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Biological Characteristics of Atlantic Salmon Smolts in Western Arm Brook, Newfoundland

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BIOLOGICAL CHARACTERISTICS OF ATLANTIC SALMON SMOLTS IN WESTERN ARM BROOK, NEWFOUNDLAND

by

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ABSTRACT

Chadwick, E.M.P. 1981. Biological characteristics of Atlantic salmon smolts in Western Arm Brook, Newfoundland. Can. Tech. Rep. Fish. Aquat. Sci. 1024: iv + 45 p.

Atlantic salmon smolt migrations were counted on Western Arm Brook, Newfoundland, from 1971 to 1979. The mean count was 9598 fish; the mean smolt age was 3.9 yr; the mean fork length was 174 mm; the mean condition was 0.90; the average sex ratio was 74% female. Size and condition of smolts had the least variance of all characteristics. Western Arm Brook produced a relatively high number of smolts for its size of drainage area. Year-class strength of smolts was correlated to numbers of kelt as potential parents. Smolt age was correlated to air temperature in the first year of life. Ovarian weight was greater in older smolts. Speculation was made on the importance of smolt size.

Key words: Atlantic salmon, smolt, year-class, length, sex, density, growth, temperature, kelt

RÉSUMÉ

Chadwick, E.M.P. 1981. Biological characteristics of Atlantic salmon smolts in Western Arm Brook, Newfoundland. Can. Tech. Rep. Fish. Aquat. Sci. 1024: iv + 45 p.

On a fait le dénombrement des migrations de saumoneaux de l'Atlantique dans le ruisseau Western Arm à Terre-Neuve, de 1971 à 1979. Le nombre moyen était de 9 598 poissons; en moyenne, l'âge des saumoneaux était de 3,9 ans, la longueur à la fourche de 174 mm, la condition de 0,90 et la proportion de femelles de 74 %. Le caractéristiques qui ont le moins fluctué sont la taille et la condition. Le ruisseau Western Arm a produit un nombre relativement élevé de saumoneaux pour un bassin hydrographique de cette superficie. On a mis en corrélation l'importance des classes d'année de saumoneaux avec le nombre de charognards potentiellement reproducteurs, de même que l'âge des saumoneaux avec la température de l'air durant la première année d'existence. Le poids des ovaires était plus élevé chez les saumoneaux plus âgés. On a fait des hypothèses sur l'importance de la taille des saumoneaux.

INTRODUCTION

In 1971, studies were initiated on Western Arm Brook as a potential donor of Atlantic salmon brood stock to nearby Torrent River. The smolts, kelt, and adult migrations were monitored, 1971-80, and fish were sampled for biological characteristics. In 1972, the watershed was surveyed for rearing habitat accessible to Atlantic salmon. In 1977, 1978 and 1979, the abundance and population structure of juvenile salmon were determined in 30 stations throughout the watershed.

In 1980, salmon migrations continued to be monitored and Western Arm Brook became a key river in Newfoundland salmon management. It was one of few wild rivers in Atlantic Canada where the salmon migrations had been carefully enumerated and yet the river had remained free of stocking, introductions, spraying, predation control, and large stream remedial projects. The smolt and adult migrations were used to estimate freshwater production (Anon. 1978), sea survival, and fishing mortality of Atlantic salmon (Chadwick et al. 1978; Chadwick and Meerburg 1978; Reddin 1981). The data series was sufficiently long to cover the life cycle of two generations and was therefore valuable for understanding the population dynamics of Atlantic salmon.

The biological characteristics of Western Arm Brook smolts were examined with several questions in mind: Are there predictable fluctuations in smolt production? How is smolt production affected by temperature, stream discharge, and the abundance of other species? What is the relative importance of changes in smolt size, condition, sex ratio, and age? Is there a relationship between spawning stock and smolt as a measure of their progeny? Is it possible to estimate the carrying capacity of Western Arm Brook by examining the interaction between stream biomass and juvenile growth?

This report is a preliminary analysis of the biological characteristics of smolts in Western Arm Brook and presents data on magnitude and timing of the smolt migrations, age, condition, sex ratio, vertebral counts, gonad weight and back-calculated growth of smolt. Juvenile standing stock, spawning stock and meteorological observations are also considered. The relative importance of each parameter is assessed by comparing its coefficient of annual variation.

STUDY AREA

Western Arm Brook flows into St. Barbe Bay on the northwestern coast of insular Newfoundland (51°11'21"N, 56°45'48"W), has a drainage basin of 150 km^2, a relief of 108 m, an axial length of 27 km and its headwaters contain 83 lakes with a total surface area of 2560 ha. The river lies on Ordovician bedrock and has a specific conductance of 109 µmhos.cm^{-1} (Murray and Harmon 1969) which is higher than most Newfoundland rivers (Jamieson 1974). The river drains predominantly sphagnum bog and *Abies* and *Picea* forest on the higher ground, which was extensively logged about 50 years ago. The community of St. Barbe (population 500) is located a short distance from the river estuary. A highway crossses the river at the mouth; otherwise the river basin is accessible only on foot or by canoe and remains relatively free of man's influence.

MATERIALS AND METHODS

A fish counting fence (Anderson and McDonald 1978) was installed each year (1971-80) during the last week in May and removed at the end of the smolt run which was usually mid-July (Table 1). Almost the entire run was enumerated in all years except 1979 when the early part of the run was missed. This was estimated from the proportion of the total migration in other years which had occurred before the first peak in daily abundance, and was calculated to be 15%. In 1977 and 1978 the fence was also installed from early September to late October to check for possible fall smolt migrants. An adult fence was used to count all upstream migrants from approximately mid-June to the end of September.

The fence was efficient in capturing all downstream migrating fish greater than 16 mm in thickness. This included the full range of smolt sizes, whose body width was always greater than 20 mm and also included larger salmon parr, salmon, kelts, trout, eels, and alewives.

The traps were checked at 0600, 1200, 1800 and 2400 h during the peak migration and at 0800, 1200 and 1600 h during the off-peak periods. In 1971, the trap was checked four times daily throughout the run. The fish were counted as they were dipped from the two traps and released downstream.

Samples of smolts for length, weight, age and sex determinations were taken in several ways. In 1975, 1976, 1977 and 1979 the last five smolts of each 200 counted were taken as a sample. In 1978, five of each 400 smolts were sampled. In 1972, one of each 25 smolts was taken until 75 fish were sampled, then one of each 50 smolts until a further 75 fish were sampled, and for the remainder of the run one of each 25 fish was taken. In 1971, 1973 and 1974 the exact method of sampling was unknown, but it was distributed throughout the runs.

All sampled fish were measured for fork length (mm) and aged; blotted wet weight (g) was taken in 1972, 1973, 1977, 1978 and 1979; sex was determined in 1971-73, 1977-79; stomach contents were identified and liver and gonad weights were obtained 1977-79; vertebrae were counted in 1977; and fork lengths were back-calculated from scales from 1971 to 1977. Scale samples were removed from the left side of the fish in the area below the dorsal fin and above the lateral line and were mounted in glass slides or rolled onto acetate strips. The scales were aged at 40x magnification with a Bausch and Lomb microprojector. Scale annuli were discerned by standard criteria (Havey 1959) and their distances were measured from the focus along the longest oral radius (Tesch 1968). Relationships between total scale radius and fork length were determined and back-calculated lengths were calculated for 3+, 4+ and 5+ smolts. Sex was determined by gross examination of the gonads. Precocious male fish were identified by their enlarged testes. Female gonads were dried at 40°C for 12 h then allowed to cool in a desiccator before weighing to 10^{-4}g. Vertebrae were counted from x-ray photographs of whole smolts.

The total annual smolt migrations were divided into smolt cohorts by using the aged samples. All smolts born in the same year were considered to belong to the same smolt year-class. The cohorts were summed into their appropriate smolt year-classes; fish older than 5+ were not used because of their small numbers. Complete year-classes were available from 1968 to 1974.

The data series was extended by estimating the cohort size of 3+ smolts in 1967 and 5+ smolts in 1975 from mean values for other years. Densities of 0+, 1+, 2+, 3+ and 4+ fish were estimated sequentially assuming instantaneous mortality rates of 1.02 between 0+ and 1+ and 0.62 for all older age groups (Chadwick unpubl. data). The densities were converted to biomass using average weights of 1.5, 4.7, 13.4, 30.2 and 45.9 g for age groups 0+, 1+, 2+, 3+ and 4+ respectively (Chadwick unpubl. data) and a rough estimate of juvenile standing stock was calculated for each growth year.

Juvenile growth was estimated from back-calculated fork lengths for all smolt ages 1971-77. Growth increments between age groups were calculated. Fish were assumed to be 28 mm at emergence and this value was subtracted from the back-calculated length at age 1 to obtain the first growth increment (0-1). These values were separated into the year when growth occurred and an overall mean was taken. This mean was calculated only for age groups 0-1, 1-2, and 2-3 as the older age groups had very small sample sizes. In years where data were incomplete, the mean was weighted to allow an equal contribution by each smolt age.

Smolt age, year-class strength and sex ratio were compared to annual variation in temperature, water level and spawning potential of upstream migrating adults and downstream migrating kelt. Mean monthly and mean annual temperatures (1950-75) were obtained from the St. Anthony meteorological station (Anon. 1950-75). St. Anthony is 90 km northeast of St. Barbe. Daily water temperature and level were taken at 0800 h at the counting fence until 15 September in most years. Temperature was taken with a mercury thermometer just below the water surface and water level was recorded as wetted measuring stick at the side of the fish trap. In 1978-79 water temperature was recorded until 31 March and used to calculate a relationship with air temperature. Water discharge was available from 1970 for St. Genevieve River (Anon. 1977) which is adjacent to Western Arm Brook and very similar in physiognomy.

Comparisons between means were usually done with a 't'-test by comparing $t_s = (Y_1 - Y_2) \div \; (S_1^2 \div N_2) + (S_2^2 \div N_1)$ to tabulated values of t, where Y_1 and S_1^2 equal the mean and variance of sample 1, and Y_2 and S_2^2 the mean and variance of sample 2.

RESULTS

TIMING AND MAGNITUDE OF MIGRATION

The smolt migration was influenced by water temperature. The migration commenced when minimum water temperature was greater than 7°C and it peaked at 10°C (Fig. 1). The duration of the run was approximately 40 days, but occasional smolts were counted into late July and early August (Table 1). In 1977, 13 smolts were counted from 8 to 27 September and in 1978, 29 smolts were counted from 26 August to 24 October (Table 2). These latter migrations also occurred when water temperature was around 10°C.

There were also downstream movements of kelt (Fig. 2), brook trout (*Salvelinus fontinalis*), American eel (*Anguilla rostrata*), smelt (*Osmerus mordax*), American shad (Alosa sapidissima), and three-spine stickleback (Gasterosteus aculeatus) (Table 2). The counts for salmon parr, trout parr and sticklebacks were not complete because of inefficiency of the fence in counting small fish, but nevertheless indicated extensive downstream movement of these species. Smolt were most numerous and the greatest exporter of fish biomass (Table 3). Smolts also had the least variance in their annual migrations, this was seen clearly in the coefficient of variation (C.V.) of 26, which was one third the C.V. for trout and one seventh the C.V. for shad (Table 2). There appeared to be no correlation between the abundance of smolt and other species.

The magnitude of the annual smolt migration appeared to vary randomly (Fig. 3), although the time series was too short for an adequate run test (Sokal and Rohlf 1968). The largest migration was in 1978 and it was 2.3 times larger than the smallest migration in 1971 (Table 4).

However, when the annual smolt migration was proportioned into year-class sizes (Tables 5 and 6), there appeared to be a more regular cycle (Fig. 3). This was also seen in the sequence of + and - values above and below the mean, where size of year-classes had a more regular pattern than size of annual smolt migrations (Fig. 3); year-classes had 4 runs and the latter had 7. Smolt year-class size (Table 6) had a significant decline ($P = 0.02$) from 1969 to 1973 at an instantaneous rate of -0.14, but this was not seen in the smolt migrations which seemed to be above the mean every second year. The C.V.'s for both year-class strength and size of annual smolt migrations were equal (Table 7).

SMOLT AGE

Smolts were predominantly age 4+, but mean age ranged from 3.5 years in 1977 to 4.3 years in 1974 (Table 4). The mean age at smoltification of smolt year-classes (Table 6) was equal to mean age of the annual smolt runs (Table 4), but with less variance. The number of age 4+ smolts had much less annual variation than smolts of other ages (Table 5). A slight increase in number of age 3+ smolts, and a decrease in age 5+ and 6+ smolts were suggested in Table 5, but these changes were not significant ($P > 0.05$). There were also no significant relationships between smolt age and size of smolt run (Table 4) or between smolt age and year-class size (Table 6). The annual variation in smolt age was relatively less than the variation in size of the smolt migration (Table 7).

SMOLT SIZE

Smolt size had the least annual variation of all other measured parameters (Table 7). However, differences between years with the smallest size (1975 and 1978) and the largest size (1979) were significant (Table 8 and Fig. 4). There were generally significant size differences ($P < 0.1$) between the three smolt ages: fish of smolt age 3+ were smaller than smolt age 4+ in all years except 1971 and 1973; fish of smolt age 4+ were smaller than smolt age 5+ in all years except 1974, 1977 and 1979; and fish of smolt age 3+ were significantly smaller ($P < 0.05$) than smolt age 5+ in all years. There were no significant size differences ($P > 0.1$) between sexes for the three smolt ages (Table 9). There was also no significant change in smolt size throughout the 1979 smolt run (Table 10), which suggested late migrants were not larger than early smolts.

Exceptionally large smolts (> 30 cm) were encountered in 1971 and 1972. In 1972 all smolt greater than 20 cm were collected; 110 specimens were found with a mean size of 236 mm, ranging from 200 to 354 mm; they comprised <1% of the migration. Unfortunately only one of these fish, a female, was sexed. The average age of the large smolts was greater than the random sample; two specimens were age 7+. Presumably these large smolts occurred in other years but were too rare to be sampled.

SMOLT CONDITION, WEIGHT AND STANDING STOCK

Mean condition was 0.90 and equal to that of the three smolt ages (Table 11). There were annual fluctuations in condition and the difference between 1972 and 1979 was significant ($P < 0.05$) for all smolt ages (Table 1). However, this difference was due to difference in fork length (Table 8) as the mean weights for both years were not different (Table 12). The C.V. for annual changes in smolt condition was 2% (Table 7). Standing stock of the smolt migration (numbers x mean weight) ranged from an estimated 275 kg in 1971 to 604 kg in 1978 (Table 12); its C.V. of 27% was similar to that for smolt numbers and suggested annual changes in standing stock were due to fluctuations in numbers of fish and not fluctuations in their average weight.

SMOLT SEX

Smolts were predominantly female (Table 13). The sex ratio fluctuated considerably between years when divided into the three smolt ages. In 1973, smolt age 3+ was 77% males, but it was nearer 20% in other years (Table 13). These large changes could have been partly a result of small sample sizes. Annual changes in the total sex ratio had a C.V. of 15%. Precocious males were also present in the smolt migration and comprised from 14% to 30% of the males (Table 13).

SMOLT VERTEBRAE

Vertebral counts for 3+, 4+ and 5+ smolts did not indicate any significant difference ($P > 0.1$) between the three ages (Table 14).

GONAD WEIGHT

Gonad weights of older female and male smolts in 1978 and 1979 were significantly larger ($P < 0.05$) than those of younger smolts (Table 15). The 1977 value for 5+ female smolts and the 1978 value for 5+ male smolts were not compared because of their small sample sizes. The greater gonad weight in older smolts was not entirely due to the larger size of older smolts. In 1977, ovaries of 4+ smolts constituted a significantly greater proportion ($P < 0.01$) of the body weight than 3+ smolts (Table 15). In 1979, ovarian weight as a percentage of body weight was significantly greater in the older smolt ages (Table 15). Female gonad weight increased an average of 30% for each additional year of residence in fresh water.

BACK-CALCULATED GROWTH

All back-calculated fork lengths were calculated using one equation FL = 5.79 + 0.21 SR, where FL equals fork length and SR equals scale radius. The relationship was calculated from smolts and juveniles sampled in 1977 and was very significant ($P < 0.01$, $r^2 = 0.81$, df = 161). Back-calculated fork length was significantly different from actual smolt fork length in 6 out of 21 cases (Table 16). Mean back-calculated fork lengths were significantly larger ($P < 0.05$) at each age group for 3+, 4+ and 5+ smolts respectively, except for the back-calculated ℓ_1 (fork length at the formation of the first annulus) at smolt ages 3+ and 4+ which were different only at the 10% level. This suggested that juvenile growth decreased with smolt age. On average at age 3, 3+ smolts had grown 127 mm, 4+ smolts 108 mm and 5+ smolts 91 mm (Table 16).

The mean growth was calculated for each year by combining all growth increments into one value. The years of greatest growth were 1969, 1973 and 1974 and the least growth was in 1971 (Table 17).

JUVENILE STANDING STOCK

The mean standing stocks of age groups 2 and 3 were approximately 65% greater than the two younger age groups (Table 18); there were no significant differences between mean standing stocks for age groups 0 and 1 or age groups 2 and 3. The total standing stock was an average of 1476 kg but had a C.V. of 12% compared to a C.V. of approximately 28% for individual age groups. This indicated that annual variation in total juvenile stock was about one half the variation in individual age groups, and suggested that a low annual biomass in one age group would be balanced by an equivalent higher biomass in the other age groups. A relationship between growth year and standing stock was suggested (Fig. 5) but it was not significant.

SPAWNING STOCK

The number of adult salmon available for spawning in 1971-78 ranged from 214 to 732 fish with a C.V. of 40% (Table 19). On average, these fish were 99% grilse and 75% female, although the sex ratio had large annual fluctuations (C.V. = 38%). The mean number of female adults available for spawning from 1972 to 1978 was 252 fish (Table 19) and it had a C.V. of only 18% which suggested spawning stock was quite constant except for the large escapement in 1971. There was no apparent relationship ($r = 0.14$) between the number of female spawners and smolt year-class strength as an index of their progeny (Fig. 6).

The kelt migration was also used as an index of spawning stock. It was coincident with timing of the smolt migration (Fig. 1 and 2) and major peaks usually occurred when there were sudden increases in water level (note 1975 and 1978 in Fig. 2). In 1979, only one kelt was counted and it was possible that most fish had migrated to sea before installation of the counting fence. However, the normally distributed counts in other years suggested they were complete (Fig. 2). The survival of adults available for spawning to kelts migrating to sea in the following year ranged from 92% in 1976-77 to 29% in 1971-72. The mean survival rate was 58% with a relatively large C.V. of 26% (Table 19).

There was a nearly significant relationship ($P = 0.08$) between number of kelt as an index of spawning stock and smolt year-class strength (Fig. 7); this relationship was very significant ($P < 0.01$) if the 1975 value was excluded. There was no apparent relationship between overwinter survival of kelt and number of spawning adults; however, there was a significant relationship ($P < 0.01$) between overwinter survival and number of kelt (Table 19). The latter might be expected because of the relatively constant spawning escapement from 1972 to 1978. It was possible the same environmental factors could have affected both kelt survival and hatching success, rather than a direct spawner to progeny relationship.

CLIMATE

Air and water temperatures above 0°C were closely related ($P < 0.01$, Fig. 8) and because air temperature was available throughout the year it was used in all calculations. Air temperature was most variable during the winter months; this was seen in the high C.V. for January, February, March and December (Table 20 and Fig. 9). It appeared that temperature during these four months explained a significant amount ($P < 0.05$) of the variation in the overwinter survival of kelt. Survival was greatest in warmer winters (Fig. 10).

The mean age of smolt year-classes was also highly correlated ($P < 0.01$) with mean annual air temperature; smolt age decreased during cold years (Fig. 11). The variance in mean annual temperature increased as temperature decreased ($P < 0.05$), which suggested colder years, such as 1972, had more clustering in their daily temperature series. The result was a significant inverse relationship ($P < 0.01$) between mean age of smolt year-classes (Table 6) and the standard deviation of mean monthly air temperature (Table 20).

There was a significant relationship ($P < 0.05$) between summer water levels in Western Arm Brook and St. Genevieve River discharge (Table 21) which suggested St. Genevieve could be used to represent Western Arm Brook on a yearly basis. Stream discharge on St. Genevieve River was variable in all months (Table 22 and Fig. 12) but it was most variable in April. However, changes in stream discharge did not appear to affect kelt survival, smolt year-class strength or juvenile growth. The years with the lowest discharge were 1973, 1974 and 1975: 1973 had the smallest smolt year-class, while 1974 and 1975 had the two largest year-classes; these years were also the best for juvenile growth (Table 16). Stream discharge was not related to temperature, and the coldest years did not necessarily have the greatest discharge; for example, 1972 was cold and had below average precipitation. Other associated variables, such as snowfall and precipitation, appeared to have no influence on the above biological characteristics.

DISCUSSION AND SUMMARY

The more interesting results are summarized as follows: 1. Western Arm Brook produced a relatively high number of smolt for its size of drainage area. 2. Year-class strength of smolt was correlated to numbers of downstream migrating kelt as potential parents. 3. Smolt age was inversely correlated to air temperature in the first year of life. 4. Mean size of smolt had the least annual variation of other biological characteristics studied. 5. Ovarian weight was greater in older smolt.

Rearing habitat is usually considered the primary limiting factor in Atlantic salmon production (Symons 1979) and it is the only way to compare the salmon-producing capacities of different rivers. Western Arm Brook has 99,300 m^2 of accessible typical salmon-rearing habitat (Porter et al. 1974) and on average produced 9.66 smolt per 100 m^2. However, there is evidence from field studies that smolts are produced in other areas as well. The smolt production of nine other rivers in Newfoundland and two in the Maritimes was considerably lower (Table 23).

The high smolt production on Western Arm Brook could indicate that either it was a very productive river or its rearing habitat had been underestimated. All of the Newfoundland rivers, with the exception of Sand Hill River (Table 23), were comparable as their habitats had been surveyed by helicopter in a consistent manner. Rearing habitat in Sand Hill River was estimated from accessible stream length and for the Maritimes rivers it was estimated from topographical maps and surveys on foot. Western Arm Brook flows over sedimentary bedrock and has a greater nutrient load than many other Newfoundland rivers. Western Arm Brook also has 1972 ha of lakes and 45 ha of slow river current (< 0.1 m sec^{-1}) which might make a considerable contribution to juvenile production (Pepper 1976). Unpublished data on juvenile production in Western Arm Brook suggest that at least half of the smolt are produced in these atypical habitats.

It is possible that Western Arm Brook was more adequately seeded than the other rivers. This could be a result of lower exploitation rates on its adults. In Western Arm Brook, sea survival rates, from smolt to upstream migrating adults (1SW fish), were approximately 6% (Chadwick and Meerburg 1978). Sea survival rates on rivers farther south were much lower and probably indicated a higher exploitation rate. For example sea survival rates for 1SW fish were 1% on Little Codroy River (Murray 1968), 2.7% on Margaree River (L. Marshall, Dept. of Fisheries and Oceans, Halifax, pers. comm.), and 2.0% on N.W. Miramichi River (Kerswill 1971). Northward, in Labrador, on Sand Hill River sea survival was 11.5% (Pratt et al. 1974).

Year-class strength of smolt appeared to be correlated to numbers of kelt as an index of their parents. This relationship became significant ($P < 0.05$) when the sex ratio and egg potential of kelt were considered (Chadwick 1980). On Little Codroy River the relationship between smolt and kelt was very significant ($P < 0.01$; Chadwick 1980). Unfortunately kelt migrations have not been monitored on many rivers.

Smolt age was positively correlated to temperature in the first year of life (Fig. 11). Size of smolt changed little from year to year, therefore changes in the age at smoltification were the result of changes in juvenile growth or mortality rates. Cold temperature could have influenced smolt age by increasing the growth rate in the first year of life or by increasing the mortality rate on smaller 0+ fish. It was conceivable that cooler temperatures would reduce energy requirements for routine metabolism outside the very short growing season. However, an increased 0+ growth rate in cold years was not seen in the back-calculated length data (Table 16). The slight trend ($r = 0.26$) for back-calclated ℓ_1 values to increase in cold years (Tables 16 and 20) was not significant. It was also possible that temperature influenced survival of larger 0+ juveniles which were able to smoltify at a younger age.

even large size changes could result from these factors

The effect of juvenile stock or biomass on back-calculated growth might be important. For juvenile stocks below 1550 kg, growth rates asymptoted at a constant high value (Fig. 5). This would suggest that below 1550 kg there was little competition for food and growth proceeded at a maximum rate. It might be expected that the possible influence of temperature on growth rates would be most pronounced at lower stock densities. Growth rate declined as the juvenile biomass increased beyond 1550 kg (Fig. 5). Presumably at maximum juvenile biomass or carrying capacity the growth rate would be at some minimum value and smolt age would be at maximum. This type of density-dependent mechanism was also suggested in Table 18, where the annual variation in biomass for individual age groups was more than twice the annual variation for their combined biomass. This would suggest the same food resource was shared by all age groups.

Smolt mean size and condition were quite constant from year to year and had the lowest annual variation of all biological characteristics. Smolt size did not seem to be affected by changes in freshwater age or juvenile stock abundance. This suggested that smolt size was a relatively fixed characteristic.

The mean size of smolt could have evolved to cope with conditions in the sea during the time of migration. This theory was supported by two pieces of evidence. In Western Arm Brook the size of smolt, smelt and brook trout were similar on their seaward migrations (Table 24). There was no significant difference ($P < 0.05$) between the 1978 size of smolt and smelt returning to the sea after spawning. Brook trout had a smaller mean size and a much greater variance, probably because this species was not strictly anadromous and there was a great deal of movement to and from brackish water for all sizes of fish throughout the summer. However the larger sized brook trout were very similar in size to smolt and smelt.

A comparison of sizes of smolts in other rivers indicated that smolt size increased with latitude (Table 25). Thus, more southerly rivers had smaller smolt, which could have been a consequence of an earlier time of migration or warmer sea temperatures. The northern rivers had a later spring, cooler sea temperatures and were perhaps nearer to the oceanic feeding grounds. Smolt size appeared then to be a local phenomenon and not related to growth rate. Therefore, within a particular river, faster-growing juveniles would become smolt similar in size to slower-growing juveniles, but would have younger smolt ages.

Ovarian weight in older smolt was a significantly greater proportion of body weight than in younger smolt (Table 15). This suggested that the ovaries of older smolt were probably in a more advanced stage of maturity and it was possible these fish would mature after one year at sea. This might explain the greater propensity to grilsification in many northern rivers, which generally produce older smolt.

In summary, smolt production was influenced by changes in egg deposition, juvenile biomass, and air temperature in the first year of life. Kelt provided a possible index of egg deposition or egg to smolt survival.

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Table 1. Dates when smolt counting fence was in operation and when the first and last smolts were counted.

Year	Fence operation		Duration of smolt run in days	Smolt count	
	Start	Finish		First	Last
1971	28 May	11 July	46	28 May	11 July
1972	5 June	19 Aug.	65	5 June	9 Aug.
1973	28 May	17 Sept.	58	28 May	24 July
1974	1 June	30 July	57	3 June	30 July
1975	23 May	11 July	46	23 May	7 July
1976	20 May	30 June	42	20 May	30 June
1977	29 May	06 July	33	3 June	6 July
1978	28 May	14 July	48	28 May	14 July
1979	26 May	3 July	39*	26 May	3 July

* 1979 was not a complete count.

Table 2. Downstream migrating fish at Western Arm Brook, 1971-79.

Year	Salmon			Trout		Other			
	Kelt	Smolt	Parr	Adult	Parr	Eel	Smelt	Shad	Stickleback
Summer									
1971	185	5734	434	7	128	91	108	3	-
1972	210	11906	431	53	167	197	181	52	11
1973	95	8484	250	429	-	97	365	5	44
1974	302	12055	267	593	216	574	539	3	338
1975	201	9733	122	851	-	92	607	0	112
1976	208	6359	148	408	-	30	926	0	16
1977	198	9640	358	340	33	65	354	12	26
1978	210	13071	899	1000	-	69	527	2	21
1979	1	9400*	235	109	-	1	53	0	21
Mean	190	9598	349	421	-	135	407	9	-
S.D.	93.7	2503.7	234.0	346.5		173.2	276.5	16.7	
S.E.	31.2	834.6	78.0	115.5		57.7	92.2	5.6	
C.V.	49	26	67	82		128	68	186	
Fall									
1977	-	13	13	59	59	53	13	-	2
1978	-	29	164	38	45	32	19	-	2

* Estimated.
S.D. = standard deviation
S.E. = standard error
C.V. = coefficient of variation: (SD x 100) ÷ mean

Table 3. Average annual biomass of smolts, eel, trout, and smelt exported from Western Arm Brook. Mean weight of eel was from electrofished sample; mean weights of trout and smelt were estimated.

Out-migrating species	Mean weight (g)	Mean numbers	Biomass exported (kg)
Smolt	48	9598	460
Eel	198	135	27
Trout	40	421	17
Smelt	30	407	12
Total			516

Table 4. Size of smolt migration and mean age of the smolt; the percentage of smolts at each river age and the sample size of smolts that were aged is also given.

Year	Smolt count	Mean age	Percent in each age group					Sample size
			3	4	5	6	7	
1971	5734	4.1	17	54	24	3	2	57
1972	11906	4.1	12	79	9	<1	-	234
1973	8484	3.9	15	78	7	-	-	87
1974	12055	4.3	11	63	24	2	-	234
1975	9733	3.6	35	61	3	1	-	245
1976	6359	4.0	15	72	12	1	-	155
1977	9640	3.5	55	42	2	-	-	235
1978	13071	3.7	37	56	7	-	-	160
1979	9400*	3.8	24	70	6	-	-	195
Mean	9598	3.9						
S.D.	2503.7	0.26						
S.E.	834.6	0.09						

* 1979 was not a complete count and it was estimated (see text).

Table 5. Number of smolts in each age group as estimated from the mean age and total smolt count.

Year	Age group 3	4	5	6	7
1971	975	3096	1376	172	115
1972	1428	9359	1072	47	0
1973	1273	6617	594	0	0
1974	1326	7595	2893	241	0
1975	3407	5937	292	97	0
1976	954	4578	763	64	0
1977	5350	4097	193	0	0
1978	4836	7320	915	0	0
1979	2256	6580	564	0	0
Mean	2423	6131	962	69	13
S.D.	1701.4	1943.3	813.0	87.0	38.3
S.E.	576.1	647.8	271.0	29.0	12.8
C.V.	70	32	118	126	292

Table 6. Size of smolt year-classes and mean age.

Year-class	Number smolt	Mean age	Percent in each age group 3	4	5	6
1967	6591[a]	3.8	37	47	16	-
1968	11169	4.0	9	84	5	2
1969	11035	4.2	13	60	26	1
1970	9224	3.9	14	82	3	1
1971	8026	3.9	17	74	9	-
1972	8178	3.6	42	56	2	-
1973	5966	4.0	16	69	15	-
1974	13234[b]	3.7	40	55	5	-
1975	12378[b]	3.7	39	53	8	-
Mean	9533	3.9				
S.D.	2557.0	0.19				
S.E.	852.3	0.06				

a) Number of 3+ smolt estimated.
b) Number of 5+ smolt estimated.

Table 7. A summary of coefficients of variation (C.V. = S.D. ÷ Mean x 100) for biological characteristics of smolt in Western Arm Brook (1971-79).

Characteristic	Units	Mean	C.V.
Smolt run	fish	9598	26
Year-class	fish	9533	27
Smolt age	year	3.9	7
Smolt fork length	mm	174	1 vs 9.5 for BSR
Smolt condition	-	0.90	2
Smolt sex	% male	26	15
Smolt standing stock	kg	460	27
Grilse escapement*	fish	577	37
Grilse harvest Area N	lbs	26025	12

* Excluding 1979.

Table 8. Smolt fork length at 3 smolt ages for samples 1971-79 in Western Arm Brook.

	Age group											
	3			4			5			Total		
Year	x	SD	n	x	SD	n	x	SD	n	x	SD	n
1971	170	9.9	10	172	11.6	30	190	18.4	12	176	15.2	54
1972	166	11.1	26	175	17.0	181	187	24.7	21	175	18.5	234
1973	170	9.0	13	173	17.9	67	157	19.2	5	172	17.5	87
1974	164	13.4	24	174	17.4	124	173	24.3	43	173	19.8	234
1975	166	13.4	83	174	14.1	141	184	13.7	8	171	14.4	245
1976	169	15.3	18	177	16.2	88	189	23.5	16	176	17.5	155
1977	170	12.9	96	176	17.3	72	181	15.5	3	172	15.2	171
1978	160	14.1	59	174	13.1	89	197	12.5	12	171	16.9	100
1979	174	13.6	46	179	15.6	136	184	28.3	11	178	13.2	195
Overall mean	168	4.1	9	175	2.2	9	182	11.6	9	174	2.5	9

* The subtotal for age groups 3, 4 and 5 do not necessarily add up to equal total n, as all fish could not be aged.

Table 9. Sex composition and mean smolt fork length (mm) at three river ages for 1977-79. Standard deviation is shown in parentheses and sample size below that.

	River age					
	3		4		5	
Year	M	F	M	F	M	F
1977	172 (8.7) 30	169 (14.3) 66	180 (10.3) 14	175 (18.5) 58	 0	181 (15.5) 3
1978	163 (6.8) 13	158 (15.5) 46	173 (8.7) 14	174 (13.8) 75	193 (13.6) 3	199 (12.5) 9
1979	173 (11.7) 13	174 (14.2) 32	180 (13.0) 36	178 (16.4) 99	182 (0) 1	185 (29.8) 10

No difference between males and females ($P > 0.1$)

Table 10. Comparison of change in mean smolt size throughout the duration of the 1979 smolt migration.

	Time period* in groups of five days							
	1	2	3	4	5	6	7	8
Mean	173	178	180	174	178	179	179	180
SD	14.7	19.7	16.4	17.3	17.3	17.2	14.4	13.8
n	20	25	25	25	25	25	25	25

* For example, time period 1 contains samples from the smolt run in days 1 to 5. F-test: P = 0.79 that there was no size difference between time periods.

Table 11. Smolt condition factor (w/l^3) for samples 1972, 1973, 1977-79, in Western Arm Brook.

	Age group								
	3			4			5		
Year	x	SD	n	x	SD	n	x	SD	n
1971	-	-	-	-	-	-	-	-	-
1972	0.92	0.062	26	0.92	0.097	179	0.93	0.090	21
1973	0.90	0.076	13	0.89	0.076	66	0.95	0.190	5
1974	-	-	-	-	-	-	-	-	-
1975	-	-	-	-	-	-	-	-	-
1976	-	-	-	-	-	-	-	-	-
1977	0.90	0.097	96	0.91	0.081	72	0.91	0.048	3
1978	0.93	0.097	59	0.90	0.059	89	0.89	0.063	12
1979	0.86	0.094	46	0.88	0.082	136	0.82	0.205	11
Overall mean	0.90	0.027	5	0.90	0.016	5	0.90	0.050	5

Table 12. Mean weight and standing stock of smolt migrations in Western Arm Brook, 1971-79.

Year	Mean weight (g)	Number	Standing stock (kg)
1971	-	5734	275*
1972	50.6	11906	602
1973	46.5	8484	395
1974	-	12055	577*
1975	-	9636	462*
1976	-	6259	300*
1977	46.5	9640	448
1978	46.2	13071	604
1979	49.5	9400	465
Mean	47.9		460
SD	2.04		121.9
SE	0.91		40.6

* Standing stock estimated using mean weight of 47.9 g.

Table 13. The percentage male smolt for smolt ages 3+, 4+ and 5+ in Western Arm Brook, 1971-79; abundance of precocious males is also indicated, 1977-79.

Year	Smolt age 3+	Smolt age 4+	Smolt age 5+	Total	Number sexed	Precocious males as a percent of total males
1971	25	32	18	27	41	-
1972	18	29	38	27	234	-
1973	77	26	0	31	87	-
1974	-	-	-	-	-	-
1975	-	-	-	-	-	-
1976	-	-	-	-	-	-
1977	31	19	0	26	171	30
1978	22	16	25	19	160	20
1979	29	27	9	26	195	14
Mean				26		
SD				3.9		
SE				1.6		

Table 14. Comparison of vertebral counts for 3+ 4+ and 5+ smolt in 1977.

	Number vertebrae	3+	4+	5+
	56	1		
	57	1	1	
	58	8	2	
	59	10	12	2
	60	8	13	
	61	3	2	
	62		1	
Mean		59.0	59.5	59.0
SD		1.17	0.96	
n		31	31	2

No significant difference ($P > 0.1$) between 3+ and 4+ smolt.

Table 15. Comparison of smolt gonad weight (mg) for both sexes and smolt ages 3, 4 and 5 in Western Arm Brook, for years 1977-79.

	Female			Male		
	3	4	5	3	4	5
1977						
Mean	25.4	33.6	23.7	12.4	13.3	-
SD	12.6	13.3	11.6	9.3	11.0	-
CV	50	40	49	75	83	-
N	60	56	3	28	14	0
%	0.057	0.070	0.048	0.027	0.026	-
1978						
Mean	26.9	37.9	50.4	5.8	14.3	8.0
SD	10.6	13.2	11.1	2.6	16.4	3.9
CV	39	35	22	45	115	49
n	45	75	9	11	14	3
%	0.072	0.079	0.071	0.015	0.030	0.013
1979						
Mean	28.8	35.8	41.3	4.4	6.7	-
SD	13.9	10.6	13.7	2.0	2.2	-
CV	48	30	33	45	33	-
N	32	99	10	12	31	0
%	0.059	0.072	0.087	0.010	0.013	-

SD - standard deviation
CV - coefficient of variation (SD ÷ mean x 100)
n - number in sample
% - Gonad weight as a percent of mean body weight.

Table 16. Back-calculated fork lengths (mm) for 3+, 4+ and 5+ smolt captured in 1971-77.

Year-class	Year of capture	Smolt age	Sample size	Fork length	Back-calculated fork length					
					ℓ_1	ℓ_2	ℓ_3	ℓ_4	ℓ_5	Total
1974	1977	3+	31	170	75	119	163			170
1973	1976	3+	18	169	72	116	149			158
	1977	4+	31	176	67	105	138	169		176
1972	1975	3+	83	166	67	112	153			165
	1976	4+	88	177	66	105	142	169		173
	1977	5+	2	181	59	95	128	164	183	187
1971	1974	3+	18	164	60	107	143			166
	1975	4+	141	174	65	102	135	164		174
	1976	5+	15	189	61	94	131	159	183	202
1970	1973	3+	12	170	69	107	142			168
	1974	4+	26	174	64	105	140	164		179
	1975	5+	3	184	59	81	105	142	156	188
1969	1972	3+	12	166	73	114	155			166
	1973	4+	50	173	61	94	124	152		169
	1974	5+	10	173	57	85	113	142	161	183
1968	1971	3+	7	170	66	121	171			168
	1972	4+	50	175	67	103	147	181		225
	1973	5+	5	157	54	85	109	135	156	159
1967	1971	4+	29	172	60	89	122	155		169
	1972	5+	25	197	59	93	131	168	196	246
1966	1971	5+	15	190	57	85	113	147	173	201

Table 17. Comparison of growth increments (mm) during years 1968-74 in Western Arm Brook.

Growth year	Smolt age	Age group 0-1	1-2	2-3	3-4	4-5	Mean*	SD
1968	3+	38	-	-				
	4+	39	29	-	-		33.8	4.97
	5+	36	34	38	-	-		
1969	3+	45	55	-				
	4+	33	36	33	-		38.9	9.08
	5+	29	31	38	34	-		
1970	3+	41	41	50				
	4+	36	33	44	33		36.4	8.29
	5+	31	28	24	37	26		
1971	3+	32	38	41				
	4+	37	41	30	34		33.6	6.35
	5+	33	22	28	26	28		
1972	3+	39	47	35				
	4+	38	37	35	28		35.4	6.25
	5+	31	33	24	29	21		
1973	3+	44	45	36				
	4+	39	39	33	24		38.4	3.90
	5+	-	36	37	37	19		
1974	3+	47	44	41				
	4+	-	38	37	29		38.2	5.02
	5+	-	-	33	28	14		
Overall mean	3+	41	45	41				
	4+	37	36	35	30			
	5+	30	31	30	32	22		

* Mean is weighted equally for each smolt age and includes only age groups 0-1, 1-2 and 2-3.

Table 18. Numbers and standing stock of 0+, 1+, 2+, 3+ and 4+ salmon present in Western Arm Brook during the years 1969 to 1977, estimated from abundance.

Year	Numbers in age group 0	1	2	3	4	Standing stock (kg) in age group 0	1	2	3	4	Total standing stock (kg)
1969	227365	70582	(22089)	(16151)	(1789)	341	332	296	488	81	1538
1970	157168	81987	37969	9459	2558	236	385	509	286	115	1531
1971	143737	56674	44105	19451	1993	216	266	591	587	90	1750
1972	120595	51831	30487	22297	1104	181	244	409	673	50	1557
1973	112428	43486	27882	15128	5378	169	204	374	457	242	1446
1974	200347	40542	23393	13673	543	301	191	313	413	24	1242
1975	(195434)	72245	21809	9177	1418	293	340	292	277	64	1266
Mean						248	280	398	454	95	1476
SD						65.0	73.6	114.8	146.1	71.0	177.1
CV						26	26	29	32	75	12

Parentheses indicate estimated values. In 1969, age group 2 for 3+ smolt, age group 3 for 4+ smolt and age group 4 for 5+ smolt were estimated from mean values. In 1975, age group 0 was estimated for 5+ smolt.

Table 19. Adult salmon and kelt migrations at Western Arm Brook, 1971-78; numbers of adults available for spawning and sex ratio are also given.

Year	1	2	3	4	5
1970				185	-
1971	732	28	527	210	29
1972	214	19	173	95	36
1973	380	22	297	302	79
1974	319	16	268	199	62
1975	394	44	221	206	50
1976	420	27	307	298	92
1977	351	25[a]	263	210	58
1978	286	18	234	1[b]	<1[b]
Mean	387	25	286	213	58
SD	154.1	9.6	106.4	65.6	22.4
SE				23.2	8.5
C.V.	40	38	37	31	26

1. Number of adults available for spawning.
2. Percentage of adults sexed which were male.
3. Number of female adults available for spawning.
4. Number of adult spawners counted as kelts in the following year.
5. Percentage of adult spawners which were counted as kelts in the following year.

a) Estimated from mean.
b) Excluded from calculation of mean.

Table 20. St. Anthony mean monthly and mean annual air temperatures (°F).

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean	S.D.
1968	15.1	18.2	20.0	30.6	37.7	44.0	54.4	51.2	50.2	42.4	29.2	23.7	34.7	13.8
1969	24.1	23.3	25.7	25.3	37.8	48.7	56.2	56.7	47.5	35.3	35.3	30.4	37.2	12.3
1970	14.4	17.6	24.7	29.3	38.1	46.1	56.5	56.8	46.6	39.6	31.6	16.9	34.9	14.9
1971	14.7	11.9	25.9	31.5	40.6	46.7	55.7	56.4	47.6	38.4	32.0	15.1	34.7	15.6
1972	7.9	6.7	14.8	24.7	32.3	44.3	54.4	52.7	45.9	35.2	27.2	4.1	29.2	18.0
1973	8.5	12.3	19.7	28.2	36.1	45.1	58.6	52.7	48.4	37.8	29.9	26.5	33.7	15.8
1974	0.5	13.1	15.8	25.2	33.1	45.9	52.1	53.6	47.6	36.7	28.9	22.4	31.2	16.7
1975	7.2	4.8	22.4	28.4	36.4	45.6	60.5	53.9	49.9	38.0	29.0	19.2	32.9	17.8
1976	14.2	8.9	14.7	30.1	39.5	46.2	54.1	55.7	48.3	37.2	27.2	15.9	32.7	16.6
Mean	12.5	13.2	20.8	28.2	36.0	46.0	55.8	54.5	47.6	38.2	30.8	19.6		
SD	6.6	5.6	4.5	2.4	3.6	1.4	2.4	1.9	1.9	2.3	3.4	7.3		
CV	53	42	22	9	10	3	4	4	4	6	11	37		

Table 21a. Monthly mean daily minimum water levels (cm) at Western Arm Brook, for 1970-76 (Anon. 1977).

Month	1970	1971	1972	1973	1974	1975	1976
June	-	99	181	62	223	101	103
July	-	78	114	45	181	55	45
Aug.	-	89	100	41	158	38	73
Sept.	-	121	-	-	-	28	92

Table 21b. Monthly mean discharges (CFS) at St. Genevieve River, for 1970-76 (Anon. 1977).

Month	1970	1971	1972	1973	1974	1975	1976
June	615	735	1060	654	749	582	434
July	401	396	642	448	492	315	209
Aug.	285	305	394	342	300	173	143
Sept.	204	339				110	135

Table 22. Mean monthly discharge (CFS) from St. Genevieve River, 1970-76 (Anon. 1977).

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean	SD	Max ÷Min	Total discharge
1970	251	235	203	259	715	615	401	285	204	236	245	353	334	48.2	6.4	242
1971	269	193	161	425	1110	735	396	305	339	264	221	190	384	79.7	11.3	279
1972	144	62	96	413	364	1060	642	394	259	220	220	237	343	79.8	28.3	249
1973	142	182	149	215	649	654	448	242	169	130	124	185	282	56.8	9.1	205
1974	163	101	78	124	550	749	492	300	187	261	267	280	296	58.7	12.8	215
1975	173	121	104	188	588	582	315	173	110	145	261	335	258	49.2	9.9	187
1976	244	230	203	772	708	434	209	143	135	219	413	396	342	61.0	8.4	248
Mean	198	161	142	342	669	690	415	277	200	211	250	282				232
SD	54.6	66.7	50.8	220	228	194.3	136.3	89.5	77.7	53.2	86.2	82.4				31.4
SE	20.6	25.2	19.2	83.3	86.2	73.4	51.5	33.8	29.4	20.1	32.6	31.2				11.9
CV	28	41	36	64	34	28	33	32	39	25	34	29				14

Table 23. Summary of estimates for annual smolt production per 100 m^2 of rearing habitat in Newfoundland, Labrador and Maritimes.

River	Rearing habitat ($m^2 \times 10^{-5}$)	Mean annual smolt production $m^{-2} \times 10^2$	References
Newfoundland			
Little Codroy River	3.89	2.57	Murray 1968
Long Harbour River	15.01	7.60	Unpublished
Come by Chance River	0.82	5.37	Unpublished
Bay du Nord River	17.54	0.48	Unpublished
Stoney Brook	2.62	1.87	Unpublished
Indian River	18.89	0.61	Unpublished
North Harbour River	1.22	0.96	Lear and Day 1977
Western Arm Brook	0.99	9.66	This report
Labrador			
Sand Hill River	21.08	2.30	Pratt et al. 1974
Maritimes			
Big Salmon River	5.09	3.95	Jessop 1975
Margaree	-	5.20	L. Marshall (pers. comm.)

Table 24. Mean fork length of trout, smelt, eel, shad, and smolt during their downstream migration in Western Arm Brook, 1977-78.

Species Year	n	Mean fork length	SD	SE	CV	Fork length (mm) Min.	Max.
Trout							
1977	100	155	36.6	3.7	24	50	140
1978	95	157	36.4	3.7	23	75	274
Smelt							
1977	100	179	18.6	1.9	10	140	230
1978	85	169	13.8	1.4	8	142	212
Eel							
1977	45	468	122.5	18.3	26	250	790
1978	20	517	69.6	15.6	13	403	665
Shad							
1977	25	277	16.1	3.2	6	255	320
Smolt							
1977	171	172	15.2	1.2	9		
1978	100	171	16.9	1.7	10		

Table 25. Comparison of fork length and age for smolt sampled in several Canadian rivers; latitude of the river mouth is also included.

River	Mean fork length (mm)	Mean smolt age (yr)	Latitude	Reference
Newfoundland				
Western Arm Brook	175	3.9	51°	This report
Little Codroy River	149	2.6	48°	Murray 1968
North Harbour River	153	3.0	48°	Lear and Day 1977
Bay du Nord River	167	-	48°	Unpublished
Labrador				
George River	215	5.9	58°	Power 1969
Whale Rver	206	5.2	57°	Power 1969
Koksoak River	206	5.0	57°	Power 1969
Sandhill River	160	4.4	53°	Pratt et al. 1974
Quebec				
Matamek River	149	-	50°	Naiman 1980
Maritimes				
NW Miramichi River	147	2.9	47°	Forsythe 1967
Pollett River	159	-	46°	Elson 1962
Big Salmon River	143	2.5	46°	Jessop 1975

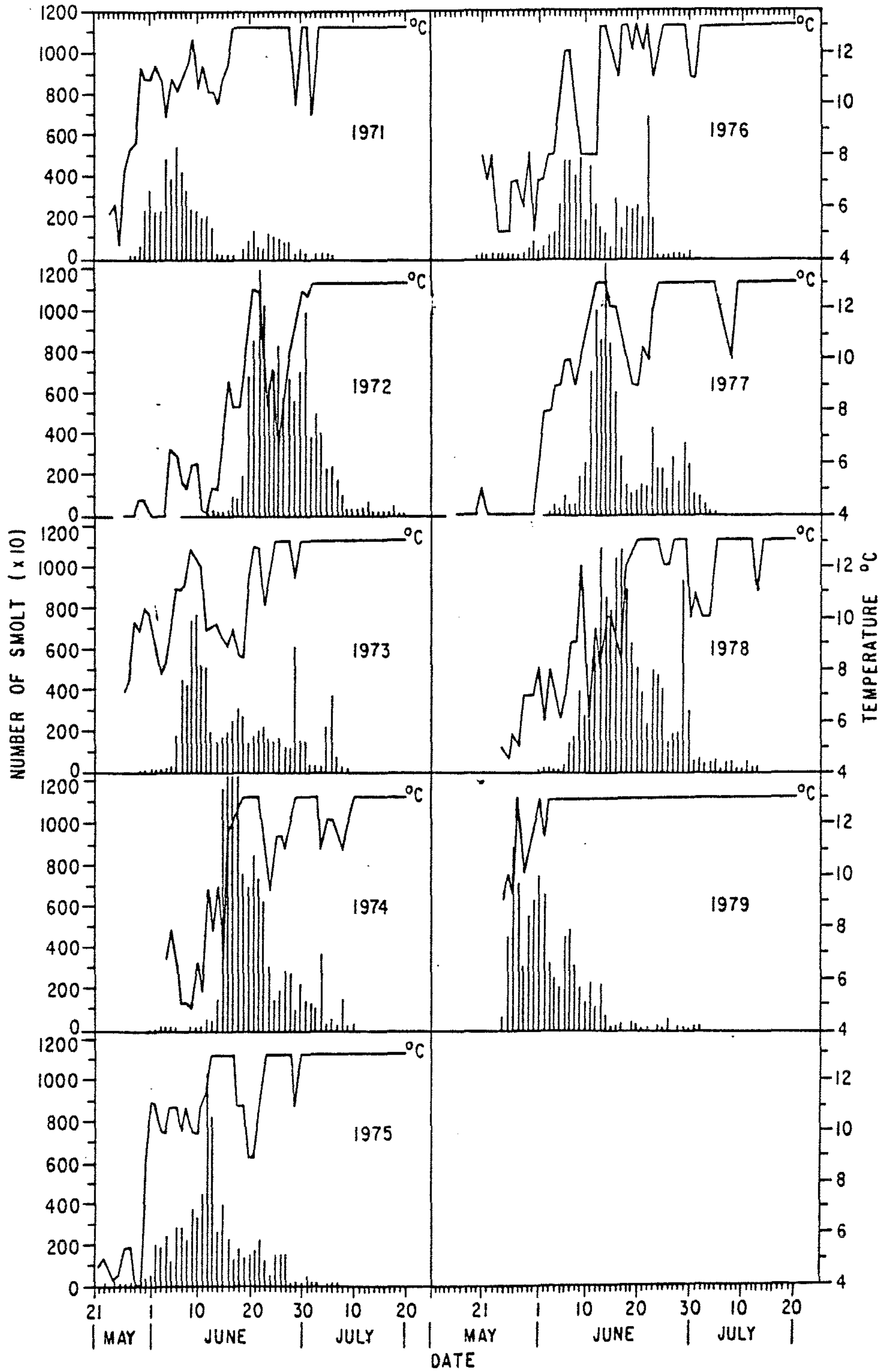

Fig. 1. Daily counts of smolt migration and daily temperature (0800 h) at Western Arm Brook, 1971–79. Temperatures above 13° are shown as a horizontal line.

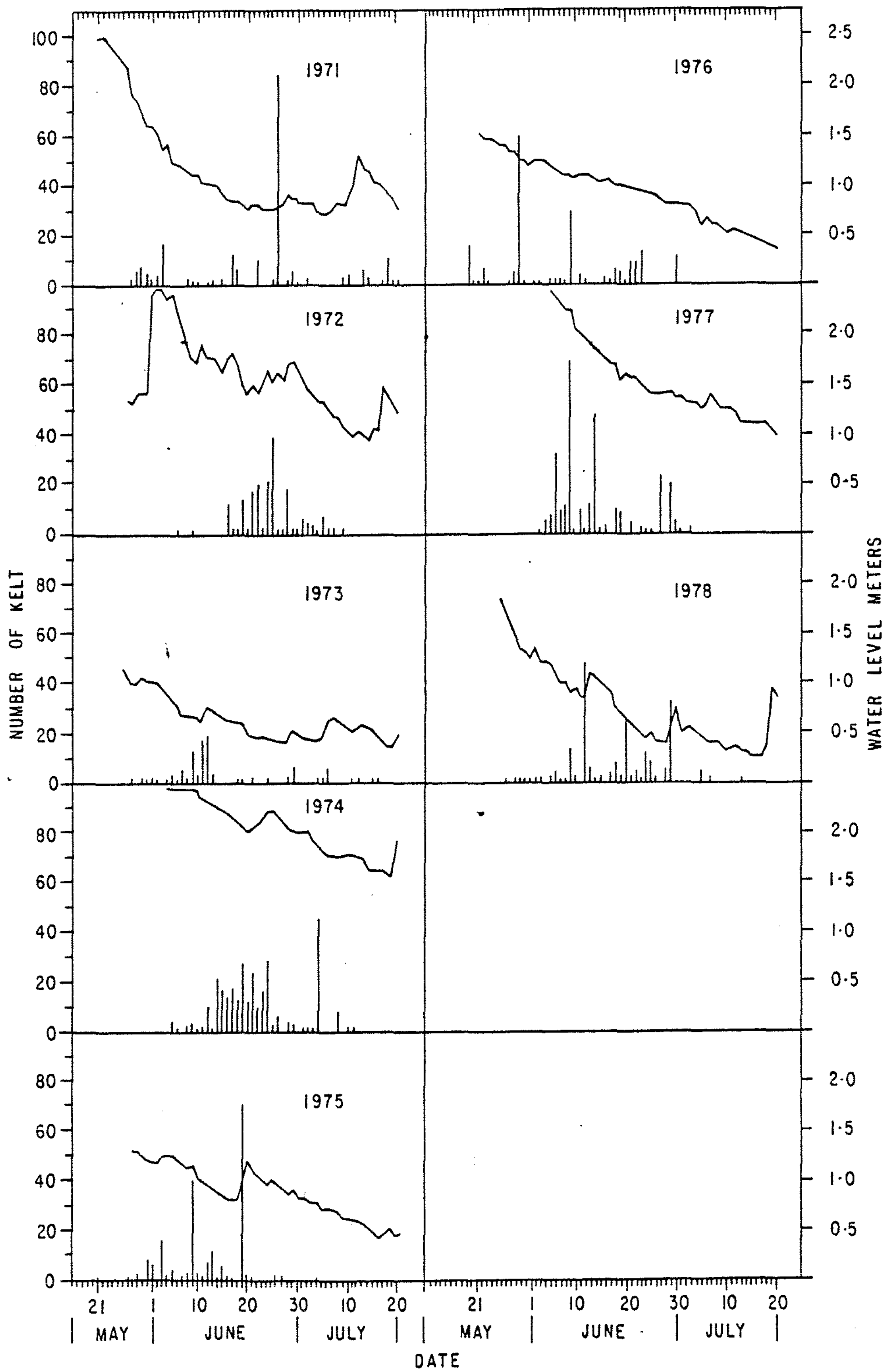

Fig. 2. Daily counts of kelt migration and daily water level (0800 h) at Western Arm Brook, 1971-78.

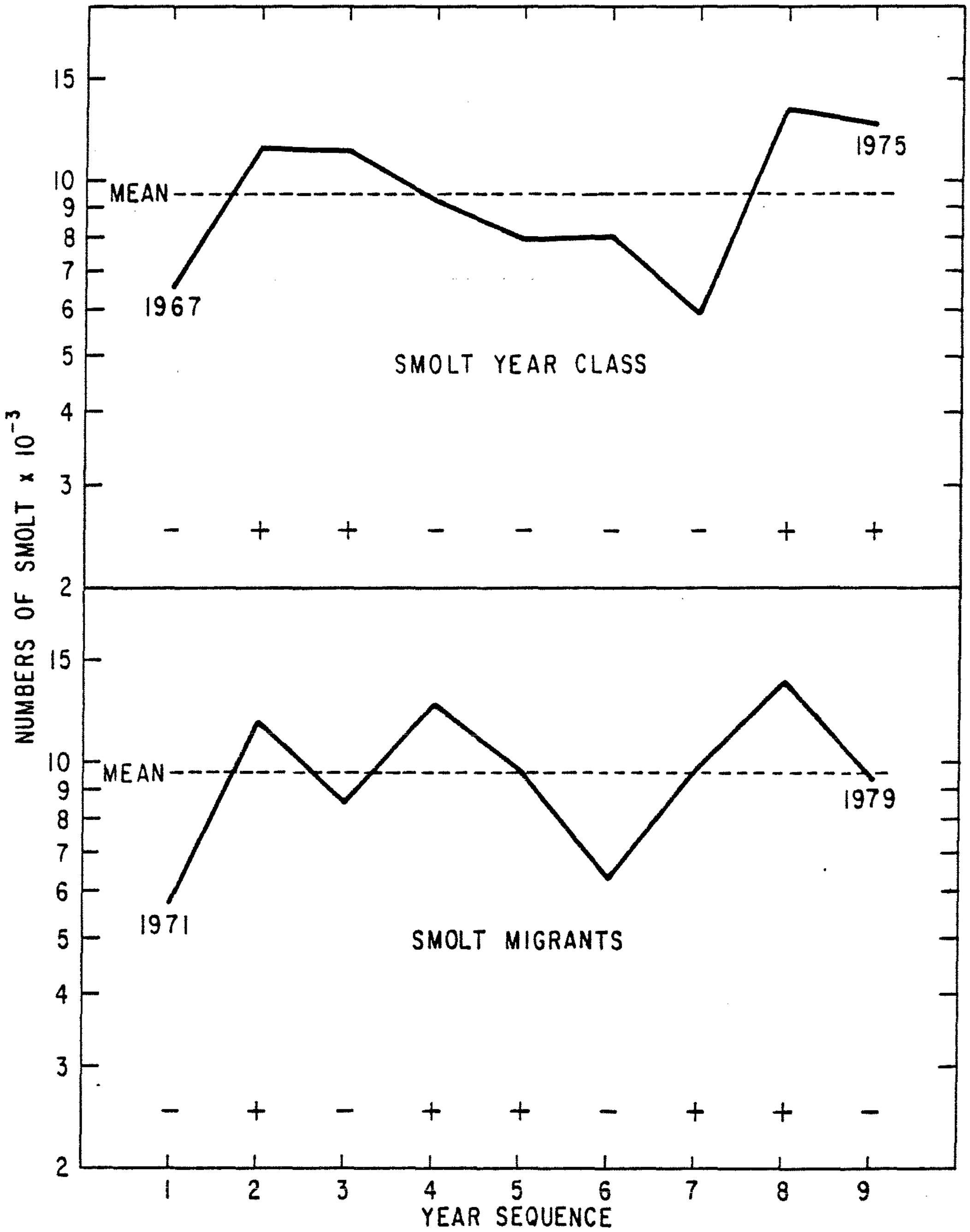

Fig. 3. Numbers of smolt migrants counted from 1971 to 1979 at Western Arm Brook; the upper figure shows the size of smolt year-classes. The sequence of + and - indicates if a value is greater or less than the preceding value.

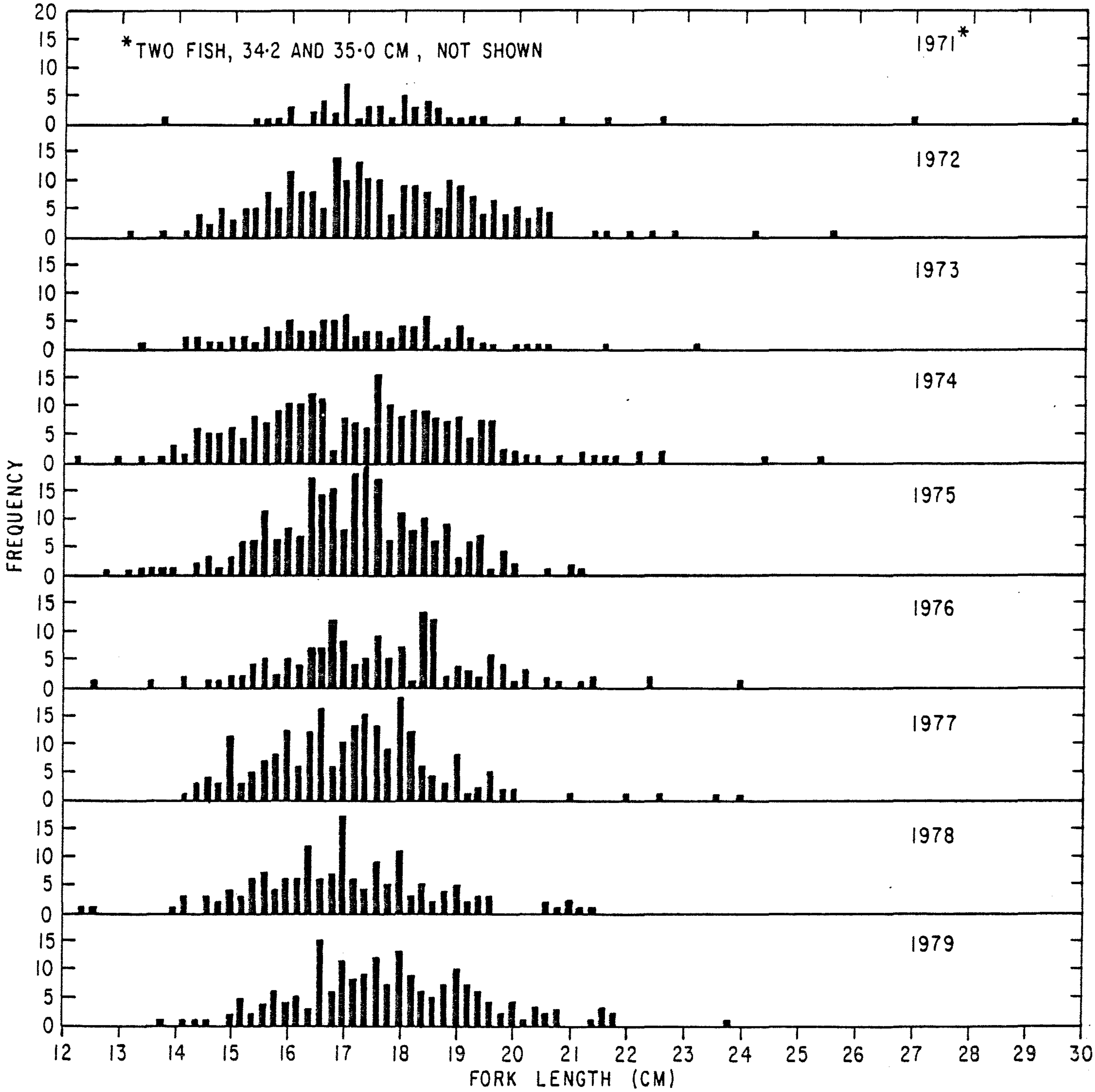

Fig. 4. Fork length frequency distribution for smolt samples taken at Western Arm Brook, 1971–79.

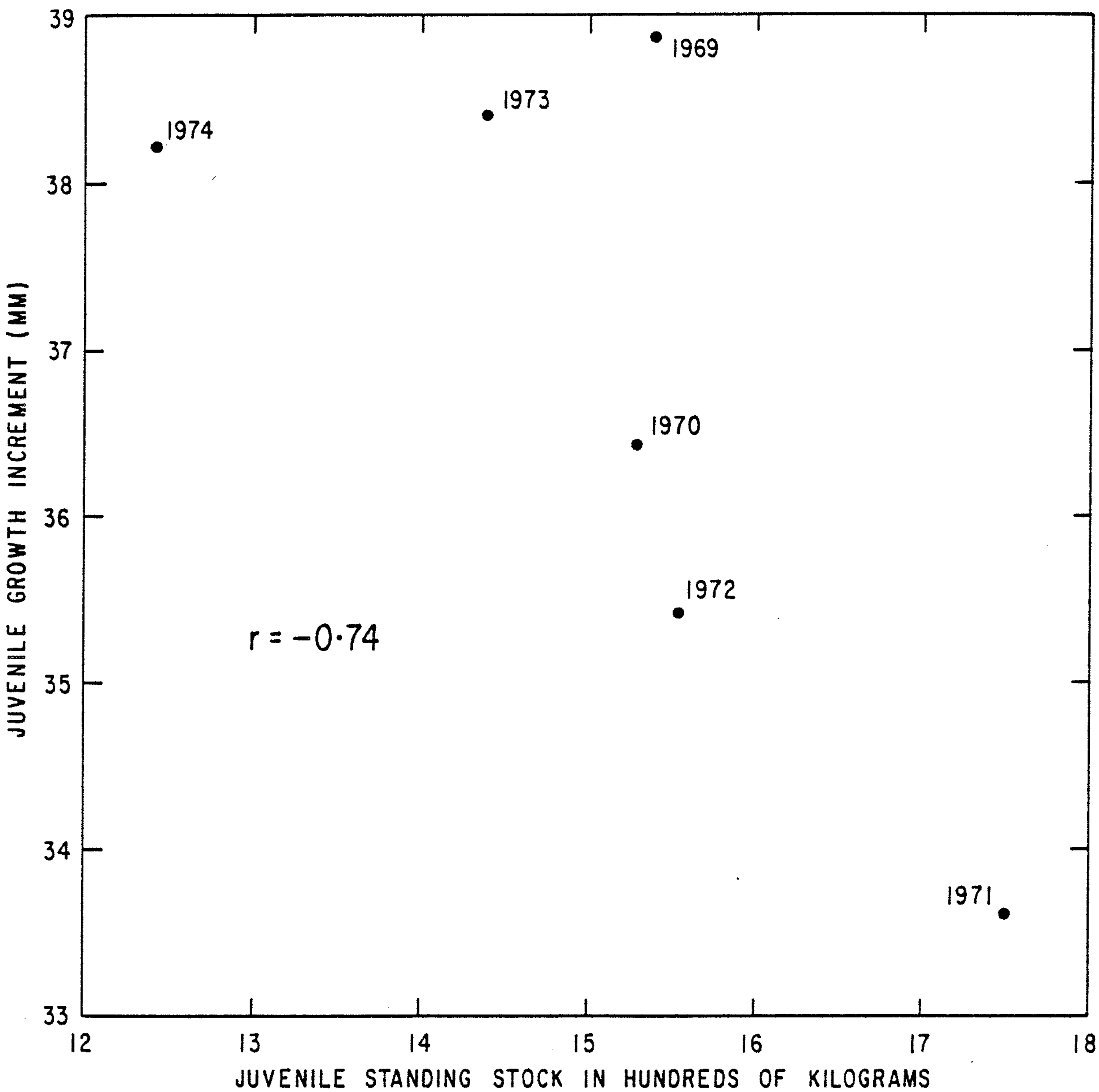

Fig. 5. The relationship between juvenile standing stock and an average growth increment during that year.

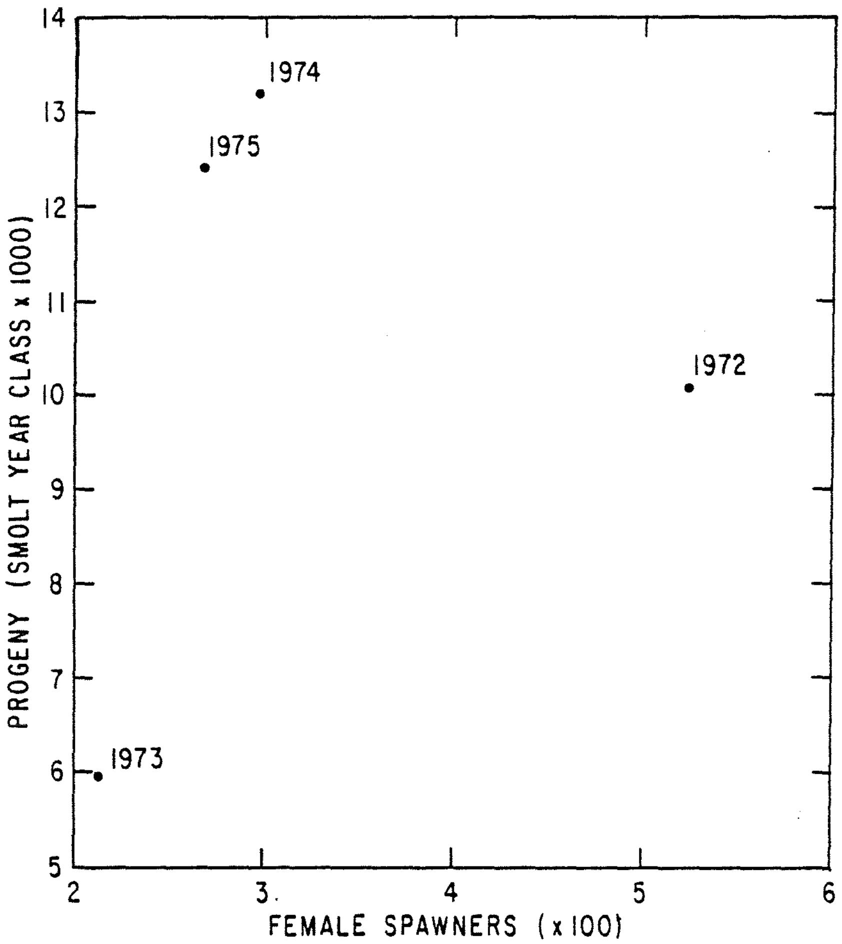

Fig. 6. Relationship between the number of female adults available for spawning and the size of smolt year-classes as an index of their progeny. Dates for the smolt year-classes are indicated.

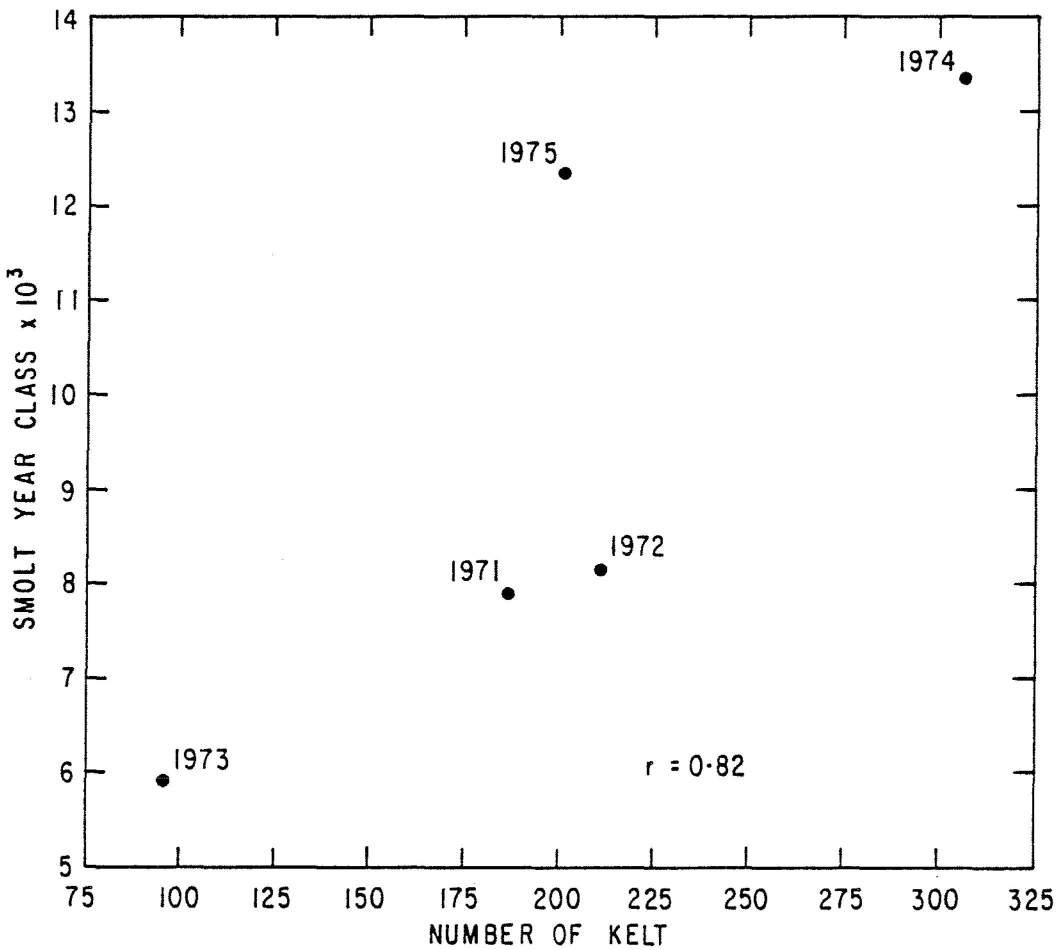

Fig. 7. Relationship between the number of kelt as an index of spawners and size of smolt year-classes as an index of their progeny. Dates for the smolt year-classes are indicated.

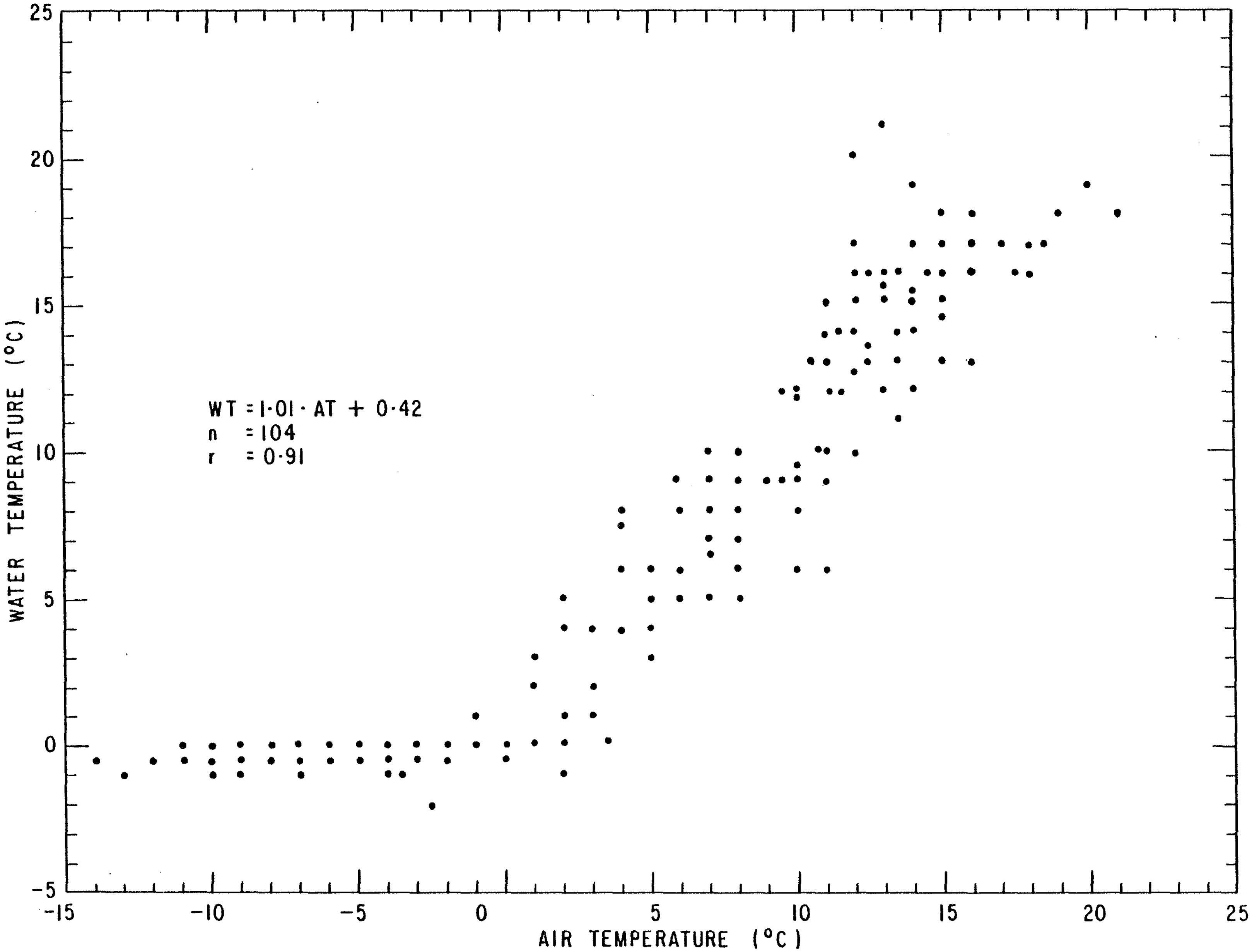

Fig. 8. Relationship between air and water temperatures at 0800 h in Western Arm Brook from 01/09/1978 to 31/03/1979.

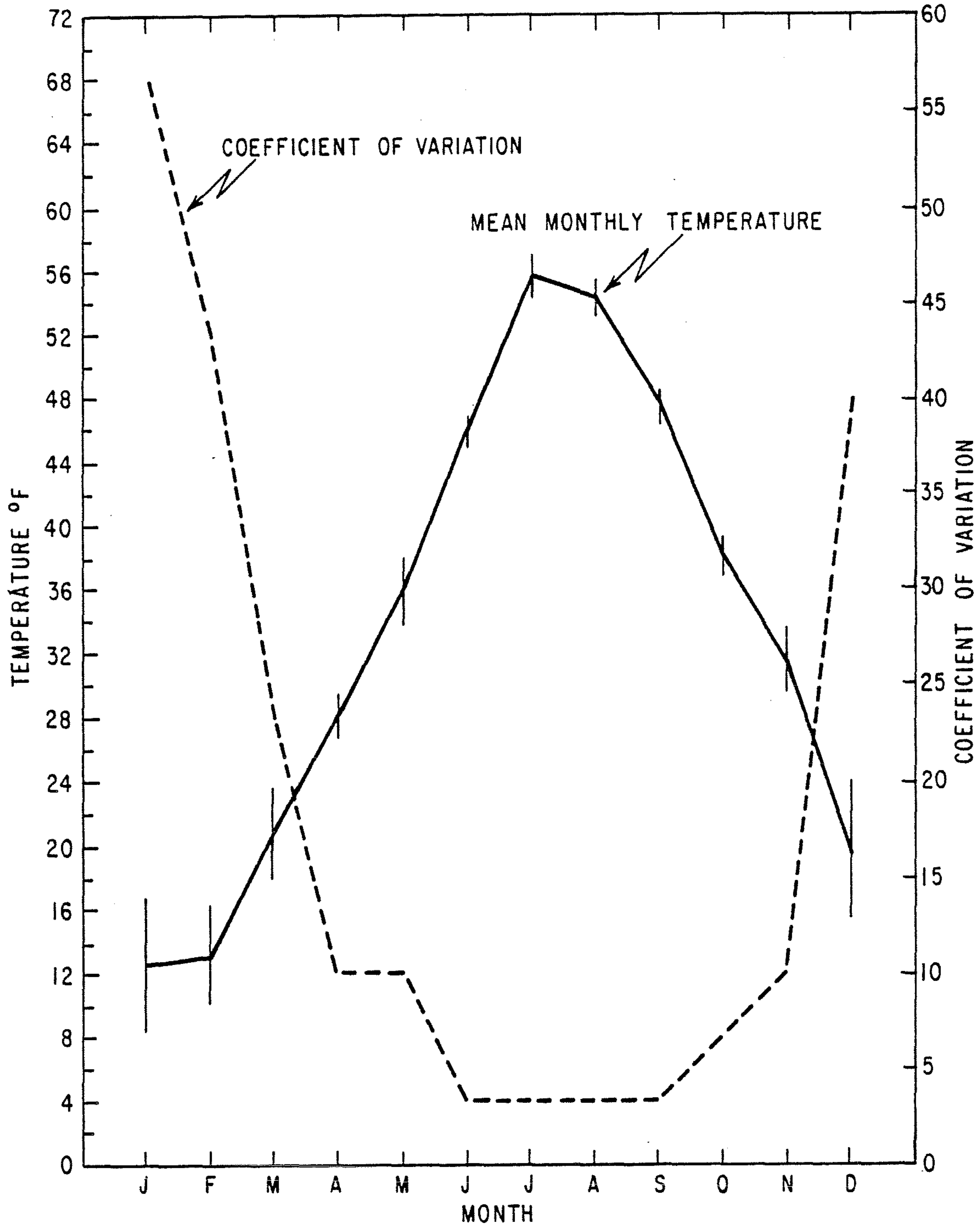

Fig. 9. St. Anthony mean monthly air temperature and its coefficient of variation for 10 years (1968–77); 95% confidence limits are also indicated.

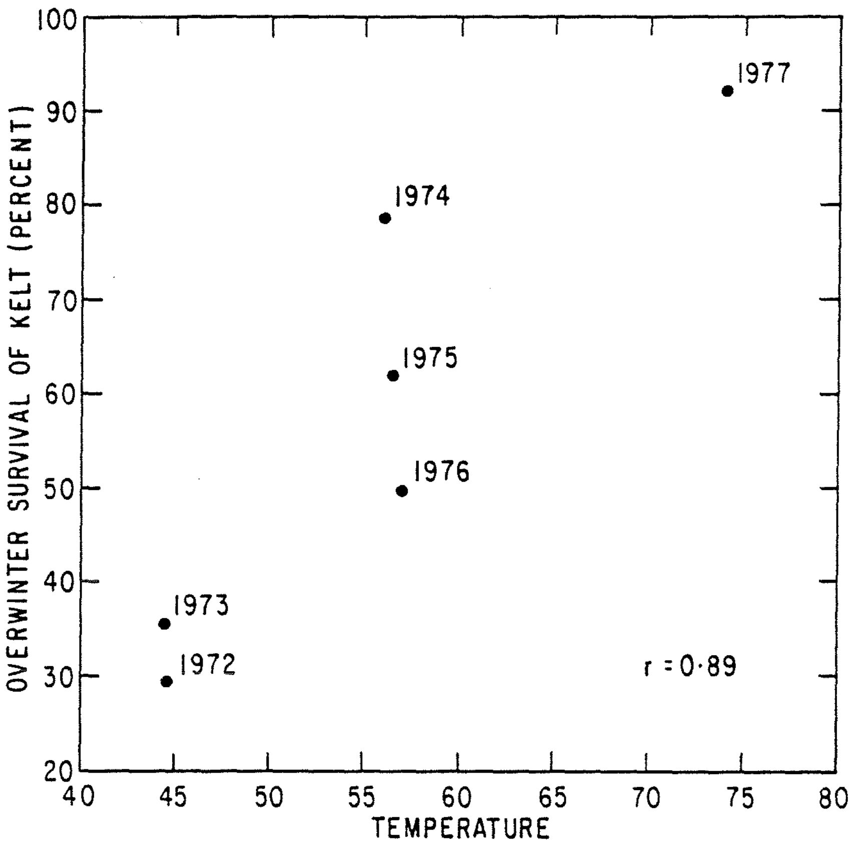

Fig. 10. Relationship between overwinter survival of kelt and an index of winter temperature. The year when kelt were counted is also indicated.

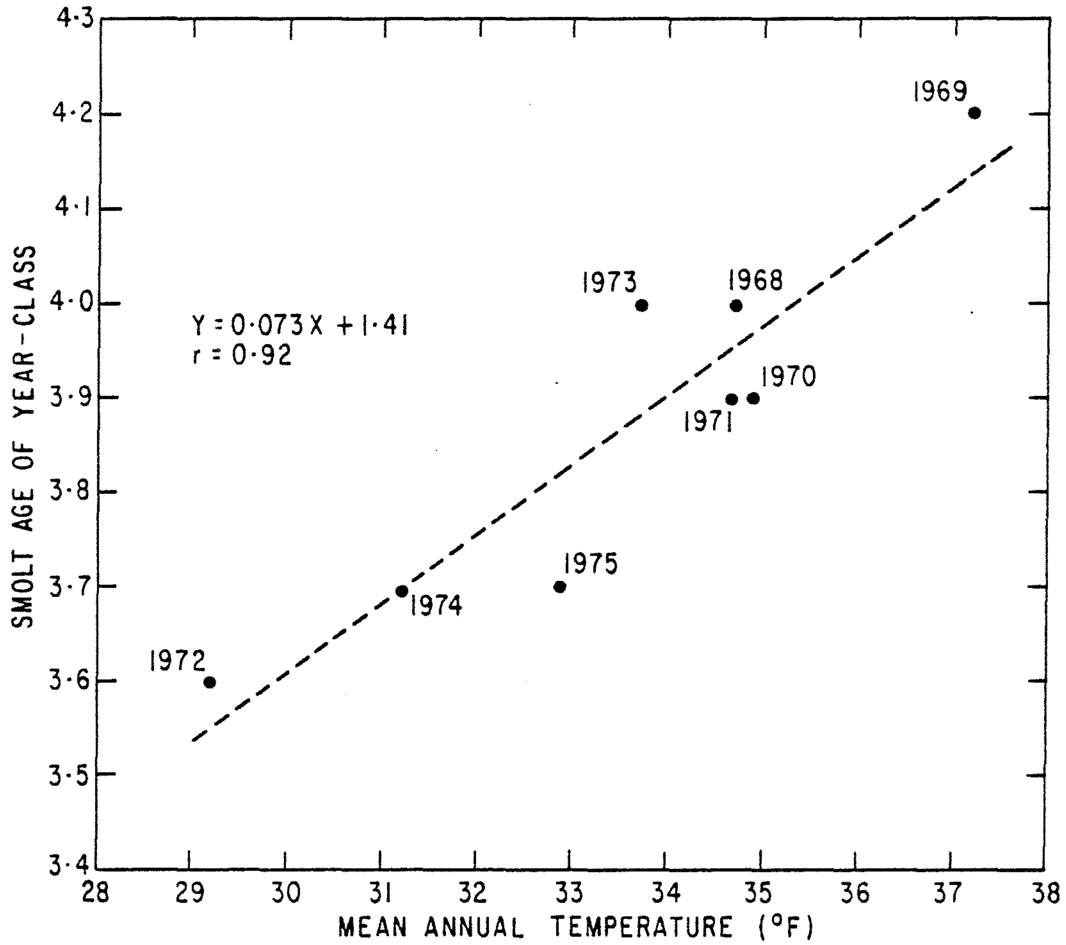

Fig. 11. Relationship between mean smolt age of a year-class in Western Arm Brook and St. Anthony mean annual air temperature for the years 1968–75.

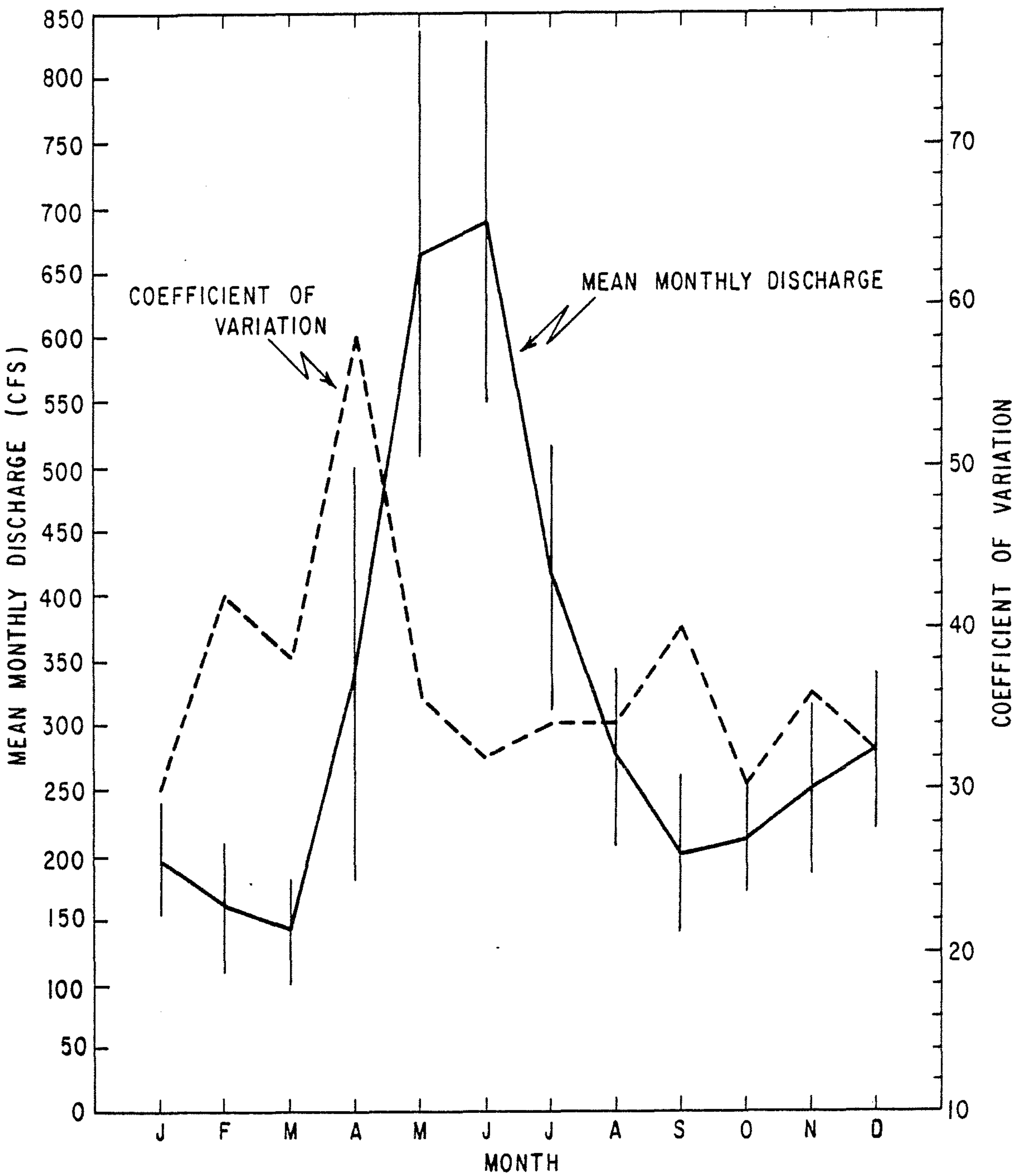

Fig. 12. St. Genevieve River mean monthly discharge (Anon. 1977) and its coefficient of variation, 1970–76; 95% confidence limits are also indicated.