, and this flow represents less than a 5-year flood event. A secondary peak was also observed in September which result in an excessive flow during that month. For Northeast Margaree River, the peak flow was observed on January 20 this year, with a discharge of 342 m^3/s. This flow represents the

highest flood event in the region with a discharge close to a 50-year event (Table 4).

Low flow conditions in 1996, were not as severe as last year (Caissie, 1996), especially during the late summer period. In New Brunswick, the low flow period in 1996 were predominantly in early winter and in September (Figure 4).

The minimum daily discharge on the Nashwaak River was observed on September 8 (day 252) at 4.92 m^3/s a flow greater than a 2-year event (Table 5). This shows that the Nashwaak River was not affected by low water conditions in 1996. For the Saint John River it was more difficult to assess the low flow conditions as the hydrograph suggests major decreases in flow at different times of year, probably due to regulation from the dam. Nonetheless, the lowest daily discharge was observed on August 18 at 67.6 m^3/s, which would be close to a 2-year event. As for Upsalquitch River, the low flow in 1996 was observed on October 8 (day 282) with a discharge of 5.69 m^3/s. This flow represent a discharge of greater than a 2-year low flow. In Southwest Miramichi River the low flow was observed on September 8 at 21.1 m^3/s, which was also greater than the 2-year low flow event.

Missing data for Wilmot River in late summer prevented the assessment of the low flow conditions in PEI for 1996 (Figure 5a). In Nova Scotia, LaHave River showed low flow conditions in late August to early September with a minimum daily discharge reached on September 1 (day 245) at 2.93 m^3/s, greater than a 2-year discharge (Table 5). Similar to LaHave, the St. Marys River reached a low flow period in early September with a discharge of 2.35 m^3/s. A flow higher than the 2-year event (Table 5) and therefore the low water conditions in 1996 were not severe in mainland Nova Scotia. The low flow period on the Northeast Margaree River was observed on September 9 with a discharge of 4.38 m^3/s. This flow was higher than the 2-year low flow event.

In general, peak flows in 1996 were close to a 2-year flood event in New Brunswick, close to a 5-year event in Prince Edward Island and parts of Nova Scotia, while a 50-year event was monitored on Cape Breton Island. As for low water conditions in 1996, most rivers in the Maritime Provinces showed similar results with discharge close to or higher than the 2-year low flow event.

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. Critical temperature for salmonids does vary between species. For instance,

Atlantic salmon are more tolerant to high water temperatures than brook trout. High water temperature events are often identified for salmonids when temperatures reach approximately 22 °C to 23 °C. Not all such events are presented in the present report, however, the most important events in the summer are described.

River water temperatures were available for different locations within the Maritimes Region in 1996. Compared to previous year, the condition this year could be characterized as having fewer high water temperature events. During these events, it was observed that the Maritime Provinces were affected by similar climatic conditions so that the high air temperature events affected most of the rivers in the region simultaneously.

During the summer of 1996, the most significant high water temperature event occurred close to August 7 (day 220). Other events were present during the summer (e.g. in June & July), but of lower magnitude.

Stream water temperature variations for Nashwaak, Mactaquac and Kennebecasis Rivers are shown in Figure 6a (see Marshall and Jone 1996 for site location). Nashwaak River showed two peak stream temperatures. The first occurred mid-June (day 164; June 12) while the second occurred on August 8 (day 221). During the June event Nashwaak River reached a daily mean temperature of 20.8 °C and 22.5 °C during the August event with a maximum of 24.2 °C. As for Mactaquac, it also reached a high river temperature on August 8 at 21.8 °C and the mean daily water temperature remained over 21°C for a period thereafter (until the end of August day 244). The maximum recorded temperature for Mactaquac River in 1996 was on August 8 at 22.6 °C. The Kennebecasis River reached its maximum mean daily water temperature on August 7 (day 220) at 18.8 °C (Figure 6a), with its maximum temperature at 21.1 °C. It was noted that the Kennebecasis River showed lower water temperatures than Nashwaak and Mactaquac Rivers especially during high temperature events.

Temperature for Tobique River (at the Fishway) and the Tobique River Barrier Pool were monitored in 1996 and are shown in Figure 4b. In the area, these two locations showed a high temperature event around August 8. The maximum mean daily water temperature at the Tobique River Barrier Pool was measured at 20.5 °C, and the maximum temperature reached on that day was 21.6 °C. For the Tobique River Fishway, the mean daily water temperature was higher at 24.1 °C

and occurred a day later (August 9; day 223). The maximum recorded temperature at the Tobique Rvier Fishway was 24.7 °C.

River water temperatures were also available for five locations in PEI. All sites were part of the Morell River basin, at Martinvale's Culvert (East Branch), at McKenna's Culvert (South Branch), at St. Patrick's Pond (West Branch), at Grants (Main Branch) and Indian Bridge smolt trap (Main Branch; see Cairns 1997 for site locations).

Both Grants and the Indian bridge smolt trap results showed very similar water temperatures (Figure 7a). Two events of similar magnitude were monitored at Grants on July 19 (day 201) and August 8 (day 221), however, the later event had the highest temperatures. The mean daily water temperature measured at Grants on August 8 was at 19.7 °C, with a maximum value of 22.1 °C. The highest temperature measured at the Indian Bridge trap was on June 6 at 17.9 °C close to the end of the available series (Figure 7a). Given the similarities between the two series (Grants and Indian Bridge), it would be expected the Indian Bridge site would have reached its maximum on August 8 with a temperature similar to Grants.

Martinvale's Culvert was the location with the highest recorded water temperature in PEI in 1996 at 25.0 °C on August 7 (day 220). The mean daily values during this high water temperature event at Martinvale's Culvert was 21.8 °C. At St. Patrick's Pond, the mean daily temperatures during this high water temperature event of August 8 was measured at 20.1 °C while the maximum recorded temperature was at 23.4 °C. Results at McKenna's Culvert showed that the high mean daily water temperatures of June 14 (day 166) was more important that those of August 8. During this day, temperatures at McKenna's Culvert reached a maximum value of 24.6 °C with a daily mean of 22.2 °C. Following the June 14, event all rivers showed a decrease in temperatures before reaching their maximum in August (Figure 7).

River water temperatures were available at five different locations within the Miramichi River basin in 1996 (Figure 8; see Chaput et al. 1996 for site locations). Water temperatures on the Northwest Miramichi River at the Barrier Fence, was generally lower during most of the warm season (Figure 8). Other rivers such as Dungarvon River experienced intermediate temperatures. Water temperatures on the Northwest Miramichi River below Big Hole Pool were similar to those at Little Southwest Miramichi River. The mean daily

temperatures at Eel Ground were less variable and higher than the others for part of the summer.

The results in the Miramichi River were similar to those from the previous rivers with high water temperature events in early July and a main event on August 8. Results showed that the Northwest Miramichi River below Big Hole and the Little Southwest Miramichi River experienced the highest daily mean temperature both in July and August. In July, the mean daily temperature reached 22.5°C and 21.5 °C while in August a temperature of 24.4 °C and 23.6 °C was measured below Big Hole Pool and Little Southwest Miramichi respectively. During these events others rivers also reached high temperatures. On August 8, Dungarvon River reached 19.6 °C and Eel Ground reached 22.9 °C. The lowest temperatures during this event were monitored at the Northwest Miramichi River at the Barrier Fence with a value of 16.5 °C.

The maximum recorded temperatures below Big Hole Pool and on Little Southwest Miramichi River were at 26.8°C and 26.1 °C while other rivers showed lower maximum values. Eel Ground recorded a high value of 22.9 °C while Dungarvon River and the Northwest Miramichi River at the Barrier Fence reached high values of 19.6 °C and 16.5 °C respectively. All these high water temperatures were recorded on August 8 (day 221).

River water temperatures in Nova Scotia were obtained from the Northeast and Southwest Margaree Rivers as shown in Figure 9. The temperature reached a maximum on August 9 (day 222) for both of these rivers and the Southwest Margaree River recorded a daily mean temperature of 22.6 °C at maximum.

To compare water temperature data between 1996 and previous years, the data from Catamaran Brook were used. Monthly water temperatures are presented in Table 6. Data showed that temperatures in 1996 were similar to those in previous years. Highest monthly water temperatures were recorded in August at 15.22 °C. June temperatures were the highest recorded temperatures since 1991 although similar to 1995 data (Table 6). Figure 9 shows the general variation in temperatures between 6 years of data at Catamaran Brook. Note that previous years of data are only shown to outline the variability in the water temperature among years. This long-term series of data shows that the water temperatures was higher than normal for a period in June (after day 151). A colder period was present in mid-July with temperatures just over 13 °C (after

day 201) and just before reaching the peak summer temperatures. The autumn temperatures were characterized as normal in 1996.

Summary

In summary, the streamflow conditions during 1996 were characterized by an above normal discharge during winter due to above freezing air temperatures. Some rivers experienced high flow during this period in the order of a 50-year flood event, in particularly in Cape Breton Island. Above normal, discharge were also present in July and September in areas of the Maritime Provinces due to higher rainfall this summer.

The spring runoff of 1996 (April and May) was characterized as normal with high flows close to a 2-year flood. Some rivers in PEI and Nova Scotia exhibited deficient flow conditions in 1996 during the high flow season (e.g. May).

The higher than normal flows during 1996 resulted in water temperatures which were not as high as in the previous year. The highest recorded temperature at Nashwaak River in 1996 was 24.2 °C compared to 28.4 °C in 1995 (Caissie, 1996). The maximum recorded temperature this year at Tobique River Barrier Pool was at 21.6 °C compared to 27.1 °C last year (1995).

In Prince Edward Island, water temperatures measured on the Morell River were also colder this year. The highest recorded temperature in PEI this year was measured at Martinvale's Culvert at 25.0 °C compared to a high value of 27.2 °C recorded in 1995 at the same location.

For the Miramichi River system, the highest recorded water temperature in both 1995 and 1996 came from the Northwest Miramichi River below Big Hole Pool and the Little Southwest Miramichi River. In 1995, these rivers reached a high of 29 °C to 30 °C (Caissie, 1995) while in 1996 high water temperatures were recorded at 26.1 °C and 26.8 °C at Little Southwest Miramichi River and Big Hole Pool respectively.

Data from Catamaran Brook showed that in 1996, the water temperatures were close to normal compared to the previous 5 years. June was the only month with temperatures slightly different with a warm period early during the month.

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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	34	35.0	761	0.80	1210
Saint John River (NB)	39900	31	810	640	0.88	1010
Upsalquitch River (NB)	2270	66	40.8	568	1.06	1080
Southwest Miramichi R. (NB)	5050	48	116	725	0.82	1090
Wilmot River (PEI)	45.4	25	0.947	658	0.49	1100
LaHave River (NS)	1250	80	34.4	870	0.59	1420
St. Marys River (NS)	1350	80	43.0	1007	0.54	1350
Northeast Margaree R. (NS)	368	79	17.4	1485	0.61	1500

[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 precipitation (mm) and conditions in 1996 for different areas in the Maritime Provinces. (First row of data represents the long-term precipitation while the second row represents the condition in 1996.

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Chatham A (NB)	85.2	69.5	86.6	86.3	88.1	84.5	97.8	95.9	87.8	95.2	104.4	105.5	1087
	77.2	91.4	116.6	125.8	89.4	45.4	217.2	30.7	92.2	105.6	78.3	-	-
Edmundston (NB)	-	-	-	-	-	-	-	-	-	-	-	-	-
	105.0	77.5	33.9	110.3	92.0	82.4	148.2	75.8	99.4	91.0	40.6	-	-
Fredericton A (NB)	93.3	84.3	90.4	83.4	94.0	86.9	84.5	99.4	92.3	93.1	110.7	118.8	1131
	90.7	78.5	60.0	74.7	98.9	62.3	161.2	21.5	89.3	76.8	90.6	132.5	1037
Saint John A (NB)	128.3	102.6	109.9	109.7	123.1	104.8	103.7	103.0	111.3	122.5	146.2	167.6	1433
	121.7	86.0	97.8	107.3	88.8	50.5	189.2	4.6	188.3	99.8	76.3	153.5	1264
Charlottetown A (PEI)	106.3	91.5	92.2	91.8	96.8	91.1	81.6	88.6	94.1	111.7	121.9	133.2	1201
	67.5	123.5	106.2	92.2	108.4	89.7	153.9	8.6	155.2	111.5	90.0	-	-
Kejimkujik (NS)	141.3	113.0	117.6	108.8	101.5	96.7	104.2	87.9	97.1	116.4	145.0	167.5	1397
	102.6	167.0	88.4	152.9	115.6	77.7	162.7	36.0	324.0	105.5	-	-	-
Maragaree Forks (NS)	-	-	-	-	-	-	-	-	-	-	-	-	-
	115.4	135.4	74.6	93.4	90.0	68.0	149.0	69.4	195.6	137.6	170.2	-	-
Halifax Int. A (NS)	146.9	119.1	122.6	124.4	110.5	98.4	96.8	109.6	94.9	128.9	154.4	167.0	1474
	117.0	209.8	63.1	134.5	114.8	39.6	181.2	20.0	308.7	94.7	72.6	169.8	1526

Table 3. Long-term monthly and 1996 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 1996 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
	60.6ER	50.4E	35.7E	101	72.8	25.3	65.0ER	12.2	9.73	14.6	-	-
Saint John River (NB)	359	389	530	2280	2360	737	418	416	402	601	646	569
	833ER	885E	752E	2259	2126	673	881E	299	306	355	-	-
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
	30.6E	35.6E	27.4E	103	145	36.6	24.9	13.3	8.06D	8.31D	-	-
SW Miramichi R. (NB)	56.6	51.2	67.6	308	320	111	60.1	56.0	55.8	89.9	114	101
	125E	98.3E	68.3E	309	263	90.2	195ER	54.7	35.6	47.7	141	-
Wilmot River (PEI)	1.06	0.978	1.57	1.97	1.27	0.795	0.586	0.514	0.452	0.528	0.676	0.980
	1.05	1.84E	1.58	1.24	0.671D	-	-	-	-	-	-	-
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
	42.2	71.7E	45.4	73.3	32.6	24.2	21.7E	9.59	60.7ER	35.8E	38.4	-
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
	61.4	80.1E	50.8	67.1	50.9	15.3	26.2E	7.40	90.0ER	43.5	41.4	-
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
	39.8E	27.7E	14.1	20.3	14.5D	10.4	10.8E	6.42	11.9	-	-	-

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

Table 4. 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
Saint John Rvier (NB)	5910	7738	8854	9867	11124	12032
Upsalquitch River (NB)	354	479	552	617	695	750
SW Miramichi R. (NB)	834	1164	1391	1613	1909	2137
Wilmot River (PEI)	11.6	15.3	17.4	19.2	21.2	22.6
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

Table 5. 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
Saint John River (NB)	70.0	54.9	48.4	43.6	38.7	35.8
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
Wilmot River (PEI)	0.295	0.223	0.189	0.164	0.139	0.125
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

Table 6. 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	1996
May	7.76	8.11 *	5.80	4.98	5.89	5.41
June	12.45 *	11.55	10.52	12.41	13.52	13.63
July	14.66	12.15	13.39	16.58	16.24	14.29
August	15.07 *	12.86	14.79	15.22	15.26	15.22
September	n/a	11.56	10.69	10.26	9.88	11.51
October	n/a	5.58	4.49	5.55	7.18	6.01

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).

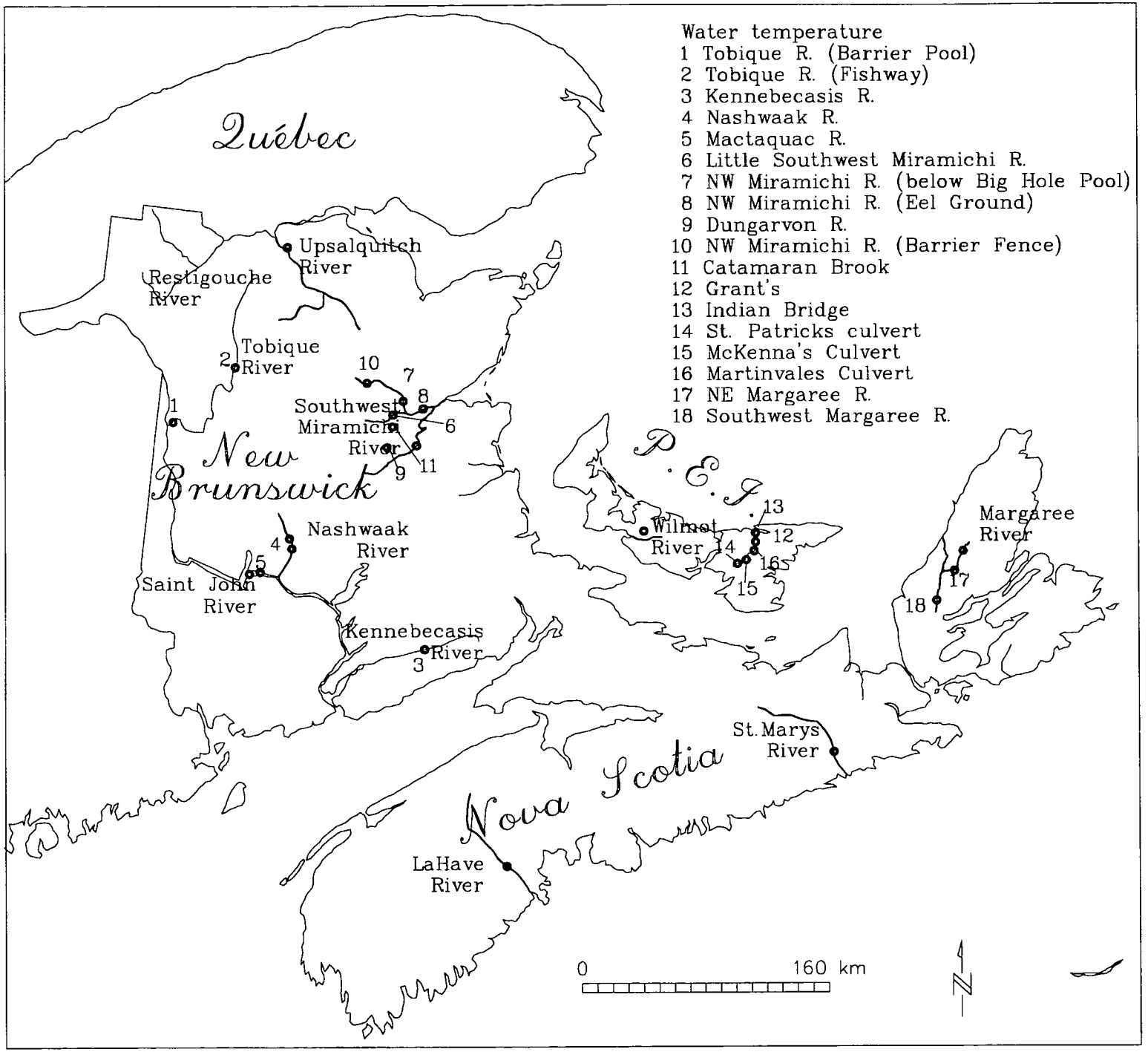

Figure 1. Location of hydrometric and water temperature stations on studied Atlantic salmon rivers in the Maritimes region.

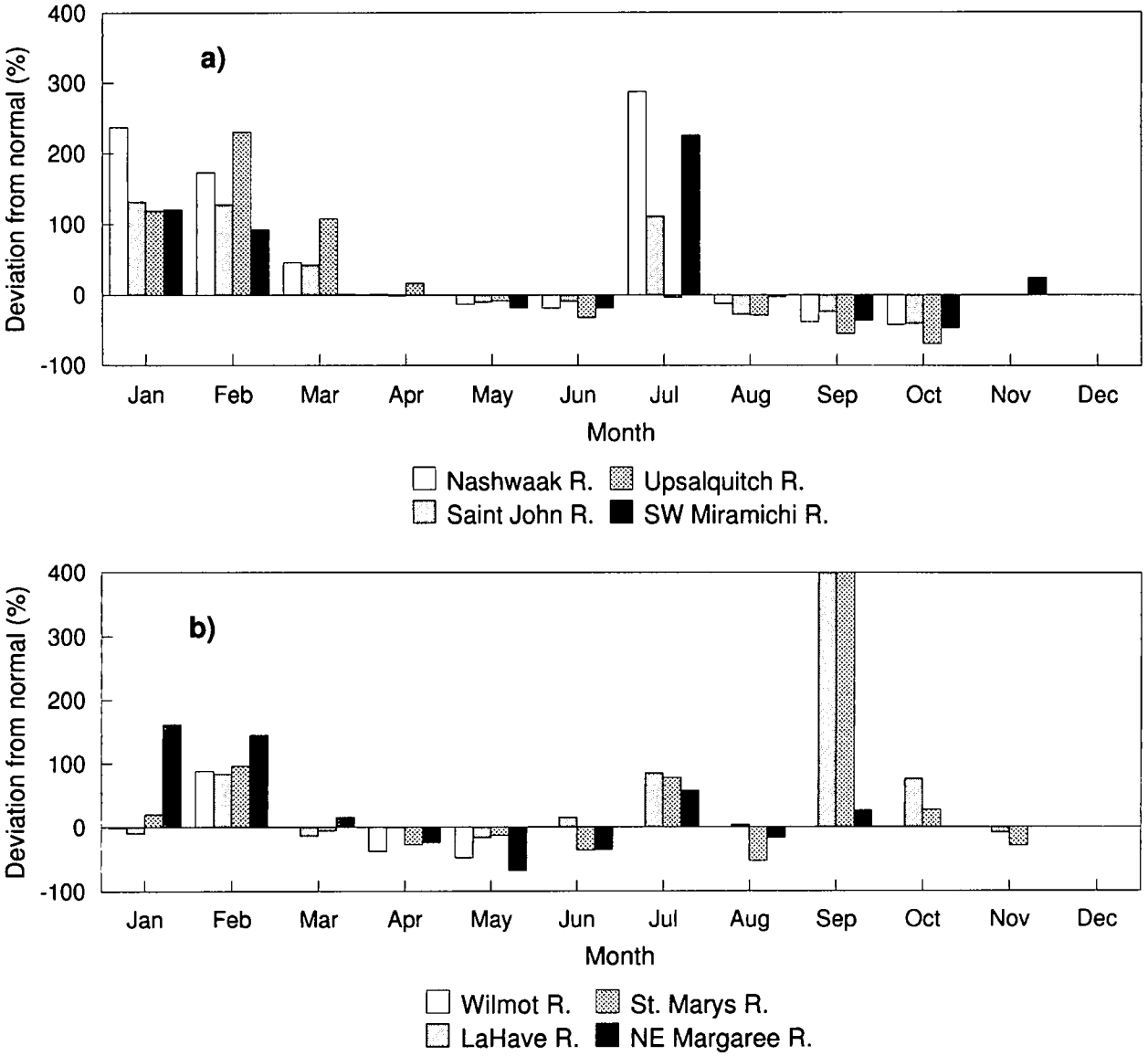

Figure 2. Deviation from normal monthly discharge in 1996 (in percentage, %) for studied rivers in the Maritime provinces.

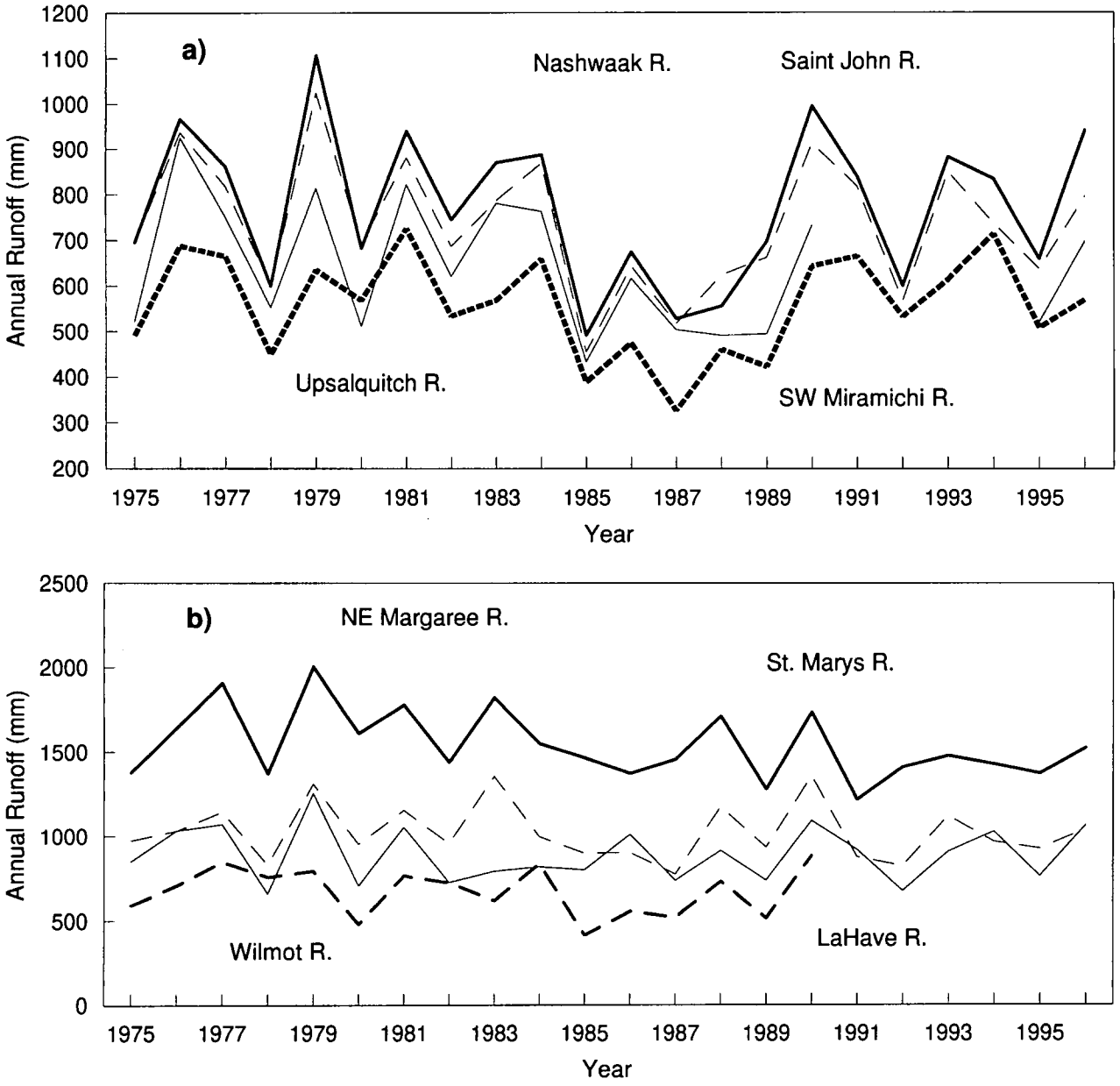

Figure 3. Mean annual runoff (mm) for Atlantic salmon rivers in the Martime provinces between 1975 and 1996.

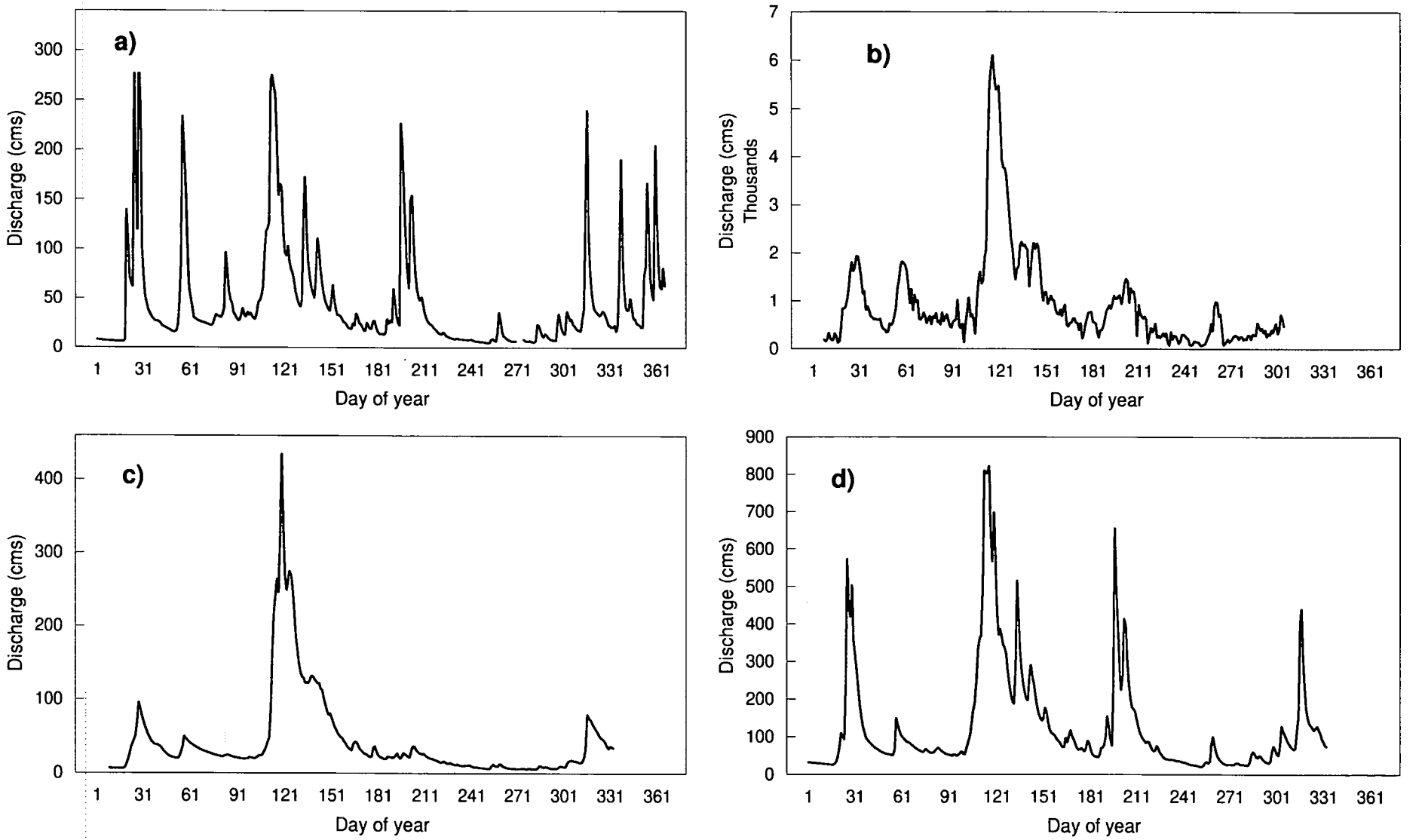

Figure 4. Daily stream hydrograph (cms) for selected rivers in the Maritime Provinces. a) Nashwaak River, NB b) Saint John River, NB, c) Upsalquitch River, NB and d) Southwest Miramichi River, NB

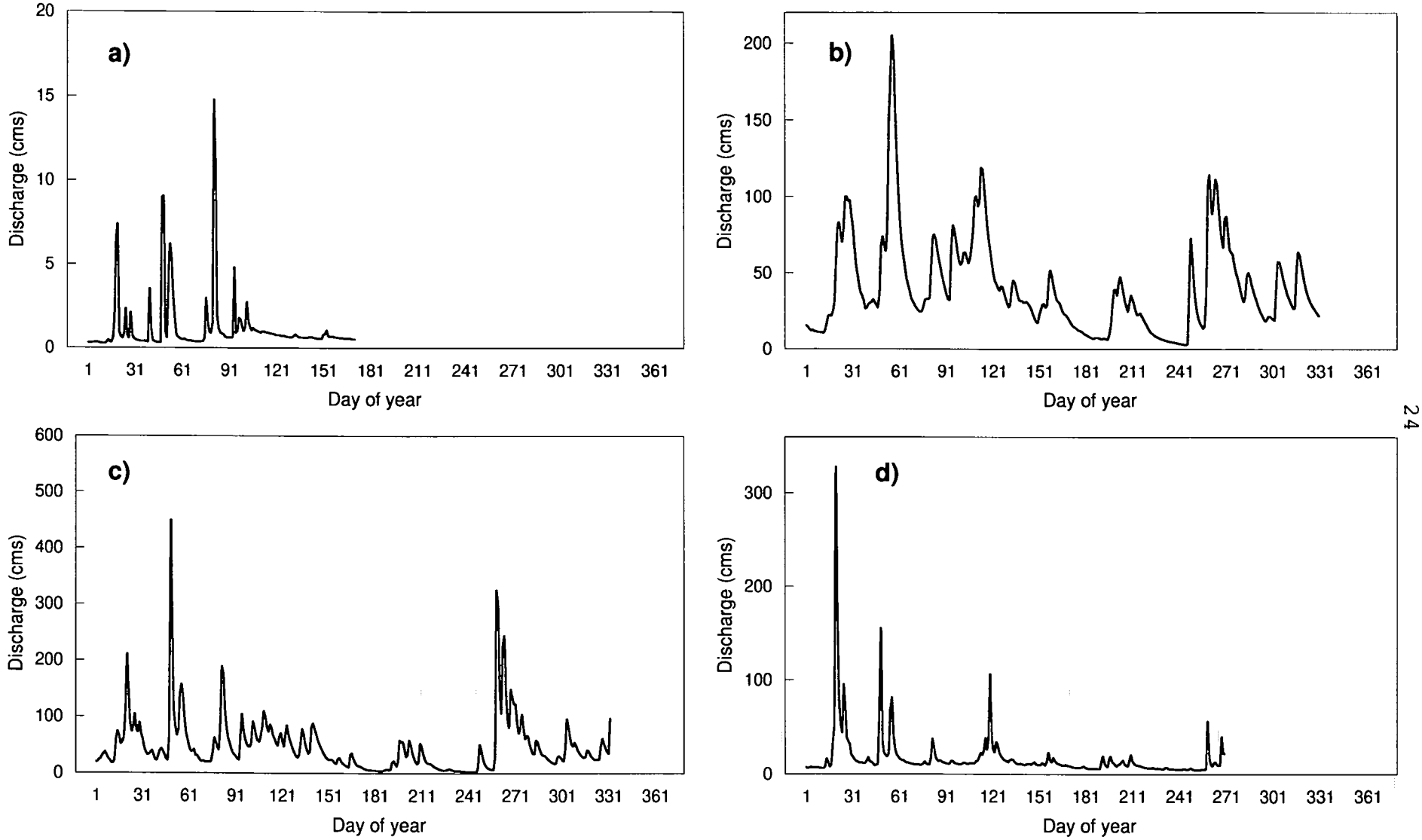

Figure 5. Daily stream hydrograph (cms) for selected rivers in the Maritime Provinces. a) Wilmot River, PEI b) LaHave River, NS, c) St. Marys River, NS and d) Northeast Margaree River, NS

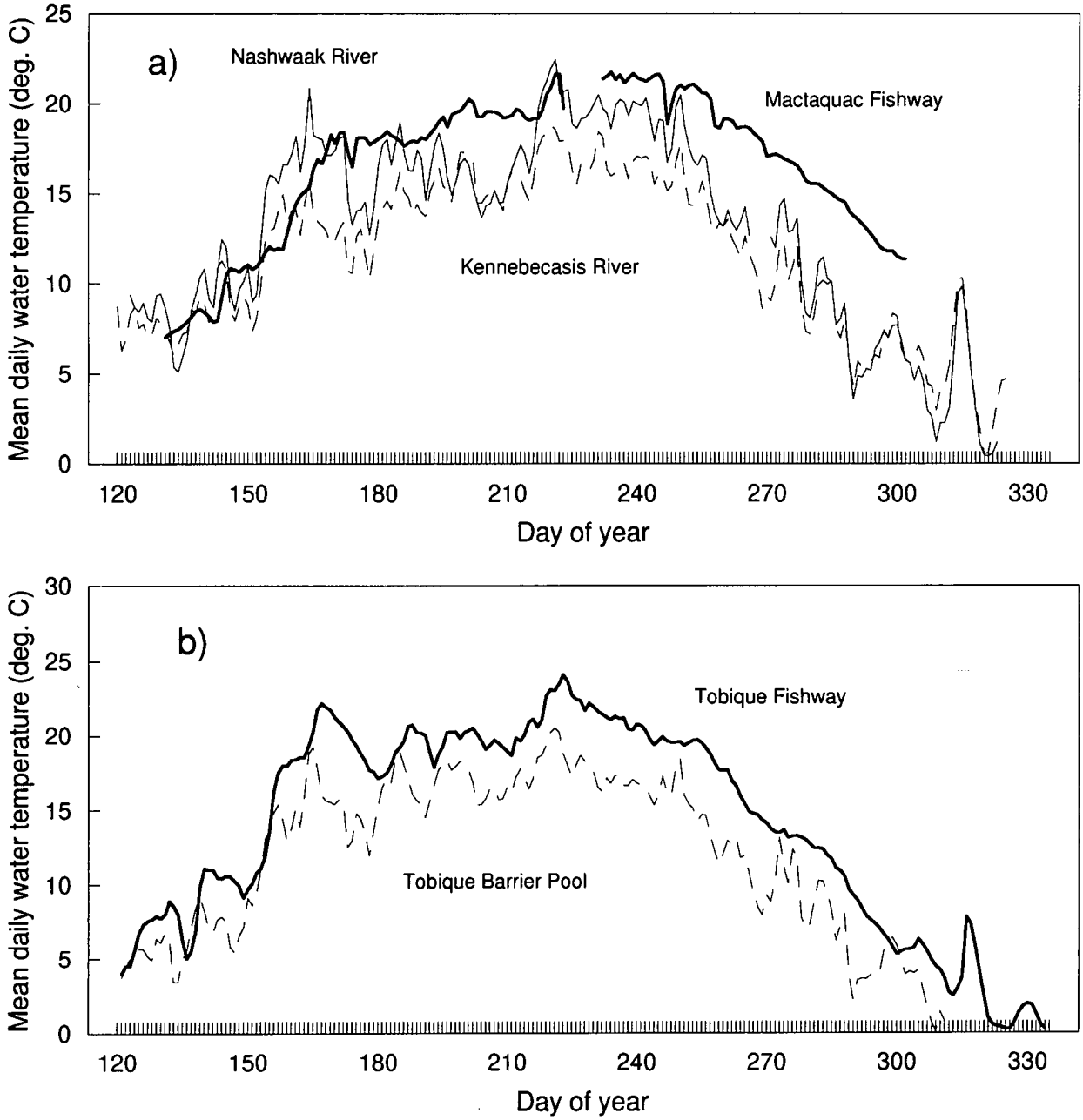

Figure 6. River water temperatures for different locations in NB in 1996. (Day 120 =April 29)

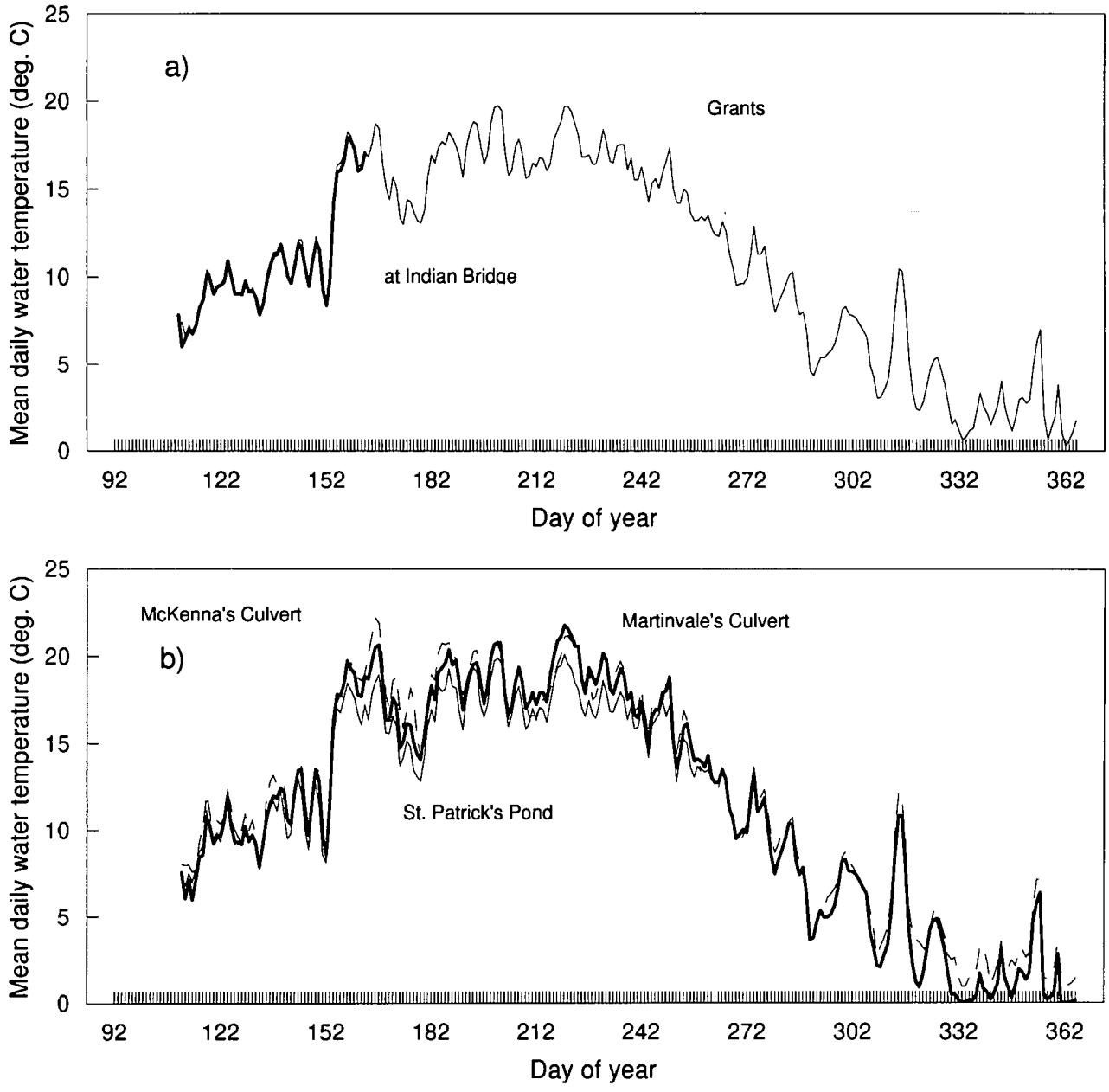

Figure 7. River water temperatures in the Morell River basin (PEI) in 1996 (Day 92 = April 1 and day 332 = November 27).

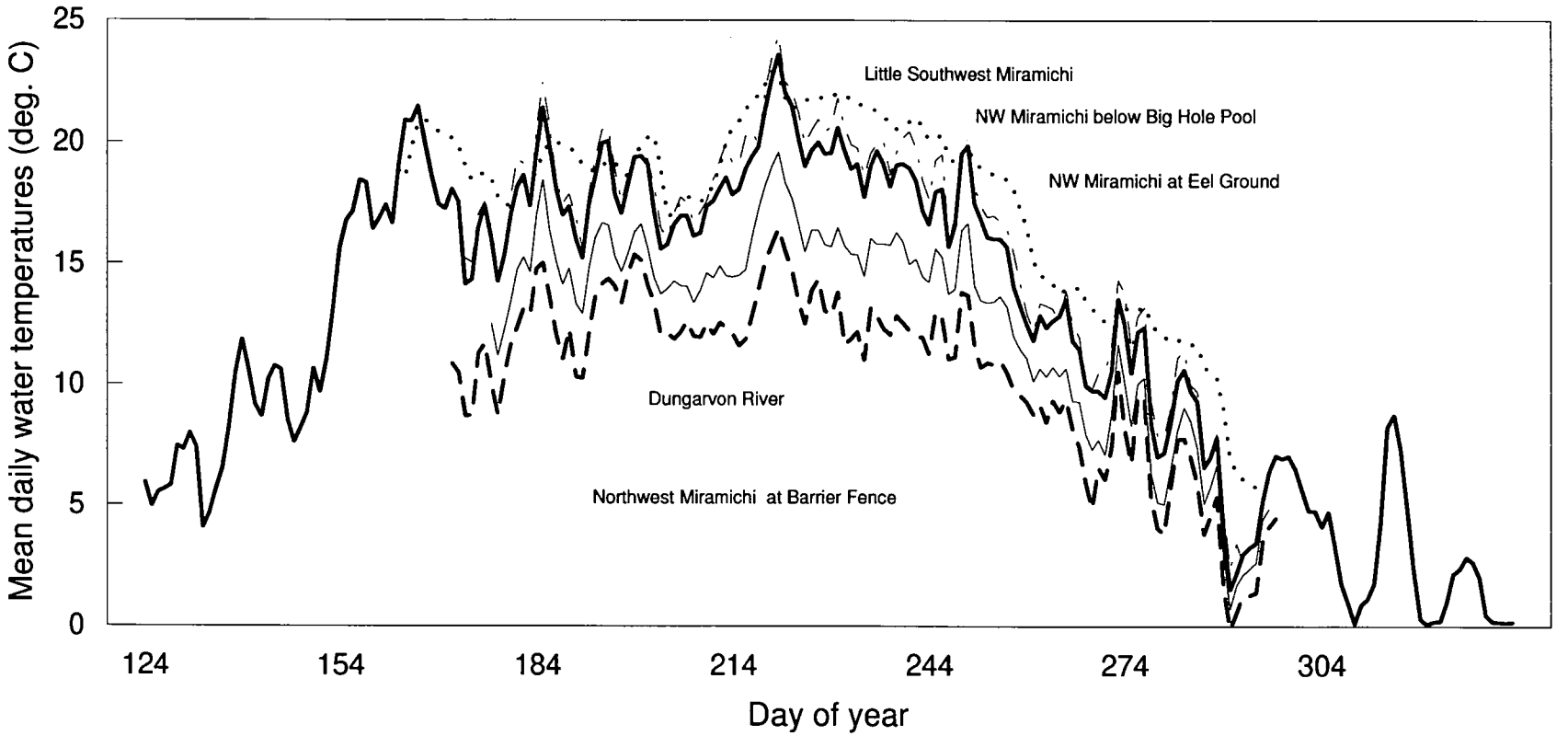

Figure 8. River water temperature for different locations within the Miramichi River basin. (Day 153 =June 1and day 273 =September 29)

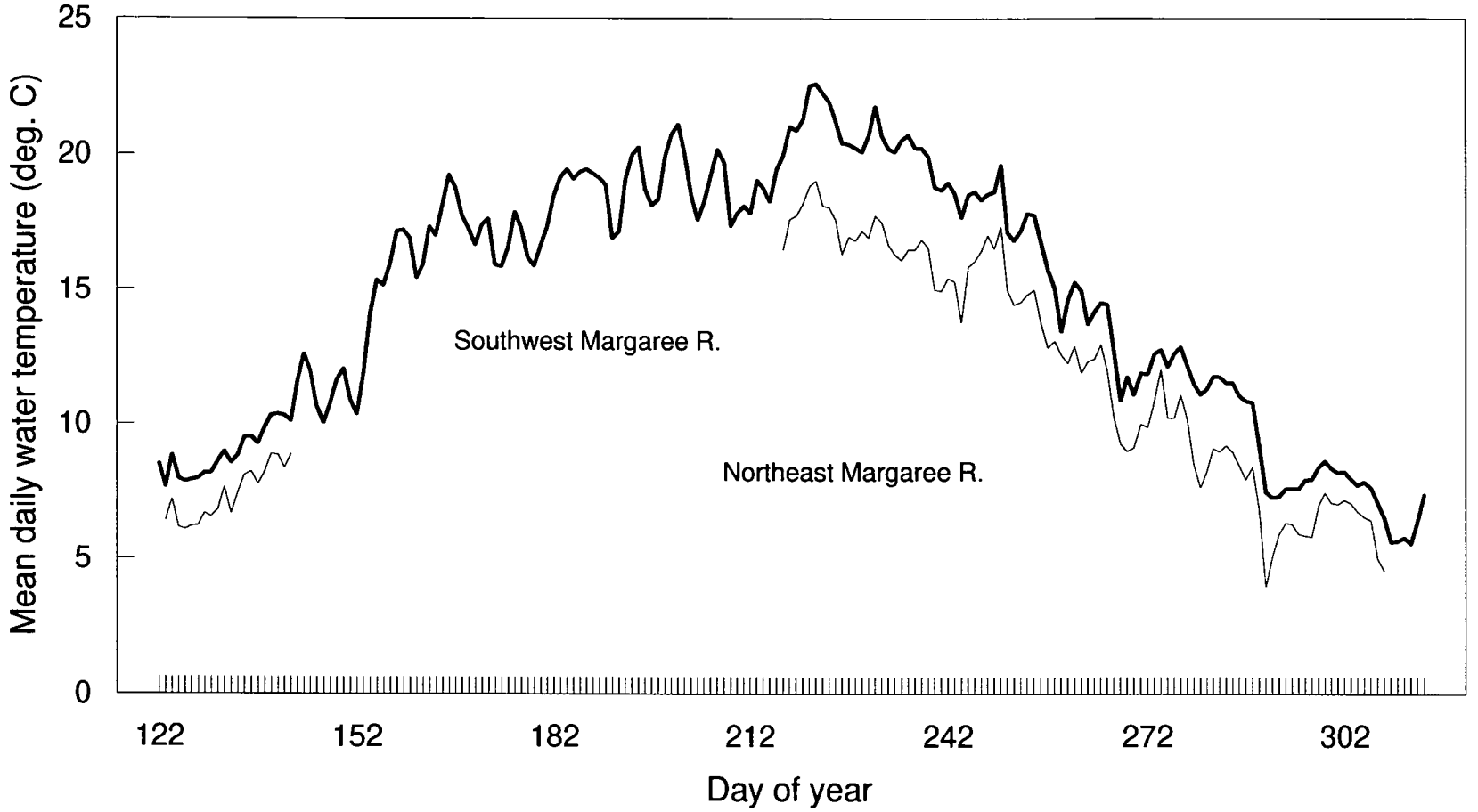

Figure 9. River water temperature for Northeast and Southwest Margaree Rivers (Day 122 = May 1 and day 302 = October 28).