## Analysis of the 1965

## Smolt Run in the

Northwest Miramichi River,

## New Brunswick

by M.G. Forsythe

FISHERIES RESEARCH BOARD OF CANADA

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# Al:ALYSIS OF THE 1965 SHOLT RUN IN THE NORTHWEST MIRAMICHI RIVER, NEW BRUNSWICK by <br> IIChael George Forsythe 

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# ANALYSIS OF THE 1965 SMOLT RUN IN THE NORTHWEST MIRAMICHI RIVER, NEW BRUNSWICK 

by
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Thesis submitted in partial fulfillment of the requirements for the degree of Bachelor of Science with Honours
in the Department of Biology
at Acadia University

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## This thesis by Michael George Forsyth

is accepted in its present form by the Department of Biology as satisfying the thesis requirement for the Degree of Bachelor of Science with Honours in Biology

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Approved by the Honours Committee


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#### Abstract

During the 1965 smolt run in the Northwest Miramichi River in New Brunswick, 1000 smolts were collected and examined for length, weight, age, plus growth, sex, and condition factor. Comparisons between the daily water level, the water temperature, and the number of smolts in the daily run were also made.

The average length of the smolts in the sample was 14.7 centimetres, and the average weight was 21.9 grams. Larger fish dominated the early and late parts of the run.

Three-year smolts formed $87.8 \%$ of the sample; 2-year smolts formed $11.1 \%$; and 4 -year smolts formed $1.1 \%$. The number of 2-year smolts increased slightly as the season advanced, while the number of 3 -year smolts decreased slightly as the season advanced. The size of the smolts increased with age.

The number of smolts showing plus growth increased as the season progressed. Females dominated the run, decreasing slightly toward the latter part of the season. More males were noted in older age groups. Of the 1000 smolts collected, 664 were female and 336 were male.


The peak of the smolt run occurred as the daily water level was dropping and the daily water temperature was rising.

The average condition factor of all the smolts was 0.7 .

## LIPE HISTORY OF ATLANTIC SAIMON

The Atlantic Salmon (Salmo salar) smolt run in any river is the migration of the young salmon to the sea. The smolt stage is the most delicate of all stages and is characterized by silvery sides, and a dorsal colouring which may vary from almost black to light green, or brown. The dorsal colouring is related to the type of bottom over which the smolts grow.

Adult salmon deposit eggs on gravel bottoms in their native river, and usually bury them several inches deep where the water is clear. Eggs are deposited in autumn and hatch during the spring of the following year. Newly hatched salmon, called alevins, are nourished from a yolk sac which is lost before swimming begins. This usually occurs late in June in the year of hatching, depending on the temperature of the water. At this stage they are about two inches long, and are termed fry.

During the fry stage scale growth commences, and by the end of the summer, the fry are fairly well marked with parr characteristics. The transition from fry to parr is assumed to occur when the fish reach a length greater "than a man's finger" (Jones 1959). The change from fry to parr is only a change in size.

If feeding conditions are good, fry become small parr the following spring. Parr exhibit 8 to 11 dark bars, and red spots on their sides, most numerous about the lateral line. From the parr stage, the fish change into amolts. No definite reason for the latter change has been found, but it is thought to be associated with size and physiological factors. The major change characterizing this stage is the deposition of guanine on the scales, giving a silvery coating to the lateral and ventral surfaces of the fish which obscures the parr bars and red spots.

The smolt stage represents the transition between the fresh and salt water life of the salmon, and the young salmon now leave their native rivers and descend to the sea until they return to spawn. Pentelow, Southgate, and Bassindale (1933) reported the size as being a factor of importance in inducing migration and that before they can migrate "they must have attained some physiological condition which is associated with a definite minimus size." Whatever the cause of the migration, it is with the exemination of this stage of Balmo selar that this paper is concerned.

## LITERATURE REVIEW

Previous work in this field has been extensive. The following reports and works were used as references in the Miramichi work in 1965.

Pentelow, Southgate, and Bassindale (1933) reported on smolts in British rivers. In the River Tees their data on age, sex, and length were collected from smolts killed by pollution and picked off the estuary shore. Their reports on other rivers were taken from works by Meek (1925), Menzies (1921), and Hutton (1932).

Blair (1934) issued a report entitled "Ages at Migration of Atlantic Salmon (Salmo salar) in Miramichi River." The fish he examined were caught in the estuary and bay of the Miramichi River in 1931, and were obtained as follows: 271 salmon from the fish house of Mr. A. F. Betts at Millerton, N.B.; 421 large salmon and 46 grilse from the A. and R. Loggie Company, Loggieville, N.B.; and 88 salmon and 128 grilse from Mr. David Kelly's stand at Loggieville, N.B. The fish from the bay consisted of 603 salmon obtained from the W. S. Loggie Company, Hardwicke, N.B. These fish were caught eastward of a straight line from Escuminac breakwater to the western end of Neguac Island, usually not more than twelve miles out. These data would represent salmon from the whole Miramichi system.

Tchernavin (1939), in hi s "Ripe Salmon Parr: a Summary of research," summarized the work of other investigators on the fertilization powers of parr, and on the ages at which they are ripe. In Ireland, Hewetson (1958) reported scale readings made from 881 large salmon. Thesa fish were taken in the River Corrib by nets, weirs, rod and line in 1956, 1957, and 1958. Jones (1959) reported a general description of salmon at all stages. He compiled a book on his own work and from the work of others. Twomey (1959) reported the age of smolts in the River Erne in Ireland. Scales for this work were taken from large salmon going through a fish pass at two hydro-electric plants, one at Cathaleen's Falls, and one at Cliff, further upstream.

Azbelev and Lagunov (1960) issued a report on smolts of the Kola Peninsula Rivers. These data were obtained from large salmon caught by fishermen in the Barents and White Seas.

Azbelev (1963) organized and assessed material on Salmo salar of the Kola Peninsula of Northern Russia. Collections of material were made by workers of the Polar Research Institute of Marine Fisheries and Oceanography (PINRO) and the Ichthyological Station, Murmangosrybvod, and since 1958 collections on the salmon of the Tuloma River stock have been made entirely by Murmangorryivod.

Österdahl (1964) compiled a report of lengths, ages, and sexes of smolts caught at a counting fence located a short distance from the mouth of the River Rickleån, in Sweden. Went (1964) reported on the 1963 smolt ages in the Rivers Foyle and Finn in Ireland. In the River Foyle, 1442 sets of large salmon scales were obtained from fish taken in the commission's own fishery, while in the River - Finn, 88 sets of scales were obtained from salmon taken by rods.

## OBJECTIVES

The study was conducted to obtain fundamental information on the Northwest Miramichi smolt run. The collection of a representative sample ( $1 \%$ ) of the Miramichi smolts was a first objective. I hoped to obtain information about Miramichi smolt characteristics and compare them with that of other areas. Smolt characteristics were also studied relative to the time of the run. The information obtained will be used in continuing the study in future years. It will make possible yearly comparisons, and give a more complete picture of the smolts as an integral part of the biology of the Atlantic Salmon, in the Northwest Miramichi River.

SCOPE

The Northwest Miramichi River is approximately 80 miles long. Figure 1 shows the river with its tributaries and the location of the Curventon Counting Fence, about 28 miles from the Miramichi Bay, where the smolts were captured. The Northwest Miramichi River is located in Northeast New Brunswick, and flows into the Gulf of St. Lawrence.

Smolts were taken from this river during the entire run in 1965. Smolt runs vary in numbers, but occur at approximately the same time each year. In 1965 the smolt run began on May 10 and lasted until June 29, with a few being caught during a small freshet on July 20 and 21.

Each day a small portion of the run was kept for a sample, and these fish were preserved in $10 \%$ formalin for future examination. The effect of formalin on the length and weight of the smolts was studied. Smolts were examined for length, weight, age, sex, the amount of plus growth shown on their scales, and their condition factor. A comparison between numbers of smolts in the run, water level, and water temperature was also made.

## TECHNIQUES

Method of Capture.

The smolts were captured in a trap at the counting fence which is located at position 6, Figure 1. A base plan of this counting fence is shown in Figure 2, and a completed section of it showing the centre and west traps, "A" frames, catwalk, and steel racks is shown in P弾te 1. This fence formed a complete barrier of the river, so the sample is a portion of all the smolts descending to the sea. A daily record of the total number of smolts descending the river was also kept.

The trap from which most of the smolts were taken for the sample was the east trap, although a few were taken from the west trap. Both the east and west traps had entrance funnels, and were set up to catch fish descending the river.

At the lower end of the east trap there was a sluiceway with water from the trap flowing into it. The sluiceway was about 20 feet long, 2 feet wide, and approximately 3 feet high. It was made of aluminum sheet with oneeighth inch holes bored every half-inch. At the upper end of the sluiceway there were 2 hinges which permitted the lower end to be lowered, depending on the water level. At the upper end of the sluiceway therre was about one foot of water, and at the lower end about 4 inches of water.

The sluiceway led to a lower east trap, which had all but one small portion of its sides boarded. The purpose of the sluiceway and lower east trap was to create a pool of quiet water with little or no water flow, where the smolts could rest easily until they could be released.

Each day before the smolts were taken for tagging and released, a seine net was run through the lower east trap and the sample was collected. On days with a large number in the run only a small portion was kept, and on days with few smolts in the run, all were kept.

Preservation of Smolts.

The smolts were kept alive in a tub with water running into it until they were examined. If time permitted, they were anaesthetized, measured, weighed, identified with a tag or fin clip, recovered in water, put in a cheesecloth bag with a tag containing the date on it, and killed in $10 \%$ formalin. The purpose of recovering the smolts before putting them in formalin was that they preserved better when placed in formalin alive. The anaesthetic used was 2-methyl-2-butanal,-tertiary-pentyl alcohol-diluted approximately 50:1.
$\left(\mathrm{CH}_{3}\right)_{2} \mathrm{C}\left(\mathrm{CH}_{2} \mathrm{CH}_{3}\right)$ OH tertiary-pentyl alcohol

The smolts taken on the following dates were measured and weighed before being put into formalint May $10,14-21$, $23-28$, June 14, 21-25, June 29, and July 20 and 21 . On all other days the smolts were put in a cheesecloth bag, labelled with the date, and placed directly into $10 \%$ formalin, as time did not permit measuring and weighing prior to preservation.

The latter process made necessary the devising of a method for the determination of the length and weight of preserved smolts as it was found changes occured in formalin. Determination of Length and Weight after Preservation.

On May 19, 30 smolts were taken and used as the basis of this method. They were measured, weighed and individually identified with tags prior to being put in $10 \%$ formalin on May 19, and were remeasured and weighed on the following dates: May 20, 21. 23, 25, 26, 27, 28, June 3, 9, and 21. While in formalin, the smolts decreased in length and increased in weight. After 3 days they had reached a stable length, and after 8 days had reached a relatively stable weight. After reaching the relatively stab?e veight, the smolts varied from day to day, being either $0-.5 \mathrm{~g}$ heavier or lighter per day. On June 21 , the change in length and weight for each smolt was determined. From these data the per cent decrease in length and the per cent
increase in weight were calculated for each smolt. The mean per cent decrease in length, and the mean per cent increase in weight for all 30 smolts were then calculated.

The following terms must be clarified before describing the remainder of the procedure.

1) Pinal length and weight are the length and weight of the smolts after being in formalin about one month.
2) Original length and weight are the length and weight of the smolts when taken from the river.

All the calculations were based on the final lengths and weights, because these were the only lengths and weights available from smolts which were placed directly into formalin on the day they were captured.

The range of length decrease was from $0.3-0.8 \mathrm{~cm}$, with a mean decrease of 0.6 cm . The range of weight increase was from $0.9-3.5 \mathrm{~g}$, with a mean increase of 2.1 g . Larger smolts gained more weight, but averaged about the same loss in length as smaller smolts. For all 30 smolts, the mean per cent decrease in length was 3.9 of the final length and the mean per cent increase in weight was 8.1 of the final weight. To obtain the original length, $3.9 \%$ of the final length was added, and to obtain the original weight, $8.1 \%$ of the final weight was subtracted. This method was used for smolts taken on May 22, Nay 29 - June 13 (inclusive),

June 15-20 (inclusive) and June 26. The length of all smolts was the total length, from the tip of the snout to the tip of the tail. The measurements were taken on a metre stick, and the fish were measured to the nearest one-tenth of a centimetre. An error in the metre stick was $\pm 0.1 \mathrm{~cm}$ and should be considered in relation to individual measurements. All calculations were made without the error.

Weights were made using a pan balance with a weight arm on the right-hand side of the pan. It was checked for accuracy with a corrected set of weights obtained from the St. Andrew's Biological Station. The balance was found to weigh 0.1 g too heavy in the following weight ranges : $0.73-1.0 \mathrm{~g}, 17.3-20.0 \mathrm{~g}, 27.3-29.9 \mathrm{~g}, 47.3-50.0 \mathrm{~g}$. Weights were taken to the nearest one-tenth of a gram with an error in the balance scale of 0.05 g .

Age Determination.

The scale reading technique was used in determining the smolt age. A sample of scales was taken from an area dorsal to the pelvic fins, posterior to the dorsal fin, and ventral to the lateral line. These scales were put in water, and read under high (80x) or medium (40x) power, using a binocular microscope. The number of rings of plus growth on
each scale was also noted. Plates 2 and 3, Plates 4 and 5, and Plate 6 show scales of a 2-year smolt with plus growth, a 3-year smolt showing plus erowth, a 3-year smolt with a possible spawning mark, a 4-year smolt with a start of plus growth, and a regenerated smolt scale, respectively. A regenerated scale is one which replaces a lost scale, and no age can be determined from it.

A year of growth is represented by a band of widely spaced dark ridges, and a band of narrowly spaced dark ridges. These can be seen in the Plates 2 through 5. The widely spaced ridges represent summer growth when the fish are feedine well, and the narrowly spaced ridges represent winter growth when the fish are feeding less. On the outermost winter bands some "cuttine off" of the dark ridges may be seen; that is the ridges are not completed, but are microscopically visible in only a portion of the complete ring which they normally form. Plus growth rings can be seen on the outer portion of the scales shown. This is growth which occurs in the spring of migration.

Most smolts do not show spawning marks, but the scale shown in Plate 4 has what possibly is a spawning mark. A spawning mark, which occurs when the smolt spawns, is an erosion of the scale causing some rings to be obliterated.

Many scales were questionable on the first reading.

Any questionable scales were set aside and ohecked by myself, Mike Dadswell, a Carleton University student, or one of the technicians at the fencesite. A decision was reached on each of these scales and the age recorded.

Sex Determination.

There was no method of distinguishing the sex of the smolts by external observation. In order to determine the sex, a smolt was cut from the pectoral region on both sides to posterior of the anal opening, and the gonads examined. Visual observation of the gonads, or microscopic examination of a section of the gonads, was the only way to determine the sex of the smolts. Plates 7 and 8 show the female and male smolt gonads, respectively, with the viscera removed. Plates 9 and 10 show a cross-section of a female and male smolt gonad respectively. By visual observation, some smolts were questionable as to sex and microscopic examination of a portion of the gonads was made.

Water Level and Temperature.

Mean daily water levels were calculated from measurements taken at 0800 hours and 1700 hours. On May 10 , the water level stick was not in operation, and no data were available for that day.

Water temperature in degrees centigrade, was also recorded at 0800 hours and 1700 hours and a mean daily water temperature was calculated. The mean dally water level and water temperature were correleted with the number of smolts in the daily run (Fig. 22).

## Condition Factor.

The condition factor ( $K$ ) for the smolts was also calculated. The formula used was: $K=\frac{100 \mathrm{~W}}{\mathrm{~L}^{3}}$, where W was the weight in grams, and $L$ the length in centimetres. This formula gives an answer approximating unity for normally fed fish. If a fish has a condition factor of one or above, it is in good, healthy condition; whereas a fish with a condition factor below one is in poor condition. Mean daily, mean 5-day period, and mean annual condition factors were calculated.

## RESULIS AND DISCUSSION

Smolt Run and Sample.

During the smolt run of $1965,26,778$ smolts descended the river. One thousand smolts, or $3.7 \%$ of the total run, were kept in a sample to be examined.

The number of smolts kept daily varied depending upon the total number in the run for a particular day. Figure 3 shows the number of smolts in each daily run, and the number of smolts kept in each daily sample. Figure 4 shows the per cent of the daily run kept in the sample. On days with a smolt run of 1-21, all the smolts were kept in the sample; and on days with a large run, only a portion of the total number was kept. Table 5 gives the number of smolts in both the run and sample during 5-day periods.

On the following days, after the beginning of the run, there were no smolts taken: May 11-13 (inclusive), June 27, 28 , and June 30 - July 19 (inclusive), and none after July 21.

## Length.

The range in length of the 1965 smolts collected was from $11.7-20.6 \mathrm{~cm}$. This range compares favourably with that of British smolts in the River Tees, where in 1930, 1,176 smolts exhibited a total length range of $10.8-20.3 \mathrm{~cm}$, and in 1931,

3,289 smolts exhibited a range of $10.8-19.0 \mathrm{~cm}$ (Pentelow, Southgate, and Bassindale, 1933).

Figure 5 shows the length of the smolts in centimetre groups. The $14.1-15.0 \mathrm{~cm}$ group contains a greater percentage of smolts than any other, and a smaller percentage of the smolts is contained in each successive group preceding and following this group.

The average length of all the smolts in the sample was found to be $14.7 \mathrm{~cm} \pm 0.1 \mathrm{~cm}$. In the River Tees in 1930, the average total length of 1,176 smolts was 14.7 cm ; and in 1931, 3,289 smolts averaged 14.5 cm (Pentelow, Southgate, and Bassindale, 1933). These lengths were taken to the nearest quarter-inch. Österdahl (1964) reported that in the River Rackleån the mean length of smolts in 1961, 1962, 1963, and 1964 was $15.3 \mathrm{~cm}, 15.8 \mathrm{~cm}, 16.1 \mathrm{~cm}$, and 15.9 cm respectively.

The average daily length of the smolts is portrayed in Figure 6 and in Table 1. The curve in Figure 6 shows a gradual increase in average length from May 27 until the end of the run, and a decrease in average daily length from May 14-27. The smolts of May 22 and 27 were noticeably shorter than the smolts of other days. The average daily length range was from 13.9 cm on May 27 to 16.4 cm on May 24, excluding small samples of May 26, and July 20-21. Data from these days are shown on Figure 6 to complete the figure. The gradual increase in average length as the season progressed
cun be more clearly aeen in Figure 7, where the average length per 5-day period is plotted. Oisterdahl (1964) reported an increase in length as the season advanced. Weight.

Figure 8 shows that the average weight during 5-day periods decreased from 24.4 g , during May $10-14$, to 20.0 g during May 30 - June 3. After June 3, there was a gradual increase in average weight per 5-day period to 27.4 g on June 29 - July 3. The fish of July 20,21 are excluded here as samples were inadequate, but are shown in Figure 8.

The weight range, for all smolts collected was 10.6-65.6 E. The same two smolts produced the extremes for both length and weight. The average weight of all smolts collected was $21.9 \mathrm{~g} \pm 0.05 \mathrm{E}$.

From Figure 9, a gradual increase in average daily woight can be seen from June 4 until the end of the run. On May 22, the average weight was light compared to the average for other days.

Table 1 provides a complete list of average daily weights and lengths. The smolts of July 20-21 were large compared to the smolts of other daily runs. The average length and weight of the smolts per weekly period of the run are shown on Table 2 .

Age.

The age of the smolts as they descended the river is positively correlated with the length and weight of the fish. As shown in Table 3, there is a gradual increase in the length and weight as the number of river years increases, except between $2+-y e a r$ smolts and 3 -year smolts. In this latter case, the 2+-year smolts averaged 14.6 cm in length and 22.2 g in weight, whereas the 3-year smolts averaged 14.6 cm and 20.8 g . Table 3 gives the average length, weight, and the total number of smolts for five age classes.

The average length of all 2, 3, and 4-year smolts in the Northwest Miramichi in 1965 was $13.7 \mathrm{~cm}, 14.6 \mathrm{~cm}$, and 15.7 cm .

The smolt age gives the number of years the smolt has been in fresh water since its hatching. In more northerly rivers with colder waters than the Miramichi, the smolts are older at migration. In the Northwest Miramichi the main bulk migrated at $3+$ years. The plus ( + ) sign indicates that the smolt has put some growth on its scales in the spring of migration. Figure 10 shows the number of 2, 3, and 4-year smolts in the daily sample. These data for 5-day periods are shown on Table 5. The per cent of 2, 3, and 4-year smolts per day is shown on Figure 11. During the first part of the run all the smolts were 3 river years with the first 2 -year smolt being taken on May 19, and the first 4 -year smolt taken on May 20.

The proportion of 2 -year smolts showed a slight increase as the season advanced, and the proportion of 3-year smolts showed a slight decrease as the season advanced, but the latter year class predominated throughout the run. Österdahl (1964) reported a similar situation between 2 and 3-year smolts in the River Rickleå. The 4-year smolts averaged one or two a day from May 20 to June 8, after which there were none.

The gradual per cent decrease of 3-year smolts during the run, and the gradual per cent increase of 2 -year smolts per 5-day period can be seen on Figure 12. The 4 -year smolts form only a small curve at the base of the figure. Such days as May 16 (one smolt) and May 26 ( 3 smolts) have samples which are too small for proper comparison and the extremities of all figures are formed by such samples. In this report, these days will be considered as being too small for proper comparison. The distribution of age classes in this study was: 2-year smolts $11.1 \%$, 3-year smolts $87.8 \%$, and 4 -year smolts $1.1 \%$. Blair reported the age class percentages in the Miramichi system in 1934, from scale readings of 1,557 large salmon, as being: 2 -year, $15.1 \%$; 3 -year, $78.1 \%$; 4 -year, $6.6 \%$; and 5 -year smolts, $0.2 \%$. He also stated that these percentages were practically the same as those of the Restigouche River of Northern New Brunswick as determined by Phelps and Beldine (1930). He reported Calderwood (1927) as noting that the

Cascapedia River, on the Gaspe Peninsula, had $34.1 \% 4$-year smolts and stated that MacFarlane (1928) on the Rivière Moisie, in Southeastern Quebec, reported 3-year smolts only slightly dominating $2-y e a r$ smolts. Blair further stated that Huntsman (1931) reported younger smolts predominating in the St. John and Minas System rivers. Pentelow, Southgate, and Bassindale (1933) reported 95\% 2-year smolts in the River Tees, and the following percentages of 2 -year smolts in British rivers: Tyne, 94\% (Meek, 1925); Wye, 90\% (Hutton, 1932); Tweed, 97\%; Forth, 90\%; Findhorn, 92\%; Spey 71\%; and Don, 62\% (Menzies, 1921).

British and Irish rivers both have smolts migrating at the age of one year. Twomey (1959) found $17 \%$ one-year smolts in the River Erne, in Ireland, in 1956, and 3.9\% in. 1957. Twomey added that, in the River Erne, 2-year smolts formed almost $80 \%$ of the total in 1956 and over $80 \%$ of the total during the years 1954, 1957, and 1959.

According to Azbelev and Lagunov (1960), 40\% of the smolts descending the Barents Sea Rivers are 4+ and 5+ years, while those of the Kola Peninsula Rivers migrate mostly at 3+ years, and those of the White Sea Rivers mostly at $2+$ years.

Hewetson's study (1958) reveals that, in each year from 1956 to 1958, about three-quarters of the smolts in the River Corrib in Ireland migrated at 2 years, and the percentage of 3 -year smolts was high. Hewetson stated that a similar high percentage (12.5) of 3-year smolts was recorded in the years

1924 to 1926 by Went (1943), but the percentage in 1945 was only 6.2 (Went, 1947). The remainder of the River Corrib smolts were one year old. Azbelev (1963) showed the main bulk of smolts of the Tuloma River, near Murmansk in Northern Fussia, to migrate at $4+$ and $5+$ years.

In Ireland, smolts of the River Foyle migrate at 2 years ( $90.1 \%$ ); 3 years ( $7.4 \%$ ); and one year ( $2.5 \%$ ). Similarly, in the River Pinn, $91.7 \%$ were 2 -year smolts; 7.1\% were 3-year smolts, and $1.2 \%$ were one-year (Went, 1964). In Sweden, of 421 smolts in the River Ricklean examined in 1962, $73.8 \%$ were 3-year smolts, $25.2 \%$-year smolts, and $1 \% 4$-year smolts (Ósterdahl, 1964).

As the Miramichi run seemed to come in two segments in 1965, the 2 and 3-year smolts each show peak increases and decreases, in the per cent of the sample which each forms. The 2-year smolts reached their maximum during the larger runs, whereas the 3-year smolts formed a higher proportion of the samples when the daily runs were smaller in number.

To obtain a good comparison of the size of smolts with and without plus growth, the 3 and $3+-$ year smolts were compared in size. The percent and the number of 3 and $3+-y e a r$ smolts in the sample that are within certain centimetre groups are shown in Figures 13 and 14 respectively. The numbers of 3 and 3+-year smolts per 5-day periods of the run are shown in Table 5. The percentages are of the total number of 3 and 3+-year smolts, the greatest per cent being
within the $14.0-14.9 \mathrm{~cm}$ group. The range of these groups differs from those in Figure 5. A greater proportion of $3+$-year smolts, however, are in higher centimetre groups than are 3 -year smolts, indicating a longer average length of $3+$-year smolts due to a longer period for feeding.

The 3+-year smolts were also heavier. The average weight of 3 -year smolts plotted over 5-day periods shows a gradual decrease as the number of 3 -year smolts decreases. Hence, larger fish migrated first. These data, shown on Figure 15, reveal a slight increase in average weight of 3-year smolts during the last 5-day period of June 4-8. The $3+-y e a r$ smolts were heavier than the 3 -year smolts at all times and decreased in average weight from the first of the run until the period May 30 - June 3. Then they increased sharply in average weight per 5-day periods from June 4 until the end of the run.

Plus Growth.

Associated with age is the presence of plus growth (+) on the scales of individual smolts. The daily number and per cent of smolts in the sample showing plus growth are represented on Figure 16.

The number and per cent of smolts in the sample showing plus growth increased throughout the run. There was no plus
growth shown on the scales of any amolt taken during the period May 10-18. After this date there was a gradual increase in the number of smolts showing plus growth until June 9, after which all smolts taken showed plus growth. This factor corresponded with the increase in length and weight during the season.

On the contrary, Pentelow, Southgate, and Bassindale (1933) stated that, in 1930 , there was no corresponding increase in the size of the smolts as the proportion of smolts showing plus growth increased. They reported, however, that, in 1931, there was a slight increase in size as the proportion of smolts showing plus growth increased, and both fectors increased as the season advanced. In both years they noted that few early run smolts had plus growth, and that few late run smolts were without plus growtir.

The percentage of smolts with plus growth is platted by 5-day periods on Figure 17. Note that the curve rases sharply to $100 \%$ of the smolts showing plus growth during the period of June 9-13. Table 5 shows the same data by the number of smolts per 5-day period.

The number of plus growth rings on each scale indicates the amount of growth, hence how much the smolts have been feeding since the last winter before the run. Iater in the season, the mean daily number of plus growth rings increased from 1.2 to 11. The mean number of rings on May 19, the
first day on which any plus growth was noted, was 1.2. A gradual decrease in the average daily number of rings from 2 on May 20 to one on May 27 was noted, but then there was a gradual increase in the mean daily number of rings to 6 on June 29 and 11 and 10 on June 20 and 21, respectively. These data are plotted on Figure 18. of 878 three-year smolts, 553 had plus growth; 88 of 111 two-year smolts; and 9 of 11 four-year smolts. From this it can be concluded that smolts with plus growth dominated the Northwest Miramichi smolt run in 1965. Similar conditions were noted in the Rivers Erme and Foyle in Ireland (Twomey, 1959, and Went, 1964).

Sex.

Another factor which may influence age at migration is the sex of the smolts. There have been many reports on the ripening and spawning of male parrs before they go to sea as smolts (Tchernavin, 1939, and Jones, 1959).

Tchernavin (1939), (after Hoek, 1902, and Tchernavin, 1938), reported that male parrs were ripe between the ages of $1+$ and $4+$ river years, and in some cases, "in the first autumn of their existence." According to Tchernavin (1939), reporting on Hoek (1910) and Huitfeldt - Kaas (1914), (after Otterstrffi, 1933), male parrs may spawn twice before going to sea. Tchernavin (1939) further stated that male
parrs of Selmo salar under natural conditions, ripen before going to sea, "and take part in spawning with females that have already been to sea," and that, "the milt of such parrs can be successfully used for artificial fertilization of the eggs of females."

According to Tchernavin (1939) female parrs are ripe much more rarely than male parrs (after Shaw, 1840, Day, 1885, Schaferna, 1934, Smirnov, 1935; and Regan, 1938). Also according to Tchernavin (1939), Schaferna (1934), and Regan (1938) found female parrs to be ripe at 8 years and $2 \frac{1}{2}$ years respectively.

Jones (1959) reported Shaw (1840) as having taken an 11pound female salmon and 4 male parr from the same spawning bed in a river and impregnating 4 lots of her eggs, "one lot by the sperm of each parr." "The four batches of fertilized egge were hatched in a stream to which no salmon had access," and matured in 18 months. "Three ripe parr from each of these batches were used to fertilize eggs from an adult female salmon, and again these matured." These experiments showed the impregnating power of male parr sperm.

Jones (1959) reported that, of a sample of parr caught in the River Dee in October, 1937, "nearly all were fourd to be sexually mature males," and that during the years 1938 and 1939, approximately "30c0 parr and smolts from 20 British pivers were examined." From the examination of these fish,
it was found that about one-half were males," and of these about 75 per cent were ripe (sexually mature), spending (in the process of spawning), or spent (finished spawning). Of the smolts examined, 60 per cent of the males were definitely spent." According to Jones (1959), (after Orton, Jones, and King, 1938, and Jones and Orton, 1940), of the 1500 females examined not one was maturing, mature, or spent.

In England male parr or smolt were classified as male (1) and male (2), depending upon the size of the testes. Male (1) parr have small testes, and male (2) have large testes. Male (2) parr tended to migrate early in the season in the River Tees (Pentelow, Southgate, and Bassindale, 1933). Comparable studies were not done on the Miramichi male smolts in 1965, but it may help to explain why male smolts will, on the average, be older and form a greater proportion of the late run than female smolts.

Although the number of 4 -year smolts was small, $72.7 \%$ of them were males. (Although male (1) and (2) smolts were noticed when sex examination was done, no record of them was kept because, at the time, I was not aware of the significance of this difference.) One of these 4-year male smolts, and one 3-year male smolt were believed to have spawning marks at the time of migration. The 3-year smolt scale is shown on Plate 4. Table 4 shows that a higher proportion of early age females migrate than early age males.

Sex ratios during the smolt run were approximately $2: 1$ favouring females. Of 1000 fish examined, 336 were males and 664 were females. Azbelev (1963) stated that females make up a larger percentage of Atlantic salmon than Pacific salmon. He reported $45 \%$ of the migrating Tuloma River stock to be males. Österdahl (1964) reported that, in 1962, of 421 smolts from the River. Rickleån, 36.1\% were males. Pentelow, Southgate, and Bassindale (1933) from the examination of 3,063 smolts, found that the female to male ratio was $1.93: 1$ in the River Tees, and they reported that Meek (1925), found the female to male ratic 1.7:1 form smolts picked up dead in the River Tyne estuary. Hewetson (1958) recorded the average sex ratio for the River Corrib, during the years 1956-1958, as 1:1.1 females to males.

The average length and weight for males and females was found to be approximately the same in the Miramichi. The average weight of males and females was 21.9 g and the average length was 14.5 cm and 14.8 cm , respectively. A similar condition was found in the River Tees where the mean size of the two sexes did not differ in either case by more than 0.3 cm (Pentelow, Southgate, and Bassindale, 1933).

Table 5 shows the number of males and females per 5-day periods of the run, and daily numbers and percentages of male and female smolts are plotted on Figures 19 and 20, respectively.

A greater percentage of female smolts was encountered during the period May 10-24 (excluding the 16 th when there was only one smolt--a male). Towards the latter part of the run, the sex ratios approached $1: 1$.

From the curve of Figure 21, it can be seen that the percentage of females decreased as the season advanced. The extremes on the ends of the lines are the result of the examination of four smolts after June 28 , all of which were females. Only during the period June 24-28, when only 8 smolts were examined, was the proportion of male to females1:1. During all other 5 -day periods the proportion of females was greater.

From the above data it can be concluded that female smolts dominated the first part of the run, and decreased in percentage as the season advanced, but never dropped below 50\% during any 5-day period.

Smolt Run Related to Water Level and Water Temperature.

The number of smolts in the daily run was correlated with the mean daily water level in feet (weter level taken as height above sea level), and the mean daily water temperature in degrees Centigrade. These data are plotted on Figure 22 where it can be seen that the water level was dropping and the water temperature was increasing when the peak of the run occurred. On the peak day, May 29 , when there were 4,254
smolts, the water level had fallen 2 inches from the day before, and the water temperature had risen 1.9 degrees from the previous day.

Österdahl (1964) reported a general drop in water level, except in 1963 when it remained relatively constant, and a rise in water temperature as the smolt run increased in number, but no "straightforward correlation between temperature, rise of temperature, or water level fluctuations and the daily catches of smolts," was revealed. He stated that the factors controlling smolt migration are rather likely "strongly coupled with water temperature and water level." Abrupt changes, he reported, more rapidly effected a peak whereas gradual changes made the run lighter on any one day, but of longer duration.

The smolt run of 1965 consisted of two segments, the peak of the first one occurring on May 22. On this day the water temperature had risen 1.8 degrees, and the water level had dropped 4 inches from the previous day. The peak of the second segment occurred on May 28.

Condition Factor.

The final calculation was the determination of the condition factor ( K ) of the smolts. The average condition factors, per day and per 5-day periods of the run, are shown on Figures 23 and 24, respectively. The mean yearly condition
factor was 0.7 . The range of the daily condition factor was from 0.6-0.8, and there was no range of the condition factor for 5 -day periods, for on each 5-day period it averaged 0.7 when taken to the nearest tenth. Neither curve for Figure 23 or 24 shows significant change.

## SUMINARY

1) A sample of smolts was collected at the Curventon counting fence during the 1965 smolt run in the Northwest Miramichi River in New Brunswick. This sample consisted of 1000 smolts, forming $3.7 \%$ of the total smolt run of 26,778 .
2) The average length of the smolts collected was 14.7 cm , and the average weight was 21.9 g .

In centimetre groups, the largest percentage, 32.8 was in the 14.1-15.0 group.

Larger smolts were caught during the early part (May 1024) and later part (June 19 - July 21) of the smolt run, with smaller smolts dominating the middle of the run.

There was a gradual decrease in average daily length from the beginning of the run until May 27, after which there was a gradual increase in average daily length.

A similar relation existed in average daily weight, with the lowest average daily weight being recorded on May 22, and a gradual increase from then until the end of the run.

The length and weight ranges were from $11.7-20.6 \mathrm{~cm}$, and from $10.6-65.5 \mathrm{~g}$, respectively, with the same two fish producing both extremes.
3) Three-year smolts dominated the entire sample ( $87.8 \%$ ), two-year smolts formed $11.1 \%$, and 4 -year smolts $1.1 \%$ of the sample.

The 2-year smolts increased in the per cent of the daily sample as the season progressed, whereas 3 -year smolts decreased slightly but dominated the first part of the run.
4) Three-year smolts with plus growth had a greater average length and weight than 3 -year smolts showing no plus growth.
5) The average length of $2,2+, 3,3+$, and 4 -year smolts was $13.7 \mathrm{~cm}, 14.6 \mathrm{~cm}, 14.6 \mathrm{~cm}, 14.8 \mathrm{~cm}$, and 15.7 cm , respectively. This was a gradual increase in average length as age increased except for $2+$ and 3 -year smolts. The average weight of smolts in these age classes was: $16.8 \mathrm{~g}, 22.2 \mathrm{~g}, 20.8 \mathrm{~g}$, 22.6 g , and 27.5 g respectively.
6) The per cent of smolts with plus growth increased as the season advanced, with no smolts from May $10-18$ showing plus growth, and all smolts after June 9 showing plus growth.
7) The average number of rings of plus growth increased from 1.2 to 11 as the season advanced. There was an increase In the size of the smolts with increasing plus growth.
8) Females dominated the first part of the run, and the proportion of females decreased slightly as the season advanced, but never dropped below male numbers during any 5-day period. On only a few individual days did the number of males surpass that of females.

Of 1000 smolts, 664 were females and 336 were males.
9) Of 111 two-year smolts, 88 ( $79.3 \%$ ) were females and 23 (20.7\%) were males. Of 878 three-year smolts, 573 (65.3\%) were females, and 305 ( $34.7 \%$ ) were males. Of 11 four-year smolts, 3 were females and 8 were males. With increasing age, the proportion of males appeared to increase.
10) The average length and weight of males and females were approximately the same. The average length of males and females was 14.5 cm , and 14.8 cm , respectively. The average weight of males and females was 21.9 g for each.
11) The peak of the smolt run occurred as the water level was dropping and the water temperature was increasing.
12) The average condition factor for all the smolts collected was 0.7 .

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Table 1. Average daily length and weight of smolts during the run.

| Date | $\begin{gathered} \text { Avg. } \\ \text { length } \\ \mathrm{cm} \end{gathered}$ | $\begin{array}{\|c\|} \hline \text { Avg. } \\ \text { weight } \\ g \end{array}$ | Date | $\begin{array}{\|c\|} \text { Avg. } \\ \text { Lengtinw } \\ \mathrm{cm} \end{array}$ | Avg. veight g | Date | $\begin{array}{\|c\|} \hline \text { Avg. } \\ \text { Iength } \\ \mathrm{cm} \end{array}$ | Avg. <br> weight <br> g | Date | $\begin{array}{\|c\|} \text { Avg. } \\ \text { Leng th } \\ \mathrm{cm} \end{array}$ | Avg. <br> weight <br> g |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| May 10 | 14.4 | 22.0 | May 25 | 15.6 | 25.6 | June 9 | 15.0 | 23.7 | June 24 | 15.3 | 25.7 |
| May 11 | --- | --- | May 26 | 18.0 | 43.9 | June 10 | 15.1 | 24.0 | June 25 | 15.6 | 23.0 |
| May 12 | --- | --- | May 27 | 13.9 | 18.5 | June 11 | 14.5 | 21.4 | June 26 | 15.9 | 27.7 |
| May 13 | --- | --- | May 28 | 14.4 | 20.6 | June 12 | 14.6 | 24.9 | June 27 | --- | --- |
| May 14 | 16.1 | 31.0 | May 29 | 14.1 | 18.8 | June 13 | 14.8 | 22.7 | June 28 | --- | --- |
| May 15 | 16.1 | 28.2 | May 30 | 14.7 | 21.0 | June 14 | 14.5 | 22.9 | June 29 | 15.7 | 27.4 |
| May 16 | 15.0 | 22.1 | May 31 | 14.3 | 19.1 | June 15 | 14.7 | 23.0 | June 30 | ---- | --- |
| May 17 | 16.2 | 29.8 | June 1 | 14.4 | 20.3 | June 16 | 14.9 | 22.9 | July 20 | 19.5 | 45.6 |
| May 18 | 14.6 | 20.4 | June 2 | 14.3 | 19.4 | June 17 | 14.8 | 22.7 | July 21 | 18.8 | 48.6 |
| May 19 | 15.1 | 23.6 | June 3 | 14.3 | 20.1 | June 18 | 15.1 | 23.6 |  |  |  |
| May 20 | 15.0 | 23.4 | June 4 | 14.1 | 18.3 | June 19 | 15.2 | 23.8 |  |  |  |
| May 21 | 14.7 | 20.9 | June 5 | 14.6 | 21.6 | Tune 20 | 15.0 | 23.7 |  |  |  |
| May 22 | 14.0 | 16.7 | June 6 | 14.5 | 21.4 | June 21 | 15.3 | 24.7 |  |  |  |
| May 23 | 14.8 | 22.3 | June 7 | 15.1 | 24.0 | June 22 | 14.9 | 22.9 |  |  |  |
| May 24 | 16.4 | 30.0 | Tune 8 | 14.6 | 22.2 | June 23 | 15.0 | 25.1 |  |  |  |

Table 2. Average length and weight of smolts per week during run.

| Week | $\begin{gathered} \text { Avg. } \\ \text { length } \\ \mathrm{cm} \end{gathered}$ | Avg. weight g | No. in weakly sample | No. in weekly run |
| :---: | :---: | :---: | :---: | :---: |
| May 10-16 | 15.2 | 25.4 | 19 | 20 |
| May 17-23 | 14.8 | 22.0 | 169 | 1,711 |
| May 24-30 | 14.6 | 21.4 | 187 | 6,931. |
| May 31 - June 6 | 14.4 | 20.0 | 291 | 13,562 |
| June 7-13 | 14.8 | 23.0 | 183 | 4,160 |
| June 14-20 | 14.9 | 23.2 | 101 | 346 |
| June 21-27 | 15.2 | 25.4 | 36 | 36 |
| June 28-July 4 | 15.7 | 27.4 | 2 | 2 |
| Fuly 19-23 | $19 \cdot 2$ | 47.1 | 2 | 10 |

Table 3. Average length, weight, and total number of smolts in five age groups.

| Age of smolt | 2-year | 2+-year | 3-year | 3+-y ear | 4-year |
| :--- | :--- | :--- | :--- | :--- | :--- |
| Total in each <br> age group | 23 | 88 | 325 | 553 | 11 |
| Avg. length <br> (cm) | 13.7 | 14.6 | 14.6 | 14.8 | 15.7 |
| Avg. weight <br> $(\mathrm{g})$ | 16.8 | 22.2 | 20.8 | 22.6 | 27.5 |

Table 4. Sexes of smolts in three age groups

| Mge Group | 2-year | 3-year | 4-year |
| :--- | :---: | :---: | :---: |
| No. in each <br> age group | 111 | 878 | 11 |
| No. of <br> females | 88 | 573 | 3 |
| Per cent of <br> females | 79.3 | 65.3 | 27.3 |
| No. of males | 23 | 305 | 8 |
| Per cent of <br> males | 20.7 | 34.7 | 72.7 |

Table 5. Numerical data for 5-day periods of the smolt run.
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| Date | Sample number | Run number | Number <br> 01 <br> 3-year <br> smolts | $\begin{gathered} \text { Number } \\ \text { of } \\ 3+\text {-yea } \\ \text { smolts } \end{gathered}$ | $\begin{gathered} \text { Number } \\ \text { of } \\ 3 \text {-year } \\ \text { smolts } \\ \text { in } \\ \text { iotal } \end{gathered}$ | $\begin{gathered} \text { Number } \\ \text { of } \\ \text { 2-year } \\ \text { smolts } \\ \text { in } \\ \text { total } \end{gathered}$ | Number of <br> 4-year smolts $\frac{i n}{\text { total }}$ | Number <br> of males | $\left\lvert\, \begin{gathered} \text { Number } \\ \text { of } \\ \text { females } \end{gathered}\right.$ | Number showing plus growth |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Tay 10-14 | 12 | 12 | 12 | 0 | 12 | 0 | 0 | 2 | 10 | 0 |
| May 15-19 | 72 | 1131 | 66 | 4 | 70 | 1 | 0 | 13 | 59 | 6 |
| May 20-24 | 111 | 1,624 | 87 | 21 | 108 | 1 | 1 | 32 | 79 | 23 |
| Tiay 25-29 | 139 | 5,762 | 60 | 47 | 107 | 26 | 3 | 48 | 91 | 63 |
| May 30-June 3 | 216 | 9,615 | 81 | 108 | 189 | 26 | 2 | 73 | 143 | 126 |
| June 4-9 | 182 | 7,072 | 17 | 152 | 169 | 15 | 2 | 62 | 120 | 164 |
| June 9-13 | 117 | 2,187 | 0 | 97 | 97 | 19 | 1 | 41 | 76 | 117 |
| June 14-18 | 84 | 300 | 0 | 70 | 70 | 12 | 2 | 37 | 47 | 84 |
| June 10-23 | 55 | 73 | 0 | 50 | 50 | 5 | 0 | 24 | 31 | 55 |
| June 24-28 | 8 | 8 | 0 | 5 | 5 | 3 | 0 | 4 | 4 | 8 |
| June $20-$ July 3 | 2 | 2 | 0 | 1 | 1 | 1 | 0 | 0 | 2 | 2 |
| July 20-21 | 2 | 10 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 2 |
| Totals | 1000 | 26,778 | 323 | 555 | 878 | 111 | 111 | 336 | 664 | 734 |

Table 5. Numerical data for 5-day periods of the smolt run.

| Date | $\begin{aligned} & \text { Sample } \\ & \text { number } \end{aligned}$ | Run number | $\left\|\begin{array}{c}\text { Fumber } \\ \text { of } \\ 3 \text {-year } \\ \text { smolts }\end{array}\right\|$ | Humber of $3+-$ year smolts | Iumber of $3-$ year smolts in total | $\|$wumber <br> of <br> 2-year <br> smolts <br> in <br> total | lumber of 4-year smolts in total | Number <br> of males | $\begin{gathered} \text { Number } \\ \text { of } \\ \text { fomales } \end{gathered}$ | Flumber showing plus growth |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| May 10-14 | 12 | 12 | 12 | 0 | 12 | 0 | 0 | 2 | 10 | 0 |
| May 15-19 | 72 | 113 | 66 | 5 | 71 | 1 | 0 | 13 | 59 | 6 |
| May 20-24 | 111 | 1,624 | 88 | 21 | 109 | 1 | 1 | 32 | 79 | 23 |
| Nay 25-29 | 139 | 5,762 | 61 | 49 | $110^{\circ}$ | 26 | 3 | 48 | 91 | 63 |
| May 30-June 3 | 216 | 9,615 | 81 | 107 | 188 | 26 | 2 | 73 | 143 | 126 |
| June 4-8 | 182 | 7,072 | 17 | 148 | 165 | 15 | 2 | 62 | 120 | 164 |
| June 9-13 | 117 | 2,187 | 0 | 97 | 97 | 19 | 1 | 41 | 76 | 117 |
| June 14-18 | 84 | 300 | 0 | 70 | 70 | 12 | 2 | 37 | 47 | 84 |
| June 19-23 | 55 | 73 | 0 | 50 | 50 | 5 | 0 | 24 | 31 | 55 |
| June 24-28 | 8 | 8 | 0 | 5 | 5 | 3 | 0 | 4 | 4 | 8 |
| June 29-July 3 | 2 | 2 | 0 | 1 | 1. | 1 | 0 | 0 | 2 | 2 |
| Ju7y 20-21 | 2 | 10 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 2 |
| Totals | 1000 | 26,778 | 325 | 553 | 878 | 111 | 11 | 336 | 664 | 650 |

PIgure 1 . NORTHWEST MIRAMICHI RIVER
AND TRIBUTARIES




Pigure 5 . Length of smolts in centimetre groups.


Figure 6 . Average daily length of smolts in centimetres.

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Pigure 7 . Average length in oentimetres of smolts during 5-day periods of run.


Pigure 8. Average meight in grans of smolts during 5-day periods of run.


Pigure 9 . Average daily weight in grans of smolts curing oun.

Figure 10. Age of smolts in years during run.

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Figure 12. Per cent of smolts in 3-year classos per 5-day periods of run.


Figure 13 . Length of 3 -year smolts in centimetre groups showing no plus growth.


Pgure 14 . Length in centimetre groups of 3 -year smolts showing plus growth.


5-day period
Pigure 15. Average weight of 3 -year and $3+$ year smolts per 5-day periods of run.


Figure 16. Number and per cent of smolts in daily run showing plus erowth.

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Pigure 17. Per cent of smolts in sample during 5-day periods of run showing plus growth.


Pigure 18. Average number of plus growth rings shown on smolt scales per day.

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5-day period
Pigure 21. Per cent of sale and female smolts per 5-day periods of run.


Pigure 22. Number of smolts in daily run versus dafly vater level (feet) an d water temporature (Centigrade).

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Plate 1. Photograph showing west leg and long leg of counting fence, taken downriver from fence. Shows west trap (left) and centre trap (to the left of the centre), catwalk, "A" frames, and steel racks on upriver face of fence. Arrow indicates river flow.


Plate 2. Scale of 2 -year smolt showing plus grouth (mag. 50x).


Plate 3. Scale of 3 -year smolt showing plus growth (mag. 50x).


Plate 4. Scale of 3-year male smolt showing possible spawning mark (mag. 38x).


Plate 5. Scale of 4 -year smolt with a start of spring plus growth (mag. 40x).


Plate 7. Female amolt gonads (mig. $1 x$ ).

Plate 6. Regenerated smolt scale (mag. 30x).


Plate 8. Male smolt gonads (mag. 1x).


Plate 9. Section of female smolt gonad (mag. 100x).


Plate 10. Section of male smolt gonad (mag. 100x).

