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Black Salmon Fishery and Repeat Spawning Salmon
of the Saint John River, N.B.

by

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ABSTRACT

The sport fishery for black salmon (post-spawners) on the Saint John River, N.B., during the period 1970-1983 totaled slightly fewer than 1,500 fish. Most were taken in the Nashwaak River tributary. At Mactaquac Dam, 1972-1982, repeat spawning (RS) fish comprised 9.5% (range: 5.2% to 20.7%) of the MSW fish sampled. RS fish contributed, on average, to about 10.6% of the egg deposition above Mactaquac. Annual survival of maiden fish to RS fish, Mactaquac-to-Mactaquac, was estimated to range from 0 to 6.7% for 1SW fish (mostly males) and 3.2% to 17.3% for 2SW maidens (mostly females). Survival from maiden spawning to RS river-returns was nearly twice that of the Mactaquac-to-Mactaquac returns. On average, twice as many females survived to repeat spawn as did males. Variation in the annual survival rates of each, however, could not be explained in terms of river discharge or local sea-surface temperatures.

RESUME

Au cours de la période de 1970 à 1983, la pêche sportive du saumon noir (après le frai) dans la rivière Saint-Jean, N.-B., s'est élevée à un peu moins de 1500 poissons. La plupart des poissons ont été capturés dans la rivière Nashwaak, un tributaire de la rivière Saint-Jean. Au barrage de Mactaquac, les saumons à frais multiples (FM) constituaient 9,5 % (étendue : 5,2 à 20,7 %) des poissons pluribermarins échantillonnés, entre 1972 et 1982. Les poissons FM ont contribué, en moyenne, environ 10,6 % des oeufs déposés au-delà de Mactaquac. On a estimé que la survie annuelle de poisson vierge à poisson FM de Mactaquac à Mactaquac, variait de 0 à 6,7 % pour les poissons unibermarins (des mâles pour la plupart) et de 3,2 à 17,3 % pour les poissons vierges dibermarins (des femelles pour la plupart). La survie de poisson vierge participant à un premier frai à poisson FM de retour en rivière était près du double de celle des retours de Mactaquac à Mactaquac. En moyenne, deux fois plus de femelles que de mâles ont survécu pour participer à un nouveau frai. Cependant, la variation des taux annuels de survie pour les mâles et les femelles n'ont pu être expliqués en fonction du débit de la rivière ou des températures locales de la surface de la mer.

INTRODUCTION

This documents assists in the formulation of advice on the management of black salmon in Atlantic Canada by summarizing sport landings of black (post-spawning) salmon or kelts for the Saint John River, New Brunswick, and biological characteristics, survival and the contribution of repeat spawning (RS) salmon to the run size and egg deposition above Mactaquac Dam, Saint John River.

METHODS

Utilization of the black salmon resource of the Saint John River and its yield relative to that of the 'bright' salmon fishery are summarized from DFO sport catch statistics of the Maritime Provinces, 1970-1983 (O'Neil and Swetnam, 1984; Swetnam and O'Neil, 1984).

Biological information on RS salmon of the Saint John River are, for this document, restricted to fish captured and sampled at Mactaquac Dam 1972-1982. All fish at Mactaquac were categorized as 1SW or MSW, measured and sexed externally. Approximately every tenth 1SW and MSW fish was scale sampled. Life history information of MSW fish was revealed from scales of subsamples of about 200 fish/year.

Scales were examined for age using a Bausch and Lomb Micro Projector. Ages were recorded such that the first two digits identified freshwater and current sea-age, e.g., age 2.2 - a virgin salmon which had spent two growth years in freshwater and two winters at sea. The third and subsequent digits indicate the sea-age(s) at which the fish previously spawned, e.g., age 2.2.1 - a fish which had previously spawned after one winter at sea (grilse) and was returning to spawn consecutively.

The average (1972-1982) contribution by repeat spawning fish to egg deposition by MSW fish (maidens and repeats) above Mactaquac was estimated by a comparison of the relative egg contribution of the RS component to that of the MSW component. Because MSW fish contributed to about 98% of the total egg deposition, 1972-1982 (Marshall and Penney, MS 1983) the comparison would approximate the contribution by RS fish to the total egg deposition. Egg contributions by RS fish were calculated as the product of the proportion of fish that were female, the number of eggs per female and the proportion of RS spawners among MSW spawners. Eggs per female were estimated from the length-fecundity relationship for salmon of the Saint John River (Marshall and Penney, MS 1983) and the mean fork length of 149 RS fish.

Estimates of the proportionate annual contribution of RS fish to the 2.4 eggs/m^2 spawning requirement above Mactaquac were derived from the product of estimates of the total egg deposition/m^2 above Mactaquac, 1972-1982 (unpublished data) and the proportionate contribution by RS fish to the total egg deposition.

Estimates of the percentage of wild maiden 1SW and 2SW fish counted at Mactaquac which survived to RS fish at Mactaquac were calculated from the sum of the estimated RS fish originating from maiden 1SW and MSW fish at Mactaquac, 1972-1979. Maiden spawners of each year were estimated as the difference between the total MSW count and the product of the MSW count and proportion of the aged fish in that year which were RS fish. The number of maiden fish which subsequently returned as RS fish was estimated as the sum of the products of their proportion of the aged sample and the MSW count in the respective years.

Estimates of survival between actual spawning (months after arrival at Mactaquac) and return to the Saint John River as an RS fish (previous to their arrival at Mactaquac) were calculated in the same manner as for Mactaquac-to-Mactaquac but using estimates of spawning escapement above Mactaquac (unpubl. data) and estimates of total river returns destined for Mactaquac (Marshall, MS 1985).

RESULTS

Black Salmon Sport Fishery

The typical open season for black salmon angling on the Saint John River has been April 15 - May 14. Of the total annual Saint John River sport catches of salmon (blacks and brights), 1970-1983, black salmon comprised 1 to 10% (annual average 3.5%) (Table 1). Of the total black salmon landings, 1970-1983, 1,349 (93%) were from the Nashwaak River (Table 2). The remainder was from the Hammond and Kennebecasis rivers. Kelts angled in the Nashwaak River represented 1 to 29% (average of 12%) and 1 to 23% (average of 8%) of respective bright 1SW and MSW fish caught in the previous season (Table 2).

RS fish as a Proportion of MSW Fish at Mactaquac

Interpretation of scales from 2,005 MSW salmon collected at Mactaquac 1972 to 1982 revealed 204 (10.2%) RS fish of 28 different age patterns (Table 3). Percentages of RS fish among MSW fish ranged from 5.2% in 1976 to 20.7% in 1979. Those which had first spawned as 1SW fish, i.e., "1" as the third digit, numbered 62 fish or 30% of all RS fish. Ten of the 62 (16.1%) were females. Of the RS fish which were 2SW or 3SW maidens (140 and 2, respectively) 131 (92.3%) were females.

Among RS fish which first spawned as grilse, 25% were consecutive-year spawners; 75% were alternate-year spawners. Freshwater age, i.e., age-2 or- 3 was not much different between consecutive and alternate spawning histories (20% of age-2 smolts were consecutive; 30% of age-3 smolts were consecutive).

Among RS fish which first spawned as 2SW or 3SW fish, approximately 40% were consecutive-year spawners; 60% were alternates. Thirty-two percent of age-2 smolts were consecutive; 48% of age-3 smolts were consecutive.

Contribution of Repeat Spawners to Egg Deposition and Spawning Requirements

Saint John River spawning requirements above Mactaquac have in past assessments been expressed in terms of 3,200 1SW and 4,400 MSW (incl. RS) salmon, 2.4 eggs/m^2 and sufficient 1SW fish to provide a M:F ratio of 1:1. Derivation of the MSW requirement was based on the average egg contribution and sex ratio of MSW fish (incl. repeat spawners) over the period 1972-1982 (Marshall and Penney, MS 1983). The egg contribution by 1SW fish was considered negligible.

Assuming proportionate exploitation of RS and virgin fish above Mactaquac, the average contribution by RS fish to total egg deposition, 1972-1982 was calculated as 10.6% (695/6,544). Derivation was as follows:

Sea-age	Prop. females	x	Eggs/female	x	Prop. pop'n	= Eggs/fish
MSW	0.86[a]		7,609[a]		1.00	6,544
RS	0.69[b]		10,605[c]		0.095	695

where "a" was derived by Marshall and Penney (MS 1983), "b" originates from Table 3 of this document, and "c" was estimated from the solution of the length - fecundity equation for Saint John River, $Y=430.19e^{0.03605X}$ where, X=mean length of 88.9 cm (SD=6.97; n=149) for RS fish at Mactaquac, 1972-1982.

The proximity of the 10.6% contribution by RS fish to egg deposition and the arcsin average 9.5% composition of RS fish among MSW fish (Table 3) indicates that the annual proportions of RS fish among MSW fish may approximate their contribution to egg deposition. However, estimates of the annual contribution of RS fish to the required 2.4 eggs/m^2 deposition above Mactaquac varied from about 3% in 1973 to approximately 26% in 1977 (Table 4). The average annual contribution to 2.4 eggs/m^2 was 9.8% (arcsin).

Survival of Maiden 1SW and 2SW fish to First Return as RS fish

The percentage of maiden salmon at Mactaquac, 1972-1979, which returned to Mactaquac at least once as a repeat spawner was estimated from the life history information of 159 RS fish (Table 5) and their sample size (Table 3), Mactaquac counts of 1SW and MSW fish and estimates of maiden 2SW fish at Mactaquac (Table 6). The procedure expanded the 24 2SW fish of 1972 (Table 5) to a total of 564 2SW fish, i.e., (6/194 x 2,367) + (17/177 x 4,775) + (1/191 x 6,200), or 12.5% (564/4,529) of those estimated at Mactaquac in 1972. Percentage returns (Table 7) ranged from 0% to 6.7% for 1SW and 3.2% to 17.3% for 2SW fish. No correlation exists between the arcsin of the values for 1SW and 2SW maidens. Respective averages (arcsin) for 1SW and 2SW salmon were 3.1% and 8.8%.

The percentage of wild maiden fish which may have spawned above Mactaquac and which subsequently returned to the Saint John River (not just Mactaquac) was based on estimates of the number of salmon which spawned above Mactaquac and estimates of river returns destined for Mactaquac (Table 8). Percentage returns (Table 9) ranged from 0% to 9.5% for 1SW and 5.0% to 34% for 2SW fish. Again, there was no correlation between the arcsin of the values for 1SW and 2SW maidens. Respective averages (arcsin) for 1SW and 2SW salmon were 5.0% and 14.6%, almost double the Mactaquac-to-Mactaquac return rate.

DISCUSSION

Sport fishing for black salmon on the Saint John River is conducted on tributaries below Mactaquac - principally the Nashwaak River. Between 1970 and 1983 the black salmon harvest on the Nashwaak was about 9% of the total Nashwaak River bright salmon harvest. The impact of this black salmon fishery on the survival of repeat spawning fish to the Nashwaak and their contribution to spawning is unknown.

RS fish comprising 9.5% (5.2% to 20.7%) of the MSW count at Mactaquac are well within, and frequently exceed, the range of recent data for North American and European stocks for which there are no black salmon fisheries and which contribute to distant, notably Greenland, fisheries (Lévesque et al., 1985). This finding is in spite of the suggestion that returns to Mactaquac are biased downward by possible mortality of kelts at three hydroelectric facilities.

Although maiden 1SW and 2SW spawners above Mactaquac 1972-1979 were in a ratio of about 1:1 (25,289:27,354; Table 8) their respective contribution to RS fish 1973-1981 was about 1:2.8 (41:114; Table 3). At the same time the proportion of females among maiden 1SW fish increased from 0.044 (Table 8 and Marshall and Penney, MS 1983) to 0.098 (Table 5) as RS fish. Females among 2SW fish increased from a calculated 0.869 as maidens to 0.921 (Table 5) as RS fish. RS survivors among maidens estimated to have spawned above Mactaquac 1973-1981 numbered 3,323 of which 0.686 were female. Equating the numbers of maiden male and female 1SW and 2SW fish, 1972-1979, to the estimated numbers of male and female RS fish, 1973-1981, allows approximation of their relative survival. Survival for 1SW and 2SW females (0.054 and 0.065, respectively) weighted by number was 6.5% while that of the 1SW and 2SW males (0.023 and 0.037, respectively) weighted by number was 2.5%. A higher survival rate for post-spawning female salmon than for post-spawning male salmon is reported among investigations documented by Lévesque et. al. (1985).

Among RS fish at Mactaquac, 25% of those which first spawned as 1SW fish and 40% of those which first spawned as 2SW fish were consecutive spawners. Seventy-five and 60%, respectively, were alternate-year spawners. Lévesque et. al. (1985) also indicate, with few exceptions, that RS fish of stocks with components which venture to Greenland are generally alternate spawners.

On average, RS fish contributed to about 10.6% of the total egg deposition above Mactaquac (Table 4). However in 3 of 11 years the contribution to egg deposition exceeded 15%; in one year it reached 26%. Hence, RS fish can in a short-fall of 2SW fish make an important contribution towards the required egg deposition. The same is perhaps even more true in tributaries below Mactaquac in which kelts are unaffected by spring black salmon fisheries or hydroelectric facilities. Further, eggs contributed by RS fish would in all likelihood carry genetic material representing a broader spectrum of year classes than the usually predominant maiden 1SW and 2SW components.

Estimates of survival of 1SW and 2SW maidens to RS fish, Mactaquac-to-Mactaquac, averaged (8-year) 3.1% and 8.8%, respectively. Estimates of survival from spawner to river-return were 5.0% and 14.6%, respectively. The time frame for these values are not comparable to those of the literature. Porter (1975) estimates overwinter survival of 10% to 90% for rivers in Newfoundland. Subsequent mortality is poorly documented but believed to be very high, in part, because of the presumed difficulty in readapting to salt water (Lévesque et. al., 1985).

The potential for hydroelectric dams to affect annually-variable survival rates, 1972-1979 (Table 9), was examined by regressing arcsin survival values for RS fish on the mean discharge at Tobique Narrows for the months in which kelts could have descended the river (survival for each of 1SW, 2SW and combined fish over 8 years as affected by discharge for each of 7 months, i.e., 21 regressions each with 6 df). Mactaquac consistently operated 4 turbines through this period. Survival in high discharge years when dams spilled during kelt descent (March to May) could presumably differ from low discharge years when kelts possibly descended through turbines.

Sea-age	r-values						
	Nov	Dec	Jan	Feb	Mar	Apr	May
1SW	-0.69	0.22	0.24	-0.40	0.10	-0.30	0.17
2SW	-0.20	-0.36	0.32	0.32	0.48	0.37	-0.80[a]
Combined	-0.55	-0.28	0.10	0.42	0.87[a]	-0.45	-0.22

[a] $p < 0.01$

Inconsistently significant r-values or signs of the slope for each of 1SW, 2SW and Combined categories prevented conclusions about the possible impact of river discharge on survival. In the absence of water temperatures for the Saint John River, sea-surface temperatures from St. Andrews, N.B., for the months of May, June and July, 1973-1980, were also examined by regression techniques for their potential impact on survival. None of these regressions were statistically significant. The absence of significant r-values for sea-surface temperatures and inconsistently significant r-values for discharge may, however, be a function of small sample sizes of RS fish used in deriving annual estimates of survival.

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Table 1. Federal estimates of sport catch and effort for bright and black salmon on the Saint John River, N.B.,1970-1983.

Year	Bright salmon			Black salmon			Black salmon as prop. of all salmon	Total effort (rod-days)	Effort for black salmon as prop. of total
	MSW	1SW	Total	MSW	1SW	Total			
1970	639	1,077	1,716	34	6	40	0.02	6,904	0.04
1971	706	884	1,590	70	50	120	0.07	7,713	0.07
1972	548	1,551	2,099	45	26	71	0.03	8,010	0.05
1973	647	1,627	2,274	40	52	92	0.04	12,162	0.06
1974	734	1,619	2,353	31	42	73	0.03	13,178	0.04
1975	1,569	1,551	3,120	54	127	181	0.05	14,300	0.07
1976	2,311	2,247	4,558	144	151	295	0.06	16,843	0.08
1977	1,661	2,360	4,021	118	133	251	0.06	19,210	0.05
1978	411	673	1,084	44	74	118	0.10	11,684	0.11
1979	1,840	500	2,340	19	28	47	0.02	13,354	0.05
1980	2,713	2,558	5,271	10	35	45	0.01	25,800	0.02
1981	1,183	1,111	2,294	16	22	38	0.02	10,518	0.06
1982	2,520	1,952	4,472	12	37	49	0.01	27,685	0.02
1983	1,696	875	2,571	3	42	45	0.02	22,772	0.01

Table 2. Sport catch of bright and black salmon on the Nashwaak River as compiled from federal statistics, 1970-1983. Figures in brackets express black salmon as a proportion of bright salmon in the year previous.

Year i	Bright salmon (yri)		Black salmon (yri+1)		
	1SW	MSW	1SW	MSW	Total
1969	-	-	34	6	40
1970	348	826	60(0.17)	50(0.06)	110
1971	538	608	45(0.08)	26(0.04)	71
1972	364	1,216	40(0.11)	52(0.04)	92
1973	215	1,279	22(0.10)	42(0.03)	64
1974	175	576	51(0.29)	122(0.21)	173
1975	505	716	125(0.25)	146(0.20)	271
1976	619	836	117(0.19)	133(0.16)	250
1977	481	666	41(0.09)	72(0.11)	113
1978	139	177	19(0.14)	28(0.16)	47
1979	123	103	6(0.05)	24(0.23)	30
1980	281	835	10(0.04)	14(0.02)	24
1981	336	547	12(0.04)	37(0.07)	49
1982	416	873	3(0.01)	12(0.01)	15
1983	419	496	-	-	
Total	4,959	9,754	585(0.12)[a]	764(0.08)[a]	1349

[a] (1970-1983)

Table 3. Numbers of male:female repeat spawning (RS) wild salmon among MSW fish aged at Mactaquac, 1972-1982.

	Male:Female (numbers)											
Age[a]	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	Total
2.2.1				:1		1:		1:	1:	1:		5
2.3.1				2:	3:	7:	4:1	1:	1:	2:	2:	23
2.3.2	:1	:1	:1	:2	:1		:4	:4	:3	:2	:1	20
2.4.1.2			:1									1
2.4.1.3									:1			1
2.4.2	:1	:1	:8	:1	1:2	:11	:2	1:12	:5	2:	:4	51
2.4.2?								:1				1
2.4.2.3								:1	:1			2
2.4.3							:1					1
2.5.2								:1				1
2.5.2.3.4			:1					:1				2
2.6.2.4											:1	1
3.2.1	2:		1:	2:		1:		2:		2:		10
3.3.1	4:1	2:1		1:	1:	2:		3:1		1:	2:1	20
3.3.2	:2	1:3			:1	:2		:7	1:	1:1	1:	20
3.4.2	1:	:2	:9	:2		1:3	:1	:1	:2	:2	:3	27
3.4.2.3						:1					:1	2
3.4.3							:1					1
3.5.1.3.4			:1									1
3.5.2.3								1:				1
3.5.2.3.4				:1							:1	2
3.5.2.4						:1		:1				2
3.6.2.3.4										:1	:1	2
3.6.2.4								:1				1
4.3.1											:1	1
4.3.2		:1			1:						:1	3
4.4.2										:1		1
4.5.2											:1	1
Total	7:5	3:9	1:21	5:7	6:4	12:18	4:10	9:31	3:12	9:7	5:16	64:140
	12	12	22	12	10	30	14	40	15	16	21	204
N of MSW fish	192	194	177	191	191	195	182	193	188	182	170	2,055
RS as % of N	6.3	6.2	12.4	6.3	5.2	15.4	7.7	20.7	8.0	8.8	12.4	9.5[b]

[a] See text for interpretation of age designations.

[b] Arcsin

Table 4. Contribution of repeat spawning salmon to a required egg deposition above Mactaquac of 2.4 eggs/m^2, 1972-1982.

Year	(1) Prop. contrib. by RS fish[a]	(2) Total est. egg depos./m^2	(3) Eggs/m^2 by RS fish (1)x(2)	(4) RS eggs as % of 2.4 eggs/m^2
1972	0.063	2.2	0.139	5.8
1973	0.062	1.3	0.081	3.4
1974	0.124	3.1	0.384	16.0
1975	0.063	4.2	0.265	11.0
1976	0.052	3.3	0.172	7.2
1977	0.154	4.1	0.631	26.3
1978	0.077	2.3	0.177	7.4
1979	0.207	1.4	0.290	12.1
1980	0.080	4.6	0.368	15.3
1981	0.088	1.4	0.123	5.1
1982	0.124	1.3	0.161	6.7

[a] Table 3.

Table 5. Numbers, sex ratio (M:F) and maiden year of 1SW and 2SW salmon sampled as repeat spawning (RS) salmon at Mactaquac, 1973-1982.

Maiden sea-age	Sex ratio	Maiden year/RS year 1972			1973		1974			1975			1976			1977				1978			1979			All
		73	74	75	74	75	75	76	77	76	77	79	77	78	79	78	79	80	81	79	80	82	80	81	82	1973-1982
1SW		0	0	0	1	3	3	4			9		2	5			5	1		3	1		1	3		41
	M:F				4:0		6:1			9:0			6:1			4:2				4:0			4:0			37:4
2SW		6	17	1	1	3	2	3	1	3	16	1	2	3	4	6	16		1	11	8	2	4	5	2	118
	M:F	1:23			0:4		1:5			2:18			1:8			1:22				0:21			3:8			9:109

Table 6. Counts of 1SW and MSW wild salmon and estimate of 2SW maidens among MSW salmon at Mactaquac, 1972-1981.

Sea-age	Number of fish										
	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
1SW	784	1854	3389	5725	6797	3506	1584	6234	7555	4571	3932
MSW	4831	2367	4775	6200	5511	7247	3034	1993	8157	2441	2262
2SW maidens[a]	4529	2221	4181	5810	5222	6132	2801	1580	7506	2226	

[a] MSW- (prop. RS x MSW)

Table 7. Estimated percentage of wild maiden salmon at Mactaquac, 1972-1979 which returned to Mactaquac as repeat spawners.

Sea-age	Percent return, Mactaquac-to-Mactaquac								
	1972	1973	1974	1975	1976	1977	1978	1979	Mean[a]
1SW	0.0	6.7	6.3	5.8	2.3	2.7	4.7	1.3	3.1
2SW	12.5	5.6	4.5	11.9	3.2	4.5	17.3	16.9	8.8
Total	10.6	6.1	5.3	8.9	2.7	3.9	12.8	4.5	6.5

[a] Arcsin

Table 8. Estimated number of 1SW, MSW, 2SW maiden and RS salmon spawning above Mactaquac and MSW returns destined for Mactaquac, Saint John River, 1972-1982. See text for data sources.

Sea-age	Number of fish										
	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Spawners											
1SW	582	1660	3036	5010	5855	2771	1192	5183	6419	3439	3011
MSW	4066	2025	3694	5686	4665	5866	2550	1691	6669	1772	1797
2SW-maidens[a]	3812	1900	3235	5329	4420	4964	2354	1340	6137	1616	1575
RS	254	125	459	357	245	902	196	351	532	156	222
Returns											
MSW	4899	2518	5811	7441	8177	9712	4021	2754	10924	5991	5001

[a] MSW - (prop. RS x MSW)

Table 9. Estimated percentages of wild maiden spawners, 1972-1979, which returned to the Saint John River and were destined for Mactaquac.

Sea-age	Percent return, spawner-to-river								
	1972	1973	1974	1975	1976	1977	1978	1979	Mean[a]
1SW	0.0	9.0	9.5	8.9	3.6	4.7	8.5	3.0	5.0
2SW	17.7	7.9	7.9	17.6	5.0	7.9	28.8	34.0	14.6
Total	15.4	8.4	8.7	13.4	4.2	6.8	21.9	9.4	10.5

[a] Arcsin