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THE EFFECT OF WATER TEMPERATURE ON ANGLING CATCH OF ATLANTIC SALMON IN THE UPSALQUITCH RIVER

by

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ABSTRACT

There is little doubt that mandatory catch and release has reduced angling mortality of multi-sea winter Atlantic salmon, but there continues to be concern that mortalities might result from angling or handling stress, especially in years of warm water temperatures. Closure of angling fisheries in warm weather has been proposed as a management solution. However, closure would be ineffective if angling effort and/or catch per unit effort at high temperatures were very low. Atlantic salmon angling catch, effort and catch rates at four Crown angling reserves located on the Upsalquitch River, New Brunswick, were examined in relation to morning water temperatures at a barrier fence located upriver. The analysis included one cold year (1992) when only one day with morning temperature ≥ 20 C was recorded at the barrier fence, two years of moderate temperatures (1993-94; 25% and 8% of morning temperatures ≥ 20 C, respectively) and one unusually warm year (1995; 97% of morning temperatures recorded at Morrissey Rock trapnet ≥ 20 C). Morning temperature (0800 h \pm 1 h) was found to be a reasonable surrogate for minimum daily temperature. Maximum daily temperature generally occurred in late afternoon. Catch per unit effort was slightly lower on days with morning temperatures ≥ 20 C in two of the three years when angling occurred at these temperatures, but the high level of effort resulted in substantial catch. In 1995, the warmest year studied, 67% of the angling effort and 55% of the angling catch were recorded on days with morning temperature ≥ 20 C.

RESUME

Il fait peu de doute que le programme obligatoire de capture et remise à l'eau a réduit la mortalité par pêche à la ligne des saumons atlantiques pluribermarins. Des craintes persistent cependant à l'effet que la mortalité pourrait résulter du stress subi comme suite à la pêche ou à la manutention, particulièrement au cours des années où les températures de l'eau sont chaudes. La fermeture de la pêche à la ligne par temps chaud a été envisagée comme mesure de gestion. La fermeture serait cependant inefficace si l'effort de pêche et les prises par unité d'effort étaient très faibles lorsque les eaux sont chaudes. Les prises à la ligne de saumons atlantiques de même que l'effort de pêche et les taux de capture dans quatre réserves de pêche à la ligne de la Couronne situées dans la rivière Upsalquitch (Nouveau-Brunswick) ont été examinés sous le rapport des températures de l'eau le matin à une barrière située en amont de la rivière. L'analyse visait une année où les eaux étaient froides (1992), c'est-à-dire où il n'y a eu qu'une seule journée où à la barrière la température de l'eau était supérieure ou égale à 20 °C; deux années de température modérée (1993-1994 : 25 % et 8 % de températures matinales se situant à 20 °C respectivement) ; et une année qui a été exceptionnellement chaude (1995 : avec 97 % de températures matinales au filet-trappe de la roche Morrissey de ≥ 20 °C). Il a été déterminé que la température matinale de l'eau (soit à 8 h \pm 1 heure) était un substitut acceptable de la température minimale quotidienne. Les températures maximales de la journée se produisaient d'ordinaire vers la fin de l'après-midi. Les prises par unité d'effort étaient légèrement inférieures les jours où les températures le matin étaient ≥ 20 °C, et ce

au cours de deux des trois années où la pêche à la ligne était pratiquée à ces températures ; la forte intensité de l'effort de pêche a toutefois donné des prises substantielles. En 1995, soit l'année la plus chaude recensée, 67 % de l'effort de pêche à la ligne et 55 % des prises ont été observées les jours où la température le matin était $\geq 20^{\circ}\text{C}$.

INTRODUCTION

Declining Atlantic salmon (*Salmo salar*) populations in the 1970's and early 1980's led to the introduction of mandatory release of multi-sea winter Atlantic salmon by anglers in New Brunswick. There is little doubt that mandatory catch-and-release has reduced angling mortality of multi-sea winter fish, but there continues to be concern that mortalities might result from angling or handling stress, especially in years of warm water temperatures (Bielak 1996). Salmon angled at water temperatures $\geq 20^{\circ}\text{C}$ experience greater physiological stress than salmon caught at lower temperatures (Wilkie et al. 1996, Wilkie et al. 1997). Most studies of salmon angled to exhaustion show no mortalities at temperatures up to 18°C , but up to 40% of salmon angled at or above 20°C may die within three days of release (Tufts et al. 1998). The effects of additional stress factors, such as disease or river acidification, are unknown.

Record low discharge levels and high water temperatures in the Restigouche River in 1995, combined with increased observations of diseased (furunculosis) and dead salmon (Locke et al. 1996) led some fisheries managers and anglers to question whether the river should be closed to angling because of the potential for high mortality of released salmon. Others felt that a temperature-related closure would have no effect since fish would be difficult to catch in the warm, low-water conditions and consequently there would be little opportunity for mortality associated with catch-and-release. Reduced catches of brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) in warm waters have been demonstrated (McMichael and Kaya 1991, Alabaster and Reid 1988, Mills et al. 1986) but the evidence for Atlantic salmon is divided between studies showing reduced availability in warm water (Alabaster 1990, Gee 1980), and no significant effect of temperature on catchability (Mills et al. 1986).

If little angling effort occurs at high temperatures, catch per unit effort is poor, or temperatures rarely exceed 20°C , then angling at high temperatures is unlikely to result in much catch-and-release mortality and closure would be an ineffective management practice. In this study we address water temperature effects on Atlantic salmon angling using catch and effort records for four New Brunswick Crown angling reserves on the Upsalquitch River, N.B. Salmon abundance and morning temperature ($0800\text{ h} \pm 1\text{ h}$) are monitored at a barrier fence located upriver. We ask the following questions:

1. What are the morning water temperatures in the Upsalquitch River?
2. How do these temperatures compare with those measured in the main Restigouche River, approximately 100 km downriver?

3. At what time of day do minimum and maximum water temperatures occur?
4. How much angling takes place at high temperatures?
5. Do high temperatures reduce catch per unit effort?

METHODS

The Upsalquitch River is a tributary of the Restigouche River, located in northern New Brunswick (Fig. 1). Angling data were obtained from four New Brunswick Crown angling reserves: Berry Brook and Crooked Rapids stretches on the Upsalquitch River, Forks stretch at the confluence of the Northwest and Southeast Upsalquitch rivers and the Northwest Upsalquitch stretch on the Northwest Upsalquitch River. Salmon returns to the Northwest Upsalquitch River were monitored at a salmon protection barrier operated by the New Brunswick Department of Natural Resources and Energy (DNRE) at a site located approximately 1.5 km above the Northwest Upsalquitch Crown angling stretch.

Daily morning (0800 h \pm 1 h) temperatures were measured with a thermometer at 0.5 m depth at the Northwest Upsalquitch salmon barrier and Morrissey Rock salmon research trapnet (Restigouche River; Fig. 1). Temperature data were not collected at the salmon barrier in 1995. The relationship of near-surface morning temperature at the two locations in 1992-1994 was evaluated using regression analysis (PROC GLM; SAS Inst. 1990). The daily timing of minimum and maximum temperatures, and their relationship to the morning temperature were evaluated using data from Hobotemp temperature recorders which collected data hourly at Morrissey Rock trapnet in 1993 and 1995.

Information on catch and effort was obtained by DNRE via a questionnaire mailed to anglers who fished the Crown reserve waters from June 15 to August 31. Crooked Rapids, Forks and Northwest stretches are regular Crown reserves where parties book the exclusive right to fish the stretch for 48 hours (from noon on day 1 to noon on day 3), whereas Berry Brook is a daily reserve where the fishing party changes daily. Effort on Crooked Rapids, Northwest and Berry Brook stretches is restricted to four rods per day, while at Forks Pool it is limited to two rods per day.

Angling data, summarized by stretch, fishing party and date, included the total number of grilse or one-sea winter (1SW) salmon (fork length < 63 cm) and multi-sea winter (MSW) salmon (fork length \geq 63 cm) kept and released, total angling effort (rod-days) of each party and the proportion of anglers who returned their questionnaire. Effort (rod-days) was calculated from the number of hours fished per angler. Four hours or less of angling was considered the equivalent of 0.5 rod-days, five to eight hours equalled 1 rod-day, nine to 12 hours equalled 1.5 rod-days and 12 or more hours equalled 2 rod-days. Salmon angling catch statistics used in this report are the sum of MSW and 1SW salmon catch. Projected catch and effort (survey results divided by proportion of anglers who returned the questionnaire) were used for comparisons of annual catch and effort, but analysis of water temperature effects considered only the reported data.

The effect of water temperature on angling catch rates was examined using either the temperature of the day of fishing (Berry Brook) or the temperature recorded for the middle day of the three-day stay (Crooked Rapids, Forks and Northwest). A planned contingency table (chi-squared) test could not be carried out since many cell frequencies were less than five.

RESULTS

Environmental conditions

Overall, 1992 was the coldest year, followed by 1994, 1993 and 1995 in order of increasing warmth (Fig. 2). In 1992, the warmest morning temperature at the Upsalquitch salmon barrier was 20 C and this temperature occurred only once (2% of the days during angling season when temperature was recorded). No temperatures ≥ 20 C were recorded at Morrissey Rock. In 1993, Upsalquitch morning temperatures peaked at 23 C with 25% of the daily observations during the angling season ≥ 20 C. Morrissey Rock morning temperatures ≥ 20 C were recorded on 24% of the days sampled during the angling season. Peak temperatures in 1994 were similar to those of 1993 but temperatures in the first and last few weeks of the season were cooler and only 8% of the daily observations were ≥ 20 C. Temperatures at Morrissey Rock were somewhat higher than at Upsalquitch barrier fence in 1994 and 17% of the days had temperatures ≥ 20 C. Upsalquitch water temperatures were not recorded in 1995. However, 97% of the morning temperatures at Morrissey Rock were ≥ 20 C, suggesting that temperatures at the salmon barrier were probably also ≥ 20 C throughout much of the season.

Regression analysis was used to compare daily morning temperatures at Morrissey Rock and at the barrier fence (Fig. 3). Upsalquitch fence temperatures (UPSTEMP) were linearly related to Morrissey Rock temperatures (MRTEMP). The relationship for the upper part of the temperature range (Morrissey Rock morning temperature > 14 C) was:

$$\text{UPSTEMP} = 0.15 + 0.89 \text{ MRTEMP} \\ (P=0.0001, \text{ adjusted } R^2=0.34, N=110)$$

Morning temperature was a reasonable approximation of minimum daily temperature at Morrissey Rock trapnet. On average, the difference between temperature measured at 0800 h and the minimum daily temperature was 0.4 C (± 0.52 SD). The maximum difference was 3 C. Minimum daily temperature most commonly occurred between 0400 and 0700 h (Fig. 4).

Maximum daily temperature at Morrissey Rock trapnet most commonly occurred between 1400 and 1700 h (Fig. 4). Maximum daily temperature (MAX) was related to morning temperature (AM) by a regression equation:

$$\text{MAX} = 0.93 \text{ AM} + 3.62$$

($P=0.0001$, adjusted $R^2=0.77$, $N=107$)

Angling catch and effort

Projected annual angling catch ranged from 441 fish in 1995 to 946 in 1994 (Table 1). Catch in the two colder years (1992 and 1994) exceeded that of 1993 and 1995. Projected total annual angling effort varied less than catch. In general the highest effort occurred in years with the lowest catch. Overall catch per rod-day was highest in the colder water years, 1992 and 1994 (Table 2) (but this also corresponds to higher salmon counts at the Upsalquitch barrier fence).

In some years there was substantial angling effort on days with morning temperatures ≥ 20 C (Fig. 5; Table 3). In 1995, most of the effort and catch occurred in the highest temperature category. More than 100 fish were reported as angled on days with morning temperatures ≥ 20 C in 1995, and 50 to 100 in each of 1993 and 1994.

The response of salmon angling catch rates (catch per rod-day) to changes in water temperature was not consistent among years (Fig. 6). In three of the four years, salmon angling catch rates declined as temperature increased from 16-19 C to ≥ 20 C, although this was not the case in 1994.

DISCUSSION

Morning temperatures in the Northwest Upsalquitch and Main Restigouche rivers occasionally exceed 20 C, and in warm years such as 1995, temperatures in this range were commonly observed during the angling season. These temperatures, measured at 0800 hours, are not the lowest temperatures of the day, but are reasonable surrogates for the daily minimum temperatures, which averaged 0.4 C lower than the 0800 h temperature at Morrissey Rock trapnet. Late afternoon (maximum daily) temperatures averaged no more than 3 C higher than morning temperatures at Morrissey Rock trapnet. However, the daily range of temperature is typically greater in higher-order tributaries (Caissie 1995, 1996) and maximum temperatures were therefore probably higher in the Upsalquitch or Northwest Upsalquitch rivers than in the main Restigouche River.

Even the morning temperatures recorded in the Restigouche system occasionally enter the range in which mortality or physiological disturbance has been reported for Atlantic salmon. Significant mortality (30-40%) in both laboratory and field studies occurred in salmon angled or exhaustively exercised at temperatures of 22-23 C (Wilkie et al. 1997; Tufts et al. 1998). Field studies of wild salmon angled at 20 C (Wilkie et al. 1996) and 6 C (Booth et al. 1995) indicate slower physiological recovery of the salmon under summer conditions. Salmon exercised in the laboratory at 23 C experienced a 30% mortality rate (Wilkie et al. 1997).

In warm years such as 1995, more than half of the angling effort in the river system may take place at the highest temperatures. Contrary to the opinions of many anglers, the results reported here indicate that it is possible for a substantial number of salmon to be caught at temperatures in excess of 20 C. In 1995, 55% of the total catch in the four Crown Reserves was landed on days when the Morrissey Rock morning temperature was ≥ 20 C. The actual temperature at the time of landing is unknown, but is unlikely to be cooler than 20 C.

The results of this study indicate that the potential for considerable mortality of Atlantic salmon angled under warm water conditions in the Restigouche and other river systems does indeed exist, but they provide no estimate of the actual magnitude of mortality. Such an estimate would require a field experiment on catchability of salmon under different temperature conditions, and a realistic means of evaluating post-angling mortality. Even physiologists admit that most physiological experiments in this field have been conducted under unrealistic conditions (Tufts et al. 1998). Other factors that need to be taken into account include river-specific conditions, such as the compounding effect of furunculosis, acidification, etc.

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LITERATURE CITED

- Alabaster, J.S. 1990. The temperature requirements of adult Atlantic salmon, *Salmo salar* L., during their upstream migration in the River Dee. J. Fish. Biol. 37: 659-661.
- Alabaster, J.S. and G. A. Reid 1988. Factors affecting angling catches of brown trout in the River don, Aberdeenshire. Congress in New Zealand 1987. Proceedings. Sladeczek, V. ed. 23 (3): 1715-1718.
- Bielak, A.T. 1996. A discussion document on the implications of catch-and-release angling for Atlantic salmon, with particular reference to water temperature-related river closures. Dept. of Fisheries and Oceans Atlantic Fisheries Research Document 96/117. 17pp.

- Booth, R.K., J.D. Kieffer, K. Davidson, A.T. Bielak and B.L. Tufts. 1995. Effects of late-season catch and release angling on anaerobic metabolism, acid-base status, survival, and gamete viability in wild Atlantic salmon (*Salmo salar*). Can. J. Fish. Aquat. Sci. 52: 283-290.
- Caissie, D. 1995. Hydrometeorological conditions for the Miramichi River basin during 1994. DFO Atl. Fish. Res. Doc. 95/88.
- Caissie, D. 1996. Hydrological conditions for Atlantic salmon rivers in the Maritime Provinces in 1995. DFO Atl. Fish. Res. Doc. 96/78.
- Gee, A.S. 1980. Angling success for Atlantic salmon (*Salmo salar*) in the River Wye in relation to effort and river flows. Fish Management 11(3):131-138.
- Locke, A. , R. Pickard, F.Mowbray, G. Landry, A. Madden, and P. D'Amours. 1996. Status of Atlantic salmon in the Restigouche River in 1995. DFO Atl. Fish. Res. Doc. 96/122.
- McMichael, G. A. and C.M. Kaya. 1991. Relations among stream temperature, angling success for rainbow and brown trout, and fisherman satisfaction. N. Am. J. Fish. Manag. 11 (2): 190-199.
- Mills, C.P.R., G.A.T. Mahon, and D.J. Piggins. 1986. Influence of stock levels, fishing effort and environmental factors on anglers' catches of Atlantic salmon *Salmo salar* L., and sea trout *Salmo trutta* L. Aquaculture and Fisheries Management 17:289-297.
- SAS Institute. 1990. SAS/STAT User's Guide: Version 6, Volume 2, 4th Edition , Cary, N.C., U.S.A.
- Tufts, B.L., K. Davidson and A.T. Bielak. MS 1998. Biological implications of "catch and release" angling of Atlantic salmon. Working Paper, Atlantic salmon meetings, Sydney, NS, February 1998.
- Wilkie, M.P., K. Davidson, M.A. Brobbel, J.D. Kieffer, R.K. Booth, A.T. Bielak and B.L. Tufts. 1996. Physiology and survival of wild Atlantic salmon following angling in warm summer waters. Trans. Am. Fish. Soc. 125: 572-580.
- Wilkie, M.P., M.A. Brobbel, K. Davidson, L. Forsyth and B.L. Tufts. 1997. Influences of temperature upon the postexercise physiology of Atlantic salmon (*Salmo salar*). Can. J. Fish. Aquat. Sci. 54: 503-511.

Table 1. Reported and projected Atlantic salmon catch and effort at four New Brunswick Crown angling reserves on the Upsalquitch River, 1992-1995.

Year	Stretch	Percent surveys returned	Reported catch and effort			Projected catch and effort		
			Salmon catch (no.)	Rod-days (no.)	Catch per rod-day	Salmon catch (no.)	Rod-days (no.)	
1992	1 (Berry Brook)	79	130	179	0.7	164	226	
	2 (Crooked Rapids)	56	114	142	0.8	204	254	
	3 (Forks)	73	152	78	1.9	209	107	
	4 (Northwest)	74	223	152	1.5	301	205	
	Total		619	551	1.1	878	793	
1993	1 (Berry Brook)	82	87	231	0.4	106	282	
	2 (Crooked Rapids)	83	69	219	0.3	84	265	
	3 (Forks)	88	180	133.5	1.3	204	151	
	4 (Northwest)	80	109	227	0.5	136	284	
	Total		445	810.5	0.5	530	982	
1994	1 (Berry Brook)	73	120	101	1.2	163	138	
	2 (Crooked Rapids)	76	88	166.5	0.5	115	218	
	3 (Forks)	68	215	93.5	2.3	318	138	
	4 (Northwest)	80	280	206	1.4	350	258	
	Total		703	567	1.2	946	751	
1995	1 (Berry Brook)	90	87	217	0.4	97	241	
	2 (Crooked Rapids)	86	103	181.5	0.6	119	210	
	3 (Forks)	77	66	100.5	0.7	169	258	
	4 (Northwest)	68	38	183	0.2	56	269	
	Total		294	682	0.4	441	978	

Table 2. Effects of morning water temperature on Atlantic salmon angling catch and effort at four Crown reserves on the Upsalquitch River, 1992-1995. Temperatures were measured at the Upsalquitch salmon barrier (1992-1994) or Morrissey Rock trapnet (1995).

Year	Temperature range (°C)	No. parties surveyed	Angling catch (no.)	Rod-days (no.)	Catch per rod-day (no.)
1992	≤ 11	9	36	30	1.2
	12-15	38	195	165	1.2
	16-19	6	4	21	0.2
	≥ 20	0	0	0	-
	not recorded	87	384	335	1.1
	Total	140	619	551	1.1
1993	≤ 11	0	0	0	-
	12-15	25	60	146.5	0.4
	16-19	51	233	299.5	0.8
	≥ 20	21	82	112	0.7
	not recorded	51	70	252.5	0.3
	Total	148	445	810.5	0.5
1994	≤ 11	0	0	0	-
	12-15	65	466	280	1.7
	16-19	36	101	167.5	0.6
	≥ 20	11	62	52.5	1.2
	not recorded	21	74	67	1.1
	Total	133	703	567	1.2
1995	≤ 11	0	0	0	-
	12-15	0	0	0	-
	16-19	41	133	222.5	0.6
	≥ 20	84	161	459.5	0.4
	not recorded	0	0	0	-
	Total	125	294	682	0.4

Table 3. Summary of Atlantic salmon catch, effort, and morning temperatures ≥ 20 C in the Restigouche system, 1992-1995.

Year	% of days with morning temperature ≥ 20 C		% of angling catch at ≥ 20 C	% of angling effort at ≥ 20 C
	Upsalquitch barrier	Morrissey Rock trapnet		
1992	2	0	0	0
1993	25	24	22	20
1994	8	17	10	10
1995	-	97	55	67

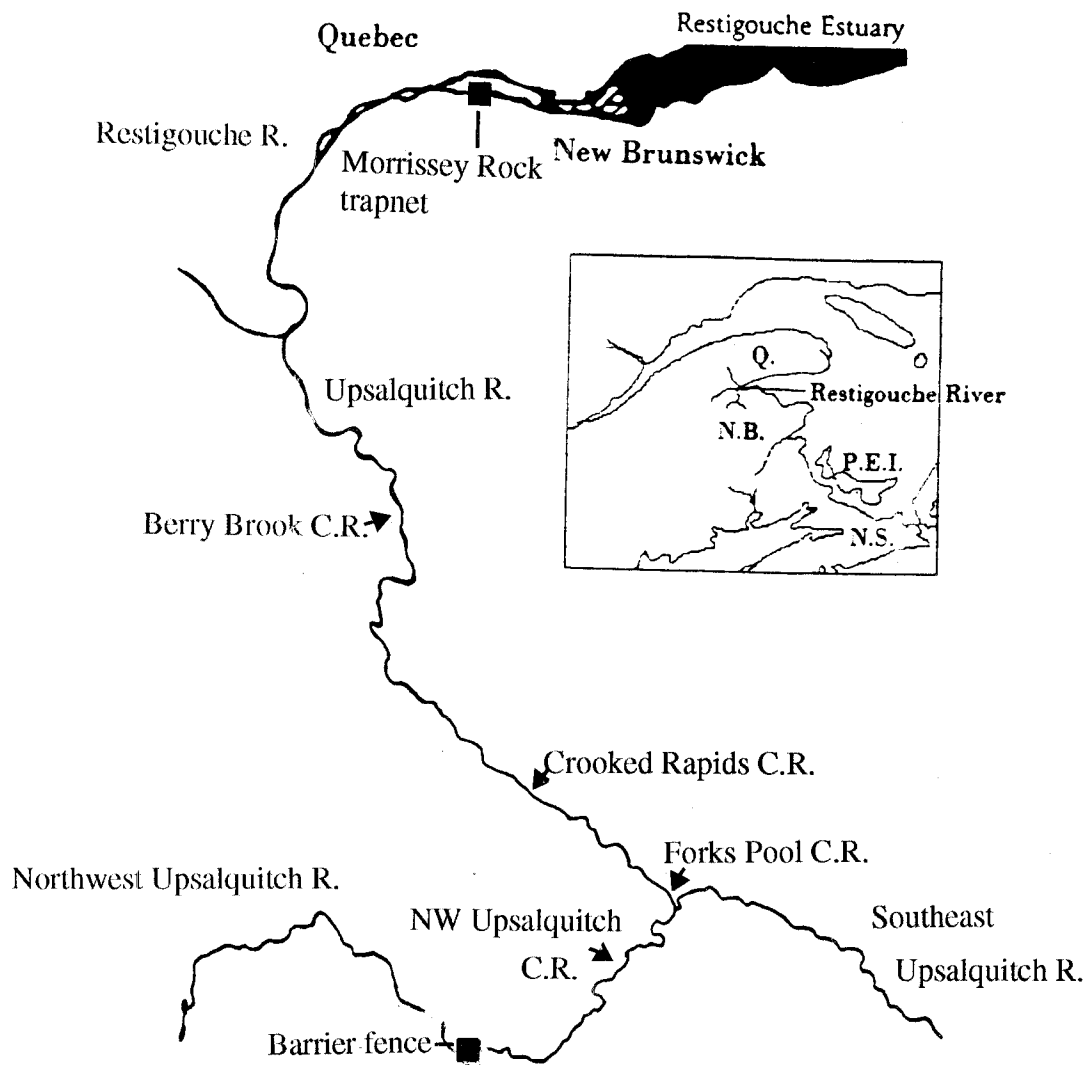


Fig. 1. Map of the Upsalquitch and Restigouche Rivers showing the location of Crown angling reserves, Northwest Upsalquitch salmon barrier and Morrissey Rock trapnet.

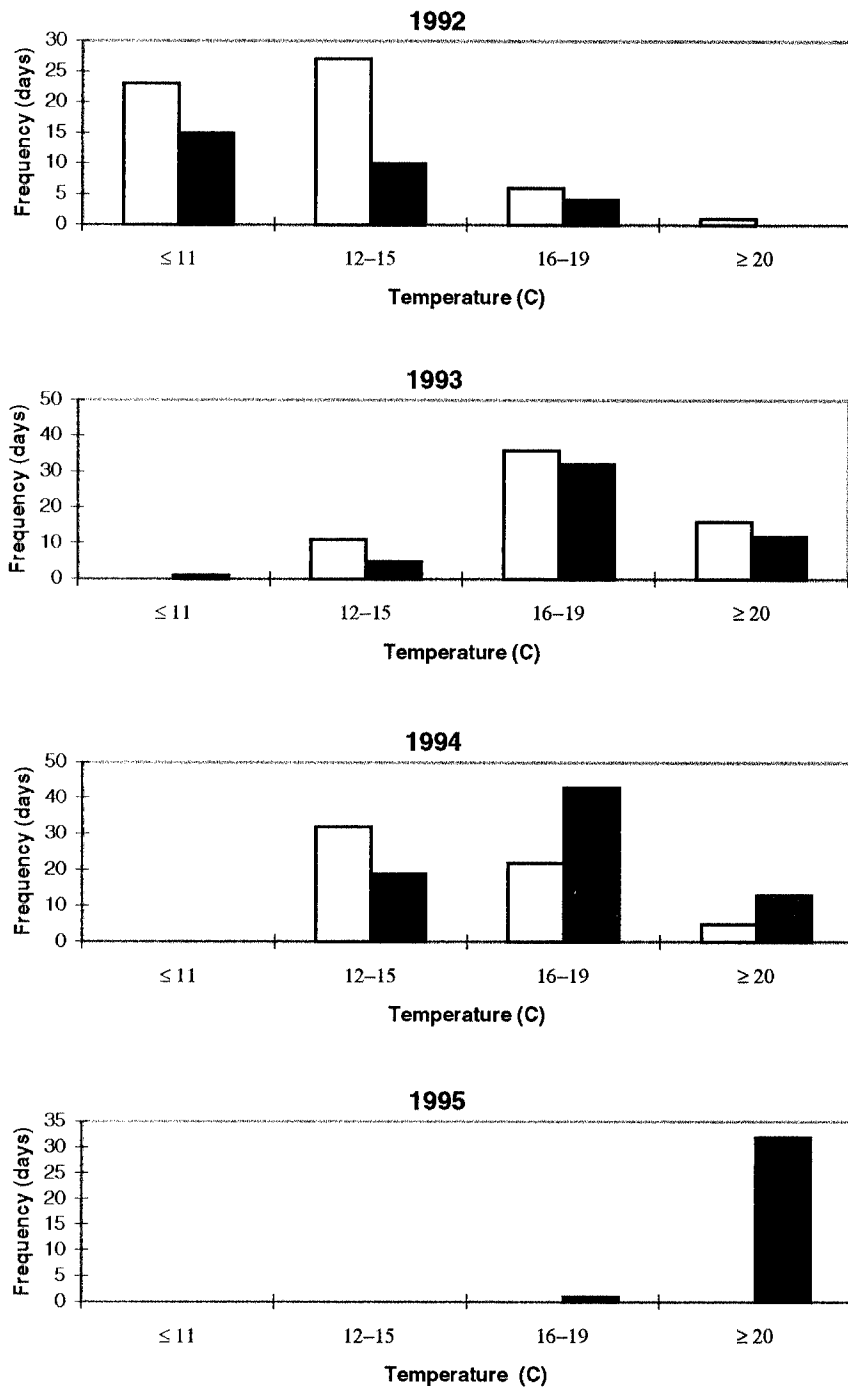


Fig. 2. Frequency distribution of daily morning temperatures at the Northwest Upsalquitch salmon barrier (clear bars) and the Morrissey Rock trapnet (solid bars) from June 15-August 31, 1992-1995.

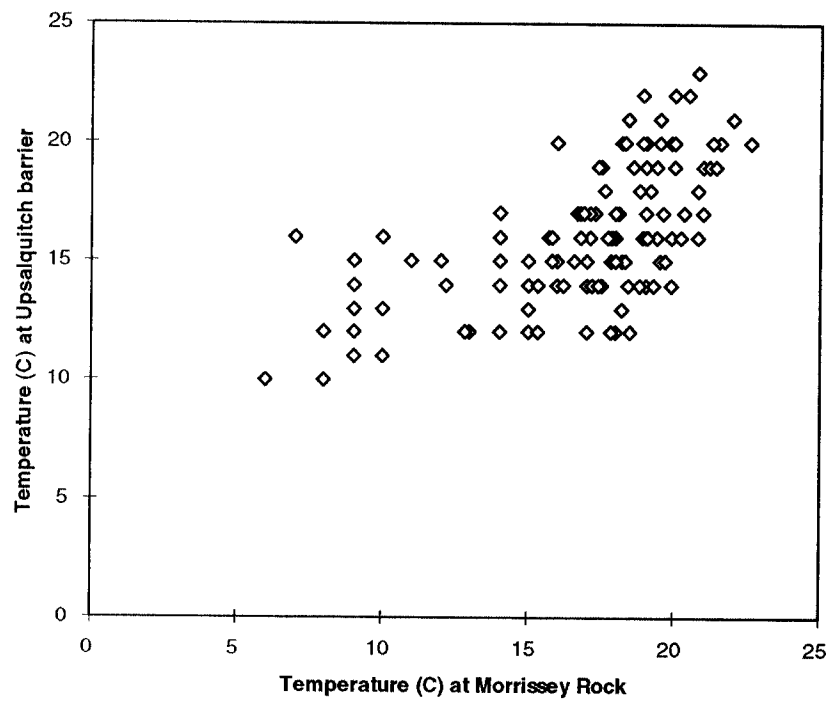


Fig. 3. Comparison of morning temperatures at Northwest Upsalquitch salmon barrier and Morrissey Rock trapnet, June 15-August 31, 1992-1994.

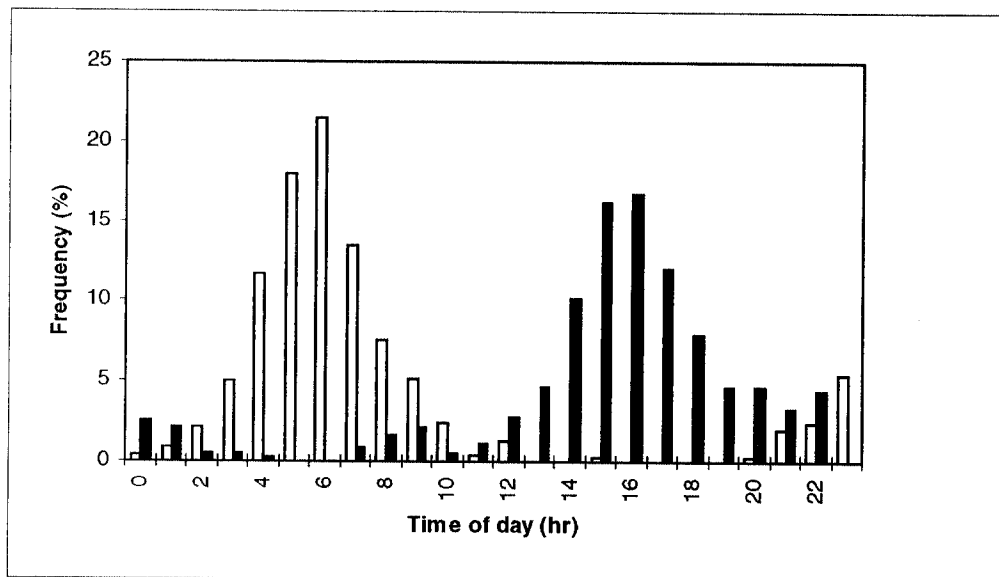


Fig. 4. Time of day of minimum (clear bar) and maximum (solid bar) daily temperatures at Morrissey Rock trapnet, Main Restigouche River, in 1993 and 1995.

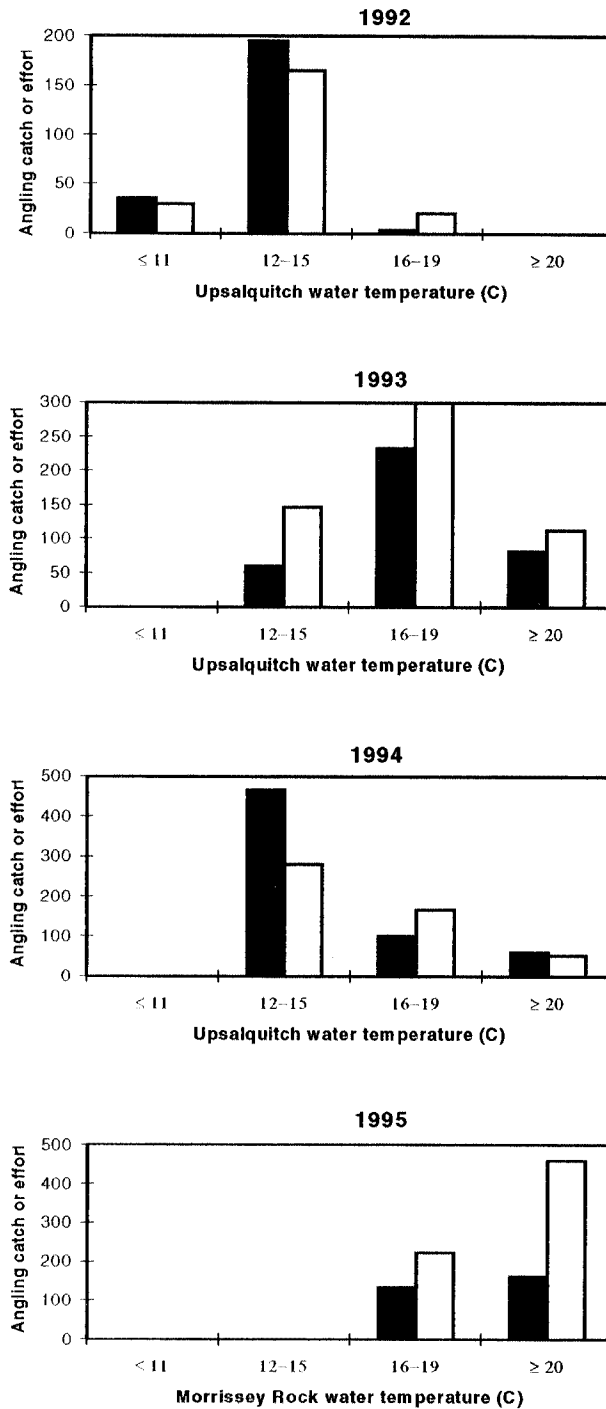


Fig. 5. Effects of temperature on Atlantic salmon angling catch (solid bars) and effort (clear bars) in Crown reserve waters of the Upsalquitch River, 1992-1995.

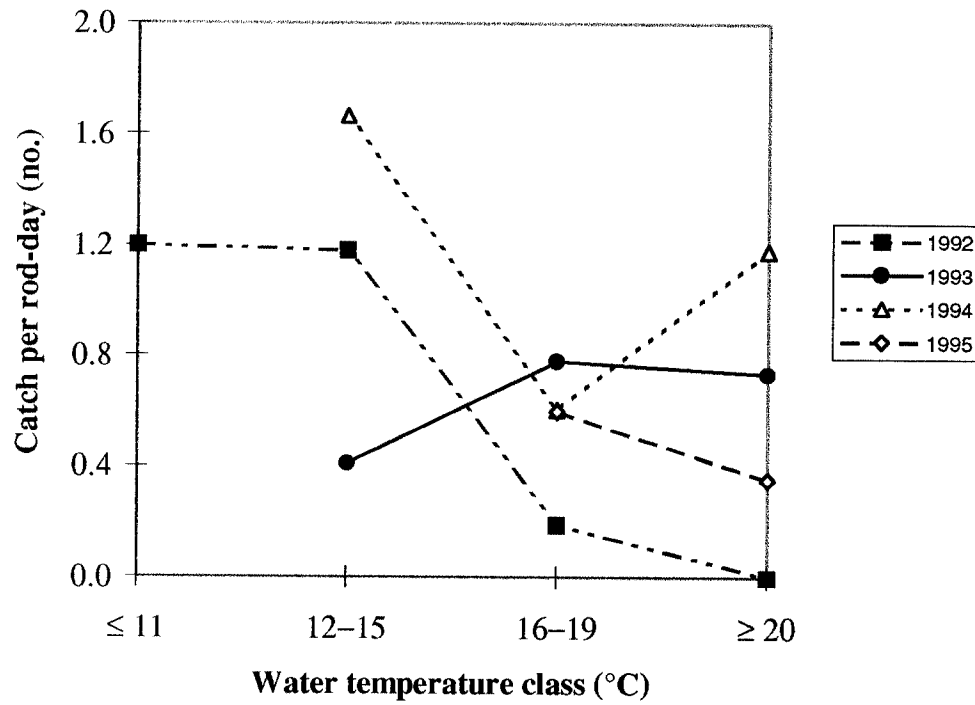


Fig. 6. Effects of temperature on Atlantic salmon angling catch per unit effort in Crown reserve waters of the Upsalquitch River, 1992-1995. Temperatures were measured at the Upsalquitch salmon barrier in 1992-1994 and at Morrissey Rock trapnet in 1995.