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Hydrological conditions for Atlantic salmon rivers in 2011

Conditions hydrologiques pour des rivières à saumon atlantique en 2011

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ABSTRACT

This paper provides 2011 and historical information on hydrological conditions for 4 selected Atlantic salmon (*Salmo salar*) rivers within the Maritime Provinces. Long-term mean as well as high and low flows for each river were presented. Air temperature and precipitation data were presented for 4 stations in close proximity to Atlantic salmon rivers within the Maritime Provinces. New Brunswick (NB) showed close to average precipitation in 2011, on an annual basis, although higher amounts were recorded in August. Summerside (Prince Edward Island, PEI) showed slightly lower annual precipitation in 2011. Sydney (Nova Scotia, NS) showed high precipitation in October (298 mm). All sites showed slightly higher air temperature in 2011 on an annual basis (between 0.6-1.0°C). Higher air temperatures were recorded in January and from September to December. Streamflow in 2011 was characterized by higher than normal summer flows, particularly in NB and higher than normal autumn flows in PEI. On a daily basis, spring flood was generally close to or higher than the 2-year flood for all rivers, with the exception of the Upsalquitch River (close to a 10-year flood). Daily low flows were mostly experienced in winter as summer flows were high and low flows were not severe (most minimum discharge were higher than the 2-year low flow). Long-term trends in streamflow showed few significant trends. No trends were detected in annual discharge at all sites. No trends were detected in the annual maximum discharge; however, when looking at daily peak vs. instantaneous discharge, the flood of 2010 (Northeast Margaree River) was most likely exceptional at 875 m^3/s. On a seasonal basis, no trends were detected in the magnitude and timing of spring floods and low flows in the Upsalquitch River. However some trends were observed in Southwest Miramichi River, particularly in the timing of spring floods (occurring earlier) and also in the magnitude of summer low flows (decreasing discharge). In the Northeast Margaree River a significant trend was observed in the timing of spring floods; however, the timing was also highly variable. No significant trends were detected in the Wilmot River.

RÉSUMÉ

Ce document fournit des informations historiques et pour l'année 2011 sur les conditions hydrologiques de quatre rivières à saumon (saumon atlantique; *Salmo salar*) des provinces Maritimes. Le débit moyen à long terme ainsi que les débits de crues et d'étiage ont été présentés pour chaque rivière. Des données sur la température de l'air et les précipitations ont été présentées pour 4 stations à proximité de rivières à saumon des provinces Maritimes. Le Nouveau-Brunswick (NB) montre une précipitation annuelle près de la moyenne en 2011, bien que des précipitations plus élevées aient été enregistrées en Août. Summerside (Île-du-Prince-Édouard, IPE) a montré une plus faible précipitation annuelle en 2011. Sydney (Nouvelle-Écosse, NE) a montré de fortes précipitations en Octobre (298 mm). Tous les sites ont montré une température de l'air légèrement plus élevée en 2011 sur une base annuelle (de 0.6 à 1.0 °C). Des températures de l'air supérieures ont été enregistrées en janvier et pour la période de septembre à décembre 2011. Le débit des rivières en 2011 a été caractérisé par des débits estivaux supérieurs à la normale, surtout au Nouveau-Brunswick et supérieurs à la normale en automne à l'IPE. Sur une base journalière, la crue printanière a été généralement près ou supérieure à la crue de 2 ans pour toutes les rivières, à l'exception de la rivière Upsalquitch (une crue près de 10 ans). Les faibles débits sur une base journalière ont été observés en hiver comme les débits estivaux étaient élevés et les faibles débits n'étaient pas sévères (débits faibles étaient plus élevés que le débit faible d'une récurrence de 2 ans). Les débits à long terme montrent quelques tendances significatives. Aucune tendance n'a été détectée au niveau du débit annuel sur tous les sites. Aucune tendance n'a été détectée aussi au niveau du débit maximum annuel, mais, quand on regarde à la crue journalière vs le débit instantané, la crue de 2010 (de la rivière Northeast Margaree) a été considérée comme étant exceptionnelle à 875 m^3/s. Sur une base saisonnière, aucune tendance n'a été détectée dans l'ampleur et la date du calendrier des crues printanières et des faibles débits dans la rivière Upsalquitch. Cependant, certaines tendances ont été observées dans la rivière Southwest Miramichi, en particulier dans la date des crues printanières (survenant plus tôt) et aussi dans l'ampleur de l'étiage (diminution du débit). Dans la rivière Northeast Margaree une tendance significative a été notée dans la date des crues printanières, mais la date d'apparition était aussi très variable. Aucune tendance significative n'a été détectée au niveau de la rivière Wilmot.

INTRODUCTION

An understanding of hydrological conditions is important in the management of fisheries and aquatic resources. Some events such as streamflow availability and variability can affect stream biota at different life stages as well as during different seasons of the year. For example, salmonids can be affected by extreme events such as high flow events (Elwood and Waters 1969; Erman *et al.* 1988) or during low flow conditions; the latter is often associated with high river water temperatures (Lund *et al.* 2002; Edwards *et al.* 1979). In order to increase our knowledge of environmental conditions of Atlantic salmon rivers for the purpose of assessing Atlantic salmon stocks, we need to study the stream hydrology for these rivers and associated extreme events (high and low flows).

The objective of the present study is to analyze hydrometeorological data for important Atlantic salmon rivers within the Gulf Region for use in aquatic resource management. The specific objectives are: a) to provide an overview of the monthly precipitation and air temperatures at 4 meteorological stations and flow conditions for 4 rivers, b) to analyze high and low flow conditions in 2011 (on a daily basis), c) to determine the frequency of these high and low flow events, and d) to identify abnormal streamflow events and long-term trends at these sites.

METHODS

Historical and 2011 data on precipitation and air temperatures were obtained from Environment Canada for 4 sites in the Gulf Region close to index Atlantic salmon rivers. A hydrological analysis was carried out using historical hydrometric data from gauged streams and rivers in the study region. The 2011 hydrometric data were obtained from Environment Canada index sites, while historical data were obtained from the online HYDATA database. Monthly flow characteristics for 2011 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 (E) monthly flow condition while a flow below the 25% percentile denotes a deficient (D) flow.

Daily data were used to calculate high and low flow characteristics for different recurrence intervals (T-year events). Annual high and low flows were fitted to a statistical distribution function (Kite 1978) and a frequency analysis was carried out to estimate the T-year events for each river. For instance, the 25-year low flow (T = 25 years) is a low flow which occurs on the average every 25 years such that 4 such low flow events would occur in 100 years on average. The high flow frequency analysis was based on a three-parameter lognormal distribution function and on historical annual flood observations (Kite 1978). In contrast, the 3 parameter Weibull (or type III extremal) distribution was used to estimate the low flow frequency events using daily minimum discharge on an annual basis (Kite 1978).

Following the frequency analysis, long-term trends were investigated for each river using the mean annual flow, peak discharge (daily and instantaneous flows) and low flows. Peak flows and low flows were also investigated both in their occurrence (day of year) and magnitude (discharge, m^3/s). This analysis consisted of calculating a 30-day running mean where spring peak flow was identified as well as summer and winter low flows. The spring peak flow analysis included the period between January 1 (day 1) and June 29 (day 180). For the winter low flow period, the analysis was carried out between January 1 (day 1) and May 1(day 121) where the summer low flow included the period from May 1 (day 121) to October 27 (day 300).

STUDY AREA

The study region comprises 4 Atlantic salmon rivers within the Gulf Region (Fig. 1). These rivers are: Upsalquitch River (01BE007, NB), Southwest Miramichi River (01BO001, NB), Wilmot River (01CB004, PEI) and the Northeast Margaree River (01FB001, NS). The meteorological stations which are in close proximity to these rivers were: Charlo A (NB) (A = Airport station), Miramichi A (NB), Summerside A (PEI) and Sydney (NS) (Fig. 1).

The drainage basin of the studied rivers ranged from 45.4 km^2 (Wilmot River, PEI) to 5050 km^2 (Southwest Miramichi River, NB; Table 1). The number of years of records was between 39 (Wilmot River) and 91 years (Northeast Margaree). The mean annual flow (MAF), which is a function of drainage area, varies between 0.93 m^3/s for Wilmot River to 118 m^3/s for the Southwest Miramichi River. To compare discharge between basins of different sizes, the mean annual runoff was calculated. This flow represents the mean annual flow (MAF) expressed in unit discharge (mm; i.e. discharge per drainage area). Gulf Region rivers can have a wide range of runoff characteristics depending on parameters such as the amount of rainfall, soil type, topography, etc. The river with the lowest runoff was Upsalquitch River (571 mm), followed by Wilmot (646 mm) and Southwest Miramichi rivers (737 mm). The Northeast Margaree River showed the highest runoff at 1466 mm. Precipitation varied from 1050 mm in Northern New Brunswick to 1500 mm in Cape Breton (NS) (Table 1).

RESULTS

PRECIPITATION AND AIR TEMPERATURE IN 2011

Long-term (1971-2000) air temperature and precipitation as well as data for 2011 are presented in Table 2. In New Brunswick, close to average precipitation was recorded in 2011 on an annual basis, although higher amounts were recorded in summer, particularly in August. At Summerside the precipitation in 2011 was slightly lower than average (871 mm vs. 1098 mm). The highest monthly precipitation in 2011 was recorded in Sydney in October with a total precipitation of 298 mm. This area showed slightly higher than normal annual precipitation with a value of 1728 mm (compare to a long-term mean value of 1505 mm). In contrast, the lowest precipitation in 2011 was recorded in Summerside with a value of 9 mm (September). In 2011, all site showed slightly higher than average air temperature (+0.7°C at Charlo; +0.9°C at Miramichi, +0.6°C Summerside and +1.0°C in Sydney). Higher than normal air temperatures were observed in January as well as for the period of September to December. These months were on average 2 to 2.5°C higher than normal. June was the only month which showed below normal air temperatures (-1.6°C, on average). Other months showed close to average conditions.

HYDROLOGICAL CONDITIONS IN 2011

In general, winter monthly flow conditions (January to March, 2011) were normal (Table 3); however, the Upsalquitch River showed an excessive flow in February (13.0 m^3/s compared to the long-term mean of 11.1 m^3/s). The Wilmot River showed an excessive flow in March (2.43 m^3/s vs. 1.63 m^3/s). The spring high flow period was normal in 2011 for all rivers, although the spring high flow period was somewhat early in Northeast Margaree. In fact, the high flow period was in April in 2011 rather than May (the normal high flow period). Summer monthly flow conditions showed higher than normal flows, particularly in New Brunswick. Excessive flows were observed in Upsalqutich River from July to September and flows were over twice the average. Similar conditions were observed for the Southwest Miramichi River. The Wilmot and Northeast Margaree rivers showed normal summer flow conditions. High monthly flows were recorded in September in New Brunswick rivers; however, for that same month, deficient flows were recorded in Northeast Margaree River. From October to December, flows were generally normal with the exception of the Wilmot River which showed excessive flows.

On a daily basis, peak flows in selected rivers occurred in May (Upsalquitch R. and Southwest Miramichi R.) whereas the Wilmot and Northeast Margaree rivers showed spring floods in April (Table 3). The Northeast Margaree River experienced its peak flow earlier than normal (in April) and the discharge was 170 m^3/s. Floods and low flow characteristics of analyzed rivers are presented in Table 4 for different recurrence intervals (T = 2-year to a 100-year event). The spring high flow at the Northeast Margaree River (170 m^3/s) was just above the 2-year flood. The Wilmot River showed a discharge of 7.88 m^3/s (lower than the 2-year flood); therefore, the least impacted by high flow this year. In the case of the Southwest Miramichi River, the spring flood was at 1250 m^3/s (Table 3) and this flow was above the 5-year flood (Table 4a). For the Upsalquitch River, the peak flow was at 546 m^3/s and this flow represents close to a 10-year flood.

On a daily basis, low flows were mostly experienced in winter of 2011, particularly in New Brunswick, as summer low flows were much higher than normal (Table 3). This was not the case for the Wilmot River, which experienced its low flow in September (0.416 m^3/s). The low flow for the Upsalquitch River was observed in March with a discharge of 7.5 m^3/s (Table 3). This flow represents a discharge that is higher than the 2-year low flow (5.5 m^3/s; Table 4b). In the Southwest Miramichi River, the low flow period was also observed in winter (March) and a low flow of 22.4 m^3/s was recorded. Similar to the Upsalquitch River, this discharge is higher than the 2-year low flow (2-year low flow = 19.8 m^3/s; Table 4b). In the Northeast Margaree River, low flows were observed in both winter (February; 3.5 m^3/s) and autumn (September; 3.6 m^3/s; Table 3) and both low flows were higher than the 2-year low flow (2-year low flow = 3.0 m^3/s; Table 4b).

To further characterize the flow regime, daily runoff (mm) was calculated for each river. This analysis consisted of calculating the mean daily discharge per unit area (expressed in mm) for each day of the year (Fig. 2). Daily runoff can then be used to compare flow characteristics among rivers. This shows the high and low flow periods as well as their relative timing for each river. For instance, the Northeast Margaree River has a higher runoff (discharge per unit area) than the other rivers (a total runoff of 1460 mm annually compared to 737 mm for the Southwest Miramichi R., 571 mm for the Upsalquitch R. and 646 mm for the Wilmot River; Table 1). For the Northeast Margaree, daily runoff was higher than the other rivers throughout the year. Peak flows in Southwest Miramichi River occurred on day 120 (April 30), i.e., 6 days earlier than the Upsalquitch River (day 126; May 6). The Wilmot River peak flows occurred the earliest (day 95; April 5) whereas the peak flows for the Northeast Margaree River occurred the latest (day 129; May 9). The low flow period generally extended between July 1 (day 182) and August 8 (day 220) for all rivers. Both the Southwest Miramichi and Upsalquitch rivers showed a similar pattern; however, the Upsalquitch River showed lower low flows in winter.

LONG-TERM STREAMFLOW CHARACTERISTICS AND TRENDS

Streamflow characteristics and long-term trends were also studied for selected rivers. Figure 3 shows the mean annual flow times series of all rivers. This figure also shows a trend line for all data (i.e., period of record) as well as the trend for the last 30 years (i.e., from 1981 to 2010). In the case of the Upsalquitch River, no significant trends were detected (all data and last 30 years). Moreover, the 30-year running mean showed a very stable flow regime over the entire period. In the case of the Southwest Miramichi River, the time series was somewhat shorter and no significant trends were detected. The Northeast Margaree River had the longest time series (1929-2010) of annual flows and although the 30-year running mean showed a high flow period towards the end of 1960s and early 1970s, no significant trends were detected. The Wilmot River annual flows were also very stable throughout the years. The coefficient of variation of mean annual flow showed more variability for the Southwest Miramichi River (Cv = 23%), Upsalquitch River (Cv = 20%) and Wilmot River (Cv = 19%) than the Northeast Margaree River (Cv = 15%) although runoff was more variable within the year for the Northeast Margaree and Wilmot rivers (Fig. 2).

Figure 4 shows peak flows (daily and instantaneous) over the period of records. No trends were detected in these time series, with the exception of the Northeast Margaree River for instantaneous flow ($p < 0.02$). Moreover, this trend was driven by the flood of 2010, recorded at 875 m^3/s. Without, this flood the trend is not significant. It is worth nothing that the flood of 2010 (on a daily basis) in the Northeast Margaree River was 389 m^3/s which was close to a 100-year flood; however, the instantaneous flow at 875 m^3/s (factor of 2.25 of the daily flood) was likely an exceptional flood (Aucoin *et al.* 2011).

Figure 5 presents the long-term trends of low flow for the studied rivers. No trends were observed in Upsalquitch, Wilmot and Northeast Margaree rivers; however, a significant decreasing trend was observed for low flows in the Southwest Miramichi River ($p < 0.02$). This decreasing trend in the Southwest Miramichi River is present event if the high value of 1970 (37.9 m^3/s) is removed from the data.

Figures 6, 7, 8 and 9 show a trend analysis of high and low flows, both for timing (day of year) and magnitude (discharge, m^3/s). For this analysis, a 30-day running mean was calculated for discharge, so that the high and low flows are better defined on a monthly time scale and not dependant on short duration events. This permits a better diagnostic of change in high and low flows. Figure 6 shows no significant trends in the timing and magnitude of high and low flows in the Upsalquitch River. For the Southwest Miramichi River no significant trends were observed in the magnitude of floods (Fig. 7b); however, the timing of floods shows a decreasing trend, i.e., floods are occurring earlier in the year. As such, over the past 30 years, the floods have occurred earlier by 6 days (Fig. 7a). A significant trend was also detected in the summer low flow magnitude where low flows would have decrease significantly over the years (by approximately 6.6 m^3/s over the past 30 years; Fig. 7d). However, the timing of summer low flows did not show any trend (Fig. 7c), nor did the winter low flows (Fig. 7e and 7f). For the Northeast Margaree River, the timing of high flows showed a significant decreasing trend ($p < 0.04$); however, it was noted that the peak flows showed a high variability (Fig. 8a). In fact, peak flows can occur from early January to June. Summer and winter low flows did not show any significant trends in timing and magnitude. In the case of the Wilmot River, no significant trends were observed in either high or low flows (Fig. 9).

SUMMARY

In summary, New Brunswick showed close to average precipitation in 2011, on an annual basis, although higher amounts were recorded in August. Summerside showed slightly lower annual precipitation this year and Sydney showed high precipitation in October (298 mm). All sites showed slightly higher air temperature in 2011 on an annual basis (between 0.6-1.0°C). Higher monthly air temperatures were recorded in January and from September to December.

Streamflow in 2011 was characterized by higher than normal summer flows, particularly in New Brunswick. In Prince Edward Island, higher than normal flows were observed in autumn for the period of October to December. The only deficient monthly flow observed in 2011 was in Northeast Margaree (Sept). On a daily basis, spring flood was generally close to or higher than the 2-year flood for all rivers. The Upsalquitch River experienced the highest floods at close to a 10-year flood. Daily low flows were mostly experienced in winter as summer flows were high and low flows were not severe in 2011 (most minimum discharge were higher than the 2-year low flow).

Long-term trends in streamflow showed few significant trends. No trends were detected in annual discharge at all sites. No trends were also detected in annual floods; however, when looking at daily peak vs. instantaneous discharge, the flood of 2010 (Northeast Margaree) was most likely exceptional at 875 m^3/s. A significant trend was observed in Southwest Miramichi annual low flows (decreasing low flows over time). On a seasonal basis, no trends were detected in the magnitude and timing of spring floods and low flows in the Upsalquitch River. However some trends were observed in Southwest Miramichi River, particularly in the timing of spring floods (occurring earlier) and also in the magnitude of summer low flows (decreasing discharge). In the Northeast Margaree River a significant trend was observed in the timing of spring floods; however, the timing was also observed to be high variable. No significant trends were detected in the Wilmot River.

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

River	Area[1] (km^2)	N[1] (years)	MAF[1] (m^3/s)	Runoff[1] (mm)	Prec.[1] (mm)
Upsalquitch River (NB)	2270	81	41.1	571	1050
Southwest Miramichi R. (NB)	5050	63	118	737	1120
Wilmot River (PEI)	45.4	39	0.93	646	1078
Northeast Margaree R. (NS)	368	91	17.1	1466	1500

[1]Area = Drainage area (km^2); N = Number of years of record; MAF = Mean Annual Flow (m^3/s), Runoff = Discharge per unit of area (mm); Prec. = precipitation (mm)

Table 2. Long-term monthly precipitation and air temperatures as well as conditions in 2011 for selected sites in the Maritime Provinces (LT = long-term; 1971-2000).

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
							Precipitation (mm)							
Charlo A (NB)	*LT*	91.9	65.2	87.3	82.0	86.4	85.6	102.3	94.9	84.6	88.9	90.0	95.0	1054
	2011	45.4	37.7	98.0	74.4	147.9	93.9	119.8	150.6	123.2	23.1	51.4	74.8	1040
Miramichi A (NB)	*LT*	95.5	72.1	94.3	89.2	97.7	89.3	106.1	89.2	85.5	97.4	99.4	99.4	1115
	2011	54.9	76.4	59.9	64.7	128.0	107.0	102.2	140.3	53.4	125.1	54.0	79.6	1046
Summerside A (PEI)	*LT*	100.1	75.1	83.8	79.7	94.0	84.4	84.8	88.3	91.7	94.5	96.7	105.0	1078
	2011	47.4	74.1	32.5	56.8	83.3	66.3	86.3	86.3	9.0	159.2	85.2	104.1	891
Sydney (NS)	*LT*	151.5	132.1	138.9	130.4	102.9	92.6	86.8	93.1	113.4	146.0	149.7	167.5	1505
	2011	183.2	188.8	41.6	109.9	119.6	191.2	130.4	90.6	67.8	297.8	155.8	151.6	1728
							Air temperature (°C)							
Charlo A (NB)	*LT*	-12.8	-11.1	-5.1	1.6	8.6	14.7	17.9	16.8	11.6	5.5	-0.9	-8.6	3.2
	2011	-9.4	-10.5	-5.3	1.1	8.1	13.6	18.1	16.9	13.4	8.1	2.0	-6.7	4.1
Miramichi A (NB)	*LT*	-10.7	-9.1	-3.3	3.1	10	15.9	19.2	18.3	13	6.6	0.5	-6.9	4.7
	2011	-9.6	-10.0	-3.7	3.0	8.7	14.5	19.2	18.9	15.1	9.1	3.8	-3.9	5.4
Summerside A (PEI)	*LT*	-7.9	-7.3	-2.8	2.8	9.4	15.0	19.1	18.6	13.9	8.1	2.4	-4.2	5.6
	2011	-6.8	-8.4	-2.8	3.7	9.6	13.2	18.7	18.8	15.5	9.9	4.3	-0.9	6.2
Sydney (NS)	*LT*	-5.7	-6.5	-2.7	2.1	7.8	13.3	17.7	17.7	13.4	8	3.3	-2.1	5.5
	2011	-3.3	-5.4	-1.7	3.5	8.6	11.1	17.0	17.5	15.3	10.0	4.6	0.2	6.5

Table 3. Monthly minimum, maximum and mean discharge in 2011 as well as long-term (LT) mean monthly discharge at selected rivers in the Maritime Provinces (m^3/s).

River		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Upsalquitch River (NB)	Min	9.63	9.2	7.5	14	50.6	34.2	24.5	25.4	26.8	13.3	11.3	12.0
	Max	35.7	18.8	25.8	381	546	82.5	81.8	67	171	26.9	24.2	27.4
	Mean	16.9	13.0E	15.4	107	191	53.3	45.6E	49E	61.5E	18.4	15.3	18.1
	LT (Mean)	14.7	11.1	13.1	93.7	155.3	51.4	26.4	18.9	17.7	26.7	36.8	26.7
SW Miramichi R. (NB)	Min	37.8	24.5	22.4	74.5	140	80.3	44.5	47.2	51	43.2	49.9	66.2
	Max	111	41.2	188	715	1250	378	130	442	285	125	194	247
	Mean	60.7	32.6	93.8	361	364	158E	76.1	100E	114E	70.2	79.1	127
	LT (Mean)	60.7	49.3	72.9	329.4	302.3	106.4	62.6	54.0	51.8	89.9	125.1	108.6
Wilmot River (PEI)	Min	1.00	0.691	0.640	1.38	1.16	0.682	0.521	0.487	0.416	0.445	0.876	1.10
	Max	1.62	0.949	5.58	7.88	2.98	1.13	0.676	0.624	0.489	2.720	3.38	3.06
	Mean	1.25	0.823	2.43E	2.49	1.42	0.870	0.593	0.520	0.459	0.824 E	1.27E	1.44E
	LT (Mean)	1.07	0.971	1.63	1.90	1.15	0.731	0.557	0.480	0.459	0.566	0.734	0.918
NE Margaree River (NS)	Min	8.99	3.5	6.62	10	8.68	7.11	4.78	3.91	3.61	4.38	14.8	13.7
	Max	22	27	47.9	170	73.2	25	11.2	12.4	9.56	49.6	83.5	40.5
	Mean	14.6	8.83	14.4	39.2	29.7	11.9	6.65	5.51	5.15D	18.2	23.9	21.2
	LT (Mean)	15.1	10.9	12.6	28.1	41.7	14.8	6.7	7.5	9.7	16.1	22.6	19.5

D= Deficient flow and E = Excessive flow.

Table 4a. Flood frequency analysis (using a 3 parameter lognormal distribution) for different Atlantic salmon rivers. All flows are expressed in m^3/s.

River	Recurrence interval (T) in years					
	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
Wimot River (PEI)	11.6	15.3	17.4	19.2	21.2	22.6
Northeast Margaree R. (NS)	166	225	266	306	359	400

Table 4b. Low flow frequency analysis (using a 3 parameter Weibull distribution) for different Atlantic salmon rivers. All flows are expressed in m^3/s.

River	Recurrence interval (T) in years					
	2	5	10	20	50	100
Upsalquitch River (NB)	5.52	3.99	3.32	2.85	2.42	2.2
SW Miramichi R. (NB)	19.8	15.1	12.9	11.2	9.7	8.84
Wimot River (PEI)	0.295	0.223	0.189	0.164	0.139	0.125
Northeast Margaree R. (NS)	3.02	2.35	2.01	1.73	1.44	1.26

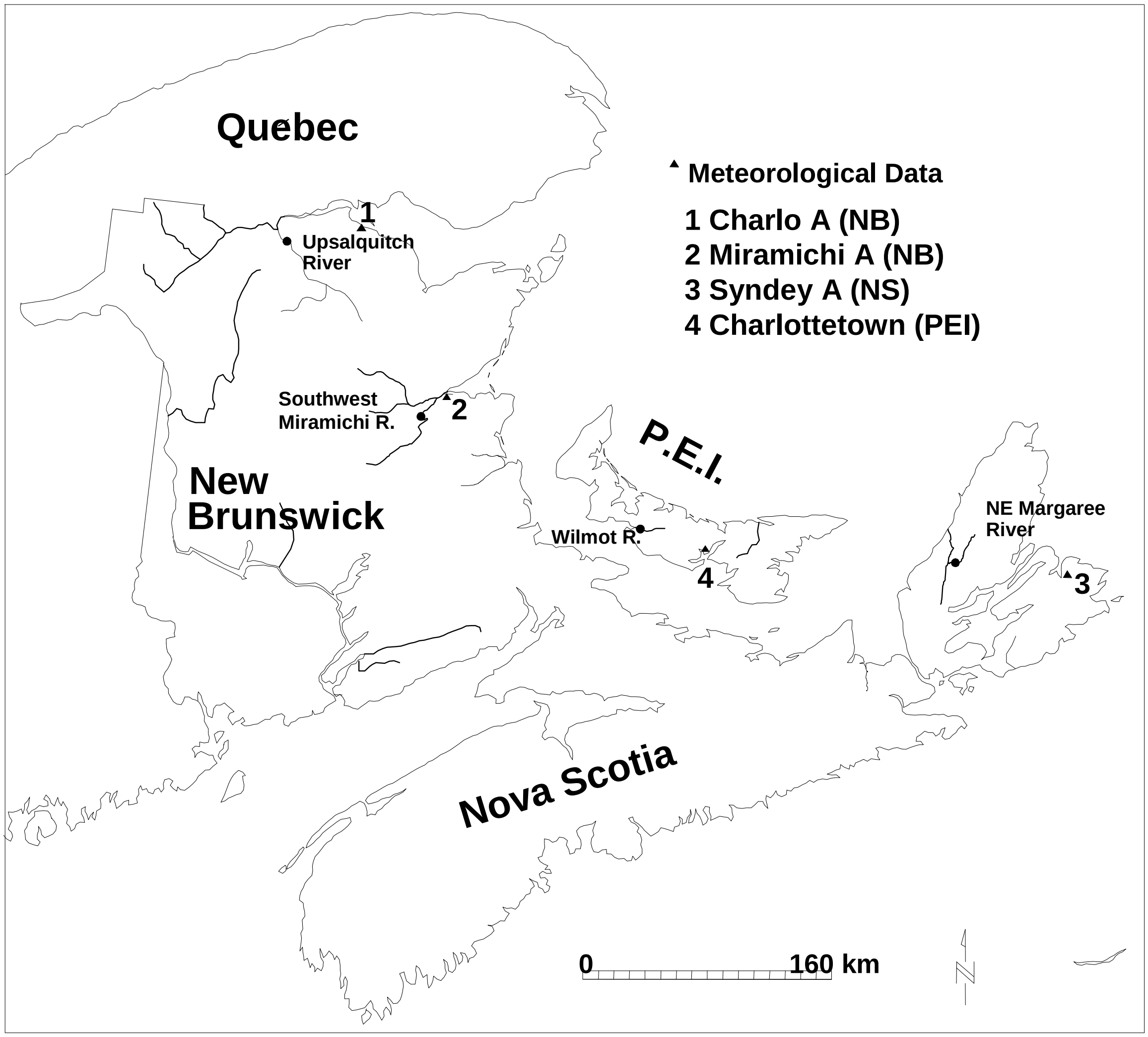

Figure 1. Location of meteorological and hydrometric stations of selected Atlantic salmon rivers within the DFO Gulf Region.

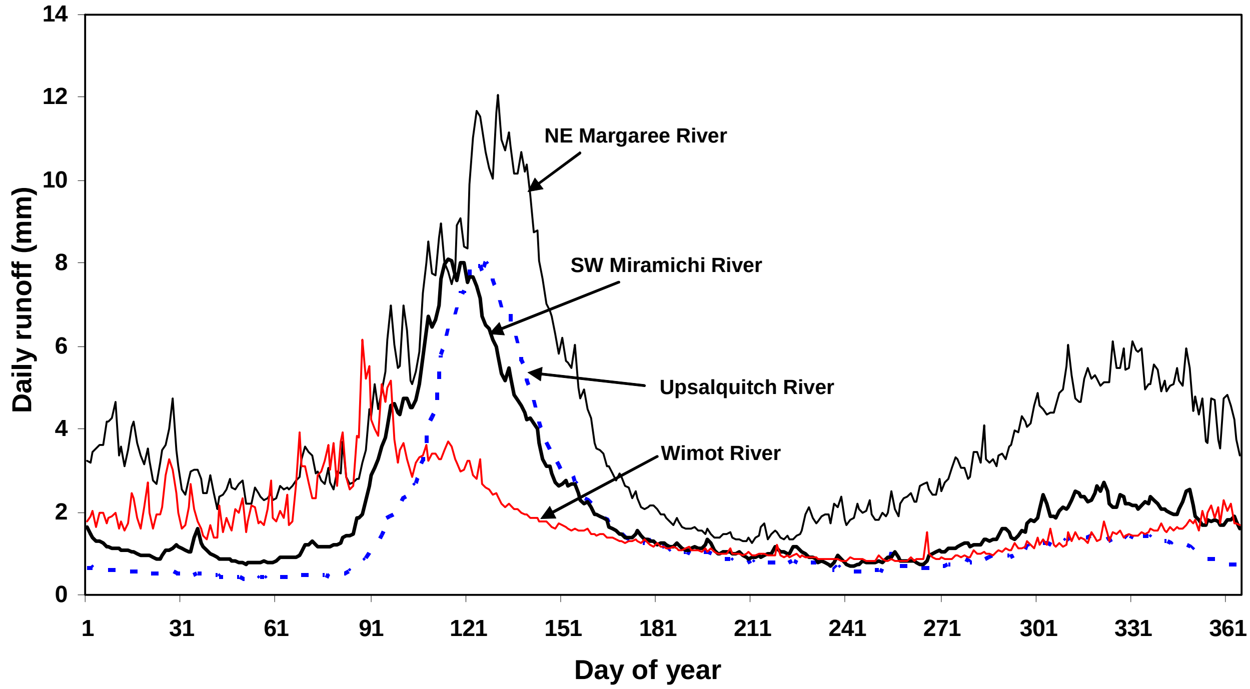

Figure 2. Daily runoff (mm) of selected Atlantic salmon rivers showing period of high and low flows.

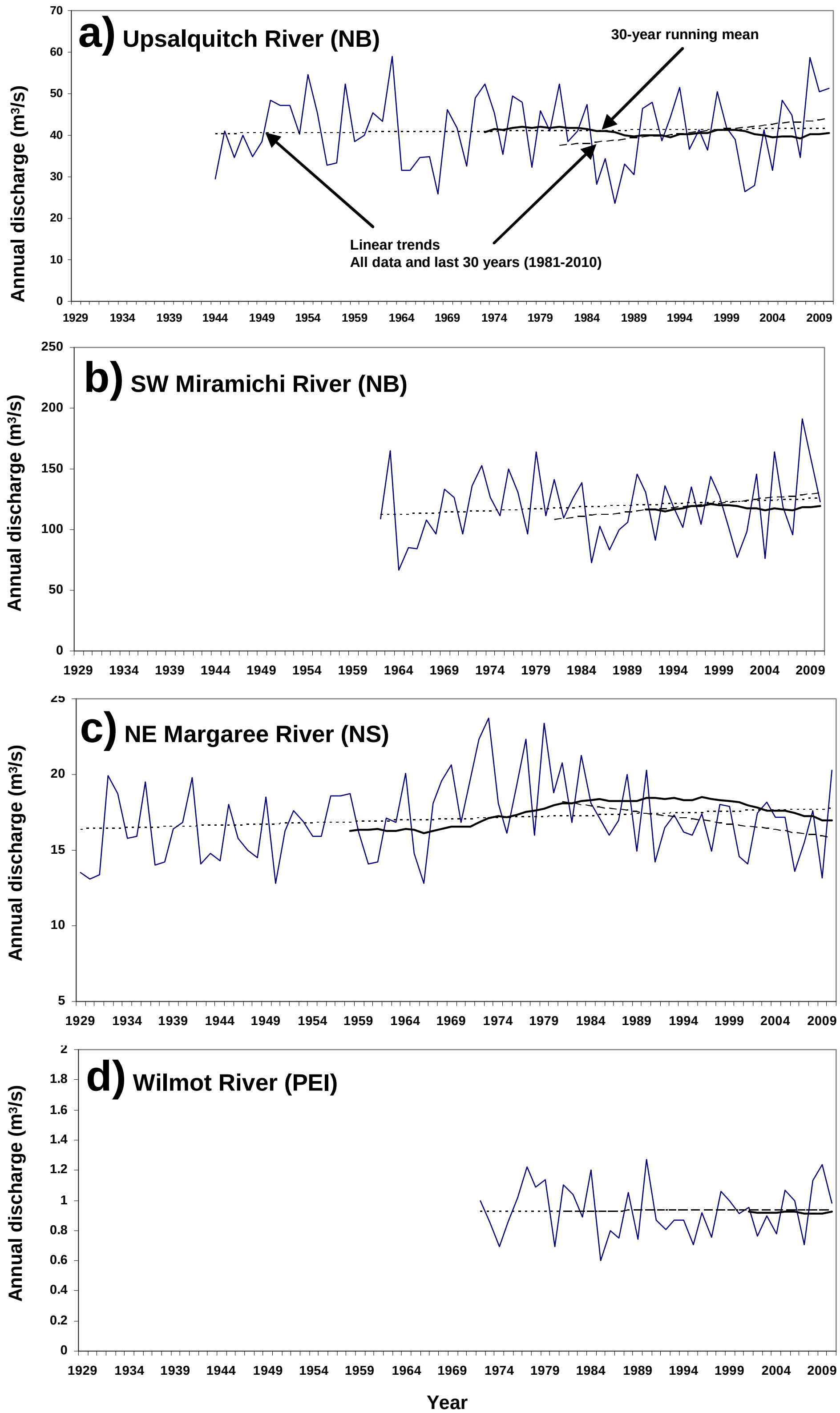

Figure 3. Mean annual flow for selected rivers and trends for different periods.

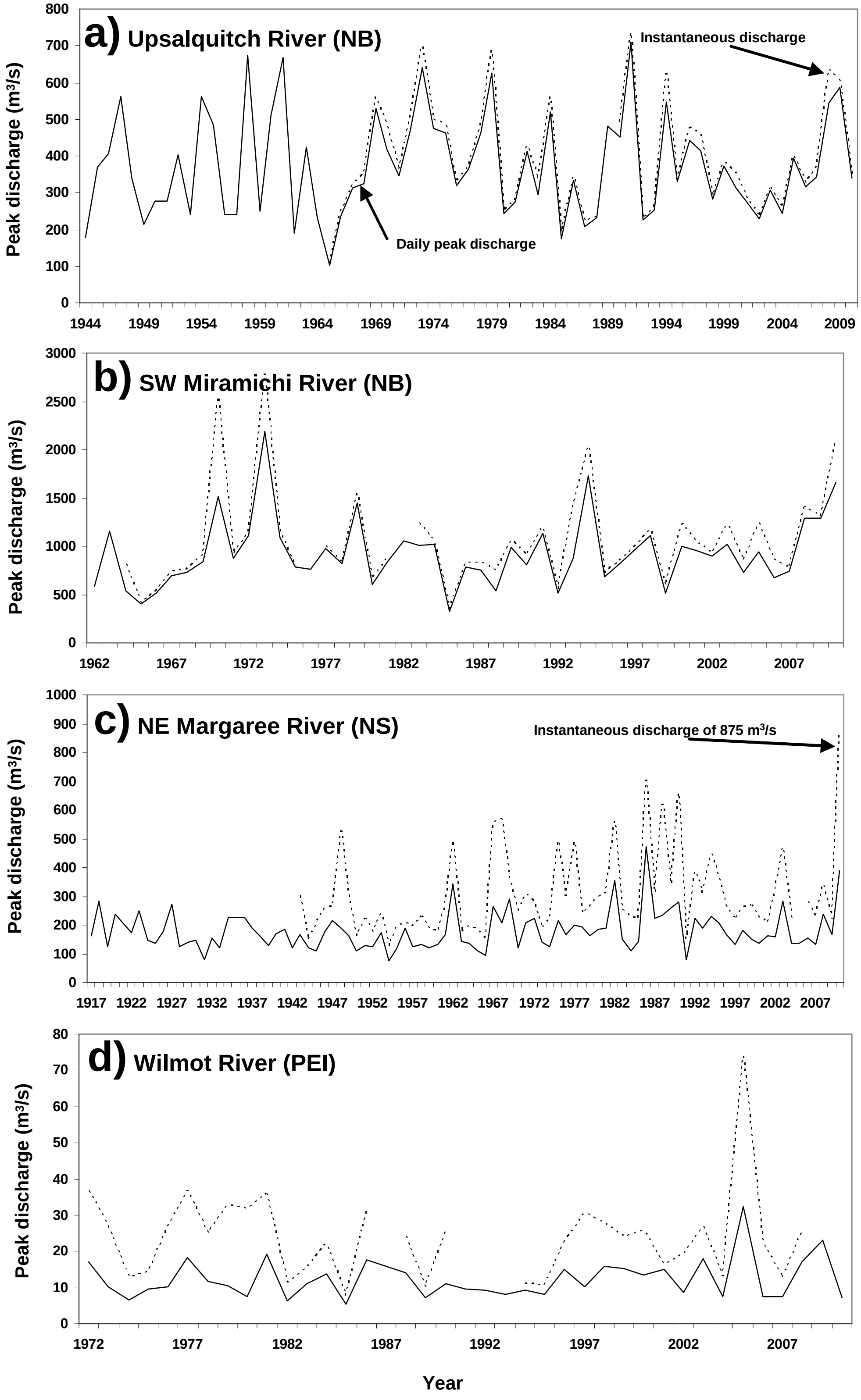

Figure 4. Peak daily and instantaneous discharge (m^3/s) for selected rivers in the DFO Gulf Region.

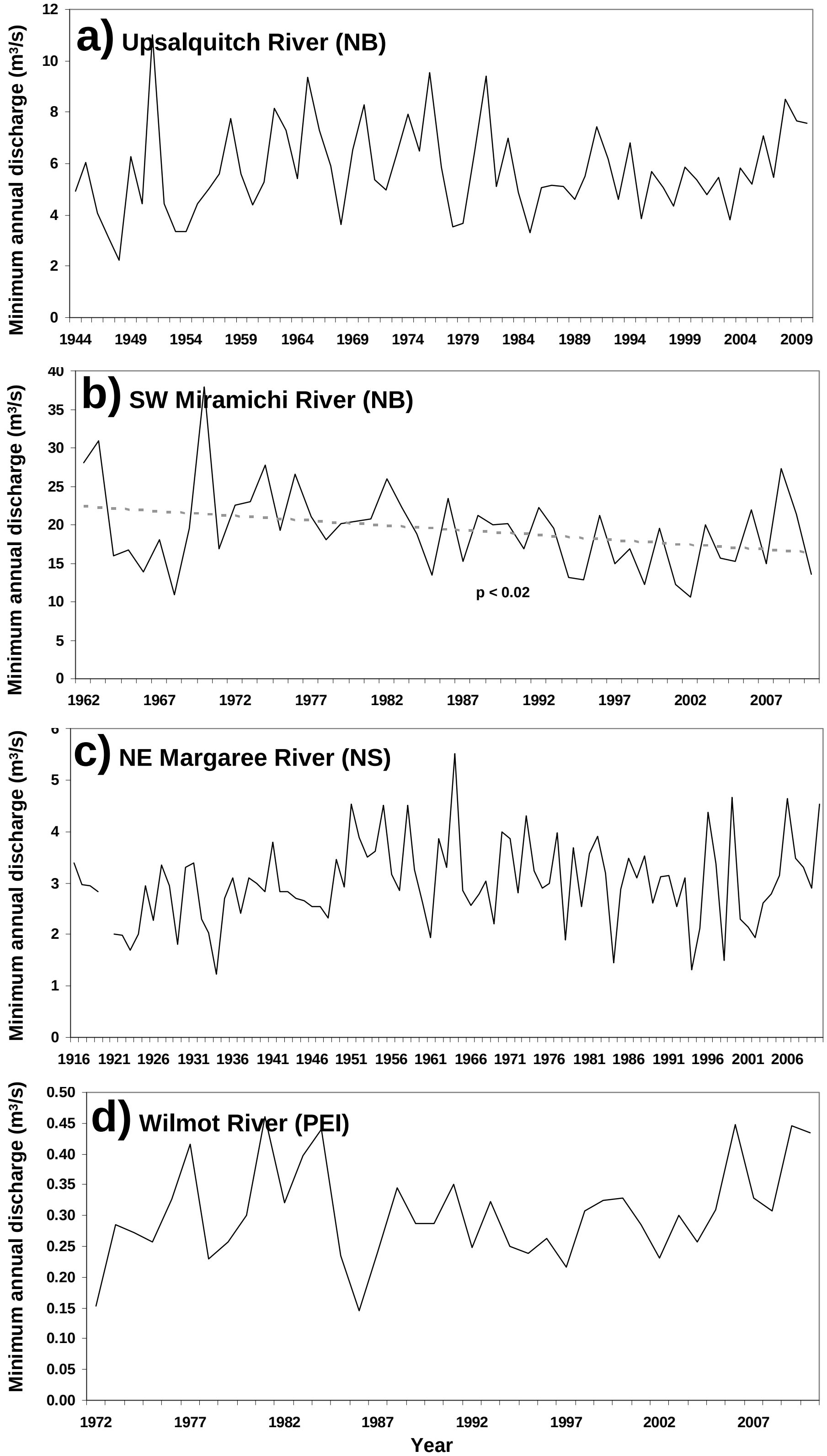

Figure 5. Minimum annual daily discharge (m^3/s) for selected rivers in the DFO Gulf Region.

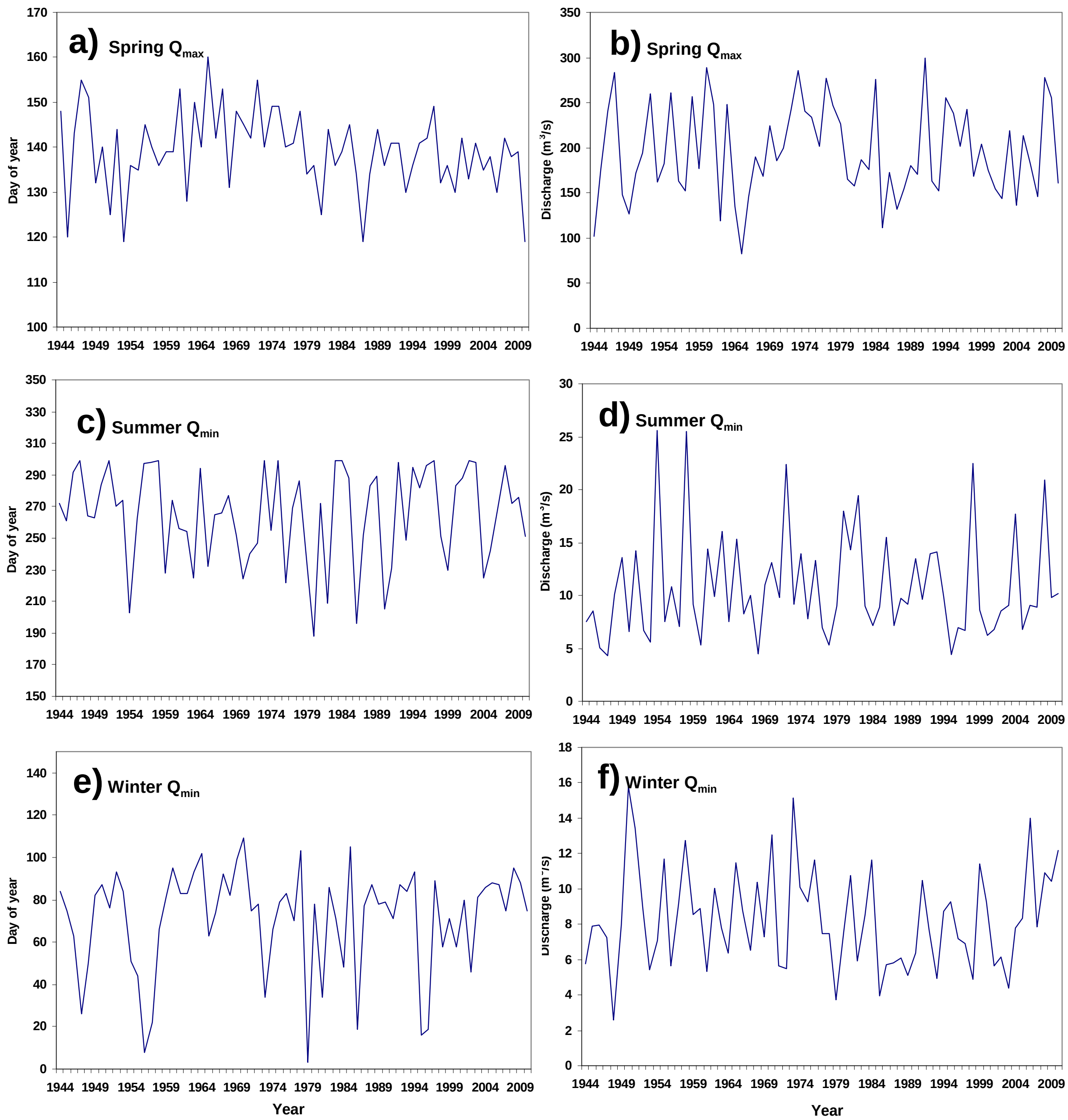

Figure 6. Streamflow timing and magnitude for the Upslaquitch River (NB).

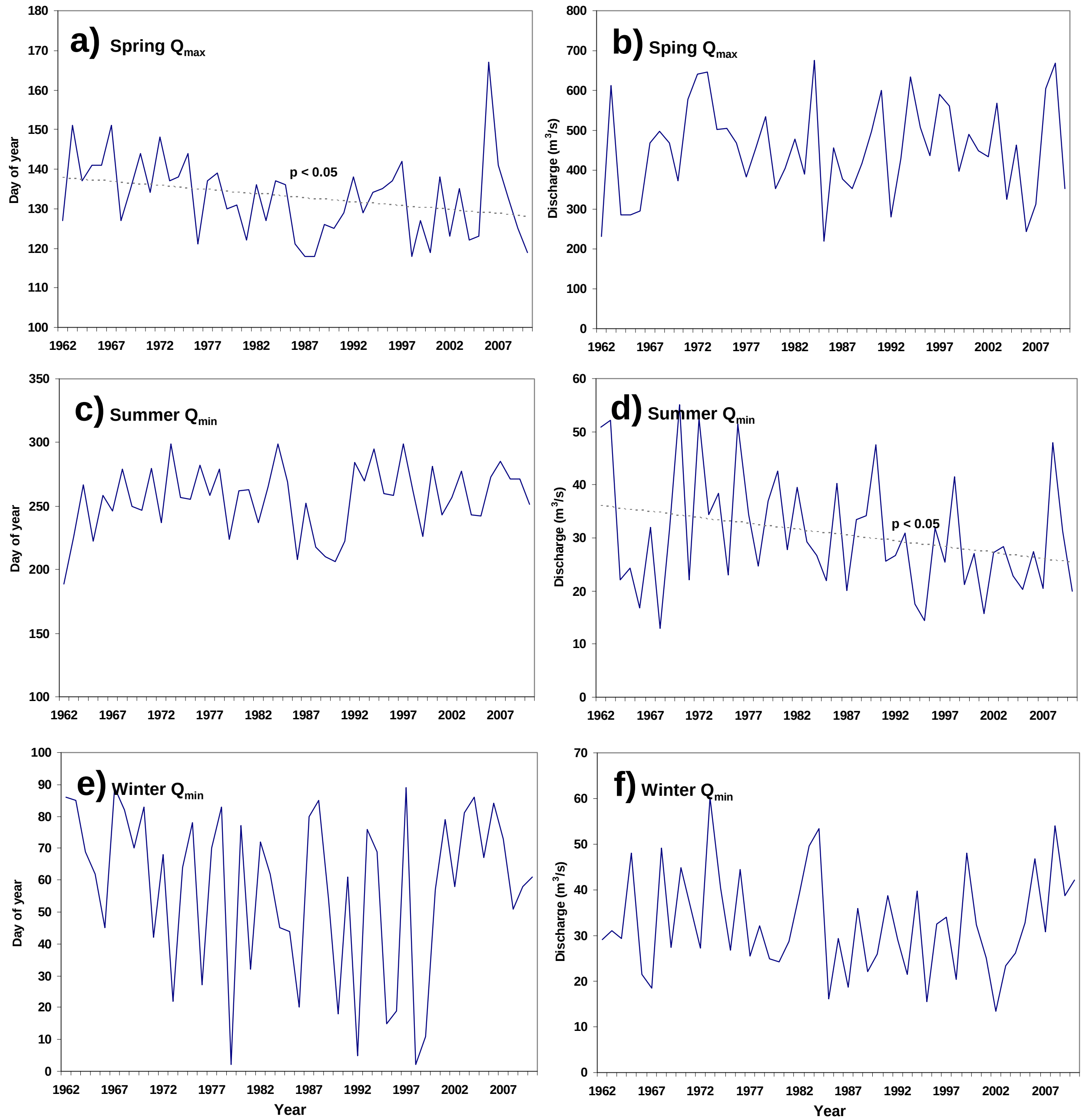

Figure 7. Streamflow timing and magnitude for the SW Miramichi River (NB).

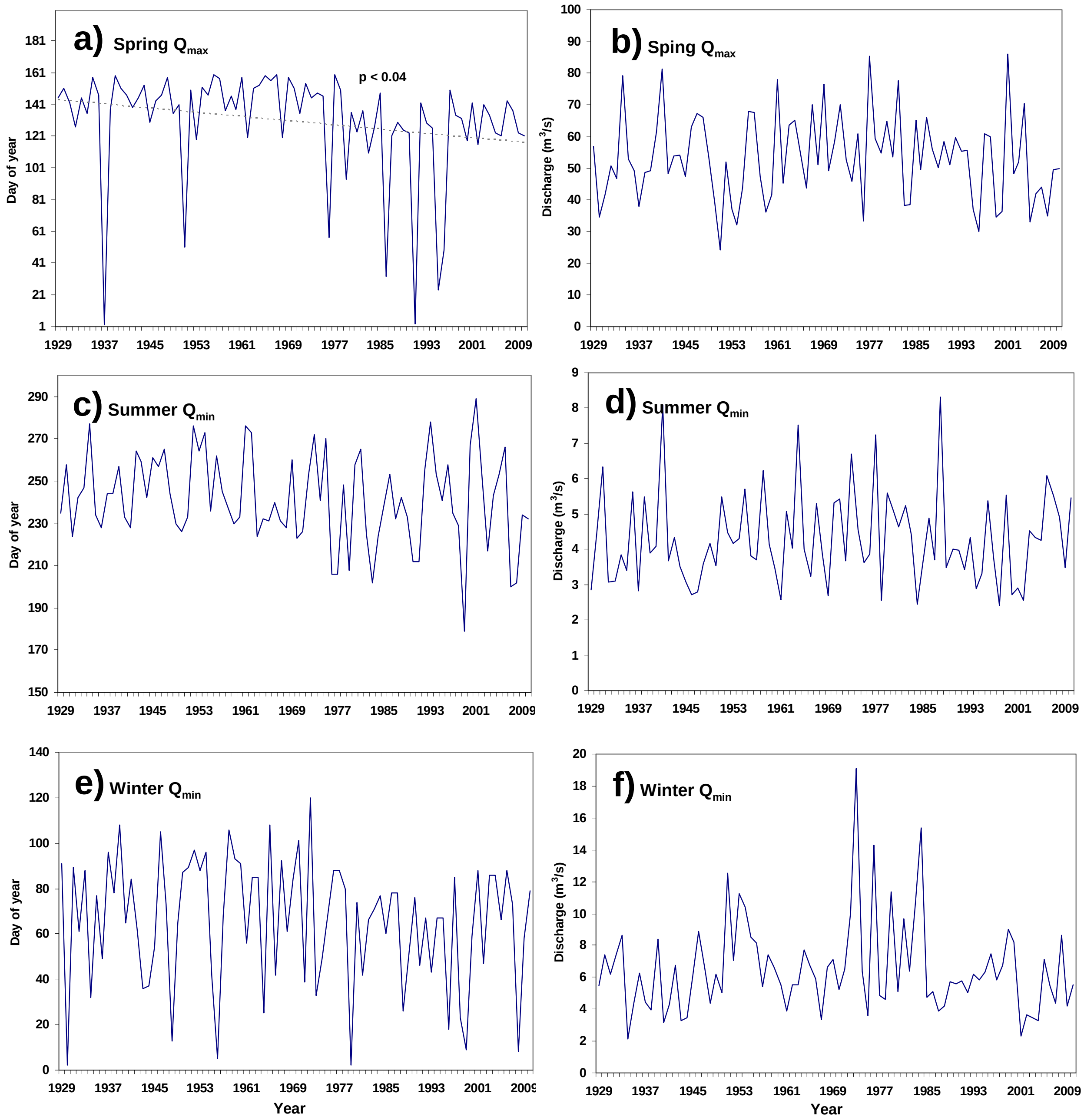

Figure 8. Streamflow timing and magnitude for the NE Margaree River (NS).

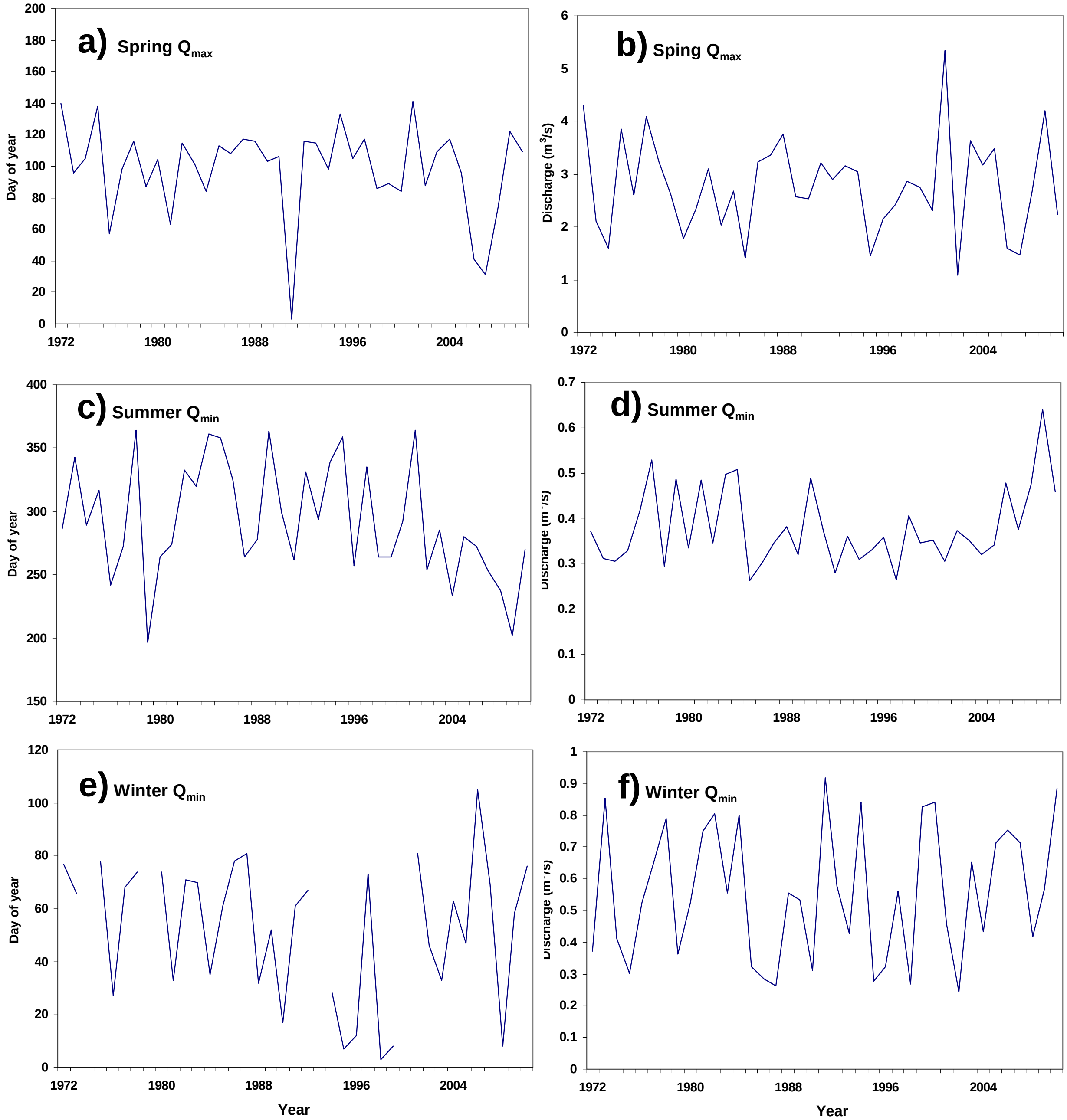

Figure 9. Streamflow timing and magnitude for the Wilmot River (PEI).