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Hydrological Conditions for Atlantic Salmon Rivers in 2000

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ABSTRACT

This paper provides year 2000 and historical information on hydrological conditions for 6 selected Atlantic salmon (*Salmo salar*) rivers within the Maritime Provinces. High and low flows for each river were calculated based on historical annual high and low flow series. Stream water temperatures were reported for 3 river systems.

Discharges were excessive in winter 2000 (NB and PEI) and became deficient in spring and early summer. Record low monthly flows were observed in April in Wilmot River (PEI). The spring breakup of 2000 was earlier with peak flows in early April in NB and January in NS. The spring breakup was generally characterized as mild with most rivers having floods close to a 2-year flood event. Wilmot River experienced the highest flood peaks this year exceeding the 5-year flood event.

The early spring flood in 2000 resulted in low monthly flows in May and June. Deficient monthly flows were observed in 4 of 6 rivers during these two months. Deficient flows were also observed in the early autumn with all rivers being deficient in September 2000. On a daily basis, most rivers reached close to or exceeded the 2-year low flow this year.

River water temperatures in 2000 were characterized by 2 high temperature events, one in late June and the other in late July. The Southwest Miramichi and Little Southwest Miramichi rivers reached 25 °C for their maximum water temperatures this year. These temperatures were lower than last year (1999), when values reached close to 30°C. The number of days with temperatures exceeding 23°C were also down this year. Both the Southwest Miramichi and the Little Southwest Miramichi showed less than 25 days with maximum temperatures exceeding 23°C. Last year, the number of days (> 23 °C) reached 60 for these river systems.

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 2000. 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'air est présentée pour 6 stations dans les provinces Maritimes. La température de l'eau a été obtenue pour 3 rivières, et les caractéristiques de température, tel que les événements de température élevés, ont été présentées.

Le débit des rivières était supérieur à la normal pendant l'hiver 2000 (Nouveau-Brunswick, NB et à l'Ile-du-Prince-Edouard, IPE) et par la suite plus faible à la normale au printemps et été. Un débit faible extrême (record) a été observé en avril sur la rivière Wilmot (IPE). La débâcle en 2000 était plus avancée que la normale au NB et en Nouvelle-Écosse (NE). Les débits de crue étaient observés en avril au NB et en janvier pour la NE. Les débits de crue au printemps étaient assez faibles et de l'ordre de 2 années de récurrence. La rivière Wilmot (IPE) démontra un débit de crue plus fort avec un débit d'une récurrence d'environ 5 années.

Un printemps avancé en 2000, contribua aux débits faibles en mai et juin. En effet, des conditions de débits inférieurs à la normale ont été observées dans 4 de 6 les rivières durant ces mois. Des conditions de débits faibles furent également observées à l'automne avec toutes les rivières démontrant des débits faibles en septembre 2000. Sur une base journalière, les débits faibles de la plupart des rivières étaient de l'ordre du débit d'une récurrence de 2 années.

Les variations dans la température de l'eau en 2000 peuvent être caractérisées par 2 événements importants, un événement en juin et l'autre à fin juillet. Les rivières Southwest Miramichi et Little Southwest Miramichi ont atteint des températures journalières maximum de 25 °C en 2000. Les températures extrêmes étaient inférieures à ceux de 1999, c'est-à-dire près de 30°C. Le nombre de jours avec des températures de l'eau supérieurs 23 °C était aussi inférieur en 2000 comparativement à 1999. Les rivières Southwest Miramichi et Little Southwest Miramichi démontrèrent moins que 25 jours avec une température supérieure à 23 °C. L'année précédante démontra au-delà de 60 jours de température supérieure à 23 °C sur ces mêmes rivières.

INTRODUCTION

Hydrological conditions can be important in the management of fisheries and aquatic resources. Some of these conditions such as streamflow variability and high water temperatures can affect stream biota at different life stages and also during different seasons of the year. Salmonids can be affected by stream discharge such as high flows (Elwood and Waters 1969; Erman *et al.* 1988) or during low flows, which are often associated with high river water temperatures (Cunjak *et al.* 1993; Edwards *et al.* 1979). In order to increase our understanding of the environmental conditions of particular Atlantic salmon rivers, for the purpose of assessing Atlantic salmon stocks, we need to study the stream hydrology of these rivers and associated extreme events.

The objective of the present study is to analyze regional hydrological data for important Atlantic salmon rivers within the Maritime Provinces for use in aquatic resource management. The specific objectives are: a) to provide an overview of the monthly precipitation at 6 sites and flow conditions for 6 rivers, b) to determine the high and low flow months in 2000, c) to determine the frequency of floods and low flow events in 2000, d) to identify abnormal streamflow events in the Maritime Provinces, and e) to analyze data on air and water temperature events for these rivers.

METHODS

Historical and year 2000 data on precipitation were obtained from Environment Canada for 6 sites in the Maritime Provinces and monthly precipitation data are presented.

Regional hydrological analyses were carried out using historical hydrometric data from gauged streams and rivers in the study region. Historical data and 2000 hydrometric data were also obtained from Environment Canada (Environment Canada 1990). 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 average every 25 years such that 4 low flow events occur every 100 years on average. Flood frequency analysis was based on a three-parameter lognormal distribution function and on historical annual flood observations (Kite 1978). In contrast, the type III extremal distribution was used to estimate the annual frequency of low flow events using daily minimum discharge.

Monthly flow characteristics for 2000 were compared to long-term monthly average flow conditions. The high and low flow months were estimated for each river system. In the present study, a flow above

the 75% percentile identifies an excessive monthly flow condition while a flow below the 25% percentile denotes a deficient flow (Environment Canada 1995).

Water temperatures were studied for 3 sites in the Miramichi River basin. Mean daily water temperature values as well as peak temperatures were considered in the analysis. Also, the number of days during which each river exceeded 23 °C was determined.

Study rivers

The study region comprises 6 Atlantic salmon rivers within the Maritime Provinces for hydrological studies and 3 water temperature sites (Figure 1). These rivers are: Upsalquitch River (01BE007, 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 5050 km^2 (Southwest Miramichi River; Table 1). The LaHave and St. Marys Rivers have the longest daily discharge time series with over 80 years of record. The mean annual flow (MAF), which is a function of drainage area, varies between 0.922 m^3/s for Wilmot River to 116 m^3/s for the Southwest Miramichi River. To compare discharge between basins of different sizes, the mean annual runoff was used. This is the mean annual flow (MAF) expressed in unit discharge (in mm) i.e. discharge per drainage area. The region has a wide range of runoff characteristics depending on parameters such as precipitation, soil type, gradient etc. Northern New Brunswick (NB) and Prince Edward Island (PEI) showed the lowest runoff with only 640 mm (Wilmot, PEI) and 568 mm (Upsalquitch River, NB) compared to more than double this value at 1485 in Cape Breton (Northeast Margaree River, Nova Scotia - NS). The precipitation varies from 1080 mm in Northern New Brunswick to 1600 mm in Cape Breton (NS) (Table 1). The coefficient of variation (CV) of monthly flow characteristics showed more stable flow regime for some rivers than for other rivers. For instance, Wilmot River has a more stable flow regime with a CV of 0.49 compared to Upsalquitch River with a CV of 1.01 (Table 1).

RESULTS

PRECIPITATION IN 2000

Long-term precipitation data (1953-1990) are presented in Table 2 for comparative purposes. The highest monthly precipitation in 2000 was recorded in Sydney in November with a total value of 351 mm. The previous record high was set in October 1969 at 334 mm of precipitation. In contrast, the lowest precipitation recorded in the region was in Northern New Brunswick at Charlo with a

precipitation in September of 35.2 mm. Most areas showed close to normal precipitation during the year 2000, however, variability was high. For instance, precipitation was high in January, especially in NS followed by lower precipitation in February. Low precipitation was observed in PEI in both February and April this year at 42.1 mm and 45.1 respectively (Table 2). Summer precipitation values were average or below average at most sites, except for PEI which showed higher than normal precipitation in July. Autumn precipitation was close to average in NB and PEI, and higher than normal precipitation was observed in NS, especially in Cape Breton.

HYDROLOGICAL CONDITIONS IN 2000

In general, winter flows in year 2000 were excessive (Table 3a). Flows were excessive in January in three rivers in the Maritime Provinces. The greatest deviation from the long-term monthly flow was observed in New Brunswick in the Upsalquitch River in March with flows over +100% (Figure 2). In Nova Scotia, excessive flows were only observed in St. Marys River in January, with flows of 69.2 m^3/s compared to a 51.1 m^3/s long term average (Table 3a).

The spring high flow of 2000 was early in some rivers, resulting in average to deficient flows later in April and May. In fact, many rivers were deficient in May (Southwest Miramichi R., NB; Wilmot R., PEI; St. Marys R., NS; and Northeast Margaree River, NS; Figure 2 and Table 3a). June was also a deficient month for many rivers. Record low flow was measured in PEI in April of 2000, with a discharge value of 0.784 m^3/s compared to the long-term average value of 1.94 m^3/s.

Summer monthly flows in 2000 were characterized as deficient between July and October in many rivers depending on the location (Table 3a). During deficient flow conditions, rivers in NS showed greater deviation from the average with values in the range of –75% (Figure 2). Deficient flows were observed in all monitored rivers in the Maritime Provinces in September. NS rivers were more severely affected by low water conditions especially the LaHave River (Figure 2). For instance, the LaHave River showed a low flow of 1.20 m^3/s compared to the average of 8.89 m^3/s for September.

In autumn 2000, excessive flows were monitored in both November and December in the Wilmot River (PEI) and St. Marys Rivers (NS) (Figure 2). The greatest deviation from normal was observed at Wilmot River in December with a flow of 1.46 m^3/s compared to the long-term average of 0.884 m^3/s (Table 3a).

On a daily basis, spring peak flows in the Maritime Provinces were similar to 1999, occurring earlier than normal (Caissie 2000). Most peak flows occurred from January to early April depending on the location within the Maritime Provinces. Spring peak flow in NB occurred in early April (Upsalquitch River, 314 m^3/s, April 10; SW Miramichi River, 981 m^3/s, April 11; Table 3b). The spring peak flow in the Upsalquitch River was below the 2-year flood whereas in the Southwest Miramichi River, the spring peak was above the 2-year flood (Table 3b and Table 4). The Wilmot River (PEI) experienced its spring peak flow on February 28 at 16.3 m^3/s and this flow was above the 5-year recurrence interval. In NS spring peak flow occurred on January 5 for Northeast Margaree River, with a peak flow of 180 m^3/s. This flow represented a discharge above the 2-year flood. Both the LaHave and St. Marys Rivers experienced their annual peak flow in December this year. The peak flow in the LaHave was 140 m^3/s (December 21) compared to the spring peak of 98.0 (April 6; Table 3b). The annual peak flow in the LaHave River was less than the 2-year flood (Table 4). At St. Marys River, the annual peak flow also occurred on December 21 of this year at 366 m^3/s. This flow was also less than the 2-year flood.

On a daily basis, only a few low flows were experienced in the winter of 2000, particularly in Northern NB (Usalquitch R., 7.1 m^3/s in Feb.) and in Cape Breton (NE Margaree R., 4.5 m^3/s in Feb.). The most severe low flow conditions in 2000 occurred in September (Table 3b), although winter low flows were close to summer low flow values. Rivers in NB experienced low flows slightly more severe than the 2-year low flow (Table 5). The Upsalquitch River experienced 5.16 m^3/s on October 05, which was a discharge lower than the 2-year flow. The Southwest Miramichi River experienced a low flow of 19.3 m^3/s, also a flow lower than the 2-year low flow and occurred on September 12. For the most part, rivers in Nova Scotia and PEI had discharges higher than the 2-year low flow, except for the LaHave River, which experienced a low flow lower than the 2-year recurrence interval, similar to NB rivers. Low flows in NS occurred in September for all rivers (Sept. 01, LaHave River; Sept. 16, St. Marys River; Sept. 30, NE Margaree River).

In general, peak flows in 2000 were close to or below the 2-year flood event in the Martime Provinces execpt for Wilmot River, which exceeded a 5-year event. For low water conditions this year, all rivers in the Maritime Provinces showed flows close to the 2-year low flow.

AIR AND STREAM WATER TEMPERATURES

Air temperatures were obtained from 6 stations across the Maritime Provinces, at Charlo (NB), Chatham (NB), St John (NB), Charlottewon (PEI), Halifax (NS) and Sydney (NS). Mean annual air

temperatures were calculated for all stations and the results are shown in Figure 3. From this figure it can be observed that air temperatures vary depending on the location within the Maritime Provinces. Halifax showed the highest mean annual air temperature and Charlo had the lowest air temperatures. The Charlo time series was also shorter than that from the other stations. Because of the shorter time series at Charlo, mean values for the Maritime Provinces will be calculated with and without the Charlo station.

The mean annual air temperature (mean of stations) was calculated for the Maritime Provinces for the year and for the summer only (Figure 4). It was observed that the overall mean annual air temperature in the Maritime Province was 5.0 °C for the year and 14.5 °C for the summer season (summer = May to Sept.; Figure 4). This figure shows a relatively warm period in the early 50s for annual air temperatures, with mean annual temperatures higher than 5 °C and thereafter they return closer to 5 °C again. The 10-year moving average also shows the long-term trends. The period ending in the 70s and 80s had lower temperatures than recent years. The most recent years (1998 and 1999) have been warmer than normal with mean annual temperatures of 6.2 °C and 7.0 °C respectively, although the year 2000 was normal at 5.3 °C. It is worth noting that the warmest year on record (1999) at 7.0 °C was +2.0 °C from normal (long-term average).

During the summer season (May to September, which corresponds to the season of most fish growth) air temperatures can be of importance to fisheries resources and these are presented in Figure 4. The mean summer air temperature varied between 13.2 °C and 16.8 °C, with an overall mean summer air temperature of 14.5 °C. Summer air temperatures have been below 15 °C since the early 60s, except for 1998 and 1999 when values exceeded 15 °C. This is also reflected in the 10-year moving average, which has been higher in recent years. The highest summer temperatures since the early 40s were measured in 1999 with a mean of 16.8 °C. The coldest summer on record was in 1986 at 13.2 °C (Figure 4).

River water temperatures were available at a few sites within the Maritime Provinces in 2000. Mean daily temperatures were generally warmer than normal in early spring as shown from the site at Doaktown (Figure 5). In May and early June (day 121 to 160), water temperatures were very close to normal. In late June of 2000, higher than normal water temperatures were monitored, followed by two colder periods in early July (day 193, July 11; and day 202, July 20; Figure 5). Following this period, water temperatures remained normal until late in the season, where water temperatures were above normal in late October (after day 301; Oct. 27). The first event with higher than normal mean daily

water temperatures occurred in June this year (from June 17 to 29) and mean daily temperatures peaked on June 26 at 25.9 °C. The second higher than normal event occurred between July 25 and August 07, with peak mean daily temperatures on August 01 of 25.6°C. It should be noted that the data from the two selected rivers, Southwest Miramichi at Doaktown and Little Southwest Miramichi River above Catamaran Brook, showed similar results (Figure 5).

To compare water temperature in 2000 to previous years, the long-term data series from Catamaran Brook were used. Hourly water temperatures have been collected at Catamaran Brook since 1991 and mean monthly values are presented in Table 6. The highest monthly water temperature to date was recorded in July 1999 at 17.2 °C. In 2000, the highest monthly temperature was also recorded in July at 15.1 °C, which was the same for the month of August 2000. Monthly temperatures were higher than normal early in the season, more specifically for the months of May and June. The following months (July-October) showed average water temperatures until the end of the season. Figure 6 shows the mean daily temperatures at Catamaran Brook from 1991 to 2000 compared with the long-term average (Fourier series). This figure contrasts the coldest summer of this time series 1992 with the warmest summer of 1999.

Maximum recorded temperatures are important for many rivers, especially when temperatures exceed critical values for aquatic biota. The maximum recorded temperature in 2000 at the Doaktown site on the Southwest Miramichi River was 25.9 °C. This maximum temperature was recorded on June 26 (day 178). In the Little Southwest Miramichi River, the maximum recorded temperature was 26.2 °C recorded on that same day. For Catamaran Brook, a cold water tributary of the Little Southwest Miramichi River, the maximum temperature was recorded on June 28 at 21.9 °C.

High water temperature events can potentially affect aquatic biota not only as a result of extreme maximum water temperature but perhaps more importantly the affect related to the duration of such events. Critical temperatures for salmonids are often reported to be in the vicinity of 23°C. Therefore the event duration or the number of days with daily maximum temperature exceeding 23 °C was determined. Catamaran Brook maximum water temperature did not reach 23 °C, therefore the duration (or number of days) was zero. The Southwest Miramichi River at Doaktown however had 25 days with temperatures exceeding 23 °C in 2000. Similar results were obtained in the Little Southwest Miramichi River with an event duration of 19 days where water temperatures exceeded 23 °C. The duration or severity of high water temperature events in 2000 were not as significant as in 1999. In 1999 water

temperatures exceeded 23 °C for 62 days in Little Southwest Miramichi River (Caissie 2000), compared to only 16 days in 1998 and 14 days in 1997 (Caissie 1999a; Caissie 1999b).

SUMMARY

In summary, the streamflow conditions during 2000 for the Maritime Provinces can be characterized as having had an earlier than normal spring freshet in January and April, which resulted in lower monthly flows in May and June. Record low monthly flows were observed in April for Wilmot River (PEI).

The spring runoff in 1999 was characterized as mild in most rivers with peak flows close to or less than the 2-year flood recurrence interval with the exception of Wilmot River. The Wilmot River peak flow exceeded the 5-year flood recurrence interval this year. Spring peak flows for many rivers occurred earlier this year, January in NS, early April in NB and March in PEI. December peak flows this year in NS were higher than spring peaks.

Low flows were not severe in the Maritime Provinces this year with most minimum discharge higher than or close to the 2-year low flow. These low flows occurred between September and October for all rivers. Winter low flows were similar to summer low flows for rivers such as the Upsalquitch R. (NB) and NE Margaree R. (NS).

Mean annual air temperature in 2000 was back to normal this year at 5.3 °C compared to a record year in 1999 (7.0 °C) in the Maritime Provinces (Caissie 2000). Summer air temperatures were slightly lower than the average at 14.1 °C compared to the long-term mean of 14.5°C. These air temperatures were reflected by water temperature conditions.

River water temperatures in the Miramichi River in 2000 were closer to normal. The Little Southwest Miramichi and the Southwest Miramichi rivers exceeded 23 °C for approximately 20 days this year. These same rivers exceeded 23 °C for over 50 days in 1999 (Caissie 2000).

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

River	Area[1] (km^2)	N (years)	MAF (m^3/s)	Runoff (mm)	CV	Prec. (mm)
Upsalquitch River (NB)	2270	70	40.8	568	1.01	1080
Southwest Miramichi R. (NB)	5050	52	116	725	0.82	1090
Wilmot River (PEI)	45.4	29	0.922	640	0.49	1100
LaHave River (NS)	1250	84	34.4	870	0.59	1420
St. Marys River (NS)	1350	84	43.0	1007	0.54	1350
Northeast Margaree R. (NS)	368	83	17.4	1485	0.61	1600

[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 of monthly flows; Prec. = precipitation in mm.

Table 2. Long-term monthly precipitation (mm) and year 2000 precipitation for different areas in the Maritime Provinces. (First row of data represents the long-term precipitation while the second row represents precipitation in 2000).

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Chatham A (NB)	*LT*	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
	2000	158.2	67.1	87.5	161.1	71.3	74.1	91.4	74.2	67.4	122.3	128.9	92.4	
Charlo A (NB)	*LT*	89.3	63.9	84.4	76.6	87.2	84.3	98.6	98.5	89.4	90.0	87.0	97.4	1039
	2000	102.3	69.1	80.0	116.7	102.4	47.3	93.5	52.8	35.2	93.2	101.0	88.8	
Saint John A (NB)	*LT*	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
	2000	185.7	75.1	138.2	76.7	95.4	47.8	66.4	59.4	108.4	128.8	70.9	133.9	
Charlottetown A (PEI)	*LT*	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
	2000	137.0	42.1	65.2	45.1	64.3	52.0	158.6	94.6	57.2	156.9	114.4	125.7	
Sydney (NS)	*LT*	143.5	126.3	129.7	113.4	101.5	87.1	82.8	97.3	107.0	125.7	154.0	152.2	1417
	2000	196.8	73.2	103.5	74.2	90.4	61.4	62.6	41.6	58.2	279.0	351.2	151.8	
Halifax (NS)	*LT*	128.9	107.4	110.8	110.1	105.0	104.1	97.8	102.6	91.5	121.7	139.9	150.8	1371
Shearwater	*2000*	199.8	66.9	134.9	136.3	111.0	69.9	106.1	70.2	96.4	173.1	133.8	204.8	

Table 3a. Long-term monthly and year 2000 average flow conditions for selected Atlantic salmon rivers in the Maritime Provinces. (First row of data for each river represents the long-term flow condition while the second row represents the 2000 discharge expressed in m^3/s).

River		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Upsalquitch River (NB)	LT	14.0	10.8	13.2	88.6	158	53.8	25.7	18.7	17.9	27.2	34.7	25.8
	2000	18.6E	11.2	26.6E	153E	138	30.7D	16.5	10.4	6.39D	7.69D	28.3	14.1
SW Miramichi R. (NB)	LT	56.7	49.8	66.4	316	318	112	60.0	54.7	54.1	89.5	116	98.8
	2000	62.4	34.3	112E	475E	188D	55.2D	56.4	35.5	29.0D	39.5D	75.8	70.0
Wilmot River (PEI)	LT	1.07	0.932	1.62	1.94	1.21	0.773	0.572	0.494	0.434	0.499	0.636	0.884
	2000	1.94E	1.73E	1.36	0.784DR	0.632D	0.566	0.460	0.401	0.356D	0.477	0.935E	1.46E
LaHave River (NS)	LT	47.0	38.4	53.3	73.3	38.9	20.6	11.3	8.97	8.89	19.8	42.7	50.7
	2000	47.9	31.5	63.7	60.4	28.7	10.3	2.43D	1.53D	1.20D	10.9	36.3	50.1
St. Marys River (NS)	LT	51.1	40.3	55.3	91.2	57.1	23.8	14.4	15.1	16.0	34.2	58.0	59.0
	2000	69.2E	6.93	54.5	80.5	34.6D	12.8D	10.4	9.66	4.90D	36.5	93.0E	83.7E
NE Margaree River (NS)	LT	15.3	11.0	12.3	27.1	43.4	15.5	6.80	7.56	9.38	16.2	22.8	19.1
	2000	20.1	6.93	18.3	29.9	14.4D	7.89D	5.98	5.04	4.49D	21.5	16.3D	20.0

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

Table 3b. Daily maximum and minimum flow conditions by month for selected Atlantic salmon rivers in the Maritime Provinces. (discharge expressed in m^3/s).

River		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Upsalquitch River (NB)	Min	10.8	7.1	15.3	73.5	57.0	14.6	11.0	7.26	5.49	5.16	11.8	10.0
	Max	30.0	36.0	40.0	314	227	57.2	27.2	16.2	8.20	12.8	51.3	21.3
SW Miramichi R. (NB)	Min	37.2	26.0	71.0	219	101	35.0	36.0	26.9	19.3	21.5	44.1	30
	Max	108	75.0	290	981	296	89.7	82.0	59.9	44.8	71.2	128	155
Wilmot River (PEI)	Min	0.66	0.52	0.55	0.64	0.54	0.49	0.43	0.37	0.33	0.32	0.635	0.837
	Max	13.1	16.3	9.4	1.13	0.99	0.66	0.57	0.47	0.40	3.25	1.91	8.32
LaHave River (NS)	Min	16.6	19.5	41.7	35.7	20.5	4.90	1.60	0.936	0.83	2.37	23.2	14.6
	Max	95.3	56.0	97.0	98.0	40.9	19.7	4.67	1.90	1.55	24.0	54.3	140
St. Marys River (NS)	Min	16.8	31.9	23.9	38.7	16.0	3.50	2.92	3.66	2.90	4.62	28.6	16.4
	Max	271	76.5	138	145	74.1	43.1	36.3	32.2	12.3	185	243	366
NE Margaree River (NS)	Min	5.80	4.50	10.0	13.0	9.60	5.40	5.03	4.61	4.15	4.79	8.35	6.31
	Max	180	14.0	50.1	103	36.2	12.8	11.6	5.94	4.87	151	55.4	94.1

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
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 an Extremal type III distribution function) for selected 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
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. Mean monthly water temperatures at Catamaran Brook Middle Reach (located in central New Brunswick, a tributary of the Little Southwest Miramichi River). All temperatures are expressed in °C.

Month	Apr	May	Jun	Jul	Aug	Sep	Oct
1991	n/a	7.76	12.45 *	14.66	15.07 *	n/a	n/a
1992	n/a	8.11 *	11.55	12.15	12.86	11.56	5.58
1993	0.35	5.80	10.52	13.39	14.79	10.69	4.49
1994	0.75	4.98	12.41	16.58	15.22	10.26	5.55
1995	0.99	5.89	13.52	16.24	15.26	9.88	7.18
1996	0.72	5.41	13.63	14.29	15.22	11.51	6.01
1997	0.38	3.84	11.48	13.91	13.72	11.04	4.79
1998	2.55	8.91	11.40	14.70	14.27	11.31	6.51
1999	1.60	9.27	15.22	17.23	16.52	14.16	5.84
2000	1.47	7.50	13.52	15.09	15.06	11.37	5.48
Mthly Mean	1.10	6.60	12.58	14.83	14.77	11.31	5.71

Note : * indicates months with missing values, and therefore the average was calculated with a reduced sample and these months were not used in the calculation of the monthly mean. Number of days included in the calculation: June 1991 (28 days), August 1991 (27 days), and May 1992 (19 days).

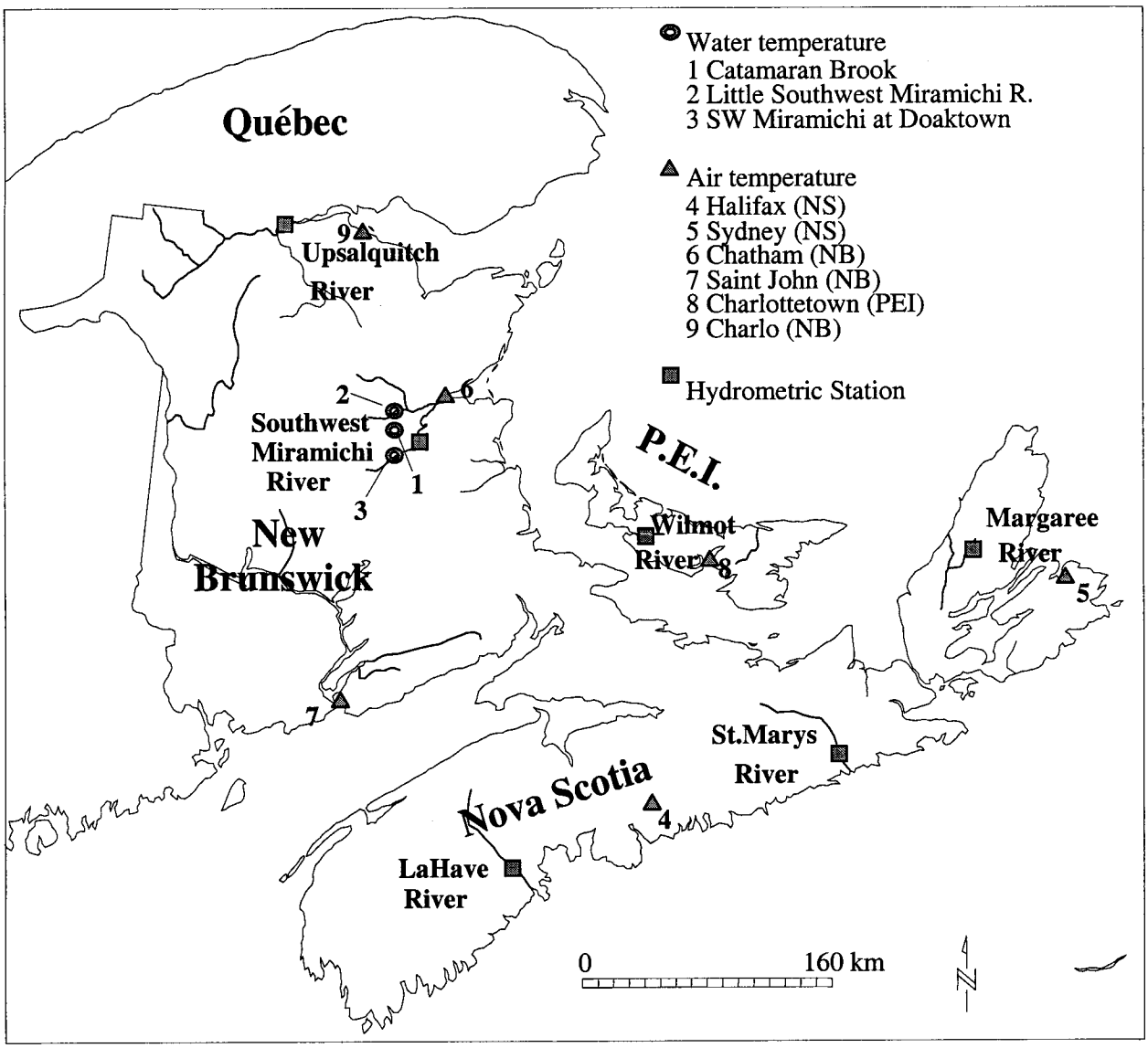

Figure 1. Location of hydrometric, air and water temperature stations on studied Atlantic salmon rivers in the Maritimes region.

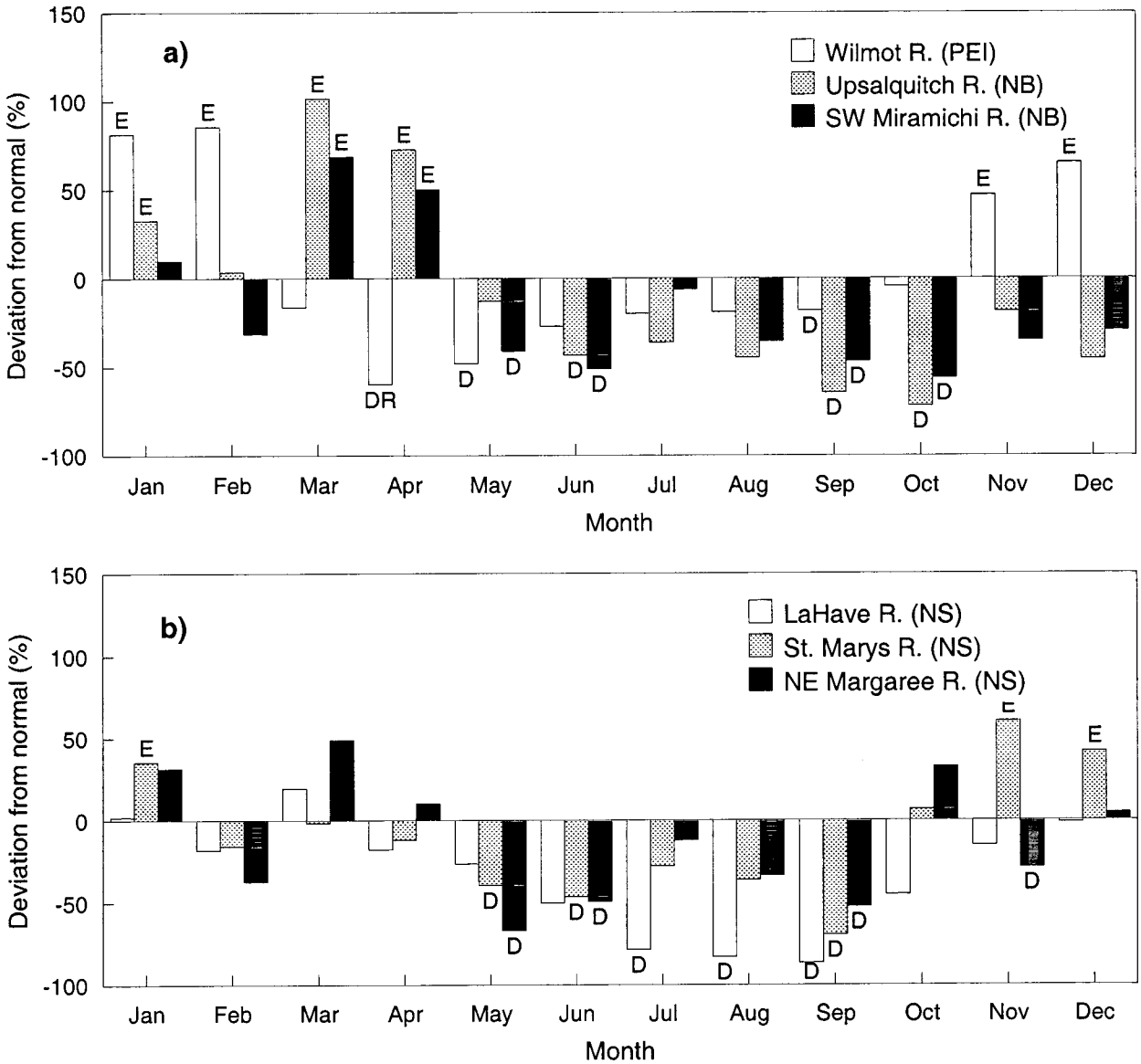

Figure 2. Deviation from normal monthly discharge in 2000 (in percentage, %) for studied rivers in the Maritime provinces. D=deficient & E = excessive see text for details.

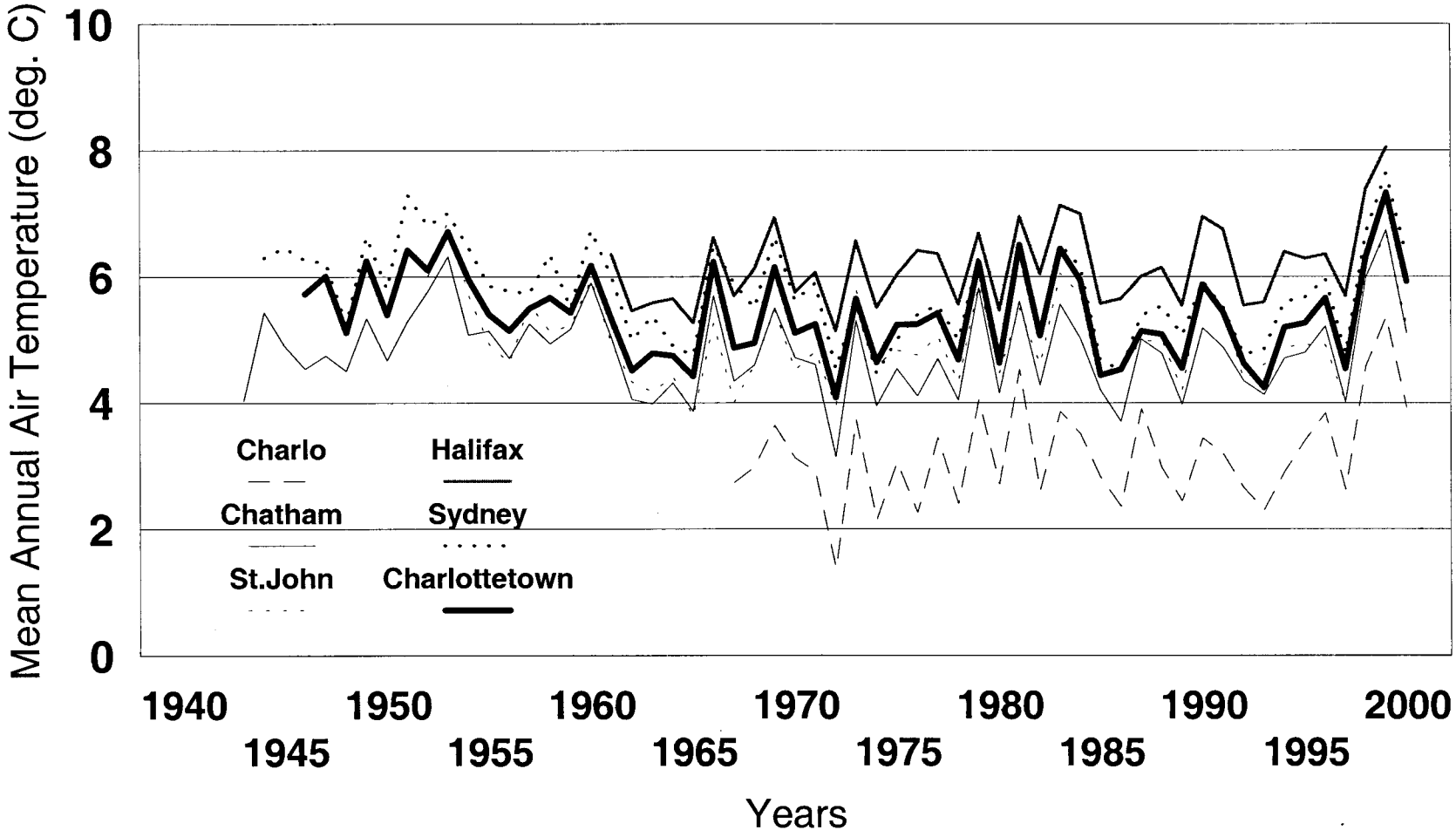

Figure 3. Long-term annual air temperature at different sites within the Maritime Provinces

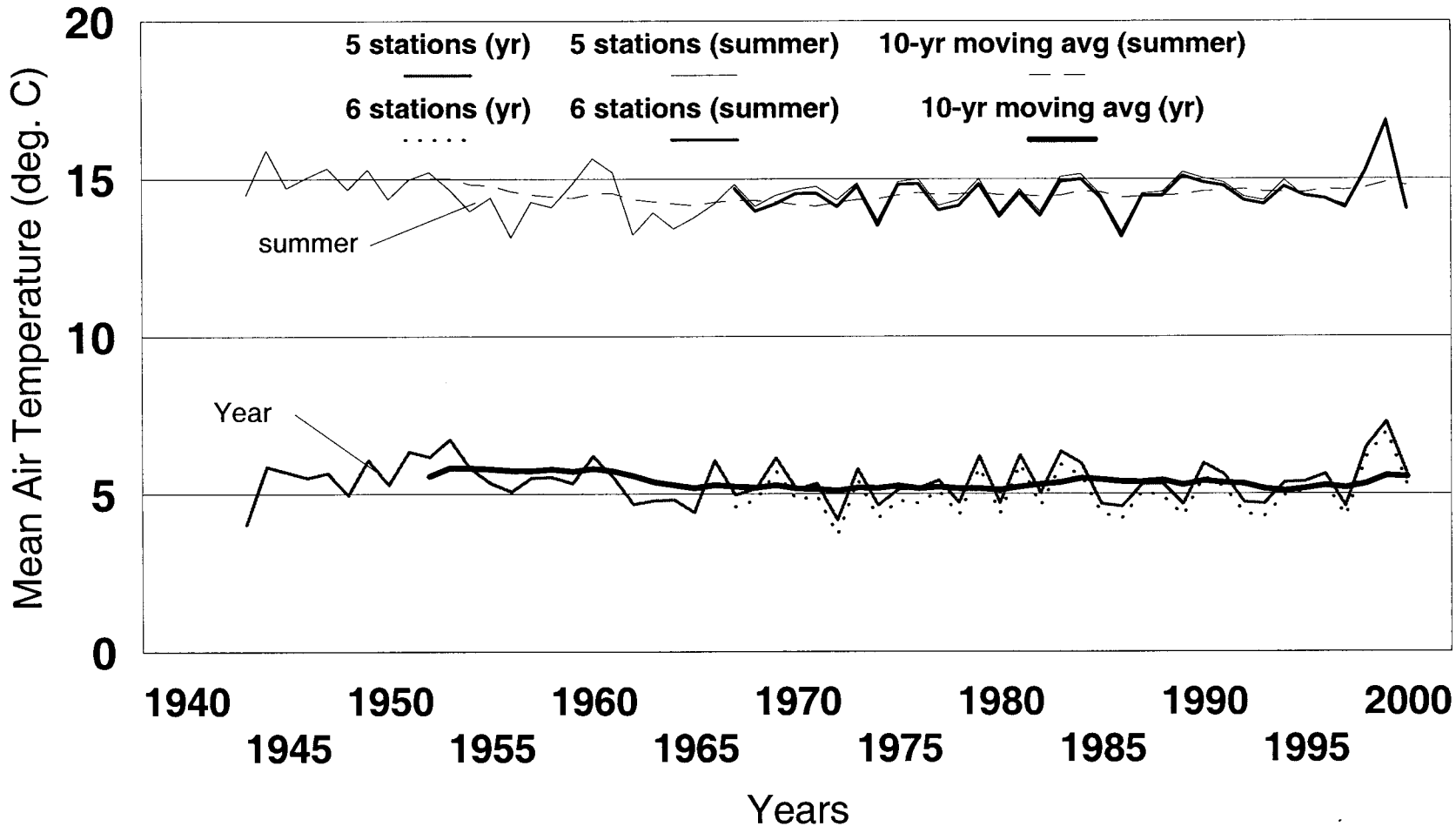

Figure 4. Long-term average air temperature within the Maritime Province in summer and on a annual basis. 5 or 6 stations were considered depending on the analysis.

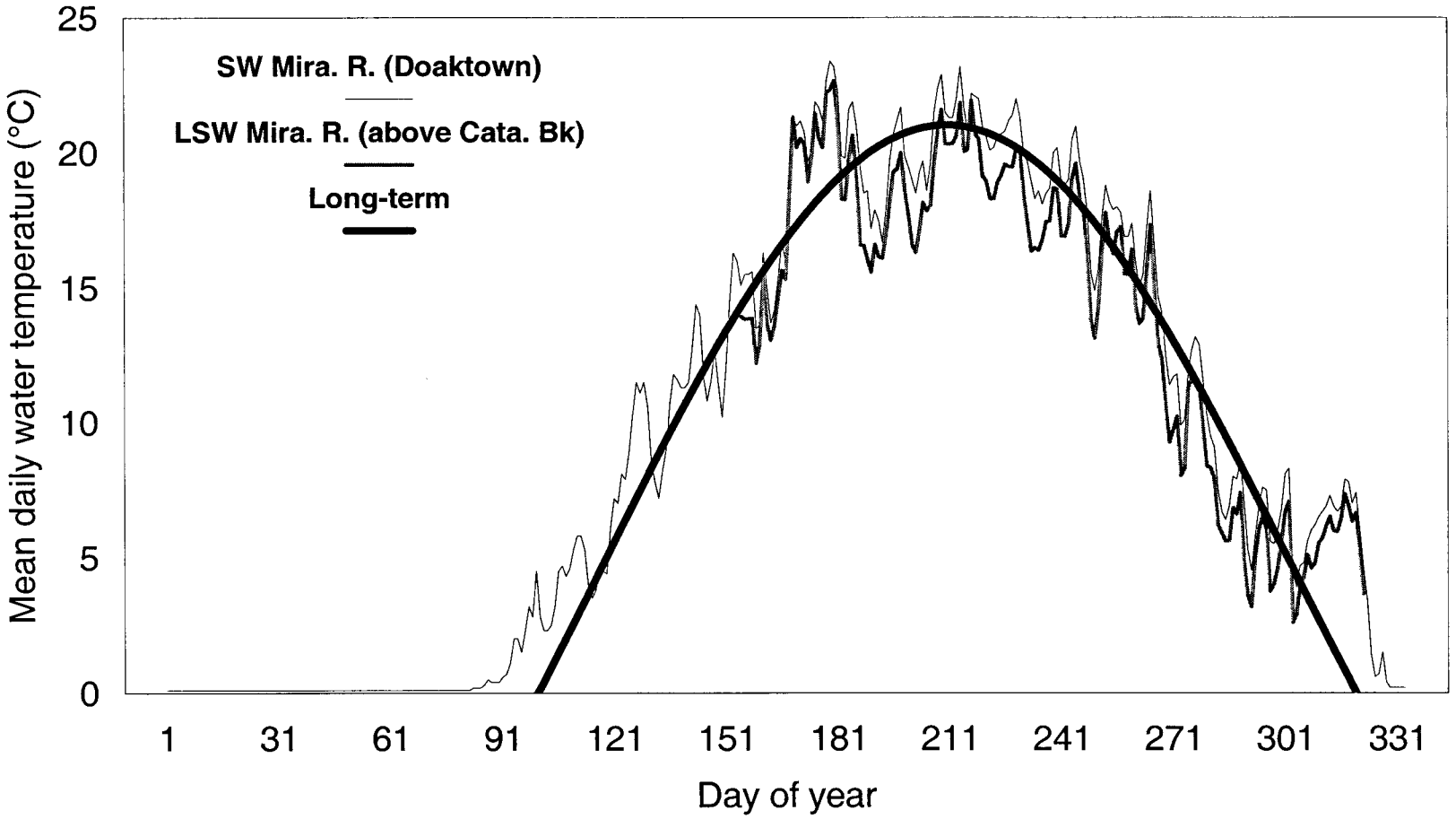

Figure 5. Water temperature at selected sites in the Miramichi River in 2000; SW Mira. R. = Southwest Miramichi River at Doaktown; LSW Mira. R. = Little Southwest Miramichi River.

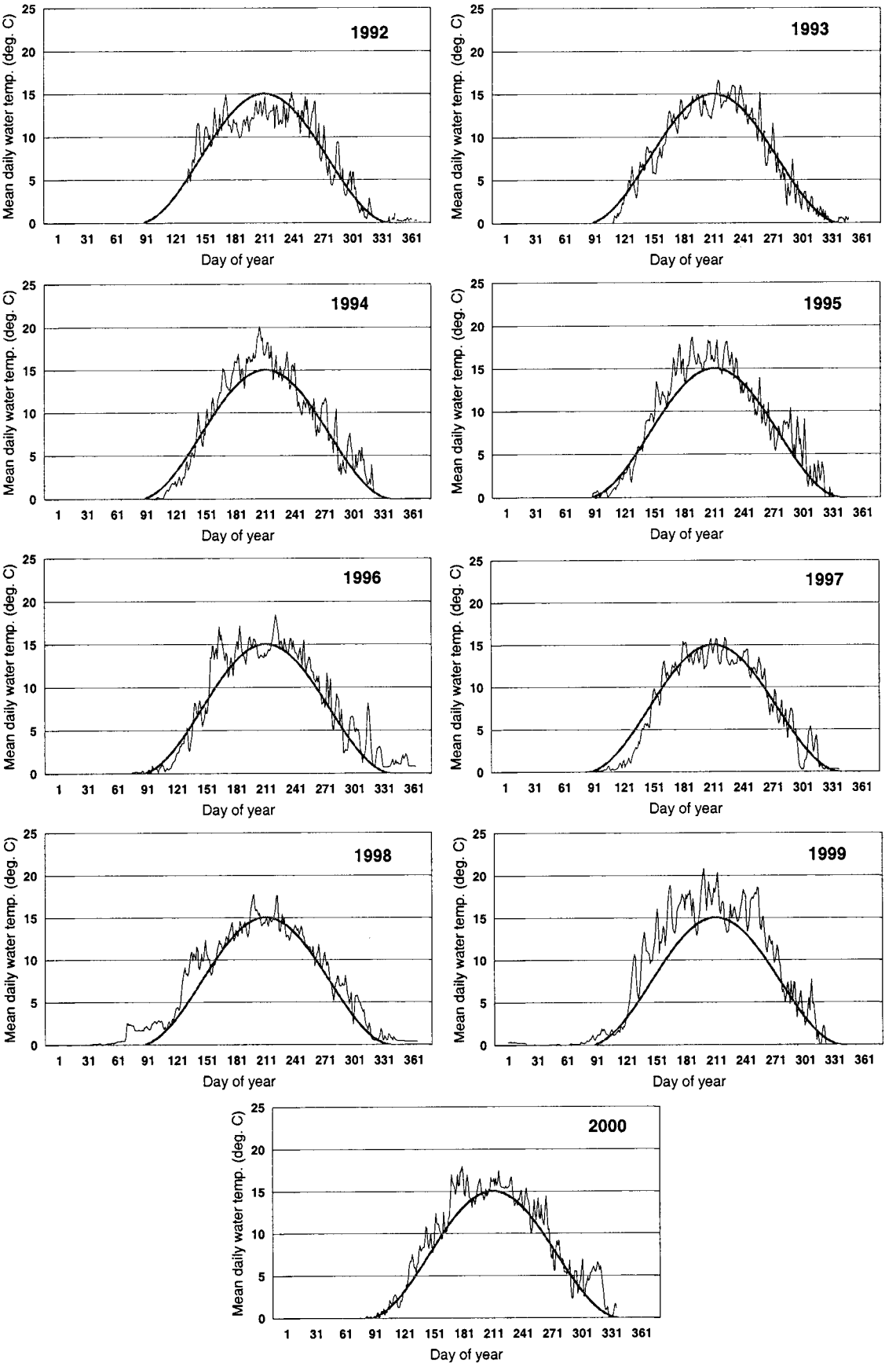

Figure 6. Stream water temperature at Catamaran Brook (Middle Reach) from 1992 to 2000; Fourier series represents long-term temperatures.