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Investigation of the Salmon *(Salmo salar)* Smolt Migration of the Big Salmon River, New Brunswick, 1966-72

by

B. M. Jessop

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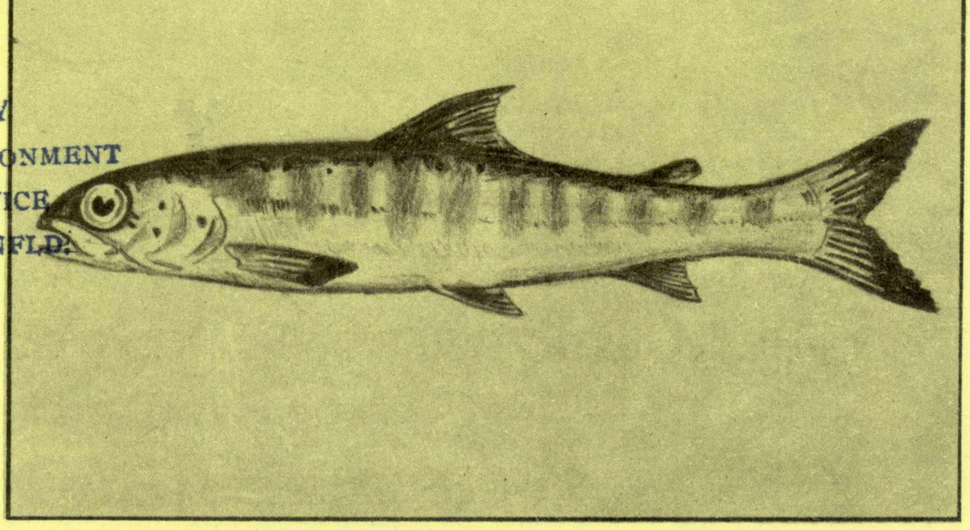

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INVESTIGATION OF THE SALMON (*SALMO SALAR*) SMOLT MIGRATION OF THE BIG SALMON RIVER, NEW BRUNSWICK, 1966-72

B.M. JESSOP

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RESOURCE DEVELOPMENT BRANCH
FISHERIES AND MARINE SERVICE
DEPARTMENT OF THE ENVIRONMENT

HALIFAX, NOVA SCOTIA

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ABSTRACT

Between the years 1966 and 1972, use of a counting fence near the mouth of the Big Salmon River, New Brunswick, enabled the collection of data on the timing and duration of Atlantic salmon smolt migration, and on smolt numbers, sizes, sex ratios and ages. Smolt migration began each year between May 7 and 28 and ended between June 15 and July 13. The numbers of smolt counted ranged from 8,812 in 1967 to 22,254 in 1970, with a 6-year mean of 15,570. Timing of the smolt run was related to water level and water temperature. Approximately 90 percent of the smolts migrated downstream during darkness. Mean smolt lengths at a given age varied significantly between years. Within a year, mean lengths of different age-groups often differed significantly. For all years combined, mean lengths of each age-group were: age-2, 13.97 centimeters; age-3, 14.62 centimeters; age-4, 15.70 centimeters. Large year-to-year fluctuations were evident in the age composition of migrating smolts. The annual smolt yield varied from 1.73 to 4.38 per 100 square meters, with a 6-year mean of 3.06 per 100 square meters.

RÉSUMÉ

Entre 1966 et 1972, une barrière de recensement installée près de l'embouchure de la rivière Big Salmon, au Nouveau-Brunswick, a permis la cueillette de données sur la période et la durée de la migration des smolts de l'Atlantique, leur nombre, leur grosseur, leur sexe et leur âge. Chaque année, la migration a débuté entre le 7 et le 28 mai pour se terminer entre le 15 juin et le 13 juillet. Le nombre de smolts a varié entre 8,812 en 1967 et 22,254 en 1970; la moyenne annuelle, calculée sur une période de 6 ans, est de 15,570. La période de migration des smolts dépendait du niveau et de la température des eaux. Environ 90 pour cent d'entre eux sont descendus de nuit. La longueur moyenne des smolts du même âge a varié passablement selon les années. Dans une même année, la variation de longueur moyenne entre les groupes d'âge différent fut souvent considérable. Voici, calculée sur le total des années, la longueur moyenne de chaque âge: 2 ans, 13.97 centimètres; 3 ans, 14.62 centimètres; 4 ans, 15.70 centimètres. D'une année à l'autre, des fluctuations importantes se sont révélées dans la proportion des smolts de même âge en migration. Le rendement annuel de smolts a varié entre 1.73 et 4.38 par cent mètres carrés; la moyenne pour les 6 années fut de 3.06 par cent mètres carrés.

INTRODUCTION

The Big Salmon River is today a fine salmon stream. It drains an area of well-forested, hilly terrain before emptying into the Bay of Fundy about 35 mi (56 km) northeast of the city of Saint John, New Brunswick. The logging dam that blocked the river mouth from the late 1920's and its attendant, variably effective fishway was removed in 1962. From less than 100 to over 1,700 salmon ascended the fishway each year.

In 1963, the Resource Development Branch installed a counting fence (Fig. 1) in order to enumerate returning salmon and in 1965 it was modified to sample the smolt migration.

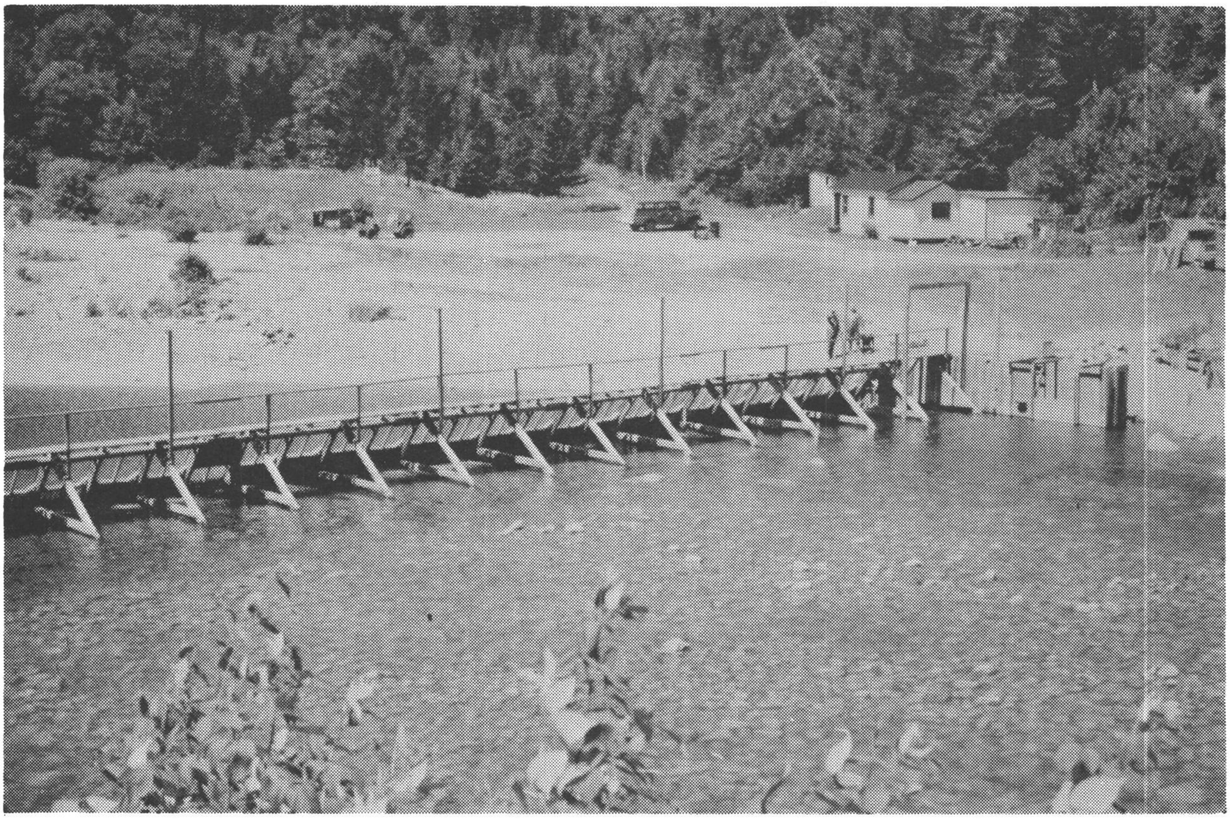


FIG. 1. Salmon counting fence, Big Salmon River, New Brunswick.

Annual enumeration of the native smolt migration began in the spring of 1966. Information on age-growth patterns, sex ratios, stock size, migration movements and angler catch-effort statistics was collected yearly with the objective of providing a base for rehabilitation and ultimately the scientific management of the salmon resource.

The Big Salmon River counting fence is located about 200 yd (183 m) above the head of tide, thereby enabling a complete monitoring of the migratory movements of smolts and returning salmon. The overall value of the smolt counting operation is derived from the management potential of the data obtained on the time and duration of migration, smolt numbers and sizes, sex ratios and ages.

This report analyses and summarizes the data collected on the native smolt run during the years 1966-72. The term "smolt", as used in this report, is defined as a fully silvered parr migrating to sea (Allan 1965). The smolt age is the number of years that the young salmon spends in fresh water before migrating to sea.

A variety of short-term experiments, such as tagging-mortality studies and counting-fence efficiency tests, have been performed in order to gain information on some particular aspect of the salmon population. Long-term experiments have involved the use of hatchery-reared smolts. During 1966 and 1967, smolts of both early- and late-run Northwest Miramichi River stocks were planted. A formal hatchery-smolt evaluation project was operative during 1968 and 1969, using smolts of Restigouche River early-run broodstock (Hyatt 1969, 1970 [MS Report. Unpublished. Resource Development Branch, Dept. of Fisheries and Forestry, Halifax]). This project was discontinued in 1970. An analysis of the hatchery-origin fry, parr and smolt plantings forms Appendix A. Appendix B is a summary of tagging information on native and non-native smolt releases.

DESCRIPTION OF STUDY AREA

The Big Salmon River drains an area of approximately 128 mi^2 (332 km^2), and discharges into the New Brunswick side of the Bay of Fundy at 45°25'N (Fig. 2). When all tributaries are included, there are approximately 79 mi (127 km) of stream; the main stem extends about 17 mi (27 km) from Walton Lake to the mouth. The river flows in a generally southwesterly direction for most of its length, while the lower 2 mi (3 km) flow south.

From Walton Lake to its mouth, the Big Salmon River falls about 715 ft (218 m) in elevation (Fig. 3). The upper portion of the river, from Walton Lake to just below the junction with Arnold Brook (Fig. 2), has a slope of about 10 ft/mi (2 m/km). As the region above Bonnel Brook is approached, the grade changes abruptly, and a drop of over 30 ft/mi (6 m/km) begins and continues to within several miles of the mouth, where the slope again decreases. The middle and lower sections contain numerous rapids and riffle areas, and are closely bounded by hills, rising steeply 300-400 ft (91-122 m).

An estimated 556,100 yd^2 (464,900 m^2) of stream rearing area are accessible to salmon, while a further 172,900 yd^2 (144,544 m^2) are inaccessible (Redmond 1971 [MS Report. Unpublished. New Brunswick Dept. of Natural Resources, Fish and Wildlife Branch, Fredericton], Dept. of Fisheries Survey 1971 [unpublished]). Approximately 18,800 yd^2 (15,717 m^2) are suitable and available for spawning.

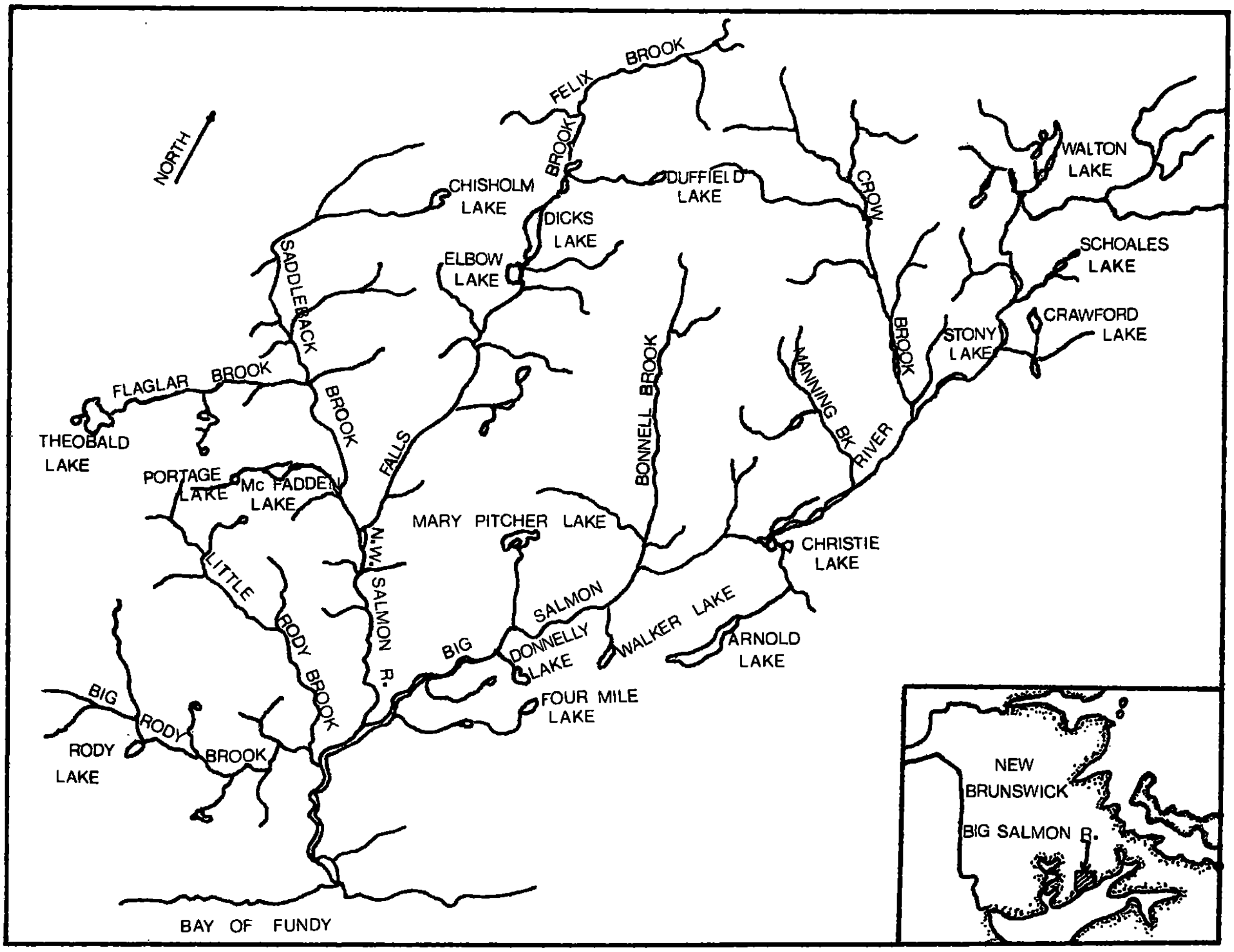


FIG. 2. Map of the Big Salmon River system.

Smith (1955 [MS Report. Unpublished. Fish Culture Development Branch, Dept. of Fisheries Saint John]) and Kiely (1970 [MS Report. Unpublished. Resource Development Branch. Dept. of Fisheries and Forestry, Halifax]) provide further details on the physical features of the river system, particularly obstructions and salmon spawning and rearing areas.

The soil composition and geology of the area is varied (Aalund and Wicklund 1949). Basically, the river flows through areas of sedimentary, volcanic and igneous rock. Loams of several types (generally sandy or gravelly) predominate, and overlay glacial till of mainly non-calcareous composition. Aalund and Wicklund (1949) note that "the climatic conditions prevalent in New Brunswick favor the development of acid leached soils known as Podsols, and favor the growth of coniferous trees and the accumulation of organic material on the surface of the soil".

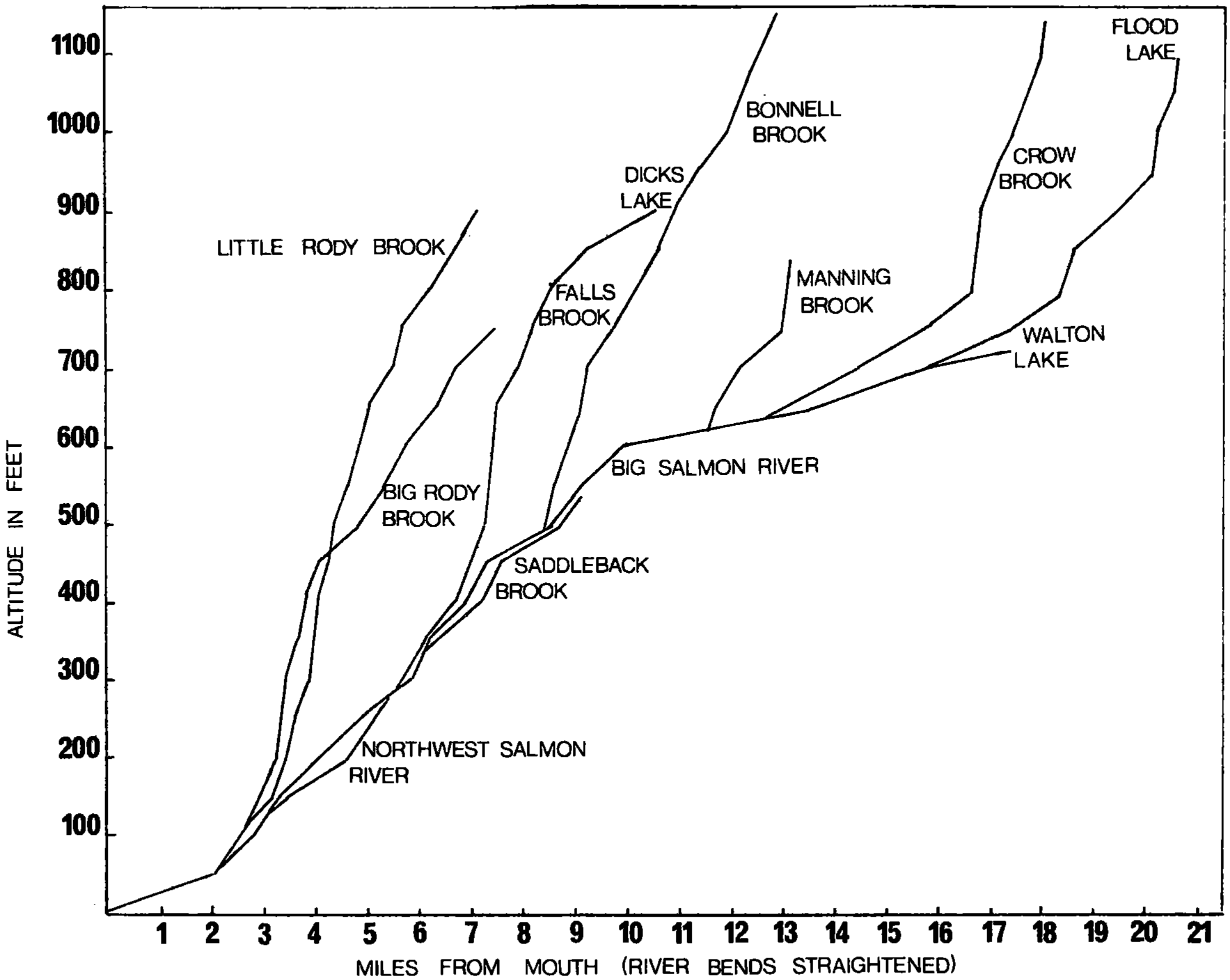


FIG. 3. Stream gradients of Big Salmon River and tributaries.

Water quality data for the river was first systematically collected in 1970. Sixteen monthly samples were collected between December, 1970 and June 1972. The mean pH was 6.3 (range 5.8-6.6); mean total hardness was 7.0 ppm (range 4.9-8.3); and mean specific conductance was 26.8 μ mho/cm (range 20.9-30.6). The concentrations of heavy metal ions were negligible. Adequate levels of dissolved oxygen for salmonids should be assured at all times by the swift and turbulent flow of the river. Redmond (MS 1971) reports that the surface pH of Walton Lake was 6.9 when sampled; the total hardness was 15.1 ppm, and the specific conductance at 25°C was 35.8 μ mho/cm.

Water discharge data was first collected in 1971. The mean monthly discharge over 22 months, from January, 1971 to November, 1972, was 397 cfs (11.24 m^3/s), with a range of 88-1,680 cfs (2.49-47.57 m^3/s). Peak discharges occurred in May and October-November, with low discharges in January-February and July-September.

Several species of fish are native to the watershed: Atlantic salmon (*Salmo salar*), brook trout (*Salvelinus fontinalis*), dace (*Rhinichthys atratulus*), American eel (*Anguilla rostrata*), lamprey (*Petromyzon marinus*), and one or several species of *Notropus* minnows. Walton Lake is unusual in that it contains one of New Brunswick's few remaining populations of Arctic char (*Salvelinus alpinus*). These fish are not anadromous, although access to the sea is unhindered. In past years, rainbow trout (*Salmo gairdneri*) were planted in the river, but this has been discontinued. A small, self-sustaining rainbow trout population appears to have become established, as adult sea-run fish have been reported at the counting fence over the past six years.

DESCRIPTION OF COUNTING FENCE

The focus of most fisheries investigations on this river is the salmon counting fence. This fence is 160 ft (48.8 m) long and is set at an angle of about 13° to the river flow. It has the capacity to take the whole river discharge except during peak flows, when overflows occur.

The original smolt racks were made of 1/4-in.-diameter metal rods with a 3/4-in.-center spacing. Effective space between bars was 1/2 in. These were in use from 1966 to 1969. In 1970, the original metal smolt racks were replaced with adult salmon racks, modified by fastening over them a heavy gauge 1/2-in.-square wire mesh.

The downstream smolt trap was originally an adult trap, which was converted by covering with 3/4-in.-square wire mesh. This set-up was in use from 1966 to 1969. In 1966, fyke nets were also used, but these did not prove to be successful and were shortly removed. In 1968, an additional funnel-and-box smolt trap was placed at the center of the counting fence.

A smolt trap of new design was used in 1970. This was designed to rise or fall with the water level and thus maintain an approximately constant water flow through the trap. The trap was connected to the upstream entrance funnel by a trough of flexible rubber.

STUDY METHODS

Since 1966, the counting fence has been installed annually following the break-up of ice on the river and generally before the smolt run has begun. Smolt counting usually began during the first two weeks in May and continued until early July. Occasional periods of high water forced the removal of the barrier screens, thus disrupting the smolt-monitoring program.

During the smolt run, the trap was checked at approximately regular intervals during the day: usually at about 0700, 1200 2100 and 2300 hr. Catches were counted and samples of various sizes were tagged with modified-Carlin tags. Both fork and total lengths of each tagged smolt were measured. All smolts were anaesthetized with MS-222 before tagging and were then allowed to recover fully before release (Bell 1964). A further subsample of the tagged smolts was weighed, and scale samples were removed from the area midway between the top of the back and the lateral line, immediately posterior to the caudal insertion of the dorsal fin. Lengths were normally measured to the nearest millimeter and weights to the closest 0.1 gram. Exceptions to this practice occurred in 1966 and 1967. In 1966, lengths were measured to the nearest 1/8 inch, while in 1967, they were measured to the nearest inch and no weights were recorded. These measurements were later converted to metric units.

Scale samples were interpreted for age using a microprojector. Arabic numerals are used in this report to indicate the number of completed annuli, while further growth is indicated by a "+" sign, e.g. 3+.

Coefficients of condition were calculated for smolts using the relationship $K = 100W \times L^{-3}$, where K is the coefficient of condition, using fork length; W is the weight in grams; and L is the fork length in millimeters. Individual K factors were not calculated; rather the mean weight and length of all samples were used to obtain an average K.

Daily water levels and temperature ranges were recorded at the counting fence site, using a staff gauge and Taylor thermometer respectively.

Counting fence efficiency as a barrier to migrating smolt was tested yearly, except in 1967 and 1968. In 1966 and 1969, tagged hatchery-reared smolts were released 8 mi (12.8 km) upstream and from 1970 to 1972, tagged wild smolts were released about 2 mi (3.2 km) upstream. Percent recovery at the fence was used as an index of efficiency.

Five-day mortality tests were conducted in 1971 and 1972 to assess the short-term effects of tagging. All test fish were captured at the counting fence. Before tagging, they were anaesthetized with MS-222. A four-compartment cage was used, containing three lots, each of 30 tagged smolts, and one lot of 30 untagged smolts. A daily record was kept of general observations and mortalities.

Diel catch patterns were determined during three 24-hour periods, following the lapse of an estimated one third and two thirds of the duration of the smolt run in 1971, and during the latter third of the estimated run in 1972.

RESULTS

Size and Timing of the Smolt Run

The numbers of smolt counted each year ranged from 8,812 in 1967 to 22,254 in 1970, with a 6-year mean of 15,570 (Table 1).

TABLE 1. Size of smolt runs at Big Salmon River counting fence, 1966-72.

Year	Numbers counted	Estimated fence efficiency (%)	Estimated total numbers
1966	14,512	79	18,370
1967	8,812	79	11,150
1968	17,189	79	21,760
1969	10,606	79	13,430
1970	22,254	75	29,630
1971	20,048	77	26,170
1972	8,395[1]	-	-
Mean[2]	15,570	77.8	20,085

[1]Incomplete count of run.

[2]Omitting 1972 count.

These counts must be regarded as minimum estimates of the total smolt migrating, since tests of fence efficiency indicated that only about 78% of the run was actually counted.

Smolt migration began each year between May 7 and 28, and ended between June 15 and July 13 (Table 2). Migration generally began as the maximum daily water temperature approached 50°F. At the onset of smolt migration, water levels were usually declining, while the migration often ended on a rise in water level. During the migration, a sharp rise in water level was usually accompanied by an increase in the smolt count, but most fluctuations in smolt count were not paralleled by changes in water level. The peak of the run was associated with a freshet in five of six years. Over the duration of the migration, there was little correlation between daily smolt catch and absolute water level or water temperature.

Graphical presentations are given of the relationships between smolt count, water level and water temperature for the years 1966 to 1972 (Appendix C).

A study of diel smolt catch in 1971 and 1972 showed that approximately 91% of the smolts migrated downstream during darkness, 2100-0600 hr (Fig. 4). During the latter part of the smolt run, the percentage of smolts migrating during daylight hours increased, particularly in the early afternoon. The hourly pattern of movement varied; in one case there was a bimodal peak at 2100-2200 and 0300-0400 hr, while in the other two cases, single peaks occurred at 2300-2400 and 2400-0100 hr.

TABLE 2. Percent distribution of smolt run in relation to date, water temperature and water level.[1]

		Percentage of run				
Year		0	10	50	90	100
1966	Date	May 6	May 26	May 29	June 7	June 24
	Water temp.	-	50.2	51.0	53.7	56.5
	Water level	-	1.9	2.6	1.6	1.4
1967	Date	May 27	June 5	June 11	June 23	July 5
	Water temp.	40.0	47.7	53.7	55.5	60.0
	Water level	4.6	2.5	1.8	1.3	3.0
1968	Date	May 13	May 21[2]	May 30	June 8	June 15
	Water temp.	49.0	50.0	54.3	59.2	55.3
	Water level	1.5	1.4	1.3	1.3	2.6
1969	Date	May 7	May 20	June 3	June 9	July 13
	Water temp.	41.0	49.2	53.2	56.3	61.0
	Water level	2.6	2.6	1.5	1.8	1.8
1970	Date	May 16	May 22	June 2	June 10	July 13
	Water temp.	44.0	49.2	51.5	53.8	62.0
	Water level	1.9	3.0	2.2	2.4	2.7
1971	Date	May 14	May 21	May 31	June 12	July 7
	Water temp.	44.0	47.8	52.5	52.2	58.0
	Water level	3.4	2.5	1.4	0.9	0.2
1972[3]	-	-	-	-	-	-

[1]Previous three-day mean of max-min water temperature (°F) and level (ft).

[2]Data available for only one day.

[3]Incomplete data.

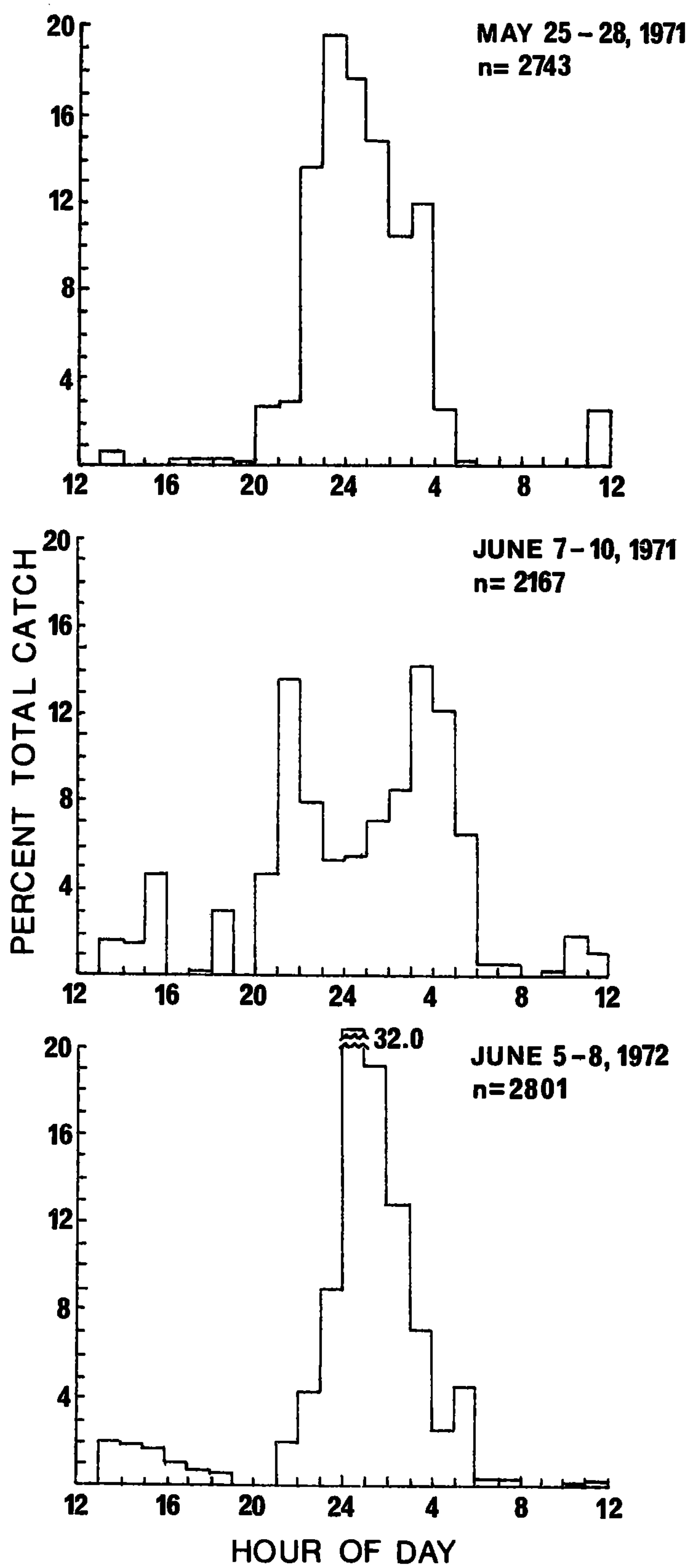


FIG. 4. Diel distribution of Atlantic salmon smolt catch at the Big Salmon River counting fence during selected 4-day time periods, 1971-72.

Fence and Trap Mortality

Smolt mortalities at the fence and in the trap varied from year to year, ranging from 2.3% in 1967 to 10.1% in 1972, with a mean of 5.0% of the counted run. High water levels resulted in increased mortality, since the increased current strength caused more smolts to be pinned against the fence and the trap entrance.

Tagging Mortality

The 5-day tagging-mortality studies conducted in 1971 and 1972 demonstrated a highly significant ($P \leq 0.01$) mortality of tagged fish compared to untagged fish when all trials are considered. There was a highly significant mortality difference between trials, with mortality of tagged fish increasing in successive trials, i.e. later in the smolt run, from about 1% to 41% (Table 3).

TABLE 3. Smolt mortality following tagging at different times during the migration period.

Year	Date	Mean water temp. (°F)[1]	Percent mortality: Tagged fish[2]	Percent mortality: Control
1971	June 1	52.2	1.1	0.0
	June 7	53.1	21.1	0.0
	June 16	54.4	33.3	3.3
1972	June 9	52.3	2.2	3.3
	June 15	51.1	41.1	13.3

[1]Mean water temperature for five days previous to start of trial.

[2]Mean of three trials.

Smolt mortality was not invariably correlated with water temperatures during the trials or with water temperatures for 5 days previous to the start of the trials, but there was a trend to increased water temperature throughout the duration of smolt movement. Tagging observations indicate that as the run progressed, smolt condition decreased, i.e. the flesh became softer and scales were more readily abraded off during fish handling.

Smolt Size

Mean smolt lengths varied significantly ($P<0.05$) between years, decreasing irregularly from 15.1 cm in 1968 to 13.5 cm in 1972 (Table 4). A decrease of approximately 1 cm separates the years 1970-72 from previous years. Mean lengths of age-3 smolts were not always significantly greater than for age-2 smolts and in 1966, age-3 smolts were significantly smaller (Table 5).

TABLE 4. Mean smolt length, weight and condition factor for all age groups combined.

Year	Sample size	Mean fork length (cm)	SD	Mean weight (g)	SD	Mean K_{FL}
1966	317	14.9	1.38	33.3	9.11	1.00
1967[1]	-	-	-	-	-	-
1968	245	15.1	0.93	31.5	5.77	0.92
1969	182	14.8	0.89	30.4	5.65	0.95
1970	600	13.6	1.10	24.6	6.50	0.98
1971	600	13.9	1.35	26.0	7.73	0.97
1972	675	13.5	1.18	25.1	7.51	1.02

[1]Length-weight data unavailable.

TABLE 5. Mean fork length of Big Salmon River smolts by age groups, 1966-72. (Data unavailable for 1967.)

Age	Mean fork length (cm)					
	1966	1968	1969	1970	1971	1972
2	15.5	15.0	14.6	12.9	12.7	13.1
3	14.9[1]	15.2	14.9	14.0[1]	14.3[1]	14.4[1]
4	-	-	-	15.6[1]	15.8[1]	-

[1]Difference significant at $P \leq 0.05$.

For all years combined, mean lengths of each age-group were: age-2, 13.97 cm; age-3, 14.62 cm; age-4, 15.70 cm. Age-length frequencies for the years 1966-72 (except 1967) have been calculated (Appendix D). Annual changes in mean lengths were reflected in the length-frequency distributions (Table 6), such that fewer large and more small smolts were produced from 1968 to 1972. The range of smolt lengths also decreased.

The relationship between fork length (FL) and total length (TL) was linear, as described below:

Year	Sample size	Equation	Correlation coefficient
1969	83	FL = 0.9116TL + 0.2707	0.988
1970	200	FL = 0.9160TL + 0.0402	0.994

The percentage of smolts showing plus growth on their scales increased until about mid-June, after which virtually all smolts showed plus growth. In 1970, for example, 19% of age-3 smolts showed plus growth at the start of migration (May 17) and all showed plus growth by June 9. At each age, smolts with plus scale growth were significantly longer ($P \leq 0.05$) than smolts without, except at age-4, where the sample size was small.

Mean smolt lengths measured at three approximately 10-day intervals were not usually significantly different ($P \leq 0.05$), with the exception of 1971, nor was the pattern consistent from year to year (Table 7). There was no apparent correlation with water temperature or level.

Smolts migrating during daylight hours were very significantly longer ($P \leq 0.001$) than smolts migrating during darkness (2100-0600 hr). The change in mean smolt length with time followed a crudely sine-shaped curve, with the smallest fish being caught about midnight and the largest fish about mid-afternoon.

Migration period mean weights ranged from 24.6 g in 1970 to 33.3 g in 1966 (Table 4), a fluctuation of about 35% of the 1970 mean weight. Mean weights increased in an orderly manner with increasing length (Fig. 5). Length-weight distributions were recorded for all years except 1967 (Appendix E). The empirical lenght-weight relationship was similar in all years and was of the form $W = aL^b$ where W = weight, L = length and *a* and *b* are empirically determined constants (Appendix F). Close agreement between the calculated and empirical plots and the high correlation coefficients demonstrate that these equations accurately represent the length-weight relationship.

Mean condition factors varied somewhat between 1966 and 1972 (range 0.92-1.02 with a grand mean of 0.97) and displayed a slight trend towards increased condition with shorter length (Table 4).

TABLE 6. Lenght-frequency distributions of native Atlantic salmon smolts, 1968-72.

Fork length (cm)	Year									
	1968		1969		1970		1971		1972	
	No.	%	No.	%	No.	%	No.	%	No.	%
10.0-10.9	3	0.0	1	0.0	0	0.0	2	0.0	5	0.3
11.0-11.9	6	0.1	10	0.3	218	5.8	99	3.3	83	5.2
12.0-12.9	119	2.1	136	3.6	826	22.1	464	15.3	281	17.5
13.0-13.9	859	14.8	775	20.5	1,309	35.0	813	26.9	542	33.9
14.0-14.9	2,139	36.9	1,524	40.4	915	24.5	731	24.2	464	29.0
15.0-15.9	1,773	30.6	948	25.1	358	9.6	536	17.8	187	11.7
16.0-16.9	652	11.3	322	8.5	96	2.6	263	8.7	33	2.0
17.0-17.9	186	3.2	41	1.1	17	0.5	87	2.9	2	0.0
18.0-18.9	43	0.7	12	0.3	2	0.0	22	0.7	1	0.0
19.0-19.9	5	0.1	4	0.1	1	0.0	2	0.0	0	0.0
20.0-20.9	3	0.0	0	0.0	0	0.0	1	0.0	0	0.0
21.0-21.9	1	0.0	0	0.0	0	0.0	0	0.0	0	0.0
22.0-22.9	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
23.0-23.9	1	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total	4,790		3,773		3,742		3,020		1,598	

Age and Sex Composition

Large year-to-year fluctuations were evident in the age composition of smolt migrations (Table 8), such that age-2 smolts ranged from 33.5% to 72.0% with a 7-year mean of 51.4%. The balance of the runs consisted mainly of age-3 smolts, with only a 2%-average contribution from age-4 smolts. From 1968 to 1971 there was a progressive decline in the percentage of age-2 smolts and a corresponding increase in the percentage of age-3 and -4 smolts.

TABLE 7. Seasonal variation in Atlantic salmon smolt length at Big Salmon River, 1968-70. (Sample size - 200 fish.)

Year	Date	Mean fork length (cm)	Standard deviation
1968	May 14-16	14.64	1.306
	May 29	14.71	0.934
	June 10	15.05[1]	1.054
	Average	14.80	1.098
1969	May 15-19	14.19	1.076
	June 2	14.86[1]	0.926
	June 17	14.78	1.104
	Average	14.61	1.035
1970	May 20	13.68	0.997
	June 2-3	13.47[1]	1.145
	June 12-19	13.63	1.168
	Average	13.59	1.103
1971	May 25-27	14.17	1.374
	May 30-June 1	13.00[1]	1.190
	June 8-10	14.44[1]	1.468
	Average	13.87	1.347

[1]Mean fork length significantly different ($P \leq 0.05$) from that of previous period.

There was no significant correlation ($P \leq 0.1$) between the age composition of the run in any given year and mean summer

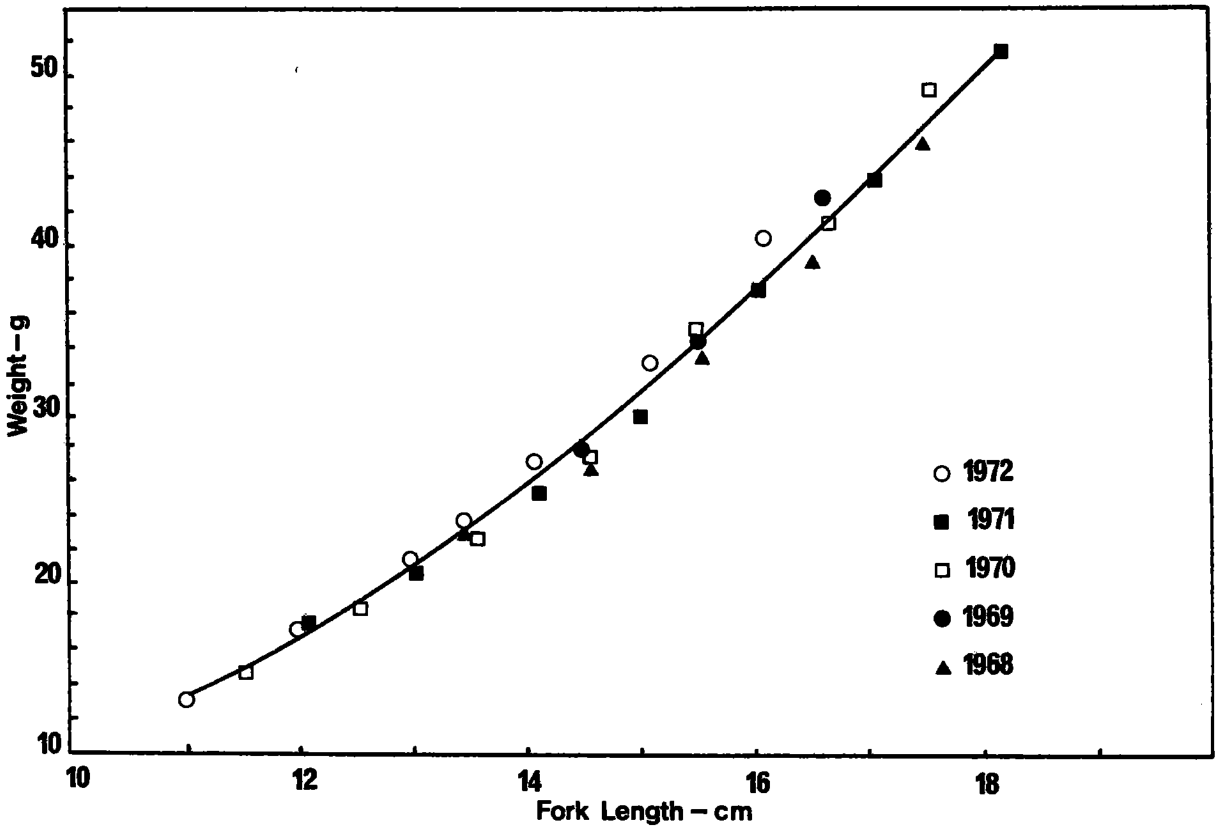


FIG. 5. Mean length-weight relationship for Atlantic salmon smolt from the Big Salmon River, 1968-72.

TABLE 8. Age composition of Big Salmon River smolt migration, 1966-72.

Year	Number in sample	Age composition (%) 2-yr	3-yr	4-yr
1966	200	72.0	27.5	0.5
1967	203	33.5	60.5	3.0
1968	245	62.9	37.1	0.0
1969	182	51.1	48.4	0.5
1970	990	36.8	61.2	2.0
1971	1,345	36.4	55.8	7.7
1972	565	66.9	32.6	0.5

water temperature in the two previous years. The highest recorded mean monthly water temperature was 65°F in July of 1965. Mean summer (June, July, August) water temperatures ran from 58° to 62°F.

Sex ratio statistics were taken only in 1971 and 1972. In both years, female smolts significantly outnumbered ($P<0.05$) male smolts, forming 60.3% and 65.7% of the respective samples (n=648 and 280, respectively).

Smolt Yield

Calculated on the basis of output per year per unit area of stream, the recorded smolt yield varied from 1.73 to 4.38 per 100 m^2, with a mean of 3.06 per 100 m^2 (Table 9). Smolt yields adjusted for counting fence efficiency were about 25% greater, i.e. the overall mean was 3.95 per 100 m^2. The calculation of adjusted yield per smolt year class provided a comparable set of figures (Table 10).

TABLE 9. Yield of Atlantic salmon smolts, 1967-72.

	Recorded			Adjusted[1]		
Year	Fence count	No. of smolts /100 m^2	No. of smolts /100 yd^2	Fence count	No. of smolts /100 m^2	No. of smolts /100 yd^2
1966	14,512	2.85	2.60	18,370	3.61	3.29
1967	8,812	1.73	1.58	11,150	2.19	2.01
1968	17,189	3.38	3.09	21,760	4.28	3.91
1969	10,606	2.09	1.90	13,430	2.64	2.42
1970	22,254	4.38	4.00	29,630	5.83	5.33
1971	20,043	3.94	3.61	26,170	5.15	4.71
1972	8,395[2]	-	-	-	-	-

[1]Adjusted on basis of counting fence efficiency estimates.

[2]Incomplete count.

TABLE 10. Adjusted smolt yield by year class.

Year class	Number of smolts[1] per 100 m^2	Number of smolts[1] per 100 yd^2
1965	2.34	2.14
1966	4.09	3.74
1967	5.66	5.18
1968	6.10	5.58
Mean	4.55	4.16

[1]Adjusted for counting fence efficiency.

DISCUSSION

It is difficult to attribute the considerable year-to-year variability in the Big Salmon River smolt count to other than natural causes. The stream is relatively isolated and is undisturbed except for a small logging operation in the upper reaches. Since 1970, the area has been sprayed with fenitrothion for spruce-budworm control, but there is no good evidence that this has materially affected the salmon stock. There may, however, be inhibition of learning processes and increased predator vulnerability for smolts moving to sea following insecticide application (Hatfield and Anderson 1972).

The mean counting fence efficiency of about 78% was comparable to that (75%) reported by Ducharme (Unpublished. Fisheries and Marine Service, Halifax.) for a similar structure.

As is typical of Maritime salmon rivers (Dymond 1963), the smolt run in this river occurs in May and June, with occasional extension to mid-July.

Initiation of the smolt run when the maximum daily water temperature approached 10°C (50°F), and its full establishment when the mean daily water temperature reached that level agrees with observations by White (1940) and Elson (1962), that temperatures of this magnitude are an important factor influencing the onset of migration. Allen (1941) reported that active smoltification does not occur until the water temperature reaches about 7°C, and Swain (1957) concluded that the immediate stimulus is either a rise in temperature or some associated factor. Although Osterdahl (1969) states that "The 10°C rule seems to be based on mere coincidence, not on a direct causal connection," the evidence presented here and by other authors appears to be more than coincidence.

The onset of migration usually occured during falling water levels, as is also observed by Osterdahl (1964). If temperature conditions are suitable, rainfall greater than a critical amount will initiate downstream movement (Bull 1931). Once migration had begun, freshets were invariably accompanied by increased smolt movement, as also noted by Berry (1933). Over the duration of the run, there was no apparent relationship between daily smolt catch and absolute values of water level or temperature. Osterdahl (1969) observed a similar situation and reported that the amount of solar radiation (cloudiness) had a much higher correlation with changes in the smolt run than did water temperature.

Most smolts migrated at night, primarily during the early morning hours, with a few migrating during the afternoon. During the latter part of the run, the number of smolts migrating during daylight hours increased.

The generally low return of tagged salmon to the Big Salmon

River is undoubtedly influenced by the significantly high immediate mortality of smolts tagged during the latter part of the run. Such mortality would bias estimates of population size and fishing rate (Ricker 1958).

Only in 1971 did an increase in water temperature accompany the increase in tagged smolt mortality, and after the start of the smolt migration it is possible that short-term water temperature changes are of relatively minor importance in this regard. Although fenitrothion was sprayed over portions of the river basin in 1971 and 1972 before and during these tests, it is unlikely that the observed smolt mortalities could be related to this (Elson et al. 1972).

More particularly, factors such as osmoregulatory distress (Parker et al. 1963), resulting from the ease with which scales were lost and the deteriorating muscular tone or condition (Beverton and Bedford 1963) of smolts caught in the latter part of the run, may greatly increase the rate of immediate tagging mortality. Also, smolts are particularly susceptible to the effects of lactate accumulation induced by the "stress" of handling and tagging, because of the physiological state associated with migration (Parker et al. 1963). Improved survival of tagged salmon could probably be achieved by tagging only during the early part of the run.

Mean smolt lengths ranged from 13.5 to 15.1 cm and were significantly different between years. Osterdahl (1964) reported roughly similar mean lengths and yearly variation in length. Northwest Miramichi smolts, at 14.7 cm mean length (Forsythe 1967), and Gulf of Maine smolts, at 13-15 cm (Bigelow and Schroeder 1953), are comparable in length to smolts from Big Salmon River. Mel'nikova (1970) observed that smolts may differ considerably in size in different rivers but for a given river, lengths vary within limits characteristic of the population.

There was little change between years in the length-weight relationship, and mean weights closely followed the trend in mean lengths. The values of b in the length-weight regression equation approximated the value of 3.0, regarded as typical for isometrically growing fish such as salmonids (Tesch 1968). Mean smolt condition factors approximated 1.0, while Forsythe (1967) determined it as 0.7 for smolts from the Northwest Miramichi River. Hoar (1939) states that migrating, well-silvered smolts have a condition factor less than 1.0.

The often significant variation in smolt length at different times within the run followed no particular trend. Osterdahl (1964) proposed that such within-year variation is related to feeding conditions and the influence of smolt size on time of migration, but the present data are inadequate to resolve the question. The strong development of the migratory urge in larger smolts, as evidenced by the earlier migration of large smolts (Allen 1944; Osterdahl 1969), may account for their increased daylight movement as the run progresses. That smolt migrating during daylight hours may be significantly longer than smolt migrating during darkness has not been reported for some smolt runs (Hayes 1953; Osterdahl 1969).

That smolts showing plus growth on their scales are longer on average than those that do not, and that the percentage of smolts showing plus growth increases throughout the run has also been observed by Pentelow et al. (1933) and Forsythe (1967). An increase in mean smolt size did not always occur as the proportion of smolts with plus growth increased, as has been noted by Pentelow et al. (1933). Part of this growth may have been reflected in weight rather than length increase, since Allen (1941) has observed that high condition factors, such as found in Big Salmon River smolts, are a sign of rapid growth.

Mean smolt length is determined by the age composition of the run as well as the growth rate of the smolts, and the length fluctuations of Big Salmon River smolts are accompanied by even greater changes in age composition. Similar fluctuations were observed by Osterdahl (1969) in the smolt run of the Ricklean River. Mel'nikova (1970) states that the smolt-age composition of several Russian rivers varied from year to year in the same river. Wide fluctuations in the age composition of the smolt run are apparently characteristic of the Big Salmon River. The factors influencing this fluctuation are unknown, but Elson (1957*b*) reported that warm streams (over about 68°F in summer) produce predominantly 2-year smolts, while cool streams may produce older smolts. This relation evidently does not hold for this river, since its mean summer water temperature rarely exceeds 61°F. The relationships between the various environmental and biological factors affecting smolt length and age composition are complex and require more data to analyze than is available here.

The predominance of female smolts in the Big Salmon River agrees well with observations by Forsythe (1967, 1968) on the Miramichi River.

Smolt yield (all ages) from the Big Salmon River, 4.0/100 m^2, is lower than the 6-7 two-year smolts/100 m^2 suggested by Elson (1967*a*) as typical of Maritime streams like the Pollet and Miramichi rivers. This may reflect the lower productivity of this river, since streams with the highest rates of salmonid production tend to be dominated by populations of young fish (Le Cren 1969) and the smolt run of the Big Salmon River is about 50% age-3. Mills (1964) reported that the River Bran had a smolt run with age distribution characteristics similar to that of the Big Salmon River and that smolt yield averaged 2.8/100 m^2.

APPENDIX A

DISTRIBUTION OF HATCHERY-REARED JUVENILES

Hatchery-reared Atlantic salmon fry, parr and smolts have been planted in Big Salmon River at various times since 1956, (Table A-1).

The Hatchery-reared Smolt Evaluation Program began in 1968, with Big Salmon River as one of the test locations. It was terminated following the 1969 season due to negligible adult returns to the river. The following sections are based on a condensation and selection of information from the 1968-69 Evaluation Program Reports by R.A. Hyatt. (MS Reports. Unpublished. Resource Development Branch, Dept. of Fisheries and Forestry, Halifax.)

The program was designed to test several factors which might influence the survival of hatchery-reared smolts and their contribution to the fishery. These factors are:

(a) Distribution site - estuarial or headwater release.

(b) Parental origin - both early- and late-run stock from several rivers.

(c) Age at smoltification.

In both 1968 and 1969, the smolts used were progeny of Restigouche River early-run brookstock.

1968

After first being anaesthetized with MS-222, all hatchery smolts were tagged with blue, plastic, modified-Carlin tags, attached with monofilament threads. A group of 4,984 smolts, destined for headwater release, was marked with tag numbers B25,000-B29,999 between April 19 and 24. These were released upriver near Schoales Dam on May 6. Smolt mortalities due to tagging and transporting were minimal (8 dead).

Presumably, the smolts migrated to sea before May 14, when the counting fence commenced operation, as only 10 were recovered in the trap.

The estuarial-release group of 4,987 was tagged April 16-19, using tag numbers B20,000-B24,999. Of these, 4,981 were released on May 1-2.

Lengths of all tagged smolts were recorded to the nearest 0.5 cm. Two percent of the smolts had both fork and total lengths recorded to the nearest 0.1 cm. Length-frequency distributions of the estuarial- and headwater-release groups are shown in Table A-2. The range in sizes is considerably broader in the group released at tidehead, from 15.0 to 36.9 cm, as compared with 15.0-28.9 cm in the headwater-release group.

At tagging, the groups differed significantly in their mean lengths (tidehead 23.5 cm, headwater 20.7 cm). To convert smolt lengths from total to fork length for estuarial and headwater groups, multiply the total length by 0.907 and 0.938 respectively.

The hatchery smolts experienced some growth during their downstream migration (Table A-3).

Twenty-two post-smolts were recovered in commercial fisheries; none were reported angled. Most recoveries were from the trap-net fisheries of the Nova Scotian coast of the Bay of Fundy, but several were taken in the Passamaquoddy area of New Brunswick. Not one of these tagged, hatchery-reared salmon returned to Big Salmon River as an adult or grilse, nor were any recovered by other means.

1969

All hatchery-reared smolts were tagged with blue, plastic, modified-Carlin tags, attached with monofilament threads. The smolts were first anaesthetized with MS-222.

Tag numbers B30,000-B34,999 were used on the smolts destined for headwater release. A total of 4,972 smolts was tagged between April 9 and 15, of which 4,956 were released to the river on May 23 and 26. Two lots of blue tags were used on the estuarial-release group (C26,216-C29,999 and C34,826-C35,999). A total of 4,925 fish was marked between April 16 and 21, of which 4,887 were released below the counting fence on May 16 and 22. Smolt mortalities induced by tagging and transporting were low (60 dead in holding ponds).

The upriver release site was just below Schoales Dam. Table A-4 presents the length-frequency distributions of both estuarial- and headwater-release smolts.

The mean total length at tagging of the headwater-release group was 16.7 cm, with a range of 14.0-35.4 cm. The tidehead smolts were significantly smaller, having a mean total length of 15.7 cm and a length range of 13.0-30.4 cm. Conversion factors for estimating fork from total length and vice versa were respectively 0.949, 1.054 and 0.946, 1.057 for headwater- and tidehead-release groups.

Those smolts released upriver moved downstream very rapidly, with 210 being counted at the fence less than 24 hours later. Almost 99% of the smolts that were recaptured were taken within 13 days of the first release. Smolt growth during the period from tagging to recapture at the counting fence was considerable. How much of this growth occurred in the river is unknown, since they were held in a hatchery for some time before release. The mean total length of 195 smolts recaptured at the fence was 16.9 cm at the time of tagging (April 9-15) and 18.5 cm at recapture (May 24-June 4).

No post-smolts were reported angled, but 26 were recovered by the commercial herring and salmon fisheries in weirs along the Nova Scotian coast of the Bay of Fundy. As of 1972, none of the hatchery-reared smolts have been recorded as having returned to the river.

TABLE A-1. Distribution of hatchery-reared Atlantic salmon in the Big Salmon River system, Saint John County, New Brunswick, 1956-72. (Except as otherwise noted, all fish originated from the Saint John Hatchery in New Brunswick.)

		Numbers distributed	
Year	Size/Age	Main River	Tributaries
1956	No. 1 fingerlings	56,000	0
	Yearlings	15,446	0
	3 years old	1,242	0
1957	Fingerlings	135,000	0
	Yearlings	61,615	0
	2 years old	3,661	0
	Older fish	18	0
1958	No. 5 fingerlings	20,000	0
	Yearlings	5,000	0
	2 years old	15,057	0
1959	No. 2 fingerlings	11,420	6,500
	Yearlings	15,960	0
	2 years old	1,771	0
	3 years old	191	0
1960	Fry	108,220	0
	No. 2 & 4 fingerlings	31,760	0
	Yearlings	9,779	0
	Older fish	132	0
	No. 1 fingerlings	0	50,000
1961	No. 1 fingerlings	34,580	21,280
	Yearlings	7,380	0
	2 years old	23,428	0
	Older fish	107	0
1962	No. 4 fingerlings	37,932	0
	Yearlings	8,565	0
1963	No. 1 fingerlings	30,000	0
	Yearlings	29,652	0
	2 years old	9,997	0
	No. 1 & 2 fingerlings	0	97,000 (unspecified lakes)
1964	Yearlings	18,746	0
1965	2 years old	19,985	0
	3 years old	335	0

Year	Size/Age	Numbers distributed Main River	 Tributaries
1966	Yearlings & 2 years old	18,379	0
1967	No. 2 fingerlings Yearlings	47,120 2,325	0 0
1968	Smolts	9,969[1]	0
1969	Smolts	9,843[2]	0
1971	No. 2 fingerlings (Native stock)	0	60,000 (Crow Brook) 18,000 (Falls Brook)
1972	No. 2 fingerlings (Native stock)	0	64,360 (Flaglar and Saddleback brooks)

[1]Smolts originated at Antigonish Hatchery, Nova Scotia.

[2]Smolts originated at Florenceville Hatchery, New Brunswick.

TABLE A-2. Length-frequency distribution of hatchery-reared Atlantic salmon smolts, Big Salmon River, 1968.

Total length (cm)	Smolt releases			
	At Schoales Dam		At tidehead	
	No.	%	No.	%
15.0-15.9	12	0.3	1	0.0
16.0-16.9	77	1.6	6	0.2
17.0-17.9	969	19.3	71	1.5
18.0-18.9	1,214	24.4	314	6.2
19.0-19.9	937	18.8	479	9.6
20.0-20.9	553	11.1	450	9.0
21.0-21.9	362	7.3	418	8.4
22.0-22.9	300	6.0	433	8.7
23.0-23.9	245	4.9	481	9.7
24.0-24.9	142	2.9	571	11.5
25.0-25.9	109	2.2	474	9.5
26.0-26.9	43	0.9	537	10.8
27.0-27.9	17	0.3	349	7.0
28.0-28.9	4	0.1	230	4.6
29.0-29.9			127	2.6
30.0-30.9			32	0.6
31.0-31.9			5	0.1
32.0-32.9			5	0.1
33.0-33.9			3	0.1
36.0-36.9			1	0.0
Totals tagged	4,984	(4,984)[1]	4,987	(4,981)[1]

[1]Numbers actually released.

TABLE A-3. Lenghts at tagging and recovery of Atlantic salmon smolts released in the headwaters of Big Salmon River, 1968.

Tag number	Date tagged	Date recovered	Length at tagging (cm)	Length at recovery (cm)	Total length at recovery (converted)
B26,113	22 April	15 May	19+	19.2	20.4
B26,867	22 April	15 May	18+	18.2	19.3
B29,567	24 April	18 May	19+	28.7[1]	
B25,534	19 April	19 May	19+	28.9[1]	
B28,971	23 April	19 May	19+	19.3	20.5
B29,819	24 April	24 May	20	19.7	20.9
B27,472	22 April	30 May	18	18.0	19.1
B27,610	23 April	30 May	18	18.0	19.1
B26,038	22 April	8 June	20	19.4	20.6

[1]Measurements are probably in error.

TABLE A-4. Length-frequency distribution of hatchery-reared Atlantic salmon smolts, Big Salmon River, 1969.

Total length (cm)	Smolt releases			
	At Schoales Dam		At tidehead	
	No.	%	No.	%
14.0-14.9	15	0.3	1,179	23.9
15.0-15.9	1,521	30.6	1,762	35.8
16.0-16.9	1,855	37.3	1,007	20.4
17.0-17.9	998	20.1	605	12.3
18.0-18.9	335	6.7	229	4.7
19.0-19.9	110	2.2	63	1.3
20.0-20.9	28	0.6	17	0.4
21.0-21.9	19	0.3	6	0.1
22.0-22.9	16	0.3	17	0.4
23.0-23.9	22	0.4	6	0.1
24.0-24.9	17	0.3	8	0.1
25.0-25.9	12	0.2	5	0.1
26.0-26.9	8	0.2	8	0.1
27.0-27.9	5	0.1	8	0.1
28.0-28.9	4	0.1	2	0.0
29.0-29.9	5	0.1	2	0.0
30.0-30.9	1	0.0	1	0.0
35.0-35.9	1	0.0		
Totals tagged	4,972	(4,956)[1]	4,925	(4,887)[1]

[1]Numbers actually released.

APPENDIX B

TABLE B-1. Tagging data summary of Big Salmon River smolt releases, 1964-72.

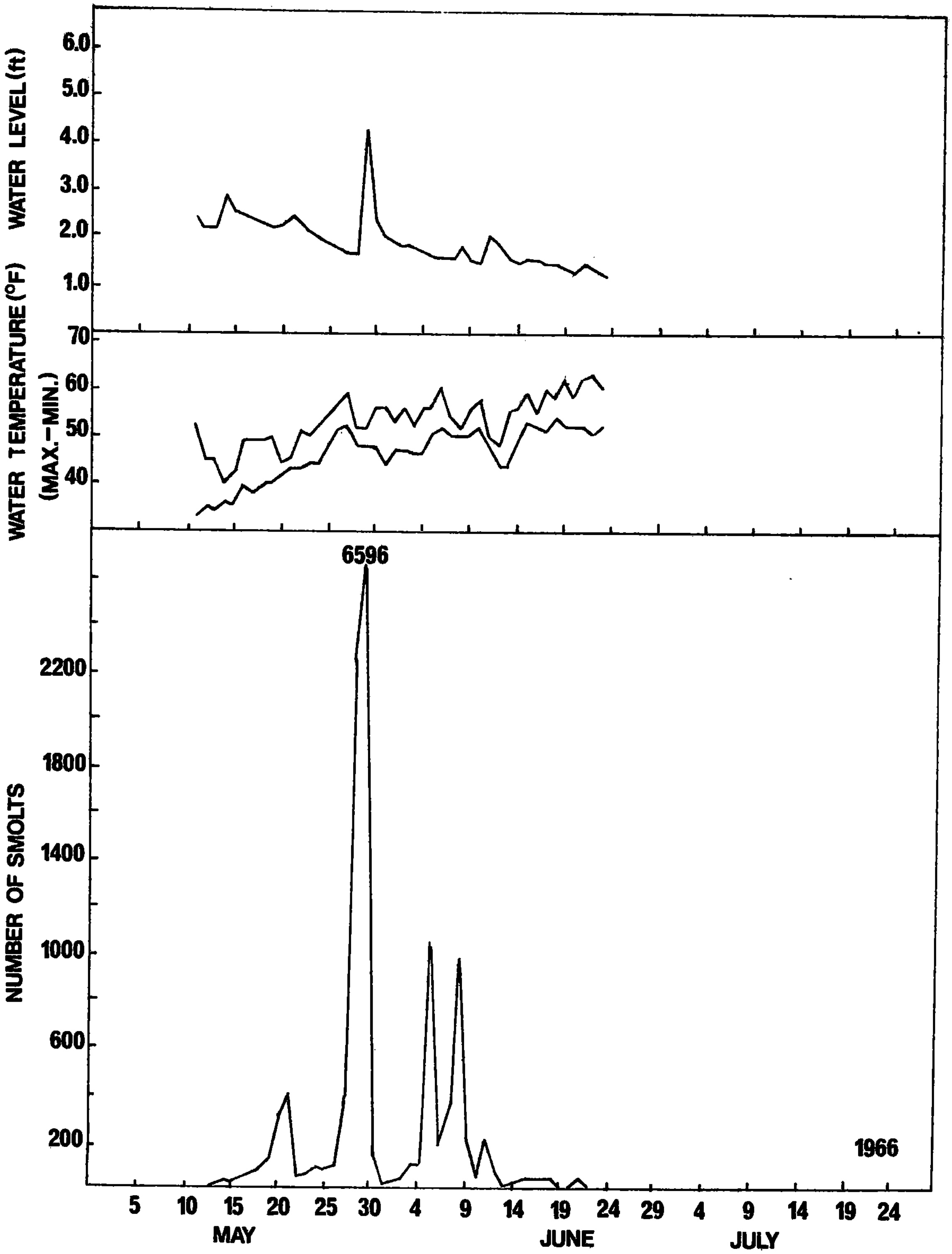
Year	Date	Stock origin	Age	Area stocked	Tag type	Numbers released
1964	Apr. 8-14	Curventon: early run	2-yr	Head of tide	Carlin (green)	9,824
1964	Apr. 14-17	Curventon: late run	2-yr	Head of tide	Carlin (blue)	7,942
1965	Apr. 6-7	Curventon: early run	2-yr	Above Walton Dam	Carlin (green)	9,963
1965	Apr. 6-7	Curventon: late run	2-yr	Above Walton Dam	Carlin (blue)	9,974
1966	Apr. 21	Curventon: early run	2-yr	Schoales Dam	Carlin (green)	7,988
1966	Apr. 21	Curventon: late run	2-yr	Schoales Dam	Carlin (blue)	9,991
1967	May 24-July 3	Wild: native	Unknown	Caught and released at counting fence[1]	Carlin (blue)	3,900
1968	May 1-2	Restigouche: early run	2-yr	Head of tide	Carlin (blue)	4,981
1968	May 6	Restigouche: early run	2-yr	Schoales Dam	Carlin (blue)	4,985
1968	May 15-June 16	Wild: native	Unknown	Caught and released at counting fence[1]	Carlin (blue)	5,200
1968	June 8-19	Wild: native	Unknown	Caught and released at counting fence[1]	Spaghetti (yellow)	719
1969	May 23 and 26	Restigouche: early run	2-yr	Head of tide	Carlin (blue)	4,956
1969	May 16 and 22	Restigouche: early run	2-yr	Schoales Dam	Carlin (blue)	4,887
1969	May 8-July 13	Wild: native	Unknown	Caught and released at counting fence[1]	Carlin (blue)	3,792
1970	May 7-July 13	Wild: native	Unknown	Caught and released at counting fence[1]	Carlin (blue)	9,864
1971	May 14-July 9	Wild: native	Unknown	Caught and released at counting fence[1]	Carlin (blue)	7,786
1972	May 31-June 15	Wild: native	Unknown	Caught and released at counting fence[1]	Carlin (blue)	1,600

[1]Fence is located approximately 200 yd above head of tide.

APPENDIX C

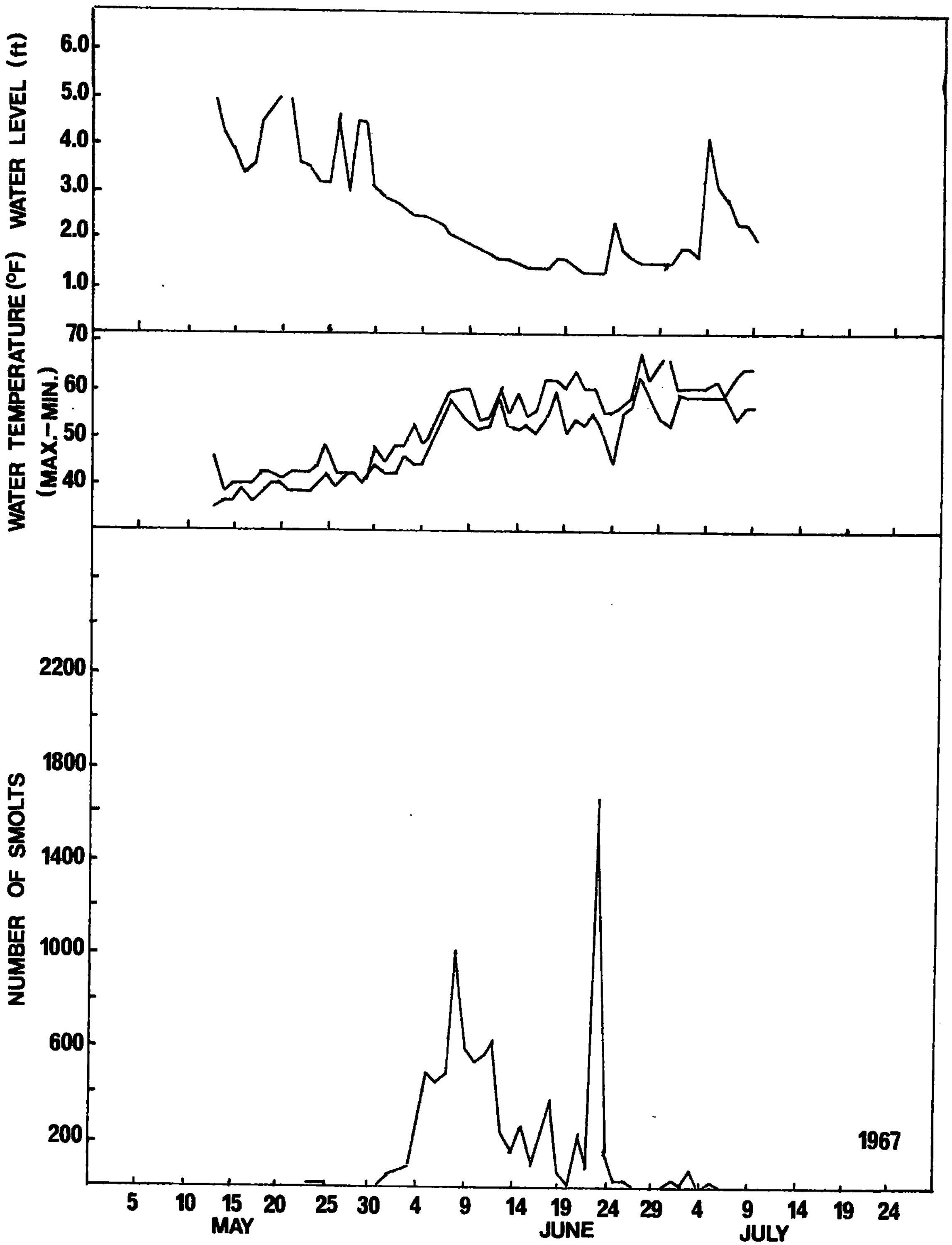
BIG SALMON RIVER SMOLT MIGRATION IN RELATION TO DATE, WATER TEMPERATURE AND WATER LEVEL

1966



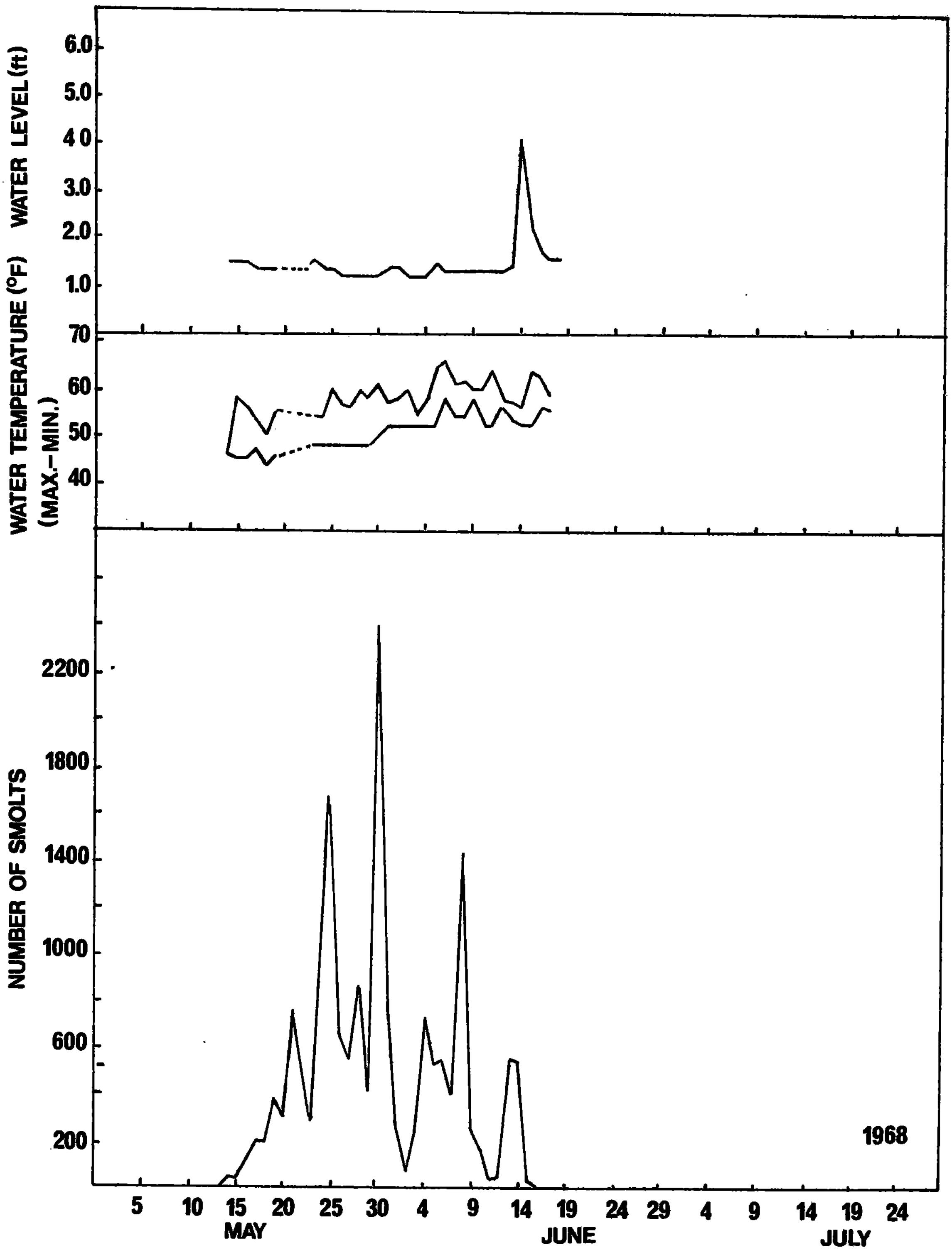
BIG SALMON RIVER SMOLT MIGRATION IN RELATION TO DATE, WATER TEMPERATURE AND WATER LEVEL

1967



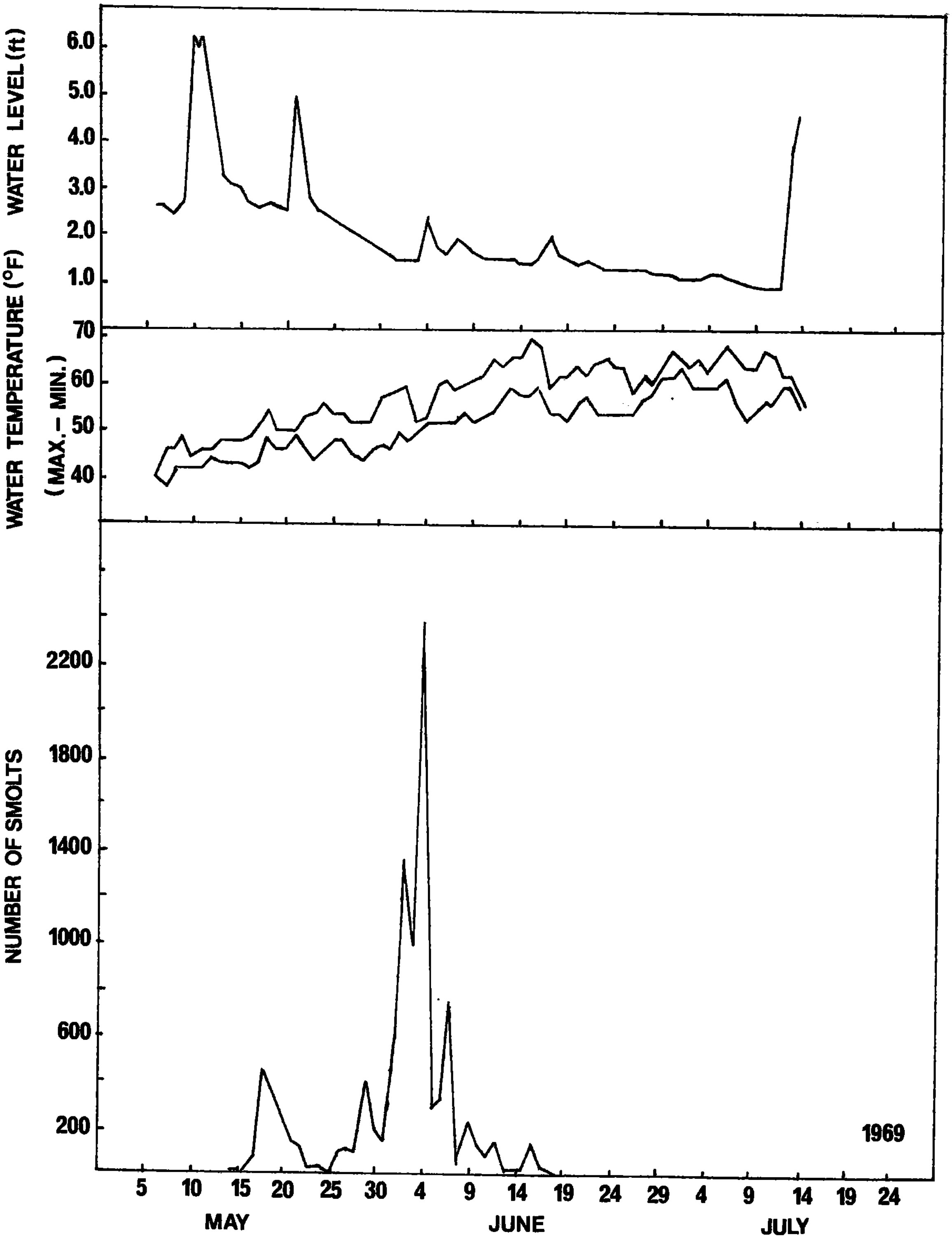
BIG SALMON RIVER SMOLT MIGRATIOU IN RELATION TO DATE, WATER TEMPERATURE AND WATER LEVEL

1968



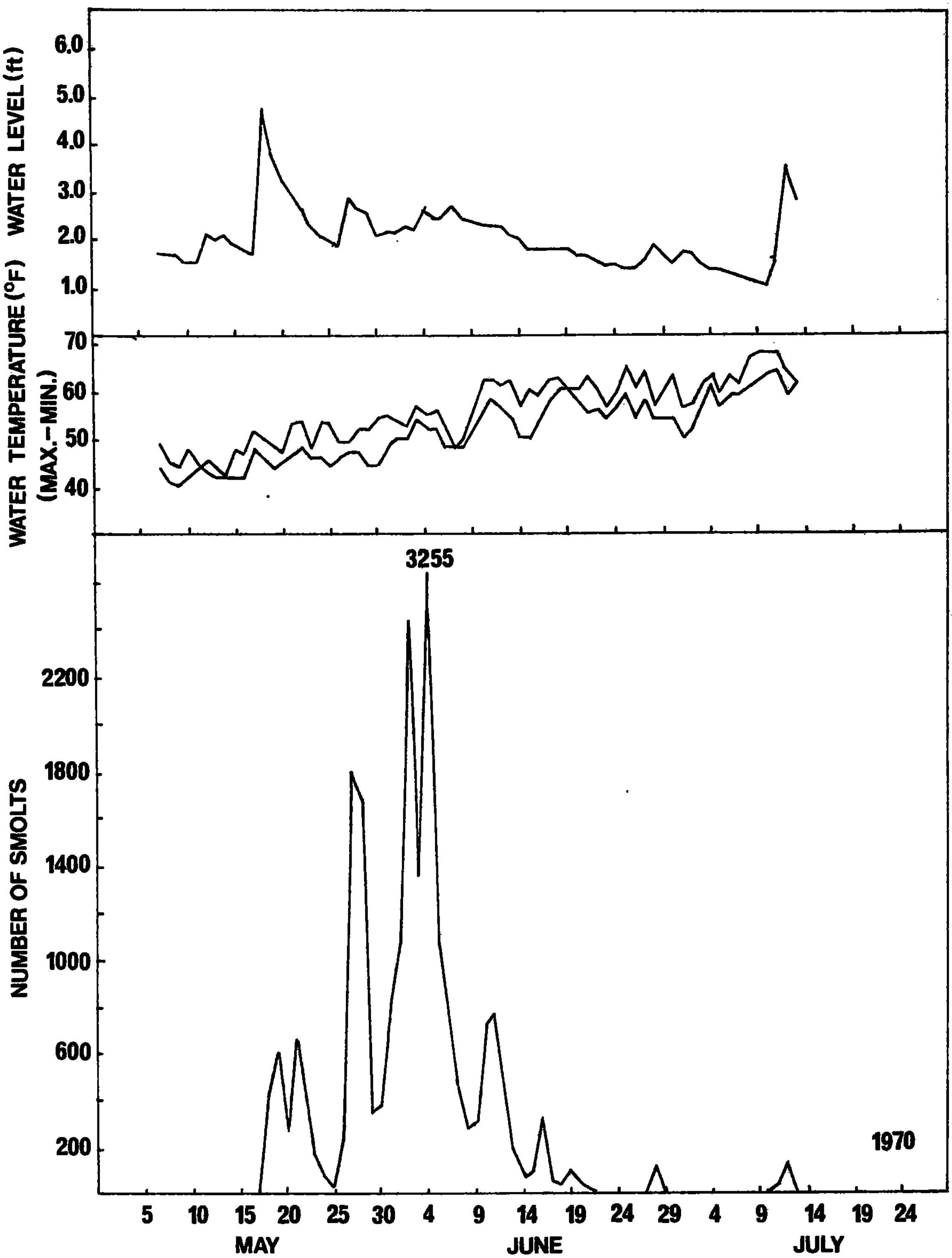
BIG SALMON RIVER SMOLT MIGRATION IN RELATION TO DATE,
WATER TEMPERATURE AND WATER LEVEL

1969



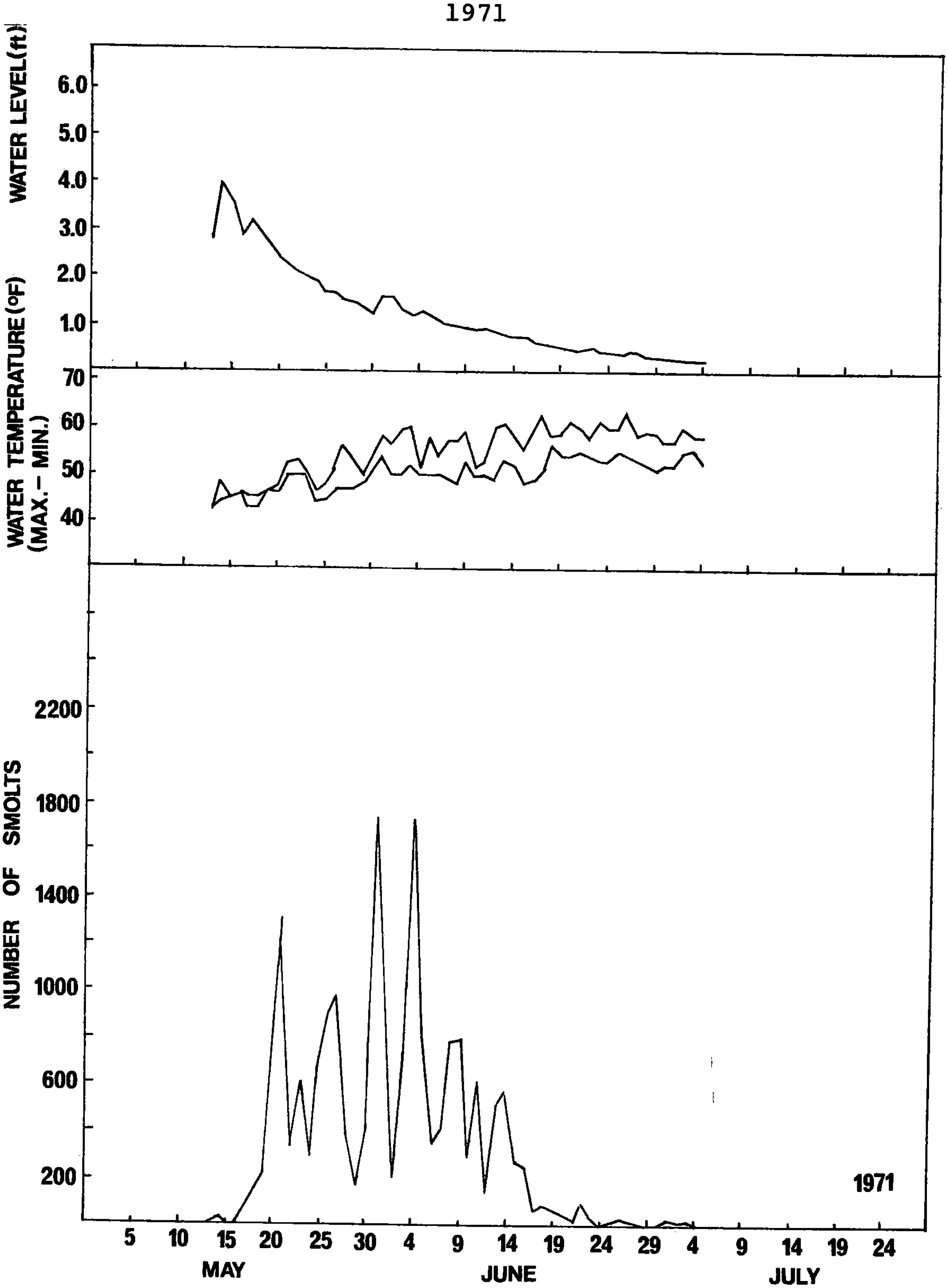
BIG SALMON RIVER SMOLT MIGRATION IN RELATION TO DATE, WATER TEMPERATURE AND WATER LEVEL

1970



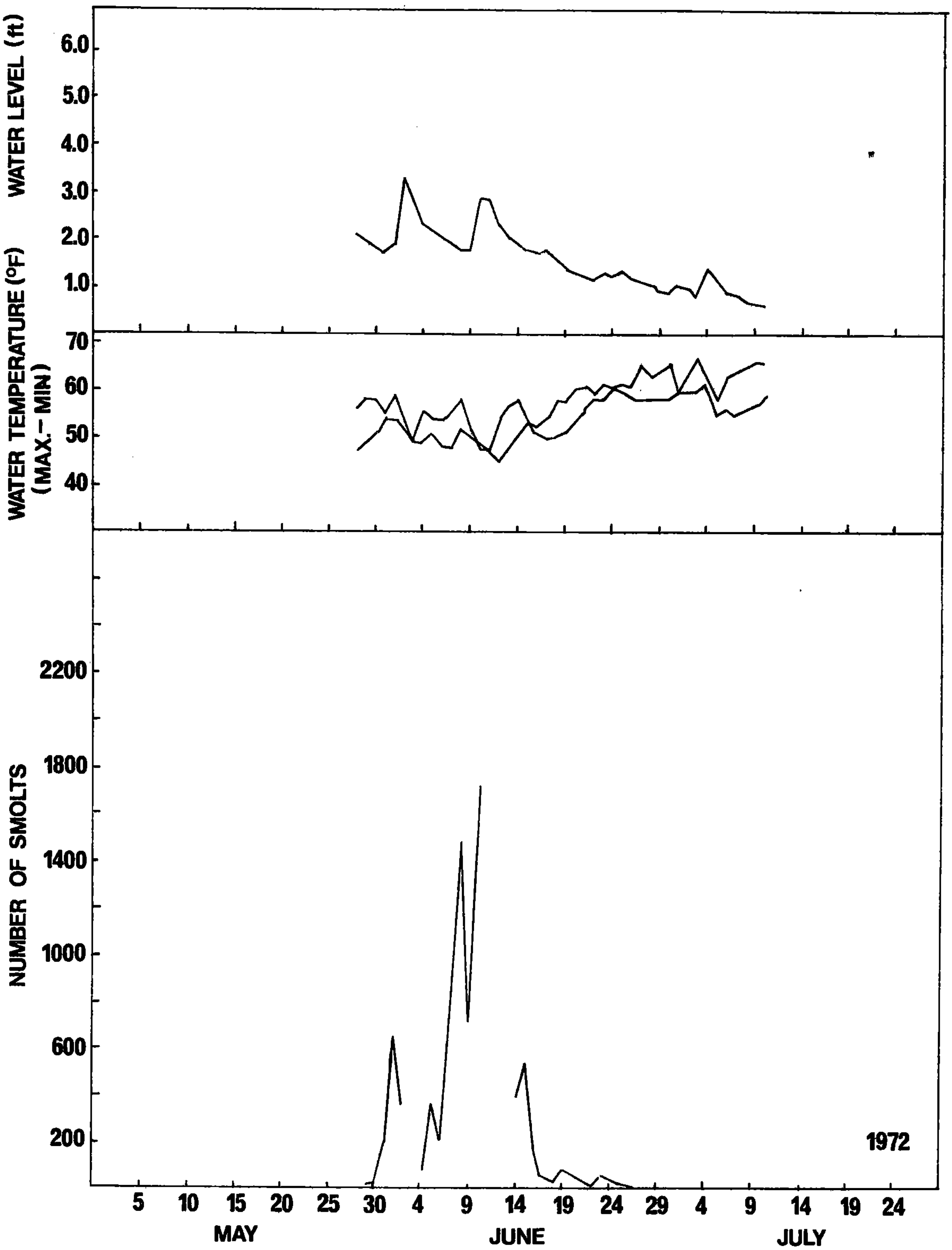
BIG SALMON RIVER SMOLT MIGRATION IN RELATION TO DATE, WATER TEMPERATURE AND WATER LEVEL

1971



BIG SALMON RIVER SMOLT MIGRATION IN RELATION TO DATE, WATER TEMPERATURE AND WATER LEVEL

1972



APPENDIX D

AGE-LENGTH FREQUENCIES OF BIG SALMON RIVER SMOLTS

TABLE D-1. Age-length frequency of native Atlantic salmon smolts, 1966.

Fork length (cm)	Age			Total
	2-yr	3-yr	4-yr	
12.5-12.9	1	2	0	3
13.0-13.4	1	2	0	3
13.5-13.9	0	3	0	3
14.0-14.4	7	5	0	12
14.5-14.9	8	7	0	15
15.0-15.4	4	4	0	8
15.5-15.9	14	4	1	19
16.0-16.4	3	1	0	4
16.5-16.9	8	1	0	9
17.0-17.4	1	1	0	2
17.5-17.9	3	1	0	4
18.0-18.4	0	0	0	0
18.5-18.9	0	0	0	0
19.0-19.4	0	1	0	1
Total	50	32	1	83

TABLE D-2. Age-length frequency of native Atlantic salmon smolts, 1968.

Fork length (cm)	Age			Total
	2-yr	3-yr	4-yr	
12.0-12.4	1	0	0	1
12.5-12.9	0	1	0	1
13.0-13.4	4	1	0	5
13.5-13.9	14	3	0	17
14.0-14.4	22	12	0	34
14.5-14.9	34	18	0	52
15.0-15.4	33	21	0	54
15.5-15.9	18	19	0	37
16.0-16.4	19	6	0	25
16.5-16.9	6	5	0	11
17.0-17.4	2	3	0	5
17.5-17.9	1	2	0	3
18.0-18.4	0	0	0	0
Total	154	91	0	245

TABLE D-3. Age-length frequency of native Atlantic salmon smolts, 1969.

Fork length (cm)	Age 2-yr	3-yr	4-yr	Total
12.5-12.9	1	0	0	1
13.0-13.4	6	4	0	10
13.5-13.9	7	6	0	13
14.0-14.4	24	20	0	44
14.5-14.9	26	17	1	44
15.0-15.4	18	20	0	38
15.5-15.9	5	8	0	13
16.0-16.4	5	8	0	13
16.5-16.9	1	3	0	4
17.0-17.4	0	1	0	1
17.5-17.9	0	0	0	0
18.0-18.4	0	1	0	1
Total	93	88	1	182

TABLE D-4. Age-length frequency of native Atlantic salmon smolts, 1970.

Fork length (cm)	Age			Total
	2-yr	3-yr	4-yr	
11.0-11.4	7	3	0	10
11.5-11.9	16	3	0	19
12.0-12.4	32	11	0	43
12.5-12.9	34	26	0	60
13.0-13.4	28	32	0	60
13.5-13.9	31	43	0	74
14.0-14.4	7	45	2	54
14.5-14.9	5	30	0	35
15.0-15.4	0	21	0	21
15.5-15.9	0	12	0	12
16.0-16.4	0	5	0	5
16.5-16.9	0	2	1	3
17.0-17.4	0	1	1	2
17.5-17.9	0	1	1	2
Total	160	235	5	400

TABLE D-5. Age-length frequency of native Atlantic salmon smolts, 1971.

Fork length (cm)	Age			Total
	2-yr	3-yr	4-yr	
10.5-10.9	3	0	0	3
11.0-11.4	21	0	0	21
11.5-11.9	56	7	1	64
12.0-12.4	120	30	0	150
12.5-12.9	152	63	0	215
13.0-13.4	64	88	3	155
13.5-13.9	40	114	5	159
14.0-14.4	16	118	4	138
14.5-14.9	4	114	11	129
15.0-15.4	6	105	10	121
15.5-15.9	5	53	21	79
16.0-16.4	2	36	24	62
16.5-16.9	0	17	11	28
17.0-17.4	0	7	7	14
17.5-17.9	0	1	5	6
18.0-18.4	0	0	2	2
Total	489	753	104	1,346

TABLE D-6. Age-length frequency of native Atlantic salmon smolts, 1972.

Fork length (cm)	Age 2-yr	3-yr	4-yr	Total
9.5- 9.9	1	0	0	1
10.0-10.4	1	0	0	1
10.5-10.9	2	0	0	2
11.0-11.4	14	0	0	14
11.5-11.9	26	0	0	26
12.0-12.4	64	4	0	68
12.5-12.9	65	4	0	69
13.0-13.4	72	33	0	105
13.5-13.9	54	28	0	82
14.0-14.4	44	46	0	90
14.5-14.9	23	24	0	47
15.0-15.4	8	28	0	36
15.5-15.9	3	11	0	14
16.0-16.4	1	4	2	7
16.5-16.9	0	0	1	1
17.0-17.4	0	0	0	0
17.5-17.9	0	1	0	1
18.0-18.4	0	1	0	1
Total	378	184	3	565

APPENDIX E

LENGTH-WEIGHT DISTRIBUTION OF BIG SALMON RIVER SMOLTS

TABLE E-1. Length-weight distribution of 316 native Atlantic salmon smolts, 1966.

Fork length (cm)	Number of smolts	Mean weight (g)	Weight range (g)	Standard deviation
11.5-11.9	1	15.2	-	-
12.0-12.4	6	18.4	15.6-19.8	1.611
12.5-12.9	9	21.0	19.0-25.0	1.822
13.0-13.4	36	24.3	21.8-29.2	1.664
13.5-13.9	16	25.7	24.1-28.6	1.293
14.0-14.4	43	27.9	23.4-33.0	2.002
14.5-14.9	61	31.5	26.4-35.3	2.127
15.0-15.4	39	33.8	28.3-39.3	2.302
15.5-15.9	47	38.4	29.9-45.3	3.225
16.0-16.4	15	40.0	29.0-44.8	4.013
16.5-16.9	26	44.3	36.4-52.5	4.067
17.0-17.4	3	44.1	36.1-48.5	-
17.5-17.9	8	51.6	46.3-59.4	4.760
18.0-18.4	2	56.0	53.0-59.0	-
18.5-18.9	0	-	-	-
19.0-19.4	2	55.6	44.5-66.7	-
19.5-19.9	0	-	-	-
20.0-20.4	2	82.3	79.2-91.6	-

TABLE E-2. Length-weight distribution of 244 tagged native Atlantic salmon smolts, 1968.

Fork length (cm)	Number of smolts	Mean weight (g)	Weight range (g)	Standard deviation
12.0-12.4	1	15.6	-	-
12.5-12.9	1	18.9	-	-
13.0-13.4	5	22.2	20.7-24.1	1.29
13.5-13.9	17	24.1	21.9-27.5	1.80
14.0-14.4	34	26.0	23.5-30.9	1.69
14.5-14.9	52	29.2	24.7-33.4	1.77
15.0-15.4	54	32.7	26.3-37.0	2.34
15.5-15.9	36	34.3	29.9-38.2	1.94
16.0-16.4	25	37.1	32.8-41.9	2.34
16.5-16.9	11	41.1	38.4-45.8	2.15
17.0-17.4	5	44.1	41.4-47.4	2.22
17.5-17.9	3	48.9	48.3-49.4	-

TABLE E-3. Length-weight distribution of 182 tagged native Atlantic salmon smolts, 1969.

Fork length (cm)	Number of smolts	Mean weight (g)	Weight range (g)	Standard deviation
12.5-12.9	1	20.6	-	-
13.0-13.4	11	21.9	17.5-24.7	2.51
13.5-13.9	12	24.8	22.5-28.6	1.69
14.0-14.4	44	27.1	22.9-34.0	2.14
14.5-14.9	44	29.7	20.6-35.0	3.05
15.0-15.4	38	32.2	28.0-35.7	1.61
15.5-15.9	13	36.1	32.1-45.0	3.16
16.0-16.4	13	39.3	36.7-41.9	1.75
16.5-16.9	4	43.6	42.3-44.2	-
17.0-17.4	1	48.3	-	-
17.5-17.9	0	-	-	-
18.0-18.4	1	52.6	-	-

TABLE E-4. Length-weight distribution of 400 tagged native Atlantic salmon smolts, 1970.

Fork length (cm)	Number of smolts	Mean weight (g)	Weight range (g)	Standard deviation
11.0-11.4	10	14.3	12.7-17.0	1.19
11.5-11.9	19	15.9	14.7-17.1	0.66
12.0-12.4	43	17.8	15.4-21.8	1.37
12.5-12.9	60	20.1	17.3-26.0	1.71
13.0-13.4	60	21.9	19.2-25.1	1.46
13.5-13.9	74	24.2	19.3-27.8	1.81
14.0-14.4	54	27.1	23.7-31.5	1.84
14.5-14.9	35	29.0	26.0-33.6	2.30
15.0-15.4	21	33.4	30.0-37.1	2.10
15.5-15.9	12	35.6	32.8-37.5	1.76
16.0-16.4	5	40.2	38.5-44.6	2.47
16.5-16.9	3	41.4	40.0-42.8	-
17.0-17.4	2	43.4	36.8-49.9	-
17.5-17.9	2	54.1	51.7-56.4	-

TABLE E-5. Length-weight distribution of 600 native Atlantic salmon smolts, 1971.

Fork length (cm)	Number of smolts	Mean weight (g)	Weight range (g)	Standard deviation
10.0-10.4	4	11.1	10.5-11.5	-
10.5-10.9	5	13.6	13.2-14.2	0.39
11.0-11.4	20	14.8	11.5-22.8	2.36
11.5-11.9	36	16.2	13.0-20.8	1.62
12.0-12.4	58	18.3	14.5-25.5	1.79
12.5-12.9	71	20.3	14.5-24.2	1.75
13.0-13.4	79	22.4	17.7-34.2	2.55
13.5-13.9	77	24.3	19.1-34.1	2.57
14.0-14.4	66	26.8	19.3-48.5	3.79
14.5-14.9	58	28.9	23.4-33.5	2.39
15.0-15.4	38	31.8	25.3-39.3	3.03
15.5-15.9	34	35.6	24.8-45.0	4.24
16.0-16.4	25	39.5	34.0-48.0	2.98
16.5-16.9	15	42.5	35.1-54.4	5.38
17.0-17.4	4	47.8	45.5-50.2	-
17.5-17.9	3	52.1	50.0-54.0	-
18.0-18.4	6	50.1	40.8-60.1	6.61
18.5-18.9	0	-	-	-
19.0-19.4	0	-	-	-
19.5-19.9	1	68.4	-	-

TABLE E-6. Length-weight distribution of 667 native Atlantic salmon smolts, 1972.

Fork length (cm)	Number of smolts	Mean weight (g)	Weight range (g)	Standard deviation
9.5- 9.9	1	9.3	-	-
10.0-10.4	1	10.6	-	-
10.5-10.9	5	12.1	11.2-13.2	0.84
11.0-11.4	16	13.6	9.4-17.2	2.03
11.5-11.9	31	16.3	14.0-20.2	1.74
12.0-12.4	77	17.9	13.9-21.7	1.57
12.5-12.9	77	20.2	17.1-25.2	1.87
13.0-13.4	122	22.5	15.0-28.1	2.08
13.5-13.9	96	25.1	19.1-39.4	3.01
14.0-14.4	102	28.2	22.0-38.5	2.66
14.5-14.9	62	32.0	22.1-38.0	2.71
15.0-15.4	43	33.8	22.7-44.3	3.90
15.5-15.9	19	38.6	34.0-45.3	3.24
16.0-16.4	9	43.1	39.5-50.5	3.48
16.5-16.9	4	47.9	43.6-54.5	4.76
17.0-17.4	0	-	-	-
17.5-17.9	1	52.5	-	-
18.0-18.4	1	67.7	-	-

APPENDIX F

LENGTH-WEIGHT RELATIONSHIPS

TABLE F-1. Calculated length-weight relationships of Atlantic salmon smolts, Big Salmon River, 1966-72.

Year	No. of fish	Length-weight relationship	Correlation coefficient (γ)
1966	317	$W = 0.0229L^{2.6858}$	0.952
1967	-[1]	-	-
1968	245	$W = 0.0156L^{2.8007}$	0.926
1969	182	$W = 0.0184L^{2.7482}$	0.906
1970	300	$W = 0.0167L^{2.7910}$	0.950
1971	400	$W = 0.0001L^{2.6546}$	0.945
1972	300	$W = 0.0079L^{3.1058}$	0.958

[1]Data unavailable.

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