GROWTH, MORTALITY, POPULATION STRUCTURE AND SPAWNING BIOLOGY OF STOCKS OF THE ATLANTIC SMELT **OSMERUS MORDAX** (MITCHILL) IN NEWFOUNDLAND

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GROWTH, MORTALITY, POPULATION STRUCTURE AND SPAWNING BIOLOGY OF STOCKS OF THE ATLANTIC SMELT *Osmerus mordax* (Mitchill), in NEWFOUNDLAND

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ABSTRACT

The length (size) and age distributions of spawning smelt are used to determine the existence of different stocks of smelt in Newfoundland. These distributions indicate that the mean size and age of smelt from Norris Arm (Notre Dame Bay) are greater than those of smelt from Port au Port Bay.

The scale radius - total length relationship of Newfoundland smelt was found to be linear. However, it varies from place to place and between the sexes. Back - calculated lengths - at - age were therefore computed separately for the sexes and for the different populations studied.

Growth curves, as constructed from back - calculated lengths, indicated that beyond the first year, females attain a larger size at age than males. The growth curves also show that Norris Arm (Notre Dame Bay) smelt live longer and grow to a larger maximum size than Port au Port Bay smelt. The latter, however, mature at an earlier age. The short life span of Port au Port Bay fish is largerly a result of a high spawning mortality. While the Port au Port Bay fish mature at the age of two to three years, their annual mortality rate is between 85% (Port au Port) and over 95% (Piccadilly) between ages 3-5 and 4-5 respectively. The Norris Arm fish mature at the later age of 4 years and have a lower annual mortality rate of 76% between ages 4 and 6. Thus most of the

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Port au Port Bay fish die at or soon after spawning while many Norris Arm fish survive and spawn more than once. In general, male smelt have a higher mortality rate than females.

Spawning smelt in the areas studied show a predominance of males over females at all times. Seasonally, the larger and older individuals enter the spawning streams earlier than the smaller and younger individuals.

The differences in size and age composition as well as in the growth pattern between the Norris Arm (Notre Dame Bay) and Port au Port Bay smelt are indicative of the existence of distinct stocks in these areas. This is supported by the fact that smelt are known to make only limited movements which are close to their spawning sites. It is apparent that Newfoundland smelt consist of different stocks that are possibly delimited by the numerous bays. The importance of this ~~on~~ to the management of the fishery are discussed.

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INTRODUCTION

Systematics:

The smelts, family Osmeridae, are small salmonoid fishes inhabiting the waters of the northern hemisphere. In their general appearance they closely resemble trout and young salmon but they are easily distinguished from the latter in that the smelts are slimmer-bodied than the salmons, have more deeply forked tails and their pelvic fins stand farther forward relative to their dorsal fins; they differ further from the salmons in lacking the fleshy appendages above the pelvic bases (Bigelow & Schroeder 1963).

There has been a dearth of information with regard to the biology of this family despite their potential economic importance due to their delicate flesh, tendency of aggregation and ease of capture. Bigelow and Schroeder (1963) and McAllister (1963) have made detailed taxonomic studies of this group and the latter author made a systematic revision of the family which stands as being the most authoritative to date. These authors recognise six genera within this family. Only two of these genera (Osmerus, Mallotus) occur in the Western North Atlantic, the others (Allosmerus, Thaleichthys, Hypomesus, Spirinchus) are confined to the northern Pacific. This paper is only concerned with the species Osmerus mordax.

The genus Osmerus consists of two species; Osmerus eperlanus (Linnaeus) and Osmerus mordax (Mitchill). Formerly, three forms of the boreal smelt were generally recognised: O. eperlanus of the North and Baltic Seas: O. dentex of the Pacific north into the Arctic and west to the White Sea; and O. mordax of the western Atlantic. Further detailed studies have led to the reduction of O. dentex to a subspecies of O. eperlanus (Belyanina 1969).

Some American authors (Kendall 1927, Baldwin 1948, McKenzie 1958, Leim and Scott 1966 and others) have treated the western Atlantic smelt as a separate species, Osmerus mordax (Mitchill), but Bigelow and Schroeder (1963) and McAllister (1963), consider that the genus includes only one species, Osmerus eperlanus (L) of which the western Atlantic form is a subspecies Osmerus eperlanus mordax (Mitchill). It is regarded as a morpho-species, a polytypic species with many geographical and ecological forms.

However, recent studies of skull structure and meristic characters by Klinkanov (1969) show that European Atlantic smelts of the genus Osmerus are specifically distinct from those found around North America and on the Asian Pacific and Arctic and European Arctic coasts (Hart 1973). Hence Klinkanov (1969) has treated dentex as specifically distinct from the European eperlanus and dentex was ranked as only subspecifically separable from mordax.

Status of smelt in the Newfoundland fishery and previous research

Templeman (1966) states that the smelt fishery is relatively minor in Newfoundland. The smelt are largely taken by gill nets in the river estuaries, mainly from September or October to May as they approach the rivers for spawning. The landings have been greatest in October and November. Fairly heavy landings of smelt are made by beach seine during autumn while ice fishing is carried out in winter on the Burin Peninsula, Notre Dame and Bonavista bays and the West Coast of Newfoundland. "The Newfoundland landings have declined in recent years after reaching peaks of 410,458, and 431 thousand lbs. in 1931, 1937 and 1939. In 1964, only 28 thousand lbs. were landed (Table I). In 1958-62 the main landings were made (see Fig. I) in Placentia Bay (District H), especially in the Burin area, in Port au Port Bay (L) and in the northeastern districts A, B, and C. In district A and C, Pistolet Bay and Gambo are the most important fishing areas. Smelt are found in many other Newfoundland Localities". (Templeman 1966).

Due to the small fishery for smelt in Newfoundland there has been little research on the species in this area. McKenzie (1958, 1964) studied the biology, life history and fishery of smelt in the Miramichi River, New Brunswick and the present study is intended to compare certain aspects of the smelt populations in these fairly adjcent areas of the Northwest Atlantic.

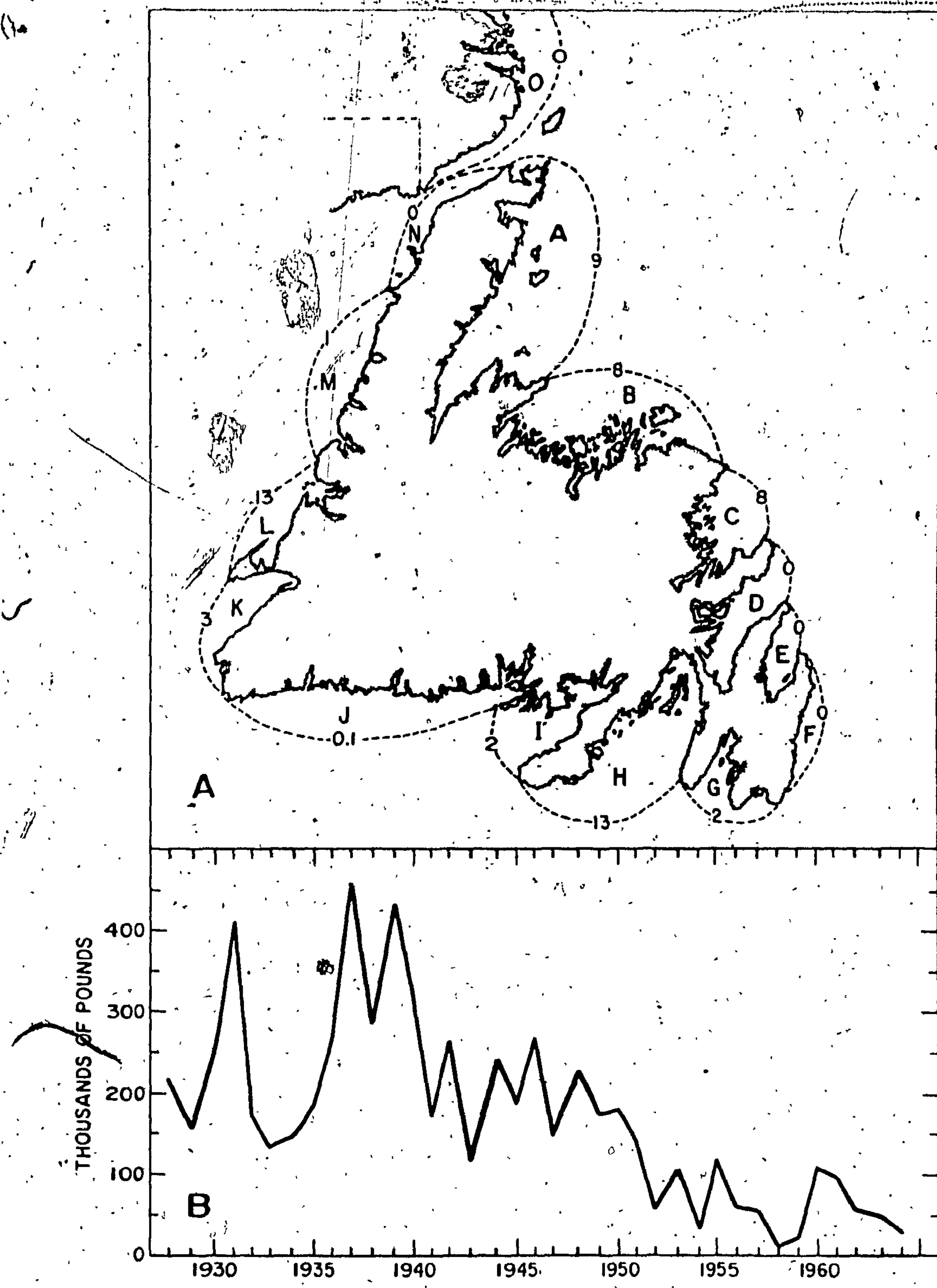


Fig. 1. A: Average yearly landings of smelt (thousands of pounds, round fresh weights) in the statistical districts of Newfoundland, 1958–62.

B: Newfoundland landings of round fresh smelt, 1928–62 (From Templeman 1966).

Apart from the fact that little is known about the smelt of Newfoundland, another reason for studying the species was its accessibility during the spawning seasons when it comes up rivers, streams and brooks to spawn. Thus it was easy to sample the spawning population with simple non-selective gear. It is realised that this does not sample the total population as invariably there is segregation of mature and immature fish at spawning. Nevertheless the samples taken should give reliable data for the adult fish and the information can be used to measure growth of younger fish from back calculation from the scales of lengths at earlier ages.

Smelt spawn in many places on the coast of Newfoundland. Information obtained from fishermen indicates that most smelt spawn in spring from late April to June. However there are unconfirmed reports of spawnings in autumn especially in Placentia, Notre Dame and Bonavista bays. It is also believed that most smelt do not go outside the influence of the water of the rivers or brooks in which they spawn. In September or October, they gather in the bays as they approach the rivers to spawn and remain there during the winter. This concentration is the basis of the autumn seine, and winter ice fishery. In early spring as the temperatures rise and the rivers and streams are cleared of ice, the spring-spawning smelt ascend the rivers and brooks to spawn.

The fact that there are numerous spawning sites around the coast raises the problem as to whether the smelt are all part of a large stock or whether there are many stocks. This study attempts to find an answer to this question.

2. MATERIALS AND METHODS

2.1. Source of samples:

Samples of smelt for this study were collected from northeastern and western Newfoundland (Table 2, Fig. 2). The type of gears used to catch the smelt were dip nets and cast nets both made of I inch (25mm) stretched mesh net or ½ inch (13mm) stretched mesh beach seine. In all cases, the netting usually retained all sizes of smelt found in the spawning runs. Samples obtained from North Harbour in St. Mary's Bay, (Avalon Peninsula) (Fig. 2) were found to be very biased and were not included in this study as the 1½ inch (38mm) gillnet used to obtain the samples retained only the larger spawning smelt.

All collecting was done in April–June of 1971. In Notre Dame Bay, fish were collected between April 22-27, from Bottom Brook near Norris Arm South at a point one mile (1.6km) from the estuary where there is a culvert over which the road to Norris Arm North passes. On the west coast of Newfoundland, smelt samples were obtained in Port au Port Bay at Piccadilly, Port au Port and Fox Island River between May 27 and June 23, 1971. In the first two places, samples were collected frequently throughout the whole of this period and up to four "24-hours" samples at one or two hour intervals were obtained from Port au Port (Table 36). One sample collection was made at Fox Island River (Little River) (Table 2).

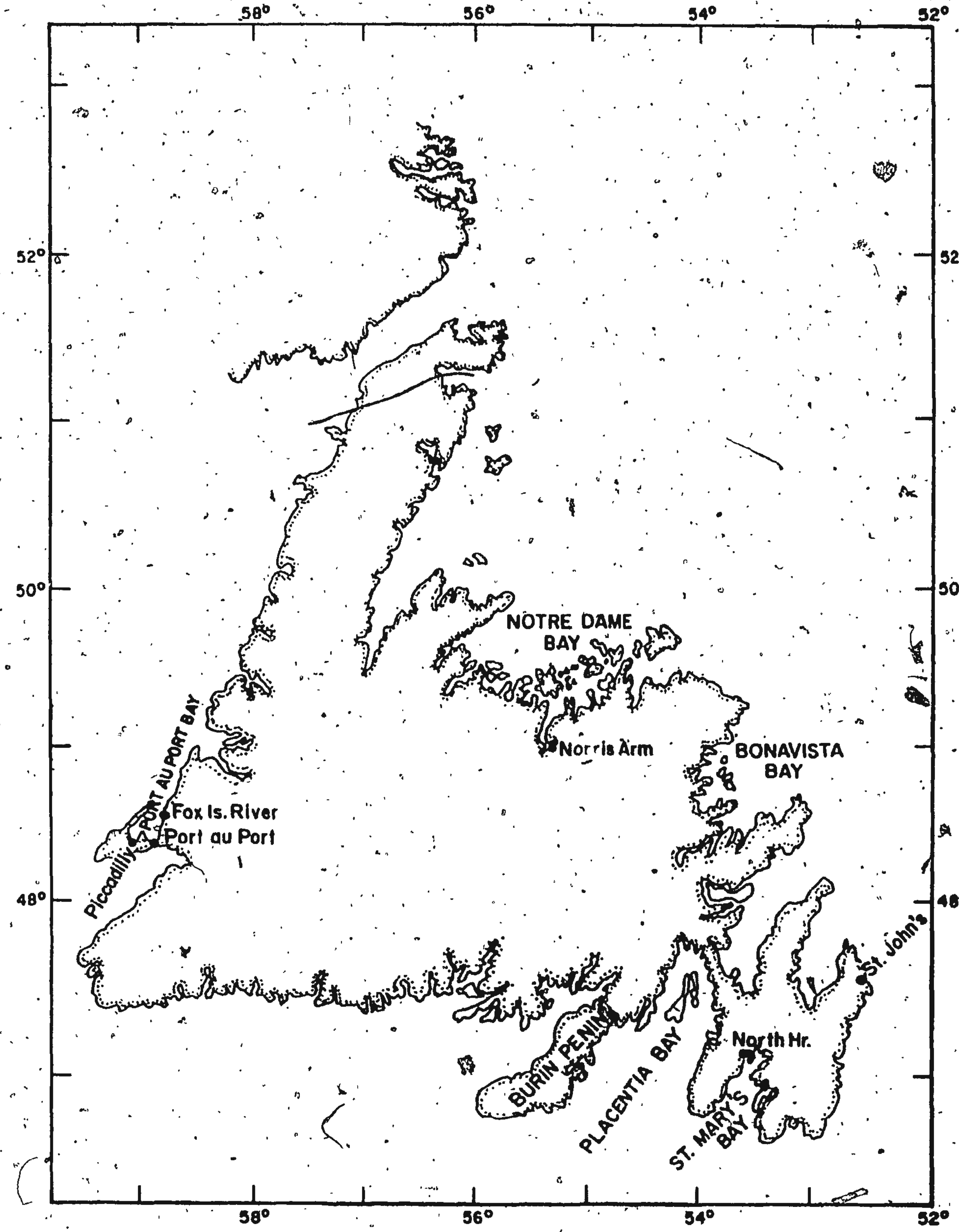


Fig. 2: Map of Newfoundland showing places mentioned in the text.

2.2. Scale collections and length-weight measurements:

Scale samples were removed by forceps from the left side of the fish in an area between the dorsal fin and lateral line (McKenzie 1958). The scales were stored dry between a folded piece of absorbent paper in a "scale envelope". The length, weight, sex, locality and time of collection were recorded on the envelope (Lagler 1956, Chugunova 1963).

The total length of each fish, determined to the nearest millimetre, was obtained using a measuring board. The total (extreme) length was the distance between the tip of the lower jaw, mouth closed, and tip of the longer lobe of the caudal fin in a straight line with the body, lobes compressed (Hall 1968). The weight was determined to the nearest gram using a compression spring balance. The lengths and weights of some samples were obtained in fresh condition within one hour after being caught. For other samples, these data were obtained from specimens which had been preserved in 40% isopropyl alcohol or frozen for periods from three to five weeks. It was therefore necessary to determine whether or not significant changes occurred on preservation (Parker 1963). A sample of 100 fresh fish was weighed and measured within one hour of being caught. The fish were then preserved in 40% isopropyl alcohol for 3 to 4 weeks and then measured and weighed again. Applying the t-test of significance (Snedecor and Cochran 1967) on the differences of individual measurements in the fresh condition and after preservation by the method of paired comparisons (Bailey 1959,

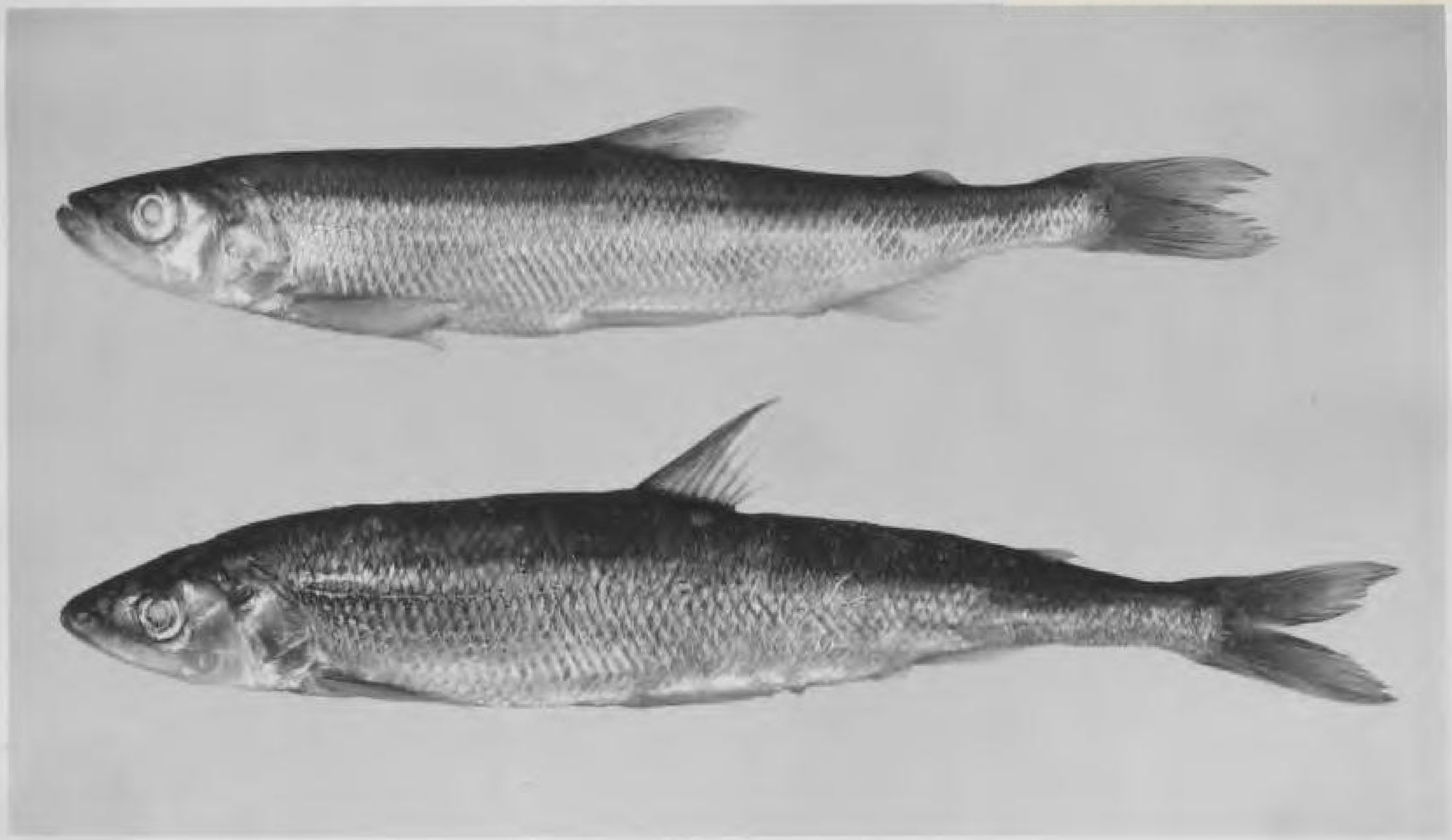


Fig. 3: Four-year old male (above and female (below) smelt.
Male total length 19.4 cm. Female total length 21.2 cm.

Speigel 1961) it was found that there was no significant difference between the length measurements at the 5% level of significance (t=1.00) while the difference between fresh and preserved weights were significant at 5% level (t = 1.95) (Table A).

Thirty three other fish were weighed and measured in the fresh condition and then frozen for up to 4 weeks. They were thawed in ice, then re-measured for length and weight. Here it was also found that no significant difference occurred between fresh and preserved lengths at the 5% level of significance (t = 0.06) while the differences in weights were significant (t = 1.96). Thus only the fresh weights are used in length-weight computations but in the case of lengths, as there was no significant difference between the fresh and preserved values, measurements taken in both conditions were included in all calculations and no conversion factors were used.

2.3. Age determination:

2.3: 1 Clearing and mounting of scales

Using forceps, scales were removed from the folded piece of absorbent paper that had been placed in the scale envelopes. The scales were immersed in 50% aqueous solution of glycerol contained in pertri dishes and were left to soak for at least four hours. They were then cleaned by gently scraping off the dirt with a pair of dissecting pins taking care that the edges of the scales were not damaged. The operation was observed under a binocular dissecting microscope using reflected light. Only four to six good scales were cleaned and poor quality or regenerated scales were avoided (Fig. 4 A, B).

The cleaned scales were removed from the glycerol solution and placed in the middle of a clean glass slide with their rough side uppermost. Excess liquid was removed by pressing a paper towel against them. A small drop of mounting medium (a solution of gum arabic in glycerol and 40% formalin) was placed onto a clean coverglass which was then gently lowered onto the glass slide such that the mounting medium covered the scales and held the coverglass onto the slide. Where necessary, minor adjustments were made to square up the cover glass and any large air bubbles trapped were removed by gently tapping the coverglass. Mounted glass slides were labelled with the information on the scale envelope and they were left flat for drying for at least 24 hours before they were placed in labelled holding trays.

By using a series of petri dishes containing the cleaning solution, a maximum of 32 slides could be mounted by a single person per day. Over 1000 slides were mounted this way and it is clear that the tedious task took much of the laboratory time in this study. The method of making impressions of fish scales on transparent cellulose acetate using a scale press was found to be unsatisfactory for the small scales of smelt as the impressions were not clear.

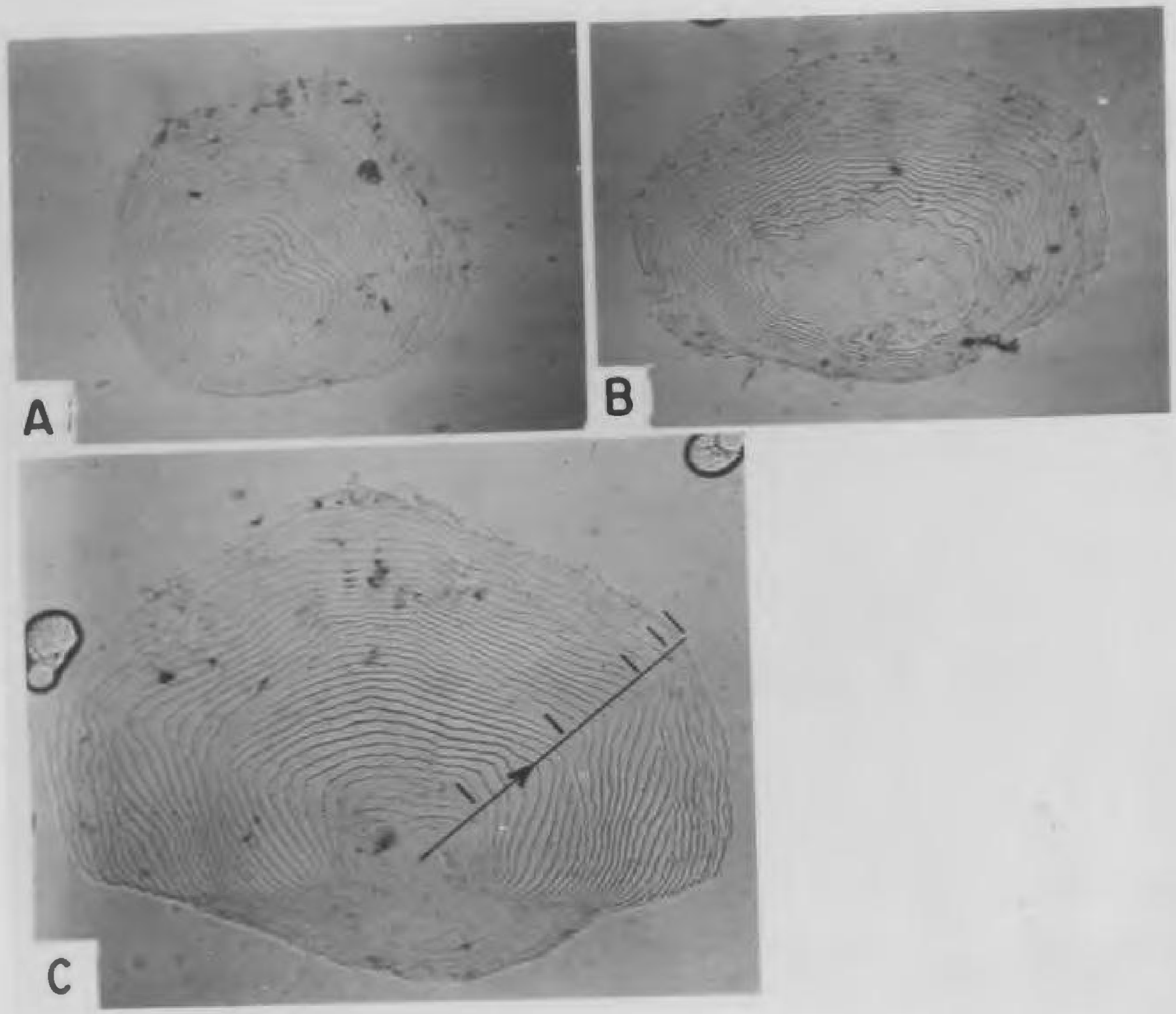


Fig. 4: Types of smelt scales.

A. Scale from dorsal region

B. Regenerated scale

C. Scale from the area between the lateral line and base of dorsal fin of 5-year old fish. Arrow indicates direction of measuring scale radius.

2.3: 2 Reading and measuring of scales

Only those scales taken from the area below the dorsal fin and above the lateral line were used in determining the body length - scale radius relationship (Fig. 5). In some small fish the scales from this area of the fish were lost in handling and preservation. In such cases, scales were collected, for age reading only, from under the pectoral fin or some other area of the body. The position from which such scales were taken was recorded on the scale envelopes and these scales were rejected for the purpose of the body-scale relationship. Also rejected were regenerated scales, scales obviously eroded at the edges and scales exhibiting breaks in structure or of irregular shape due to damage or injury. Only one, the "best" of the four mounted scales was selected for measurement.

Measurements were made from the centre of the scale to the end of each annulus and to the scale edge in the direction indicated in Fig. 4C. Only one radius of the scale was measured (the postero-ventral radius).

The annuli were interpreted according to the "shiny line criterion" (McKenzie 1958).

The scale measurements were made by means of a Bausch and Lomb VH microprojector fitted with two mirrors which reflected the scale image onto the top of the table on which the microprojector was mounted. Scale measurements, at a magnification of approximately 45 diameters, were made to the nearest 0.05mm using a ruler made of stiff paper and calibrated from

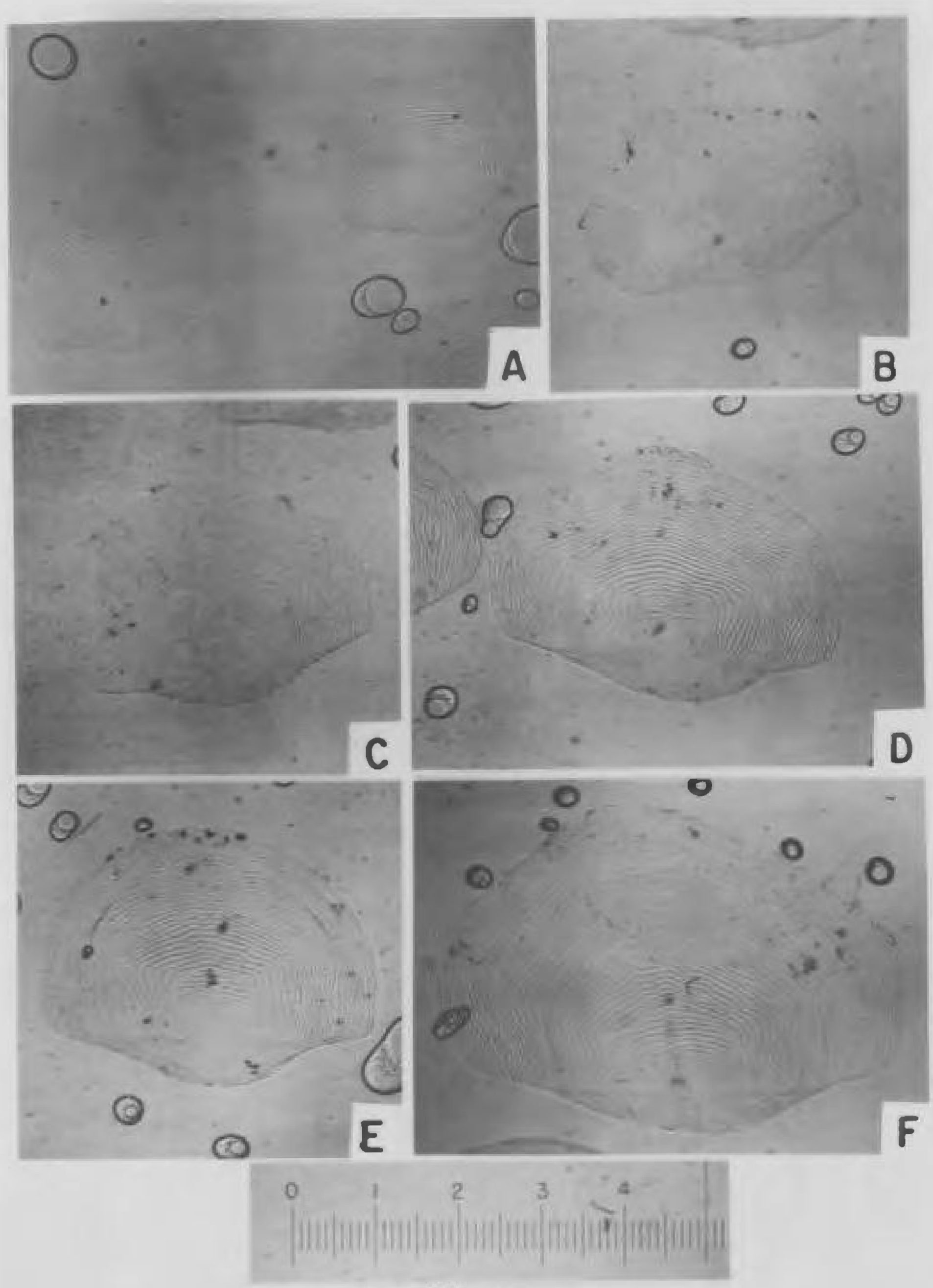


Fig. 5: A. Scale of 2-year-old fish
B. Scale of 3-year-old fish
C. Scale of 4-year-old fish
D. Scale of 5-year-old fish
E. Scale of 6-year-old fish
F. Scale of 7-year old fish

the image of a micrometer scale mounted on the microprojector. The ruler was frequently checked against the micrometer before and after a series of scale measurements. Distortion of the scale image within the field of measurement was found to be negligible.

All the fish collected in the Norris Arm samples as well as all the females from the other areas were analysed for age determinations and most of the scales were measured to obtain the radii of the annuli. It was, however, not possible to do this for all the male fish collected from the other areas due to the large bulk of these samples. A means was therefore sought by which a relatively small number of age determinations and scale measurements would be utilised to calculate age distributions using a large number of length measurements of the samples. The method of stratified subsampling established by Ketchen (1950) was employed. In this method, a length-frequency polygon is drawn for the sample of fish to be studied. From each size group (length interval), the same number of scale samples is examined, the number depending upon the frequency level chosen for the subsample. If the length (or class) frequency is below this level in the outlying or indeed any size groups, all available individuals are examined. Thus the number of individuals in any age group found in a particular size class in the subsample is proportional to the number of individuals of that age group and size, in the sample. For example, if five 3-year-olds are found in a subsample of 10 from a sample of 30 individuals in a given size class, the number of 3-year olds in the sample is 5/10 x 30 or 15 (Ketchen 1950).

As the size of the samples examined from the different areas and at different times were similar to the examples used by Ketchen, the level of stratified subsampling was chosen as 10 individuals from each length interval - this is the number found by Ketchen to be statistically realiable for samples of 300 to 375 individuals. It was also the level that could be conveniently handled by one investigator. Age-length keys were computed from these samples for the purpose of age composition analyses and calculations of mortality rates (Table 12 to 20). But for the purpose of growth curves, only the actually measured subsamples data were used in back calculation of lengths at earlier ages.

3. RESULTS

3.1 Length (size) distributions:

The length frequency distribution of age groups of Newfoundland smelt was based on total fish length, according to sex (Tables 12 to 21). Sex was easily determined for all fish by applying slight pressure to the abdomen when either milt or eggs were extruded. Moreover, the males were rough to the touch due to "nuptial" tubercles on their scales, the females were smoother. Age determination was made for nearly all Norris Arm fish while that for Port au Port, Piccadilly and Fox Island River was made by stratified subsampling according to Ketchen (1950) as detailed in section

2.3: 2. Age-length keys were made from the age determinations of sub-samples from which were calculated the total sample length frequency distributions in Tables 12 to 21.

The Norris Arm smelt show considerable overlap of length ranges for all the age groups represented in the sample. The range in length of 3-year old males is between 18.5 to 22.9 cm while that of 4-year old males is between 17.0 to 24.0 cm showing total overlap of the older fish over the younger fish. However, in the 4-5-and 6-year olds, overlap occurs only in the intermediate length intervals. In general younger ages have more fish of shorter lengths. Thus the length range of 17.0 to 20.4 cm is represented by fish 4 years old or younger, and these form 39.7% of the total sample. After 20.4 cm, there is considerable overlap of age 4 over ages 5 and 6 and the bulk of ages 5 and 6 are in the same length range of 22.4 to 27.4 cm. It can therefore be concluded that for over 60% of the fish in the Norris Arm sample, length is a poor index of age. This also applies to fish over 3 years old in the samples from Port au Port (length range 16.5 to 21.9 cm) and Piccadilly (range 16.5 to 22.9 cm). That length is generally a poor index of age for smelt older than 2 years old has also been shown in smelt from Gull Lake, Michigan (Burbidge 1969), Western Lake Superior (Bailey 1964) and Miramichi River, New Brunswick (McKenzie 1958). Fox Island River smelt, Newfoundland, seem to show almost complete separation of length range according to age for 2-and 3-year olds but overlap occurs for 4-and 5-year old fish (Table 20).

Newfoundland smelt also show that on the average females were longer than males for all ages (Table 12-19 & 32, Fig. 6) and this is also the case for smelt from the other areas mentioned above. The shortest smelt was a 2-year old male smelt from Port au Port which was 13.0 cm long while the longest was a 7-year old female from Norris Arm, which measured 31.1 cm.

Examination of the length frequency polygons of the smelt from the various areas of Newfoundland (Fig. 6 and 7) reveals a number of interesting aspects. The Norris Arm length distribution is from 17.0 cm to 31.1 cm (14.1 cm range) Port au Port from 13.0 to 23.2 cm (10.2 cm), Piccadilly from 14.2 to 24.2 cm (10.0 cm), and Fox Island River smelt from 15.2 to 21.7 (6.5 cm). This is related to the fact that the Norris Arm smelt mature at a larger size than smelt from the other areas. This larger size is related to maturing at a later age as will be further discussed later. The extended length distribution after the peak at the 19.7-20.2 cm mark, indicates that Norris Arm smelt reach a much larger maximum size compared to the other populations of smelt in Newfoundland and also suggests that they are longer lived than the other smelt.

While the length frequency distribution of Norris Arm smelt has one prominent peak which is formed of mostly 4-year-old fish, the length frequency distributions for Port au Port and Piccadilly are both double peaked, the second mode being higher than the first. The first mode contains only one age group, that is, two-year-old fish while the second mode is very skewed and contains different age groups i.e. 2-, 3-, 4-, 5- and 6-year-olds.

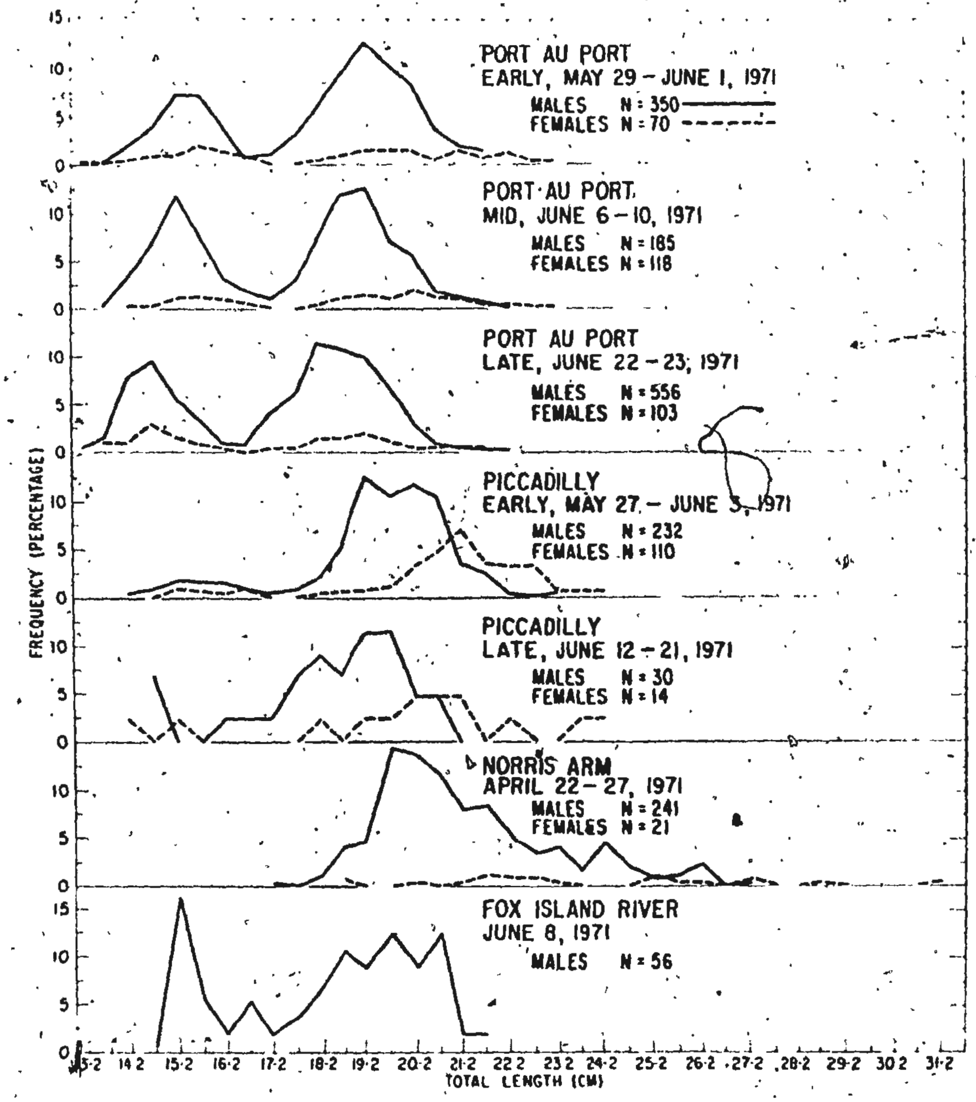


Fig. 6: Seasonal length-frequency distributions of spawning Newfoundland smelt.

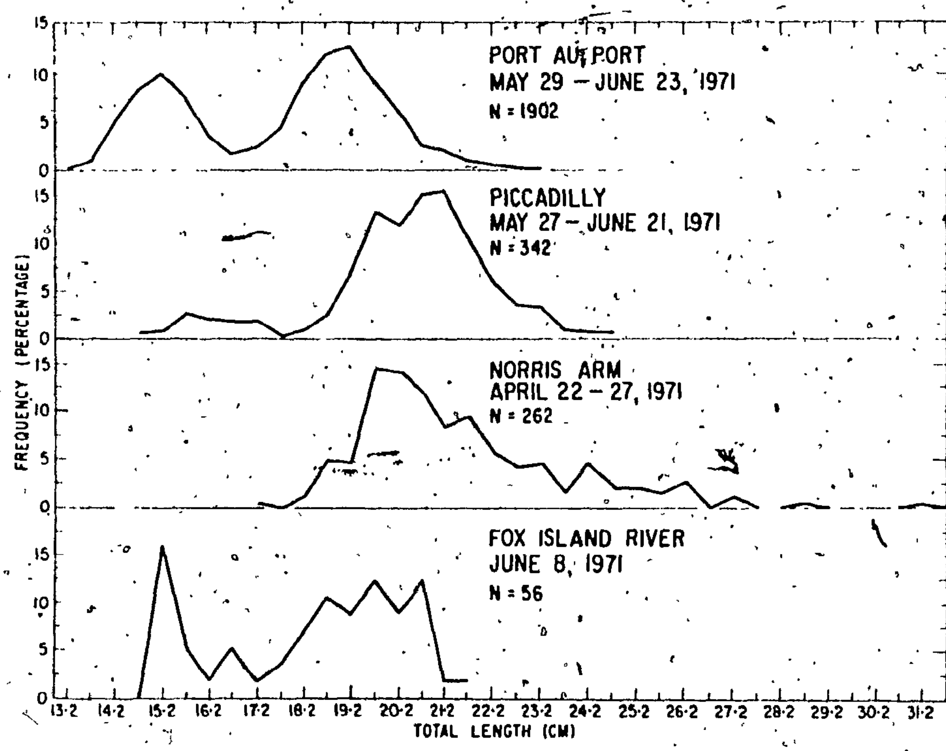


Fig. 7: Length - frequency distributions of spawning Newfoundland smelt.

It is therefore apparent that length at first maturity is between 13.0 cm and 16.7 cm for Port au Port smelt and 14.2 to 17.2 cm for Piccadilly smelt. This length range corresponds with the length rage of 2-year-olds in both areas indicating age at first maturity being 2 years. This strongly contrasts with Norris Arm smelt for which, as mentioned earlier, first maturity is attained at a greater length (over 17.0 cm) and a later age of 4 years - only five mature 3-year-olds were found in a sample of 262. Note that in Fig. 6, the modes for females in all cases appear at a greater length than those of males showing the larger average size of females compared to males.

3.2 Change in size with season:

Fig. 6 presents the length-frequency distributions of smelt from Port au Port and Piccadilly according to the time of spawning. The Port au Port data are divided into early and late spawning season. The Norris Arm sample was obtained late in the season hence it has been made into one graph as in Fig. 6. The Fox Island sample consisted of only one collection made in mid-spawning season.

The length frequencies show a progressive decrease in size of the spawning smelt with the season for both sexes in Port au Port and Piccadilly. Most small-sized fish which are first time spawners, (2-year-olds) come up to spawn late in the season. As can be seen in Tables 13, 14 and 15, the total percentage of male and female of 2-year-olds in the Port au Port sample that

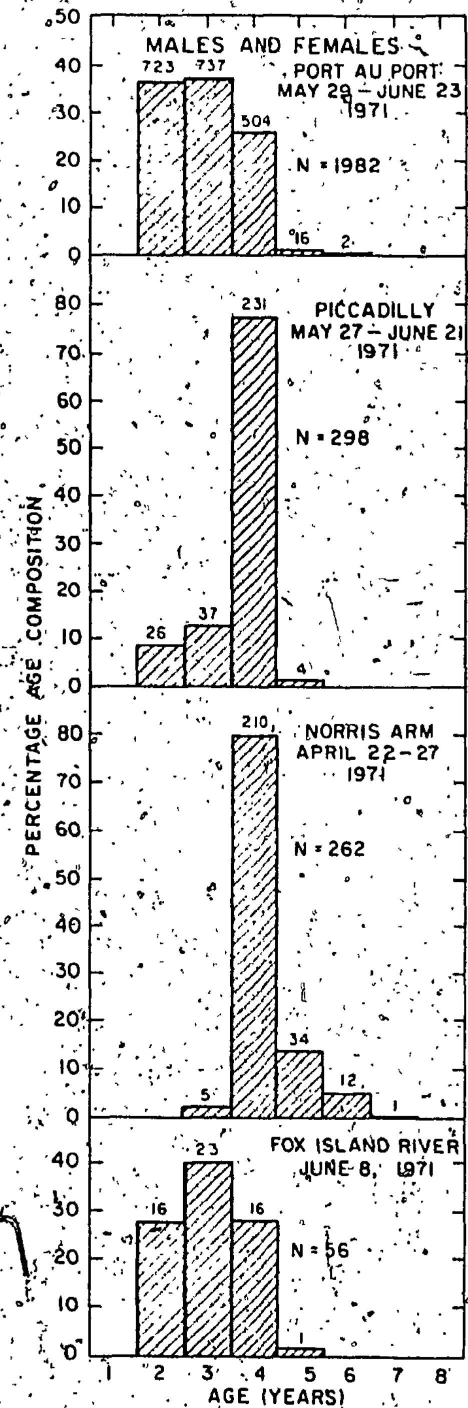


Fig. 8: Percentage age composition of spawning Newfoundland smelt.

are in the size range of 13.0 to 16.9 cm rises from 33.1% early in the season to 38% in mid-season and 36.5% in late season. The apparent decline of 1.5% between mid-and late season may be a chance error especially when viewed in the light of the rise of 5% between early and mid-season (from 33% to 38%). This decrease in size as the spawning season progresses is also seen in the Piccadilly smelt where the percentage of 2-year-old smelt between 14.0 cm and 16.9 rises from 8.7% in early season to 13.6% in late season (Tables 16, 17, Fig. 6). Furthermore, both the back-calculated and empirical lengths-at-age decreased with the season for both areas as is shown in Tables 27 and 30. The decrease in size of the different ages of spawning smelt as the season progresses has been reported by McKenzie (1958), Miramichi smelt, as well as by Bailey (1964), western Lake Superior smelt, and by other workers on smelt and other anadromous fishes (Belyanina 1966, 1969, and Alm 1959): most of the older and larger individuals spawn first while the smaller and largely first-time spawners come in late in the season.

3.3. Age:

3.3: 1 Age distribution in different populations

Fig. 8 and Table 22 show the percentage age composition of spawning smelt from Norris Arm, Port au Port, Piccadilly and Fox Island River. For Norris Arm fish, 210 (79.8%) of 262 fish in the sample, were 4 years old. There were only 5 fish (1.9%) which were 3 years old and none of younger age.

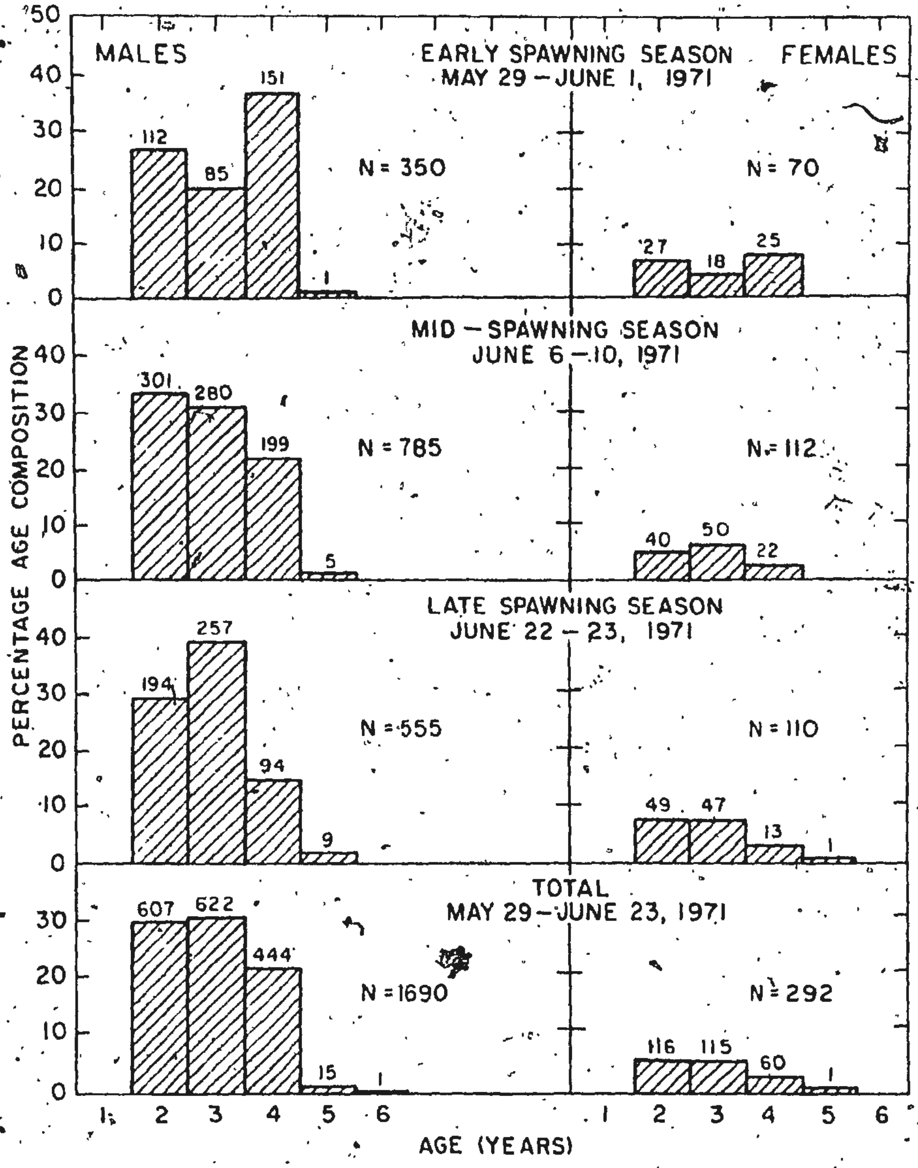


Fig. 9: Seasonal percentage age composition of Port au Port smelt.

The other age groups consist of 34 (12.9%) five-year-olds, 12 (4.6%) six-year-olds and one (0.4%) seven-year-old.

The Port au Port smelt age composition is quite different in that the bulk of the fish in the sample were 2- and 3-year-olds. Thus of a total of 1,982 smelt in the sample, 723 (36.5%) were 2-years old, 737 (37.2%) were 3 years old, 504 (25.5%) were 4-years old, 16 (0.8%) were 5 years old and only two (0.1%) were 6 years old. These data indicate that the Norris Arm fish are long lived (more than 98% were 4 years old or more) reaching the age of 7 years while most of the Port au Port fish are short lived (over 70% 3 years old or less) only a few reaching the age of 6 years. Fox Island River smelt have a similar age composition to that of Port au Port and are similarly short lived. Their age composition out of a total of 56 fish is 16 (28.6%) 2-year-olds, 23 (4%) 3-year-olds, 16 (28.8%) 4-year-olds and 1 (1.8%) 5-year-old. Thus 70% of the fish were 3 years old or less, which is the same as the Port au Port fish.

Piccadilly fish are mid way between the long-lived Norris Arm smelt and the short-lived Port au Port and Fox Island River smelt. Like the Norris Arm fish, most Piccadilly smelt were 4 years old or more as can be seen from the data in Table 22 which show that from a total of 342 fish collected, there were 32 (9.3%) 2-year-olds, 48 (14%) 3-year-olds, 256 (74.9%) 4-year-olds and 6 (1.8%) 5-year-olds. Therefore 76.6% of the fish were ~~fish~~ 4 years old or more. However, compared to the Norris Arm fish, there was a considerable number of younger fish present (23.4% 3 years or less) but less than the Port au Port and Fox Island smelt which had 70% 3-year or younger fish.

3.3: 2 Age at maturity or first spawning

As discussed in the foregoing section, the Norris Arm fish consist mostly of 4-year old or older fish. Only 1.9% of the fish are 3 years old, these presumably being the largest sized fish of this age. The age composition of spawning smelt from Port au Port, Piccadilly and Fox Island River shows the presence of a large percentage of 2-year old fish (36.5%, 9.4%, 28.6%, respectively). It is therefore evident that most Norris Arm fish mature first at the age of 4 years and only a few large 3-year olds are mature. This is a greater age at first maturity than that of the smelt populations from the other three areas where a considerable percentage of the population first matures at the age of two years (Tables 21, 22, Fig. 8). In the Miramichi River, over a period of five years, on the average 66% of the spawners were 2-year olds, 30% were 3-year olds and only 4% were 4-year olds (McKenzie 1964). Thus, the age at maturity of Norris Arm smelt is greater than that of most smelt populations in North America (McKenzie 1958, 1964). Belyanina (1969), however, reports populations which mature at 5 to 6 years in the White Sea and East Siberia.

Another interesting factor of the age composition of Newfoundland smelt is the distribution of the different age groups of the spawning populations. Referring to Fig. 8, the percentage age composition graph of the Norris Arm spawning population is skewed to the right showing that most fish reach maturity at the same age i.e. four years old. The Port au Port graph is similar to that of Norris Arm with maturity being reached by most fish at the earlier age of two years. However, the percentage age distribution of the population at Piccadilly differs from the above two mentioned in that the skew is to the left, that is although maturity starts at the age of two, only a small percentage reach maturity at this early age (9.4%) increasing to 14% at 3 years of age; 74.8% of the spawning population are 4 years old and 1.8% 5 years old. Thus since most of the spawning smelt are four years old or older, maturity in the Piccadilly population is complete only at this age although it sets in at the age of two years for some individuals in the population. The Fox Island River age distribution of spawning smelt indicates that some of the fish mature at 2 years old and most fish in the population are mature at the age of 3.

Due to the fact that all individuals examined in the spawning runs had reached maturity, it was not possible to investigate what differences existed between the mature and immature individuals at ages two and three. Nevertheless, it is known from other studies of smelt populations (McKenzie 1958, 1964, Bailey 1964, Burbridge 1969, and Belyanina 1966, 1969) as well as from the study of other fish species (Alm 1952, 1959) that maturity sets in early among a small number of large size young fish.

It is therefore more appropriate to consider size at first maturity when dealing with recruitment to the adult population rather than age at first maturity (see paragraph 3.1). It is also noted that male and female Newfoundland smelt mature at the same ages according to the population to which they belong (Fig. 9, 10 & 11).

3.3: 3 Age distribution changes during a spawning season

Fig. 9 and 10 and Tables 13 to 19 indicate the percentage age composition of Port au Port and Piccadilly smelt according to the time of the spawning season. As in the case with seasonal size distribution, (section 3.2) the Port au Port data are divided into early, mid and late spawning seasons while the Piccadilly data are divided only into early and late spawning season. Again, Norris Arm and Fox Island data could not be similarly treated due to inadequate material (Fig. 11). The Port au Port sample shows a general increase in the percentage of first time spawners (2-year-olds) as the season progresses. Thus at the start of the spawning season, 33.1% of the population are 2-year-olds (Table 13); this increases to 38% in mid season (Table 14) and 36.5% (Table 15) at the end of the season. There is thus an increase in the proportion of 2-year-old fish by 3.4% between early and late spawners. It is, however, surprising that although there is a 5.1% increase in the proportion of 2-year-olds between the early and mid-season spawners, it is followed by a fall of 1.5% in the

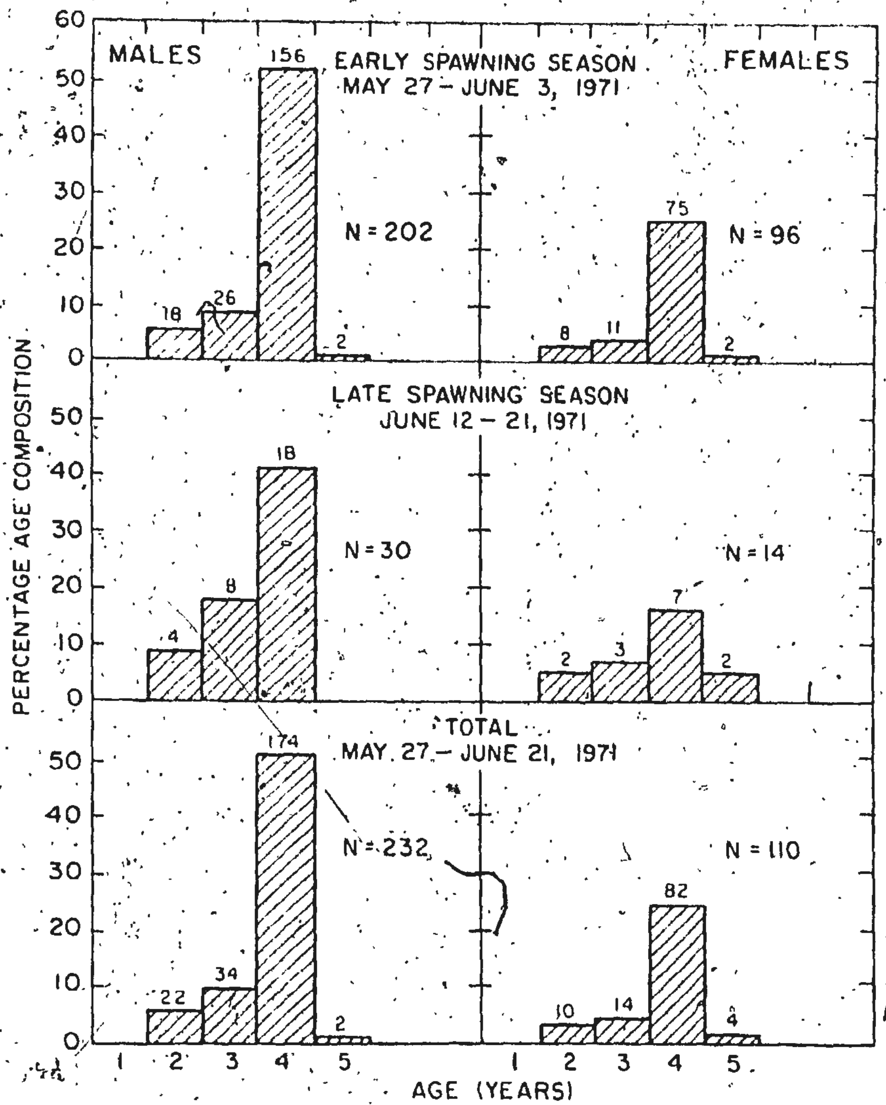


Fig. 10: Seasonal percentage age composition of Piccadilly smelt.

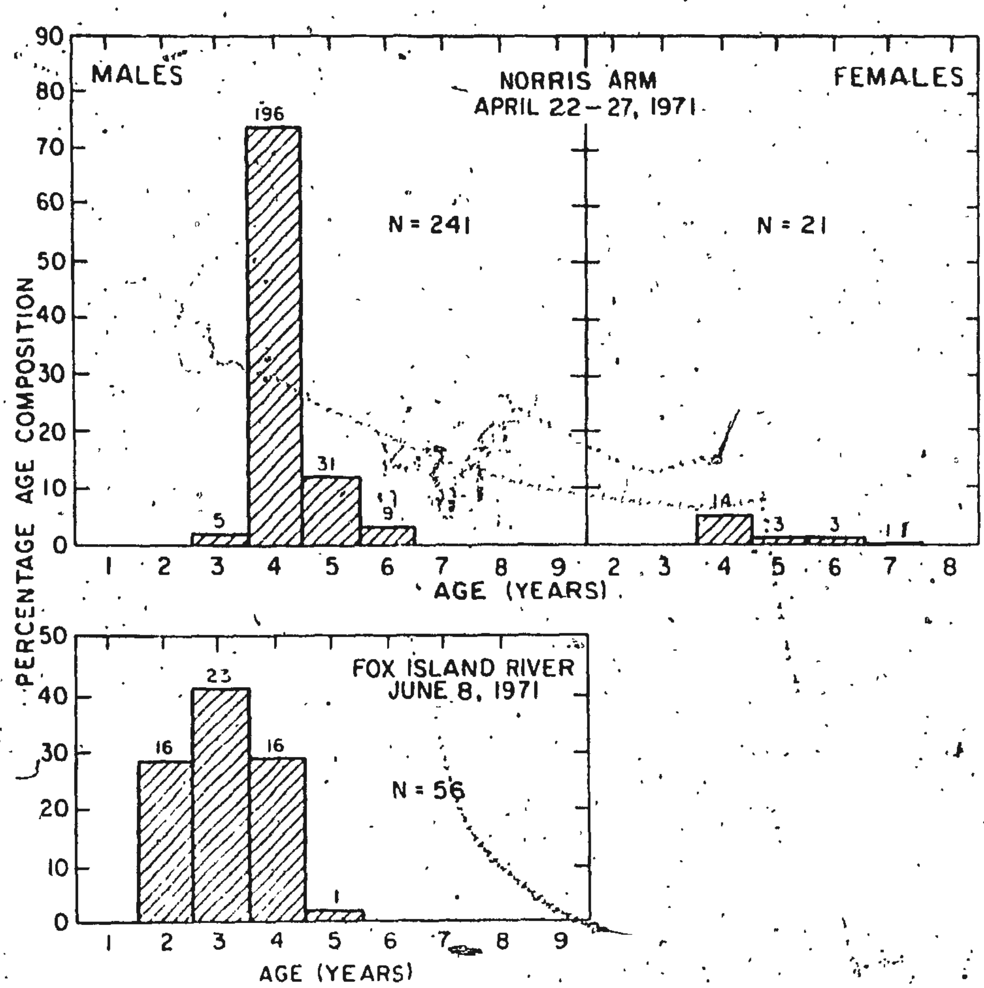


Fig. 11: Percentage age composition of Norris Arm and Fox Island River smelt.

proportion between mid-season and late spawners. Because there is an overall increase of first time (2-year-old) spawners as the season progresses, this apparent decrease may be due to sampling variation. The increase in the proportion of young fish with season is also clearly indicated in the rise of the percentage of 3-year-old fish in the population from 24.5% in early season to 36.8% in mid-season and to 45.6% in late season. No fish younger than 2 years old were found in the samples of this spawning population. It is therefore reasonable to conclude that the age at first maturity is 2 years. On the other hand, not all two-year-old fish would mature at this age; some, especially the small sized ones would not reach maturity until they are 3 years old. This is the possible explanation regarding the increase in proportion of 3-year-olds in the population with season which has been indicated above. It may further be noted that taking two- and three-year-olds together, there is a very clear and definite percentage rise of these two age groups with the progress of the spawning season. In early season, these two age groups comprise only 57.6% of the population but rise to 74.8% in mid season and 82.1% at the end of the spawning season. Thus a large proportion of late spawners are first time spawners.

At the same time, the percentage composition of 4-year-olds and older fish falls with the progress of the spawning season, being 42.4% at the beginning, 25.2% in mid-season and only 17.7% at the end of the season.

The Piccadilly population also shows a rise in the percentage of first time spawners with the progress of the spawning season. As the graph at Fig. 10 shows, both 2- and 3-year-old fish are only partially "recruited" to the spawning population and it is only 4-year-olds that are all mature. Thus the proportion of 2-year-olds rises from 8.7% in early season (Table 17) to 13.7% in late season (Table 18) while that for 3-year-olds also rises from 12.4% to 25%. The total proportion of first-time spawners therefore rises from 21.1% of the early spawning population to 38.6% of the late spawners. As in the case of the Port au Port smelt, the percentage of 4-year-old and older fish in the spawning population shows a drop from 77.5% in the early spawners to 56.8% among the late spawners. It is therefore true to say that the spawning smelt populations from the west coast of Newfoundland undergo changes in percentage age composition such that the early spawners comprise a large percentage of old fish that have spawned once or more previously whereas most fish of minimal spawning age, that is 2-year or 3-year olds, spawn late in the season. This phenomenon is related to the decrease in size of smelt during the spawning run noted earlier; hence the older and larger individuals spawn first while the younger and smaller ones spawn late. This is in conformity with observations made by other workers on smelt populations in North America and Europe (Belyanina 1969).

3.4 Growth:

3.4:.1 The body length - scale radius relationship

The body length-scale radius relationship has been examined by analysis of regressions of total body length on scale radius (May 1964, Whitney and Carlander 1956). The scale-radius measurements were grouped into intervals of 0.05mm and these were ploted against average total length for each scale radius interval. Data from each area and each sex were examined separately to determine whether the body length - scale radius relationship was consistent. The regressions invariably took a linear form and straight lines were fitted to the data by the method of least squares(Snedecor and Cochran 1967), the equation being,

$$L = a + bS \qquad (1)$$

Where (L) is the total length of the fish, (S) is the scale radius, (b) is the slope of the regression line and(a) the L-intercept.

Fitted regressions of body length on scale radius for males and females separately are shown for Norris Arm, Port au Port, Piccadilly and Fox Island River(Little River) smelt in Fig.12,13 and 14 respectively. The average total lengths of fish at each scale radius interval, as well as the numbers of fish on which these averages are based are listed in Tables 3 to 9.

Analyses of covariance by the method of Snedecor and Cochran (1967) were used to test the differences in slope and intercept for the males and females from Norris Arm and Port au Port (Table 10A, 10B). These analyses were carried out by comparing regressions of total length on scale radius

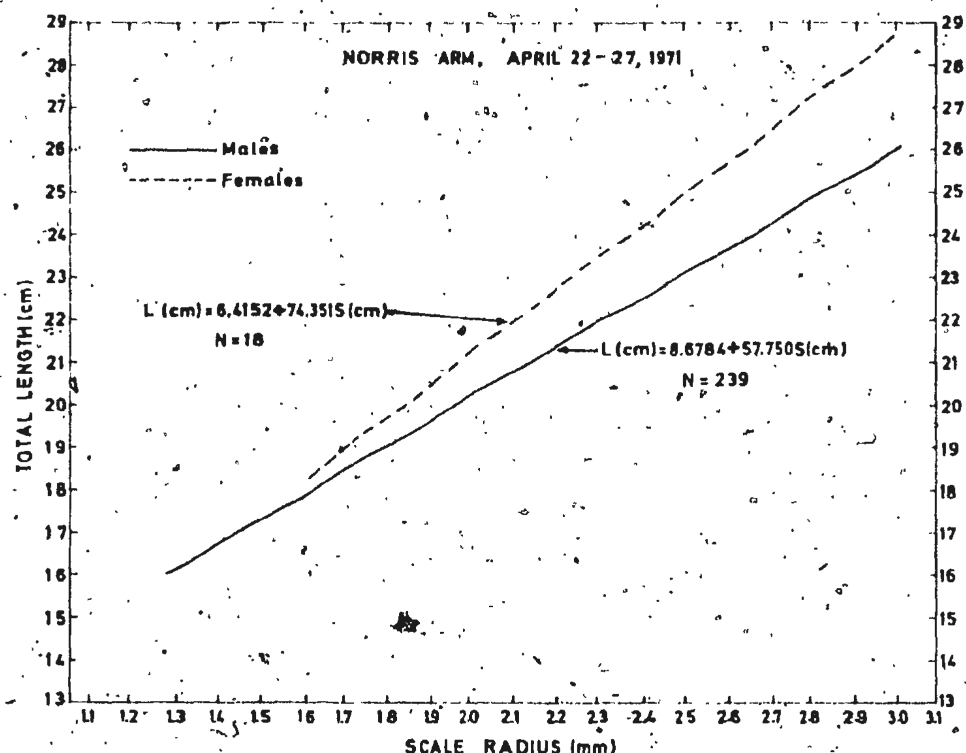


Figure 12: Regressions of body-length on scale - radius for Norris Arm smelt.
(Regression formulae were derived from the individual scale-radius body-length data.)

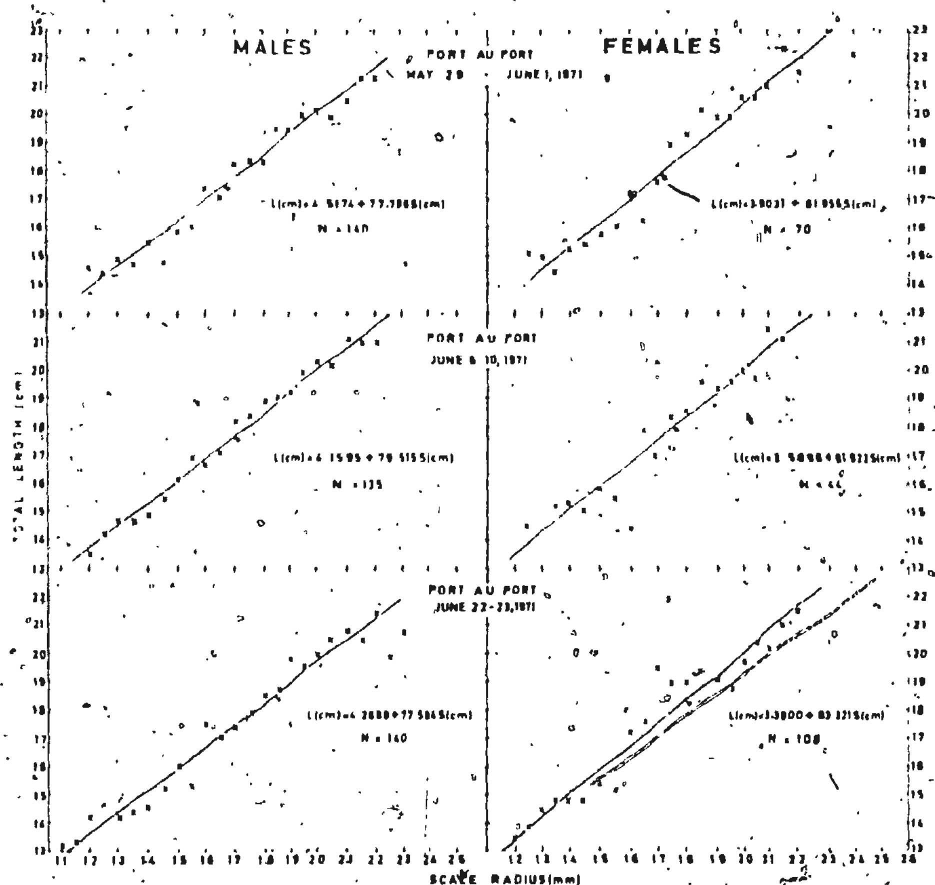


Figure 13: **Regressions of body-length on scale - radius for Port au Port Smelt.**
(Regression formulae were derived from ~~average~~ scale radius at each 0.005 cm and the corresponding average fish length in cm (to 2 decimal places) weighted by the number of fish at each scale radius and fish length average, Tables 4-6.)

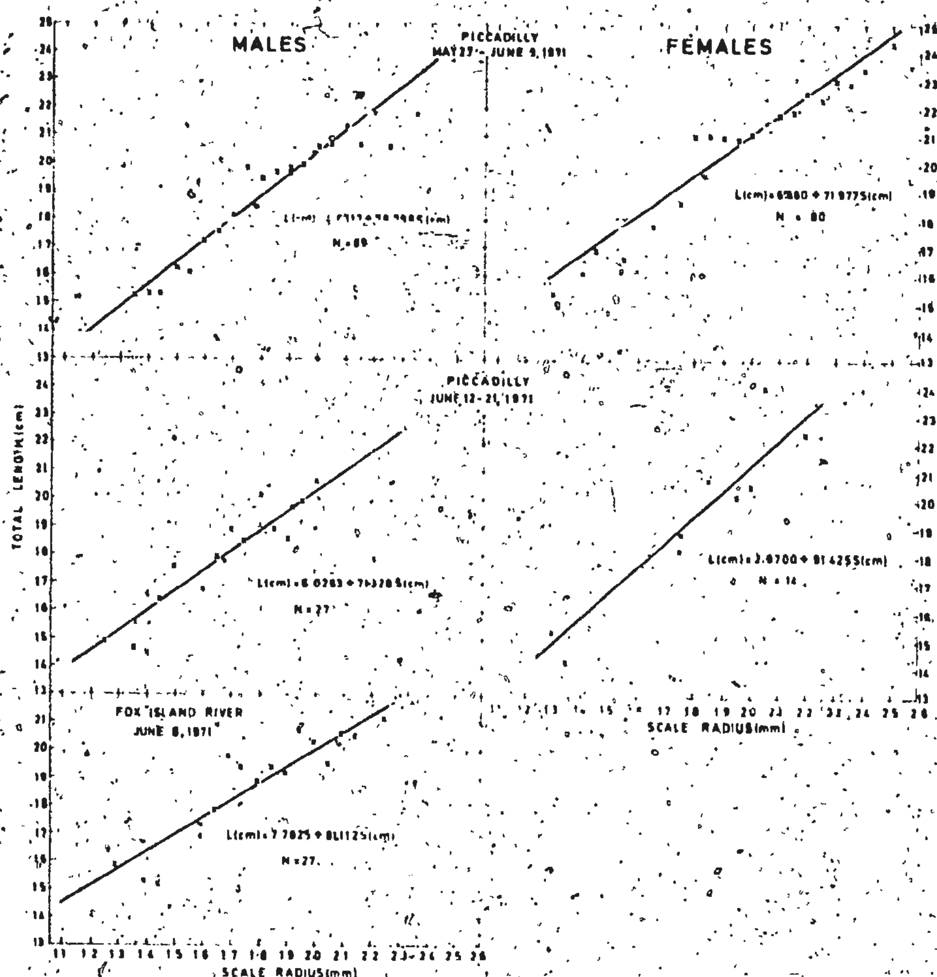


Figure 14: Regressions of body-length on scale - radius for Piccadilly and Fox Island Smolt.
(Regression formulae were derived from ~~average~~ scale radius at each 0.005 cm and the corresponding average fish length in cm (to 2 decimal places) weighted by the number of fish at each scale radius and fish length average, Tables 7-9.)

of individual fish and were not based on data of average total lengths of fish at each scale radius interval indicated in Tables 3-9. The ratio of the mean square for regression coefficients to the mean square within samples, is the F-value which measures the significance of differences in slope of the regression lines. The significance of differences in intercept is measured by the F-value derived from the ratio of mean square for adjusted means to mean square for common regression. Snedecor and Cochran (1967) point out that if the slopes (regression coefficients) are found to differ significantly, in which case the lines are not statistically parallel, the question of differences in elevation (intercept) has little meaning.

Tables 10A and 10B, which summarise the analyses of covariance for the sexes show the regression coefficients (slopes) as well as the intercepts from the Port au Port smelt are not significantly different at the 1% level (Pearson and Hartley 1956) indicating that the two regressions of total length on scale radius for both sexes are not statistically different. However, the regression coefficients (slopes) of the males and females from Norris Arm are significantly different at the 1% level indicating the two regression lines are not statistically parallel.

The discrepancy between the two results of the analyses of covariance may be partly explained by the fact that the relative numbers of males to females in the two areas were not the same. Whereas only 18 females were compared with 239 males in the Norris Arm sample, 69 females were compared with 140 males in the Port au Port sample. It is apparent, from the Port au Port data, that sex differences are not significant in the body length - scale radius relationship of Newfoundland smelt. However, Hile (1970) points out that there exists sample to sample variability in body-scale curves as well as "possible sex differences". Thus the significant difference between sexes depicted in the Norris Arm sample may be real. On these grounds, the regressions of total body length on scale radius were analysed separately for males and females in all thesamples according to the areas from which they were obtained (Table 11).

3.4: 2 <u>Back-calculated growth from scale measurements</u>

Back-calculations of length at each annulus were made separately for each sex in each area of investigation. The calculations were not made for individual fish. Instead the scale radii were first averaged for each age, according to sex and then length estimates were back calculated from the average data. The corrected proportionality formula (Carlander 1950, Whitney and Carlender 1956, May 1964) given below was used to compute the back-calculated lengths

$$l_n = C + \frac{Sn}{S}(L - C) \qquad (2)$$

Where l_n = fish length at annulus <u>n</u>

S_n = scale radius at annulus n

L = fish length at capture

S = scale radius at capture

C = intercept on the fish length axis.

Tables 23 to 33 show the back-calculated average lengths-at-age by sexes of the various year-classes in the areas indicated. It may be noted that the calculated length of each year class closely approximates the actually measured (empirical) length of the fish. Lee's phenomenon (a progressive decrease in back-calculated lengths-at-age when these calculations are made from successively older fish) Lee (1912), is evident in Tables 22-30 and Fig. 15 for all of the areas investigated, except that in Port au Port Bay, the 1967 year-class grew more considerably than the others. Furthermore, the back-calculated lengths at the age of one year (L_1) for the Port au Port smelt for each year-class and sex show progressive decrease during the spawning season (Table 27). The Piccadilly data (Table 30) also show a decrease in L_1 from early to late spawning season for females but an increase for males. This discrepancy in the trend of L_1's from male Piccadilly smelt is rather surprising and difficult to explain from the present data.

As regards growth, it is seen from Tables 23 to 31 and the summary of comparison in Tables 32 and 33 that the calculated average lengths of females tend to be greater than those of males at each age. Fig. 16 and 17

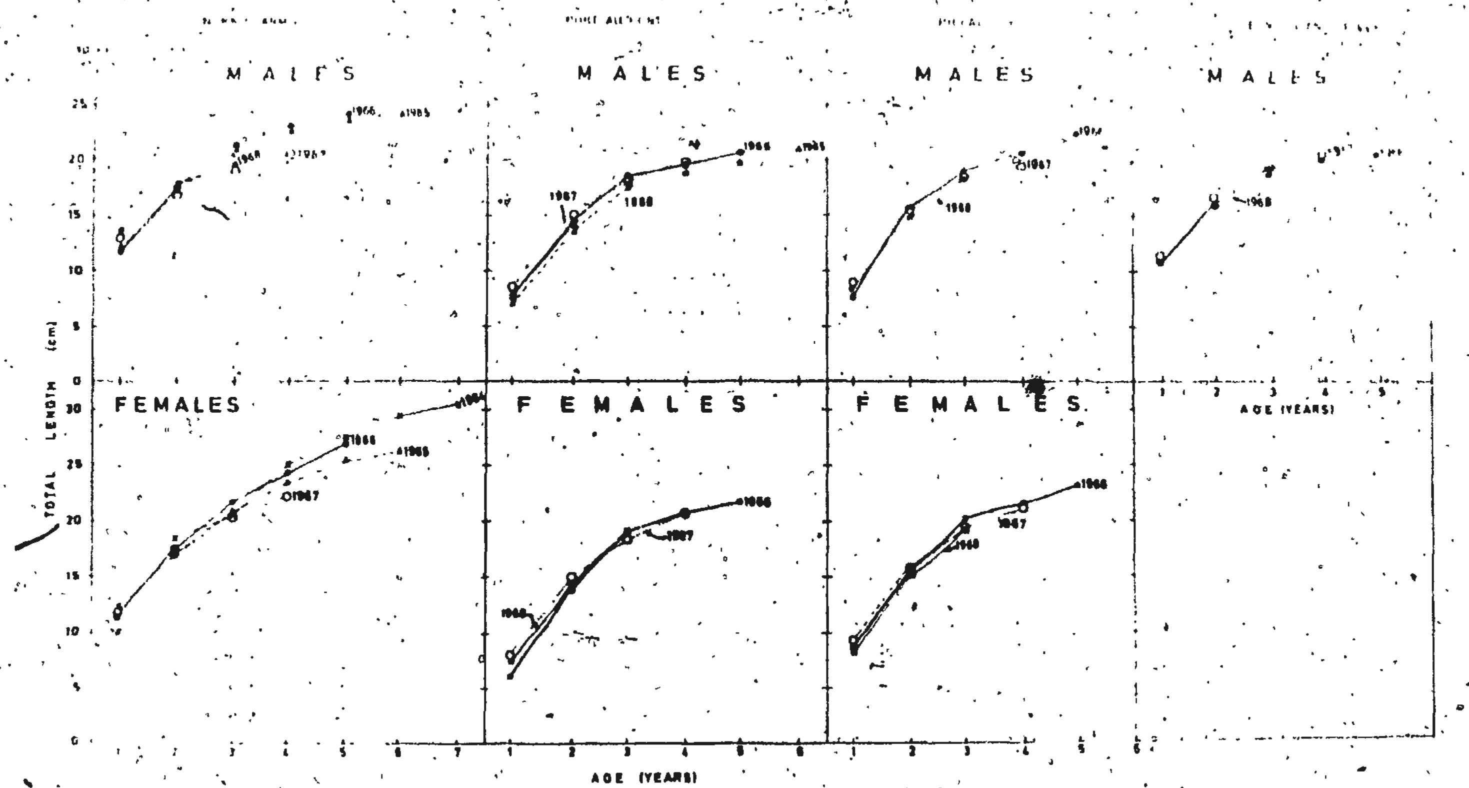


Fig. 15: Back-calculated lengths-at-age of the year-classes of Newfoundland smelt.

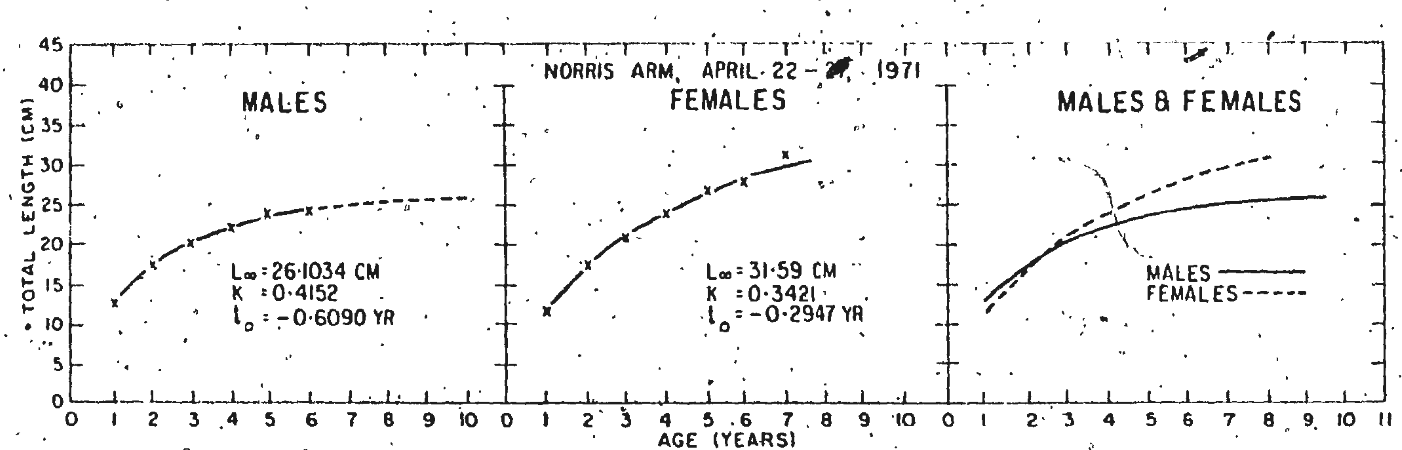


Fig. 16: Growth curves of Norris Arm smelt.

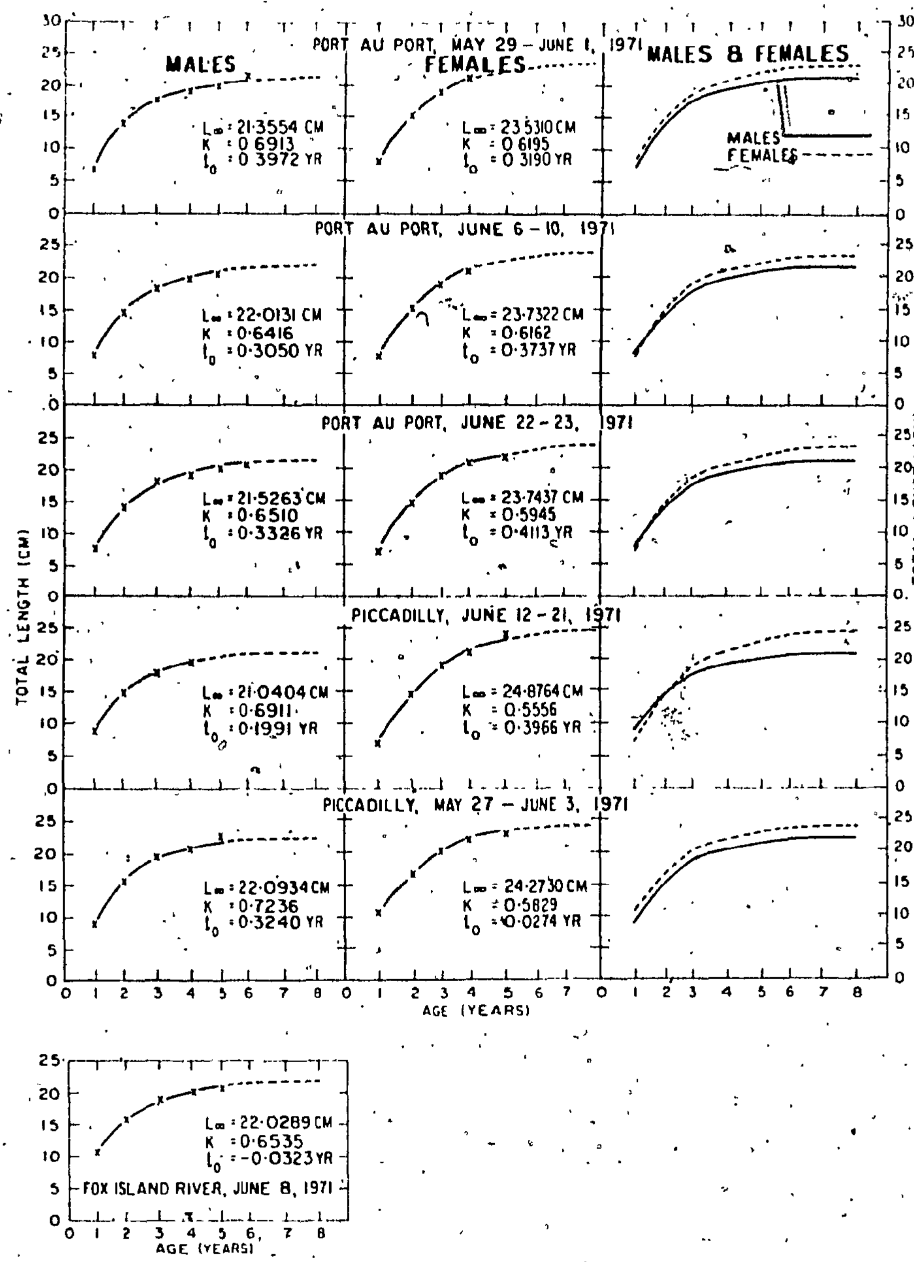


Fig. 17: Growth curves of Port au Port, Piccadilly and Fox Island River smelt.

graphically present the data in the tables. The curves are fitted to the mean back-calculated lengths according to the Von Bertalanffy growth equation:

$$l_t = L\infty \left(1 - e^{-K(t-t_o)}\right) \qquad (3)$$

where l_t = length of fish at age t years

$L\infty$ = maximum length towards which the length of the fish is tending

K = a measure of the rate at which length approaches $L\infty$

t_o = the theoretical age at which the length of the fish is Zero.

The fitting was done by the method of least squares as described by Allen (1966).

It is clear from Table 23 and Fig. 16 that female smelt from Norris Arm attain a higher maximum (final) size than males. This is also evident in Fig. 17 where the growth curves for Port au Port and Piccadilly smelt, shown according to the spawning season, indicate that females attain greater maximum (final) total lengths than males. The growth curves also show that beyond the first year, females have greater average lengths than males at each age. These differences in growth between sexes are in agreement with the growth patterns of smelt from Miramichi, N.B., (McKenzie 1958, 1964) the Great Lakes (Bailey 1964) Gull Lake, Michigan (Burbidge 1969) as well as growth in other fishes such as haddock (Melanogrammus aeglefinus) (May 1964) and perch (Perca fluviatilis) (Alm 1952, 1959).

Table 34 compares the growth parameters of the studied populations. Mean asymptotic lengths ($L\infty$) are similar for the smelt populations from Port au Port, Piccadilly and Fox Island River. Their values are within 1 cm range for both sexes i.e. mean $L\infty$ is between 21.04 cm and 22.09 cm for males and 23.53 to 24.88 cm for females. The mean growth rate coefficient (K) values are also similar and consistently higher for males (0.641 to 0.7236) than for females (0.5556 to 0.6195). This means that the growth patterns of Port au Port Bay smelt populations do not differ appreciably and the populations could belong to a single stock. This is further supported by the fact that while the confidence interval estimates for mean $L\infty$ and K for the Port au Port Bay fish show considerable overlap, they are, however, quite outside the confidence interval estimate for mean $L\infty$ and K for Norris Arm fish (Table 34). It may also be noted that the mean asymptotic length ($L\infty$) is higher for females than for males.

When the back-calculated lengths of the Port au Port Bay smelt are compared with the data of Notre Dame Bay (Norris Arm) smelt, (Tables 32 and 33) it is clearly seen that Notre Dame Bay smelt have higher values of length at each age for both sexes. Table 34 also shows that Notre Dame Bay smelt attain greater maximum length (26.10 cm males, 31.59 cm females) than that attained by Port au Port Bay smelt. The Norris Arm samples were however, obtained late in the spawning season. It can be inferred that, on the grounds of the spawning pattern of Port au Port Bay smelt and of populations of smelt and other fish from elsewhere, the Norris Arm samples, therefore, consisted of a greater percentage of small-sized fish in that population as it has been observed that the majority of late spawners are small size fish. Comparison of data in Tables 32, 33 and 34 and Fig. 16, 17 and 18 shows that the Port au Port Bay smelt have a higher rate of approach (K) to their asymptotic length than the Norris Arm (Notre Dame Bay) smelt. Thus the growth of Port au Port Bay smelt is greatly reduced soon after three years while that of Norris Arm smelt continues to more than five years before it levels off. This, taken in conjunction with the percentage age composition (Table 22 and Fig. 8) leads to the conclusion that the Port au Port Bay smelt populations have a short life-span whereas those from Notre Dame Bay attain a larger size and live about twice as long.

3.4: 3 Length - weight relationship

Growth represents the excess of food digested and absorbed over and above that needed for maintenance requirements (Brown 1957) and in the case of mature individuals, for production of genital products. The end-product of growth is increase in size (weight or volume) (Rounsefell and Everhart 1953). For population analysis and estimation of yield

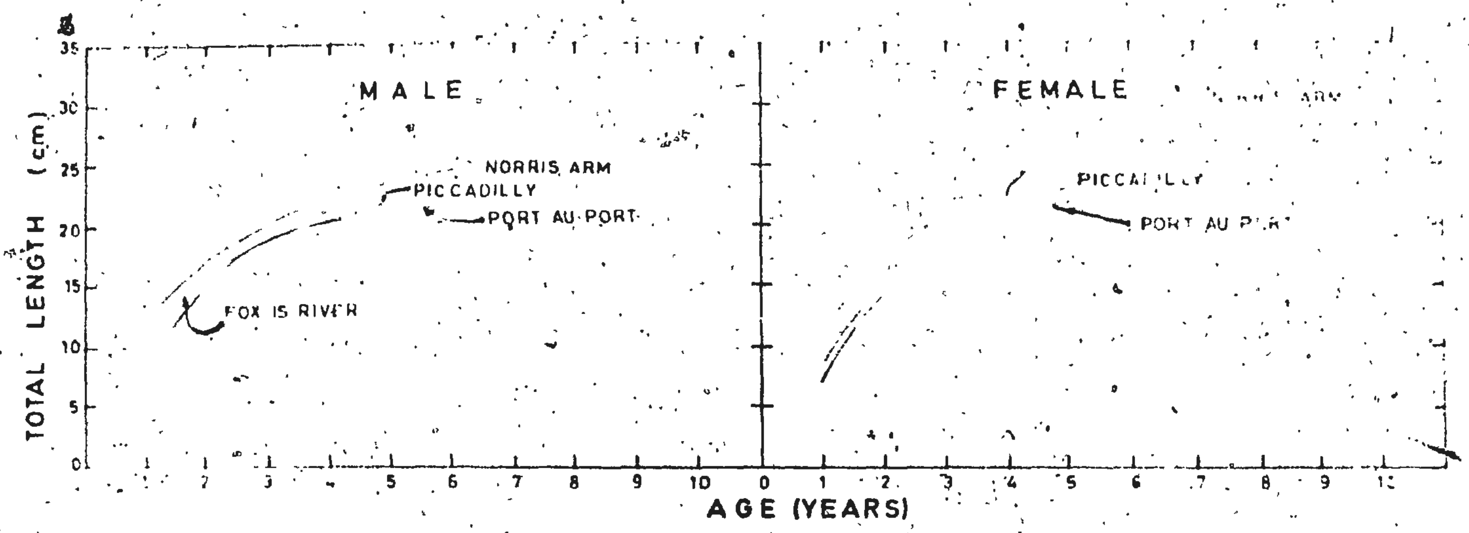


Fig. 18: Comparison of growth curves for Newfoundland smelt.

(Beverton and Holt 1957, Gulland 1969) it is desirable to express the growth of fish in a mathematical expression.

Most data for growth studies are collected at sea or elsewhere in the field and so it is both difficult and time consuming to obtain accurate weight or volume measurements. The length measurement, therefore, is the one most often used in growth studies since fairly rapid and accurate measurements of this variable can be obtained under field conditions (Graham 1956).

The growth history of Newfoundland smelt has been obtained in terms of length for each population as discussed in the last section. For the purpose of determination of yield it may be desirable to express growth in terms of weight.

In fishes, the length - weight relationship is usually adequately represented by the equation:

$$W = aL^b \tag{4}$$

Where W = weight of the fish of length L

a = a constant

b = an exponent with a value between 2 and 4, often close to 3

If the value of $b = 3$ it indicates that the fish grows symmetrically or isometrically (provided its specific gravity remains constant). Values other than 3 indicate allometric growth (Ricker 1968).

The above equation can be expressed logarithmically as:

$$\log W = b \log L + \log a \tag{5}$$

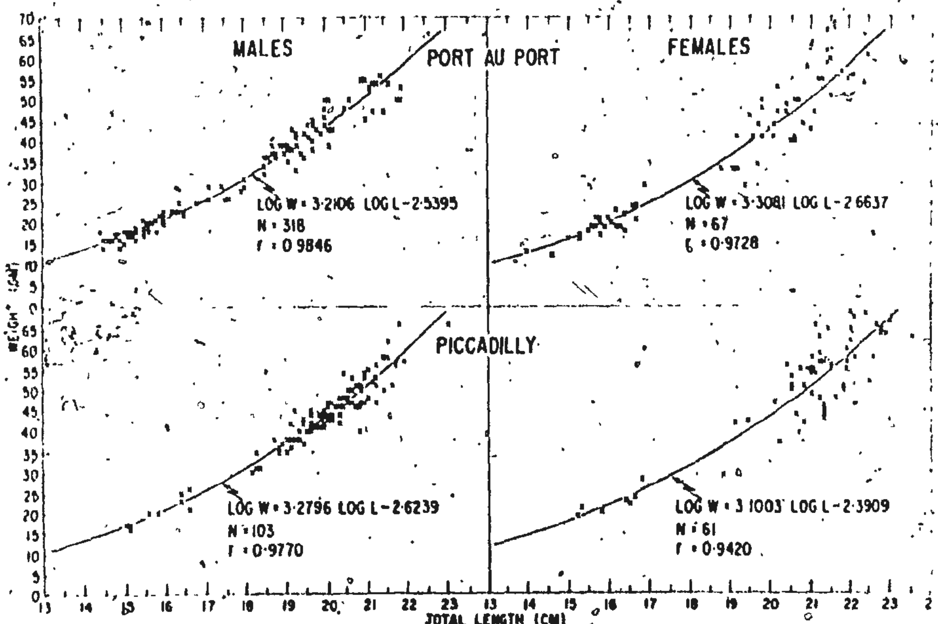
This is the form in which the length-weight equations of Newfoundland smelt have been expressed at Table 35, where

W = weight in grams

L = total length in cm.

The length-weight equations for each area and sex were determined by mathematical fitting of a stright line to the logarithms of length and weight by the method of least squares (Snedecor and Cochran 1967). The regression coefficient gave the value of b and the intercept of the regression line with the Y-axis was the value of log a.

The weights computed from individual lengths were the bases for the curves in Fig. 19 and 20 with empirical data plotted as points, N and r indicating in each graph the numbers of fish and correlation coefficients respectively. The correlation coefficients of the length-weight relationships for both sexes in the areas studied have values ranging from 0.9331 to 0.9852 indicating a high degree of relationship and predictability between length and weight. The length-weight equations and curves for Port au Port Bay smelt are very similar (Fig. 19) and there seems to be little difference between males and females (Fig. 20). The Norris Arm smelt length-weight relationship differs significantly from that for Port au Port



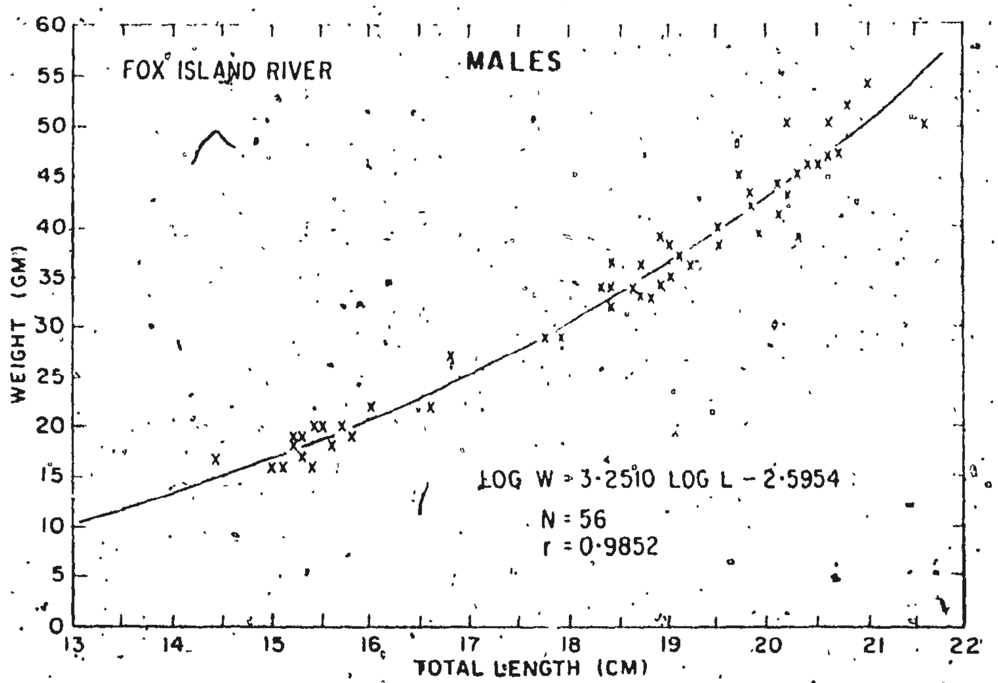


Fig. 19: Length-weight relationship of Port au Port, Piccadilly and Fox Island River smelt.

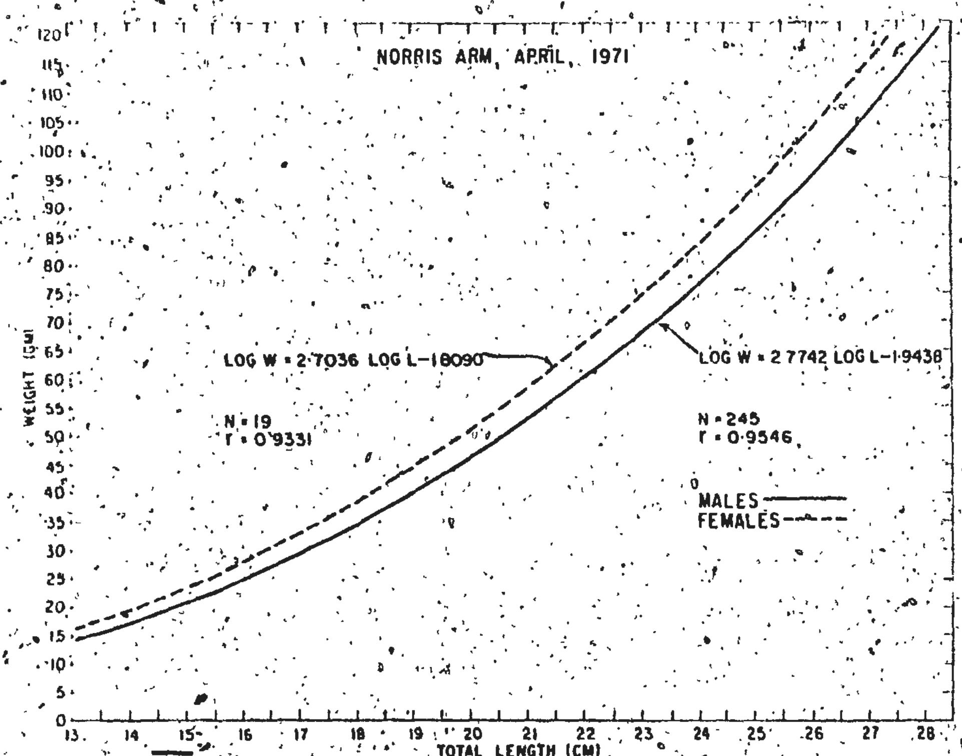


Fig. 20 A: Comparison of length-weight relationship of the sexes for Norris Arm smelt.

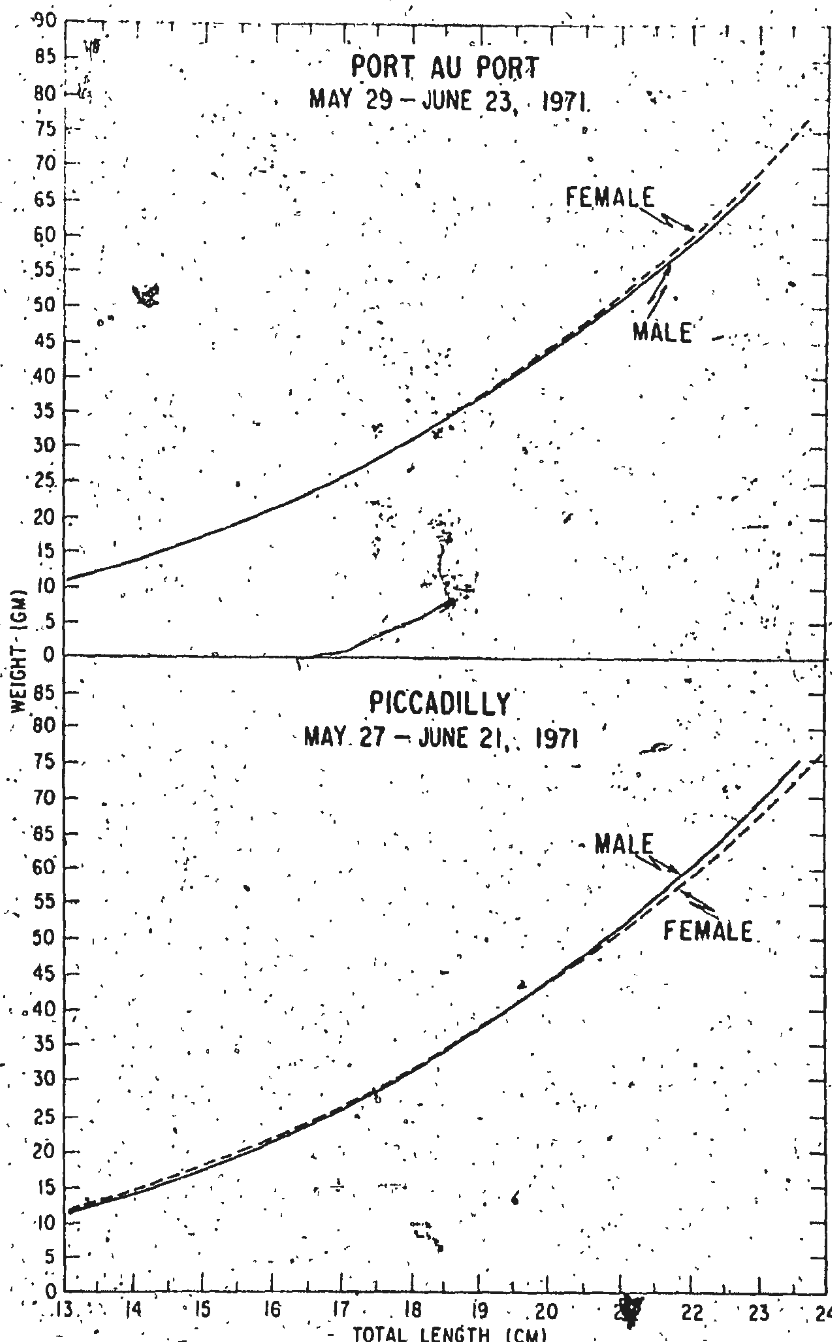


Fig. 20. B: Comparison of length-weight relationship of the sexes for Port au Port Bay smelt.

Bay fish in both the exponent value as well as the value of the constant a. Both of these have lower values from Norris Arm fish in both sexes (Table 35). Moreover, Norris Arm fish show a definite difference between the sexes such that females are heavier than males of the same length and this difference increases with increase in length (Fig. 20). Table 35A is a summary of an analysis of covariance of the length-weight regressions of male and female fish from Norris Arm and Port au Port Bay. The F-values indicate that there is a significant difference between the length-weight relationship of males and females in the Norris Arm population while there is no significant difference between the sexes for the same length-weight relationship in the Port au Port Bay smelt. McKenzie (1958), Bailey (1964) and Burbidge (1969) found little difference by sex in the length-weight data of the smelt that they studied. The lack of difference persisted among specimens caught just before and during the spawning seasons and hence these authors determined general length-weight equations from data of both sexes. McKenzie (1958) concludes that the "... average weight of females varies little from that of males of similar length". This seems to be the case for the Port au Port Bay smelt but the definite difference between the sexes in the Norris Arm smelt does not appear to have been reported in other smelt populations.

3.5. Mortality:

In fish population studies, we are often concerned with considering separately two causes of removal from the population. One of these is natural mortality which is death of fish due to diseases, predators, senescence and a large number of environmental factors. In exploited populations death due to fishing or fishing mortality is a very important factor causing removal from the population.

Studies of mortalities are concerned with rate of change i.e. the rate at which the numbers in the population are decreasing as a result of natural and fishing mortalities. According to Beverton and Holt (1957), the rate of natural mortality at any time t, which is denoted by (dN/dt), depends on the number (N) of fish present at that time and can be written as

$$_M\left(\frac{dN}{dt}\right) = -MN \qquad (6)$$

where M= instantaneous natural mortality coefficient.

Similarly, the instantaneous rate of decrease in numbers due to fishing may be defined as

$$_F\left(\frac{dN}{dt}\right) = -FN \qquad (7)$$

where F = instantaneous fishing mortality coefficient.

Finally, the rate of population decrease due to both natural and fishing mortality, called total mortality, is defined as

$$\left(\frac{dN}{dt}\right) \quad \text{total} = -ZN \qquad (8)$$

where Z = instantaneous total mortality coefficient.

In a very short time interval dt, the deaths due to fishing will be equal to FNdt, natural deaths MNdt and total deaths ZNdt, therefore

$$F + M = Z \qquad (9)$$

i.e. instantaneous mortality coefficients are additive (Gulland 1969).

In the estimation of mortalities, it is convenient to estimate first the total mortality and subtract from it the estimate of fishing mortality to obtain the natural mortality. Only the total mortality has been estimated in this study.

Estimates of total mortality can be calculated or obtained semi-graphically as was done in this case. If Z (the total mortality) is constant, the numbers of a year-class at any time, t, after it is subject to full mortality is given by

$$N_t = N_o e^{-Zt} \qquad (10)$$

where N_o = numbers at time t = o

therefore,

$$\log_e Nt = \log_e No - Zt \qquad (11)$$

If $\log_e Nt$ is plotted against t, it will give a straight line of slope - Z. This plot can be made for numbers of different year-classes at the same time, giving the so-called "catch curve" (Ricker 1958) in which deviations will be caused by inequalities in original year-class strength.

Fig. 21 shows the estimates of the instantaneous total mortality

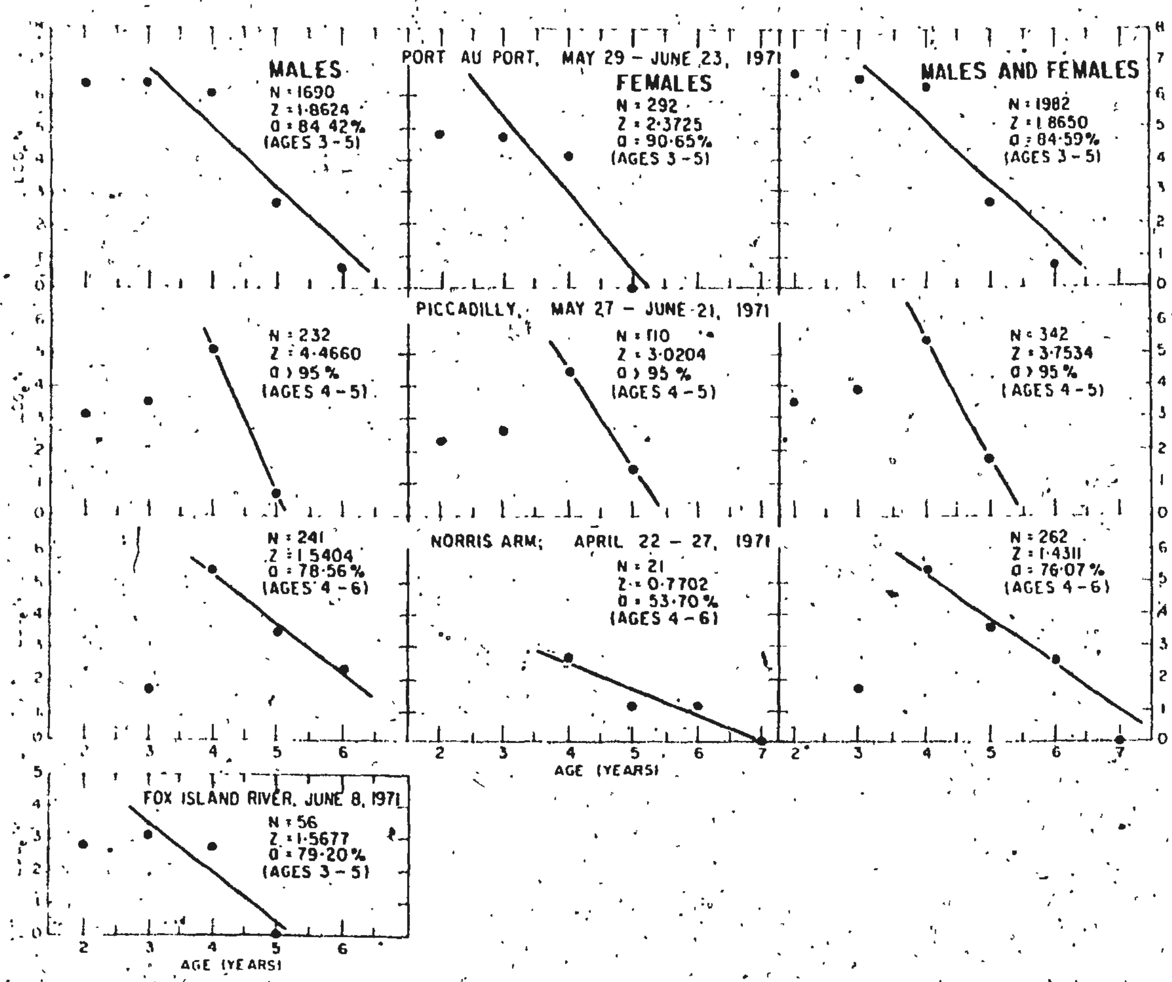


Fig. 21: Estimates of instantaneous total mortality coefficients.

coefficients (Z) and annual mortality rates (a) for male and female smelt for Port au Port Bay and Norris Arm. The Z-values apply only to the older fish as incomplete recruitment makes it impossible to use the points for younger ages. In Piccadilly and Norris Arm, the female mortality rates (Z) were lower than those for the males while the Port au Port fish showed higher mortality rates for females (Z = 2.37) than for males (Z = 1.86). Piccadilly smelt showed the highest mortality rates for both sexes (males Z = 4.47, females Z = 3.02), while Norris Arm smelt had the lowest value for both sexes (males, Z = 1.54; females, Z = 0.77) so that the estimated annual mortality rate (a) is over 95% for both sexes (ages 4-5) in the case of Piccadilly but only 78.56% for males and 53.70% for females between the ages 4-6 for Norris Arm.

3.6 Sex ratio:

Data in Table 36 relate to the sex ratio of unaged Port au Port smelt observed overnight at one station of a spawning stream (Smelt Brook) during each quarter of the spawning season. The data show that the males consistently outnumber the females at any time of the spawning run, i.e. at no time does the percentage of females in the run reach 50% of the population. Fig. 22, which graphically presents the percentage sex composition or sex ratio indicates lack of a significant correlation between fluctuations in the sex ratio with time of night. This is not in

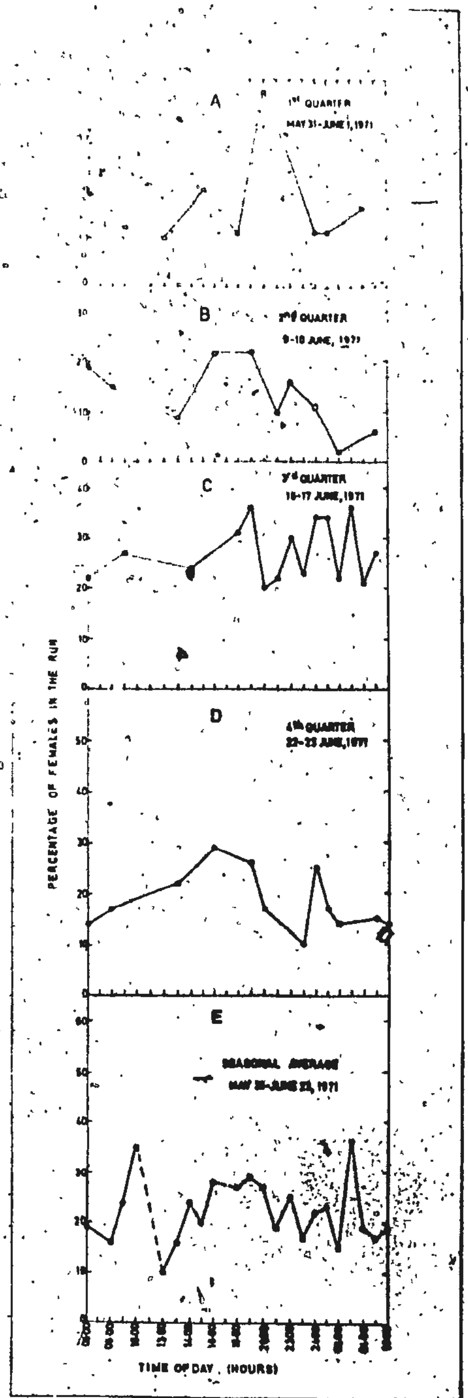


Fig. 22: Variation in the percentage of females to the total number of smelt examined during "24 hour" periods at the same point on Smelt Brook, Port au Port.

accordance with the findings of Hoover (1936) which were that "..... the females exceed 50% of the total at 3 distinct times during the night. The number of females rapidly increases and rapidly decreases". On the other hand, the seasonal average percentage composition of the sexes shows a slight rise of the proportion of females from 15% at the beginning of the run to 26% during the third quarter, falling to 18% towards the end (4th quarter) of the run (Table 36, Fig. 22 A, C, D).

McKenzie (1964) states that "the sex ratio during the spawning run varies from place to place and time to time ...". This is also confirmed by the data in Tables 36 and 37, the latter data concerning the sex ratio of aged fish sampled at a different point on the same spawning stream as that from which data in Table 36 were obtained. This sample, as shown in Table 37 shows a fall in the percentage of females from 17% at the beginning of the run to 12% during mid-season, rising again to 17% at the end of the run. This is contrary to the findings of the variation in sex ratio that is depicted in Table 36 and Fig. 22. The seasonal percentage sex composition in another spawning stream at Piccadilly shows no variation in sex ratio during the entire run. It remains 32% female during the early and late part of the spawning run (Table 38).

Table 37 also shows that of the 1,982 smelt aged from Smelt Brook, Port au Port, both ages 2 and 3 (74% of the fish) were 16% female, age-

4 was 12% female while age 5 was only 6% female. Both of the two 6-year-old fish were males. The Port au Port sample, therefore, shows a decrease in the proportion of females in the older members of the population. This is not in agreement with Tables 38 and 39 which show an increase in the proportion of females with increase in age in Picadilly and Norris Arm smelt. The latter findings agree with McKenzie (1964) and Belyanina (1969) as well as other workers, who also found that the percentage of females in the spawning runs increases with age. This is to be expected since the mortality rate for males is higher than that of females as discussed earlier in section 3.5. In Port au Port (Smelt Brook) however, the mortality rate for females is higher than that for males, hence the decrease in the proportion of females in the higher age groups.

From the foregoing information, it may be deduced that the diurnal and seasonal sex ratio patterns of spawning smelt are similar in the predominance of males at all the different times of the run. The Piccadilly and Norris Arm samples (Table 38 and 39, Fig. 22) indicate that the males concentrate first to a large extent at the spawning sites where the majority of them tend to stay throughtout the season, many of them dying there out of exhaustion and fasting. On the other hand, the females seem to have a more limited stay, coming up the spawning brooks at night and returning to sea after spawning. In this way their chances of survival are greater as reflected in their lower mortality rates.

3.7 Spawning behaviour

The smelt spawn in rivers, streams and brooks or near their mouths. As a rule they spawn once a year (Belyanina 1969). In Newfoundland, like elsewhere within its range, smelt spawning lasts for about a month (early April to beginning of May in Norris Arm, late May to end of June in Port au Port Bay). According to Belyanina (1969) peak spawning usually lasts only 2-4 days but there may be several spawning peaks, depending on weather conditions and population heterogeneity (sub-populations). In Smelt Brook, Port au Port, the "peak" season was found to be between 6-22 June during the 1971 spawning run. Thus peak spawning activity lasted for some two weeks. This is in accordance with McKenzie (1964) who observed peak spawning which lasted 5-10 days in Miramichi River N.B.

Rupp (1959) reported that the character of the spawning run depends on ice conditions: the spawning run of smelt in Maine, U.S.A. (in 80% of cases) begins within the first 10 days after the ice has broken. Sometimes the spawning run is delayed because of ice movements.

Within its great range the smelt is known to begin to spawn when the water temperature is about +4°C but the spawning peak occurs at water temperatures of 6-9°C (McKenzie 1964, Belyanina 1969). It is probably due to this preference for an optimal water temperature that spawning begins at different times in Newfoundland. The temperature of the water in Bottom

Brook, Norris Arm, at the time samples were taken was between 6-7°C during the period 21-26th April 1971. The night of 26/27 April experienced a fairly heavy snowfall. As a result the temperature of the water in the brook fell suddenly to about 4°C during the night of 27/28 April. It is not surprising that very few smelt remained in the stream during this night compared to the previous one. In fact, this may have led to the termination of the run in this brook as no smelt were observed or reported later. In Port au Port Bay, the water temperature in the brooks during the spawning run ranged between 5.6 - 12.2°C in Smelt Brook, Piccadilly, 3.4-6.1°C in Smelt Brook, Port au Port, and 15.6°C in Little River, Fox Island River. The upper temperature limits observed were taken during the day time when smelt do not spawn. At night the temperatures remained within the 3.4-6°C range which is about the same temperature observed elsewhere during the spawning peaks.

Belyanina (1969) reports that "smelt enters rivers and spawns at high tide". In this study, it was observed that there was increased activity, presumably spawning, during high tide in Bottom Brook, Norris Arm as well as in Smelt Brook, Piccadilly.

As a rule, smelt ascend rivers and streams to spawn but some fresh-water smelt populations spawn near river mouths (Belyanina 1969 quoting Russian authors). In this study, it was observed that smelt spawned as far as about 1.6 km (one mile) upstream from the mouth of Bottom Brook, Norris Arm and about 0.4 km (¼ mile) from the estuary of Smelt Brook, Port au Port. They were probably prevented from going further upstream by road culverts which caused waterfalls about 15 centimetres high or more. In Smelt Brook, Piccadilly, spawning took place at the mouth of the stream as a road culvert which prevented progress upstream was right at the mouth of this stream. It is therefore confirmed as reported by McKenzie (1964), Hoover (1936) and others that spawning in smelt is prompted by the presence of obstacles which prevent the upstream movement of the fish, provided other conditions like substratum, temperature, and current are suitable.

Many authors note that water depths at smelt spawning grounds vary from several centimetres to several metres. In this investigation it was noted that spawning activity was most pronounced in water depths from about 30 to 100 cm. The suitable substrata included stones, pebbles, submerged logs and parts of bushes. No spawn was observed on muddy bottoms.

The spawning habits of smelt have been well described by Hoover (1936). According to him "..... at approximately 6 p.m. the males that had remained in the pools during the day became active, and began to move slowly upstream to distribute themselves over the spawning beds. It is believed that some of the males, after selecting their positions over spawning beds, remained in the same area of the stream during the entire night. Barriers in the brook, such as logs, tended to induce spawning, provided the downstream bottom was suitable. As they took their places over the spawning beds, the males oriented themselves in relation to the current with heads pointing upstream. They began to move in a seething, milling manner, first to one side then to the other; moving upstream against the current, only to float back to their original positions, but always keeping their heads upstream ... Males deposit milt only when associating with females ... The sexual importance of the tubercles on the scales and the undulating sidewise motion of the males now became evident. At almost every movement to the side, the body of one fish came in contact with that of another. When a male contacted another male, the two fish quickly separated and resumed their undulating motion; but when a tubercle - covered male came in contact with a non-tuberculated female, the male immediately assumed a position slightly anterior and slightly dorsal to the female ... and violently drove her into the bottom shoreward ...". Although no such detailed observations on the spawning of smelt were made in this study, there are a number of instances which confirm some of Hoover's observations. For instance, at Smelt Brook, Port au Port, during mid-spawning season (10th June 1971) between 00.20 and 00.35 hours, smelt were seen to swim slowly upstream over stones, logs and other obstacles. In the quieter, deeper waters (60-90 cm) smelt were seen pairing and presumably spawning. A number of female smelt were observed to suddenly splash and leap out of the water onto the bank of the stream. Again in the same brook, on 15th June 1971 between 19.15 and 19.45 hours, smelt were seen swimming slowly upstream in large schools. Within the schools some appeared to be paired (male and female) and on a number of occasions a single fish suddenly splashed the water as it broke surface and skimmed the water surface to the bank of the stream where its head emerged from the water. This was repeated when the fish was forcibly returned into the water. Moreover many more eggs were observed in areas below obstructions like logs or stones than elsewhere confirming that obstructions hastened spawning. Most of the bottom of all the spawning streams examined was made up of small stones or pebbles and this appears to be a suitable substratum for smelt spawn.

A diurnal and seasonal variation in density of smelt was observed in the spawning streams. Even at the peak of the run, the density of smelt was lower during the day than at night. During daylight smelt were confined to the deeper and sheltered sections of the streams and they tended to be less active than at night. As darkness fell, there was a progressive increase in abundance and activity which reached a "peak" between 2200 hrs and midnight and gradually decreased so that at sunrise, the fish which had spread all over the stream at night were once more confined to the deeper sections of the streams. The fluctuation in density during the day is probably due to more fish of both sexes ascending the stream to spawn at night and then returning to sea when the sun comes up. Most of the fish which remained in the streams during the day were males. Hence the increased activity at night was very likely a result of spawning as the percentage of females in the population increased at night. McKenzie (1964) found that "more than 80% of spawning occurs at night".

Seasonally, the population of smelt in the spawning brooks increased to a maximum at mid-spawning season and fell towards the end of the run. As indicated in section 3.6, the sex ratio during the spawning run varied from place to place and time to time and so it did not show any clear tendency towards equality in numbers of males and females at the peak of the season. It remained definitely dominated by large numbers of males over females. Greene (1930) observed that "The beginning of the run is commonly composed of a very high percentage of male fish which are usually small. The females and larger males appreared at the height of the run and the last of the run is again composed of smaller fish ... almost all males". These observations have not been fully confirmed by this study. The sex ratio of one series of runs differs from others and the runs of one brook from those of another. Due to these variations it is not possible to estimate accurately the relative abundance of males or females without making observations for a prolonged period of time at a selected spot in the stream.

4. DISCUSSION AND CONCLUSIONS

Both sea and freshwater smelt populations have been described as often being biologically heterogeneous; within the same waterbody there are ecological forms differing in size and rate of growth, age and size of maturity, age composition of spawning stock, period and place of spawning and other peculiarities. This has been found to be so in smelt populations of the Baltic Sea bays, lakes of east Europe and North American populations (Belyanina 1969).

Newfoundland presents many opportunities to study this population heterogeneity of the Atlantic smelt. Anadromous populations spawn in the numerous streams that enter the equally numerous bays around the island. Some of the [redacted] smelt are migratory, going to sea and returning to freshwater at will, but in a number of lakes, they are unable to gain access to the lake from the sea because of steep gradients (waterfalls) in the connecting rivers. Thus although they may be able to leave the lake by going over the falls and hence down to sea, they cannot return to the lake. Smelt in lakes of this type are said to be land-locked. Scott and Crossman (1964) list the following Newfoundland lakes as known to contain land-locked smelt:

Lake	Drainage
Gull Pond	Salmonier River, St. Mary's Bay
Butt's Pond	Freshwater Bay, Bonavista Bay
Deer Lake	Humber River system
Terra Nova Lake	Terra Nova system
George's Pond	" " "
John's Pond	" " "
Gander Lake	Gander River, Gander Bay.

According to the Department of Fisheries and the Fisheries Research Board of Canada in Newfoundland, there are many other small lakes (known as ponds) which contain land locked smelt.

It is worth noting that the northernmost limit of range of smelt on the western Atlantic coast has been established to be the Hamilton Inlet - Lake Melville estuary of Labrador (about 54°N Latitude) (Low 1895, cited by Scott and Crossman 1964). Newfoundland, therefore, presents the opportunity of comparing populations in the northern limit of the distribution of this species with those in warmer waters to the South.

Fish populations can easily and rapidly be compared by considering their size composition. In fisheries biology studies, the most widely used technique of determining the size of fish is the length measurement. Several possible measures of over-all length of fish are used depending primarily on the ease and speed with which the measurement can be taken under given working conditions and on the state of fish. As stated earlier, total length was the measure employed in this study.

The length distributions of fish give the simplest index of the composition of the stock or population which can be used for comparison within the population at different times or with other populations. Considering the length distributions of spawning Newfoundland smelt (Fig. 7, Table 21) the Port au Port (Smelt Brook) and Fox Island River populations have the greatest proportion of small fish (13.0-16.9 cm) of both sexes (29.4% and 28.6% respectively). Only 8.8% of the Piccadilly (Smelt Brook) population are in this size range. It can be noted from

Tables 13 to 20 that this size range consists almost exclusively of the 2-year age group which form a large percentage of Port au Port and Fox Island River populations (see Table 22). None of the Norris Arm (Bottom Brook) fish are within this size range and not surprisingly, this population does not have the 2-year age group in its spawning run (Tables 12 and 22). Therefore, the first mode in the bimodal length distribution of Port au Port, Piccadilly and Fox Island River spawning smelt populations consists of one age group i.e. 2-year olds. Thus this length range appears to be a reliable index of age of most 2-year old spawning smelt from Port au Port Bay. This is not true for smelt larger than this size range. It is clear from Fig. 6 and 7 and Tables 13-21, that the second modal length distribution which falls in the range 17.0 to 24.4 cm consists of fish of all ages found in the spawning run i.e. from 2-year to 6-year age groups. In this case, length is a poor index of age although the "peak" of the distribution seems to consist largely of one age group i.e. 3-year-olds in the case of Port au Port and Fox Island River and 4-year-olds in the case of Piccadilly and Norris Arm fish. Table 33 confirms that Port au Port smelt have the shortest average length at any age. This is obvious from Fig. 6 and 7 which indicate the "peak" of the second modal distribution for Port au Port occurs at a shorter length (19.2 cm) than those for Piccadilly and Fox Island River (20.7 cm). Nevertheless, the similarity in the length composition of all Port au Port Bay smelt still remains. Most of them are within the range of 14.0 to 23.4 cm and that is quite distinct from the length composition of Norris Arm fish which is very much protracted, extending from 17.0 cm to 31.1 cm. This population does not show any predictability of age by length although the peak of the distribution tends to be formed by 4-year old fish which comprise the majority (79.8%) of the spawning run. Thus, from the length frequency distributions depicted in Fig. 6 and 7, it is clear that the Port au Port, Piccadilly and Fox Island populations are very similar to each other and that they could belong to the same stock or sub-stock of Newfoundland smelt while the Norris Arm population presents a very different size distribution suggesting it could well be part of a different stock.

The picture presented by the length distributions is borne out by the age compositions of the population. This is to be expected since size (length) is a function of age. Fig. 8, therefore, tells a similar story to that of Fig. 7. The Port au Port (Smelt Brook) and Fox Island River (Little River) smelt have the largest percentages of young fish in their spawning runs compared to that of Piccadilly (Smelt Brook) and Norris Arm (Bottom Brook) runs. The age at first maturity as indicated by the youngest fish in the spawning population, is 2 years for the Port au Port Bay smelt. Although this is the minimal spawning age, most fish of the Piccadilly population do not mature until they become 4 years old (74.9%) and only a small proportion (9.3%) reach maturity at the age of 2 years, increasing to 14% at 3 years. This contrasts with the pattern in Port au Port and Fox Island River in which the spawning populations are formed largely of fish of minimal spawning age (Fig. 8, Table 22). It is not known what proportion of the 3- and 4-year-old fish were first time spawners as, unlike in some fish like salmon and cod, it was not possible to determine from the scales of Newfoundland smelt at what age a spawning individual had spawned for the first time as there were no recognizable "spawning rings" (distinct from annual rings) on the scales.

The Norris Arm sample was obtained towards the end of the spawning season in which case it is reasonable to expect that most first time spawners of minimal spawning size, would be included in the sample. This is the case with both the Port au Port and Piccadilly population where it was noted that there was a progressive decrease in size (Fig. 6) and an increase in the proportion of young fish in the run as the spawning season progressed (Fig. 9, 10, Tables 13-18). McKenzie (1958, 1964) noted the same for Miramichi River N.B. smelt and the majority of workers have noted the larger and older individuals in the spawning run spawn before the younger and smaller individuals. The same situation occurs in other species of fish (Alm 1952, 1959). Thus the minimal age at first maturity for Norris Arm fish is three years although most fish do not spawn unitl they are 4 years old as is indicated by the great rise in the percentage of this age group in the spawning population.

There has been considerable discussion in the literature on whether size or age is the chief determinant of maturity. For many years, it has been thought that the onset of maturity in fish is a function of their size rather than of their age. Thus it is commonly stated in the literature that many fish become mature at a size which is some rather constant proportion (about $\frac{2}{3}$) of their final (maximum) length (Holt 1962). Beverton and Holt (1959) have examined the relation between mean length at maturity (lm) and the asymptotic (maximum) length ($L\infty$) for different species of fish. They show that the ratio $^{lm}/L\infty$ shows considerable variation with values ranging from 0.3 to more than 0.9. Although some of the variability of the ratio can be ascribed to errors in estimating $L\infty$ and also to lack of precision in both definition and measurement of maturity size, these authors are satisfied that the data do not support the contention of maturity being attained at a size which is a constant proportion of final size. It is further pointed out that some of the variability of the ratio $^{lm}/L\infty$ is due to differences in growth rate up to onset of maturity. It appears that fish which grow rather rapidly towards their asymptotic size (i.e. have high K values) mature at a size which is larger relative to that asympote than that of fish which approach the asymptotic size relatively more gradually (low K values). It has also been reported that faster growing fish mature at an earlier age than slower growing ones, though they may be absolutely smaller in size at maturity than the later maturing fish. This is the case with Salmo and Onchorhynchus species (Parker and Larkin 1959) and in Tilapia esculenta of Lake Victoria in which Garrod (1959) has shown that fish that matured when relatively young and small had higher K and lower $L\infty$ values than those which matured at a relatively older age and larger size. Although separate K and $L\infty$ values for the year-classes have not been determined for Newfoundland smelt and in spite of the realisation that these values depend on the accurancy with which age determinations are made, it can still be said that the average values of K and L∞ computed from back-calculated lengths-at-age present a fairly accurate picture of the average growth rate and asymptotic length attained by the populations studied. Consideration of data in Table 34 therefore confirms the apparent inverse relation between K and L∞. Norris Arm fish have high L∞ but low K values. They mature at a late age. Port au Port fish have low L∞ and high K values and attain maturity at an earlier age. It may also be noted that the early and late spawning Piccadilly smelt present an exception. Both the L∞ and K values for the early spawners are higher than those for late spawners. Beverton and Holt (1959) mention several fish species where the apparent inverse relation between these two growth parameters does not hold.

From the foregoing it appears the generalization that size rather than age as the chief determinant of maturity is only partly true not only because, within a species, individuals reach maturity over a range of both age and size as seen for the populations of Newfoundland smelt (2-4 years in Port au Port Bay, 3-4 years in Norris Arm) but also L∞ depends on the growth rate, or specifically on K, the rate at which the asymptotic length L∞ is approached. Both L∞ and K also vary with temperature. Thus Taylor (1958, 1959) has shown that K increases with increasing temperature in cod (Gadus morhua) and in the Pacific razor clam (<u>Siliqua patula</u>). It has also been found in many species of fish and in smelt (Belyanina 1969) that populations of the same species show a decrease in size with increase in temperature of their environment. However, the temperature coefficients for K and L_∞ are different in which case the effect of temperature on these growth paramaters is not to the same extent. This being so, it would be expected that on the basis of temperatures alone, the size and age composition of Newfoundland smelt should be similar in the areas studied as the temperature regimes of these areas do not differ to any great extent (May <u>et al</u> 1965). Furthermore, Copeman (personal communication 1971) states that a population of "stunted" smelt spawns in a brook near Sandringham, Bonavista Bay. Spawning runs of smelt in Bonavista Bay are known to take place at about the same time as the Norris Arm runs and the temperature regimes of the two bays are similar. It therefore seems that temperature does not feature prominently in determining the growth rate, maximum length and ultimately size at maturity for Newfoundland smelt. Other environmental factors, including the availability of food may be responsible for the differences in the growth pattern. Further studies need to be carried out to establish the role of temperature in defining different growth patterns of Newfoundland smelt.

A comparison of the growth curves of smelt is made in Fig. 18 based on data of back-calculated length at age given in Table 32. The male Port au Port, Piccadilly and Fox Island River fish show a close relation in their growth pattern. The curves have steep slopes between ages 1 and 2 followed by a growth inflection which reduces the slope between ages 3 and 4 and even more at greater ages. There is thus a rapid approach to $L\infty$ as indicated by the high K values in Table 34. The growth curve of Norris Arm male fish imply very fast growth during the first year of life so that at the age of one year they have a larger size than any smelt of that age from the Port au Port Bay. This larger size at age is maintained throughout life but beyond one year, the growth rate is slower so that approach to $L\infty$ is more gradual than for the Port au Port Bay smelt. These fish maintain their growth to a greater age than Port au Port Bay fish. The female smelt from all localities have a greater size at age than the males and attain greater maximum lengths ($L\infty$) at a lower rate (K). The Piccadilly females show a greater $L\infty$, lower K and slightly greater size at age than the Port au Port fish. Again the Norris Arm fish have a larger size at the age of one year and attain the highest maximum size ($L\infty$ = 31.59 cm) of all the smelt investigated. They also reach greater ages as shown by one female which was 7 years old and was 31.1 cm long.

It is therefore quite obvious, from the consideration of the growth pattern and both size and age distributions that the Port au Port Bay populations belong to one stock or sub-stock whose constituent populations have close similarities in their growth parameters ($L\infty$, K and t_0) and so they have very nearly the same values of size and age at maturity as well as longevity. On the other hand, the Norris Arm (Notre Dame Bay) population has a longer life-span, larger average and final size, higher size and age at maturity and lower K than the Port au Port Bay populations. These differences are indicative of the possibility of the Norris Arm fish belonging to a different stock from the Port au Port Bay fish.

This explanation is supported by the known habitat of smelt throughout its range of distribution. According to a number of authors (Bigelow and Schroeder 1963, Scott and Crossman 1964, Leim and Scott 1966, and Belyanina 1969) this anadromous species occurs in shoal inshore waters. "During the marine phase of their life, smelt are confined to so narrow a coastal belt that none has ever been reported more than six miles or so out from land and seldom below 2-3 fathoms; the deepest record for them is 9-10 fathoms at the mouth of Port au Port Bay on the west coast of Newfoundland..." (Bigelow and Schroeder 1963). Leim and Scott (1966) mention one tagged fish which was caught 100 miles away but they add that "this is exceptional". The smelt, therefore, do not migrate to any large extent while at sea. Their seaward movement after spawning depends chiefly on the temperature of the water; they move only far enough out and deep enough to avoid high temperatures and find cooler water (Bigelow and Schroeder 1963, Belyanina 1969). Because of these short migrations to feeding grounds, it is highly likely that populations in different bays of Newfoundland remain there throughout their entire life forming separate local populations or stocks. Indeed Port au Port Bay is far enough separated from Norris Arm (Notre Dame Bay) that taking into account the migratory habits of the smelt it is not unrealistic for these populations to be visualised as belonging to separate stocks.

Further evidence pointing to the existence of separate stocks of smelt in Newfoundland can be had from the examination of the mortality rates of the studied populations and their possible causes. Referring to Fig. 21 and Table 34 the instantaneous total mortality coefficients for the Port au Port Bay populations are higher than those for the Norris Arm population for both sexes. Values of instantaneous total mortality coefficients (Z) have been converted to annual mortality rate (a) using tables of mortality coefficients by Ricker (1958). The Piccadilly smelt population has the highest annual mortality rate (a) being more than 95%

for both sexes. Port au Port follows with an average annual mortality rate of 84.6% (84.4% for males and 90.7% for females) while the Fox Island River male annual mortality rate is 79.2%. The Norris Arm annual mortality rates are lower, being 78.6% for males, 53.7% for females and an average of 76% for both sexes.

These mortality rates may be in error due to the small numbers of fish in the older age-groups and due to possible inaccurracies in the ageing of older fish. However, since these shortcomings apply equally to all the populations, it seems valid to utilise the results for comparative purposes. Hence it is apparent that Norris Arm smelt suffer less mortalities than Port au Port Bay smelt.

In the spawning brooks entering Port au Port Bay it was observed that towards the end of the spawning run there were very many dead smelt at every place reached by the spawners. Some of the dead fish, mostly male, were found to have bruises in different areas of the body and these were frequently covered with a white slimy substance, possibly the water fungus Saprolegnia sp. Such high death rates were not observed in Norris Arm although this population was sampled towards the end of the run. It therefore appears that mortality in Port au Port Bay smelt is largely caused by spawning mortality so that a large percentage of the population spawn once and die, only a few surviving to spawn another time. This is also reflected in the age-composition data.

Beverton and Holt (1959) examined the connexion between natural death and reproduction in fish. They state that the "reproductive drain" in fishes may be apparent from the seasonal variation of the ratio of the weight of a fish to the cube of its length, the so called condition factor. This ratio is highest just before spawning and lowest in spent fish. In the plaice (<u>Pleuronectes platessa</u>) variation in this ratio has been found to be greatest in older than in younger individuals and "it seems that as the fish gets older (or, perhaps, merely bigger) the strain of meeting the reproductive demand increases to a point at which recovery is not possible" (Beverton and Holt 1959). This effect is most evident in species with high K which mature at an early age but at a relatively large size in relation to the asymptotic length $L\infty$. As stated earlier, these species are short-lived and their lifespan ends abruptly as death usually occurs at or soon after spawning i.e. they do not recover from the strain of meeting reproductive demands. Fish with a low K (e.g. sturgeon) do not show a decline in their reproductive capacities. Newfoundland smelt lend support to this theory. Port au Port Bay smelt have a high K and a low asymptotic length ($L\infty$). Therefore they mature at a relatively larger size in relation to their maximum length than the Norris Arm fish whose $L\infty$ is large but have low K. The Port au Port fish have high mortality rates and death largely occurs after spawning while Norris Arm fish show low mortality rates. It is therefore apparent that a positive correlation exists between K and mortality rate

(M or Z) and this is also evident where sexual differences in growth rate occurs. Usually the males are smaller (lower L∞), have a faster rate of growth (high K) and a higher mortality rate (M or Z) than females. From Table 34, the values of total mortality rates (Z) are higher for males than females in Piccadilly and Norris Arm. However, the males have lower mortality rates than females in Port au-Port although the growth rates are still higher for males than for females. This anomaly may be due to error in age determination of the two male fish aged as 6 year olds in the Port au Port sample. Beverton and Holt (1959) established the positive correlation between growth rate (K) and mortality rate (M or Z).

From the foregoing discussions, two main aspects of the population structure of Newfoundland smelt emerge. Firstly, taking into account their habitat and movements at sea which are very limited, it is evident that the Port au Port Bay populations are a separate stock from the Notre Dame Bay populations owing to geographical separation. Growth patterns are different in the two stocks. The Port au Port Bay stock consists of populations of fast growing (high K) early maturing (2-year-old) smelt which attain relatively small size (L∞) and have a short life-span that ends abruptly at or shortly after spawning. The Norris Arm population appears to be part of a different stock which attain a large size (high L∞) and greater age. However, they grow slowly (low K) attaining maturity when fairly old (3-4 years) while they continue to grow up to 5-6 years before they approach their asymptotic size. Mortality does not seem to be largely caused by the spawning act alone as is indicated by the presence of a large proportion of the older age groups in the population and also by the low mortality rate compared to the Port au Port Bay stock. The example of the Port au Port Bay and Norris Arm populations suggests that Newfoundland smelt, like those found elsewhere on the North American Atlantic coast (Bigelow and Schroeder 1963, Leim and Scott 1966) and in Europe (Belyanina 1968, 1969) tend to form distinct local populations constituting distinct stocks which may differ from one bay to another. It therefore appears that the many bays in Newfoundland have distinct stocks of smelt. If this is the case, caution is essential in interpreting results of studies conducted on one or two stocks and applying them to other stocks in other situations. For example one needs to take into account the great variability of the age and size of maturation and age (as well as size) structure of stocks to be able to predict the probable effect of a fishery on a discrete smelt population. In the short-lived spawning populationsof Port au Port which consist largely of 2-3 year age-groups, recruitment abundance will depend on changes in one or two year classes. When recruitment is high, such populations may recover their density very rapidly from the effects of a fishery due to their fast growth and early maturation. However, in years when recruitment is low and the main spawning population consists of older fish the number of which would be relatively small, the effects of a fishery would be much pronounced and unless restricted, could lead to over-exploitation of the stock. This would be even more serious if survival of spawn is affected by adverse conditions like reduced volume of water in spawning streams. In the long-lived populations like that at Norris Arm, reproduction is more stable as more year classes contribute to the spawn. Therefore fluctuations in the abundance of separate year-classes would have less effect on the number of spawning age groups. However, the fish of these populations grow slowly and mature later, hence such populations recover their density more slowly and an intensive fishery may result in overfishing (Belyanina 1969).

The second aspect of the population structure of Newfoundland smelt concerns the biological heterogeneity, mentioned at the beginning of this discussion as also occurring in most smelt populations (Belyanina 1969). The Port au Port Bay populations afford an example of this. Although the growth pattern and range in size and age indicate that this is a single fish stock, the Piccadilly population has a different size and age composition from that of both the Port au Port and Fox Island River populations. While in the latter two populations most individuals reach maturity at the age of 2-3 years, the Piccadilly smelt show a gradual increase in maturity within the age groups. Some fish mature at 2 years old, more at 3 years, but it is only at the age of 4 that most of fish in the population attain maturity. These differences in age and size at maturity are reflected in the size and age distributions indicating the Piccadilly fish have a higher proportion of slightly larger fish than either the Port au Port or Fox Island River fish (Fig. 6 & 7, Table 21). It is therefore apparent that the Port au Port Bay stock is formed of at least two ecological forms differing in size and age composition as well as age and size at maturity. Belyanina (1969) suggests that the existence of such ecological forms is common in smelt and it promotes the more complete use of food supply and spawning grounds as usually the smaller and earlier maturing form is non-migratory while the larger and later maturing one is more likely to move greater distances between feeding and spawning grounds. According to Lillelund (1961, cited by Belyanina 1969) the existence of different forms in the same stock or population of smelt may be a result of differences in growth rates of year-classes. Slowly growing year classes mature later than faster growing year-classes. This difference may in time cause changes in the age and size composition of a stock from a short-lived one to a long-lived stock. Obviously this is only possible in the natural situation, but where a fishery exists the consequences would be similar to what has been stated above regarding short-lived and long-lived populations or stocks.

Commercial smelt landing statistics for Newfoundland during 1936 to 1968 (Table 1, Fig. 1) show a steady though irregular decline. The same trend has been recorded for the Miramichi, New Brunswick smelt landings from 1931 to 1963. This latter fishery used to provide about one-third of the annual Canadian smelt catch of 7 to 8 million pounds. However, by 1963, over one-half of the North-American catch originated from the Great Lakes with a 12 million lb (5.4 million kg) annual production. McKenzie (1964) attributes the decline in landed catch of smelt from the Miramichi to price competition from the well-organised Great Lakes fishery which offers large sized fish at lower prices than those from elsewhere in Canada. This has led to the decline in prices of smelt and resulted in reduced fishing effort not only in the Miramichi but also in Newfoundland. For example, during the 1946-47 fishing season in the Miramichi, 3,066 licenced trap nets operated landing 23,433 cwt of smelt at a total value of $ 475,325 which was a price of $ 20.3 per cwt. The catch per net was only 764 lb. In the 1962-63 season only 464 licenced trap nets operated which landed 6,916 cwt at a catch per net of 1,491 lb. which is about twice the catch rate of the 1946-47 season. However, the catch fetched only $ 40,958 at a third of the 1946-47 price i.e. only $ 5.9 per cwt. Furthermore, investigations over a period from 1941-1963 in the Miramichi indicated that the commercial fishery took an average of only 4% of the stock each year. It is therefore clear that the steady decline in the landed catch is not a result of reduced abundance, but rather of reduced fishing effort resulting from low prices. Recently, there has been increasing concern about the effect of pollution on the fish populations of the Great Lakes and that fish from these lakes have accumulated quantities of mercury in their flesh above the safe limit for human consumption. It is therefore likely that smelt from the relatively unpolluted waters of the Atlantic Provinces, including Newfoundland, will be in increased demand to replace the Great Lakes supply and this will lead to improvement in prices. If this happens, the smelt stocks around Newfoundland will likely be subjected to increased fishing effort and unless this is regulated, the species could face the dangers of overfishing.

It is therefore important that, to enable the formulation of sound principles of management on which to base the fishery regulations, further biological studies be carried out on the population structure, growth and abundance of stocks of smelt in Newfoundland. It is also necessary to assess the existing fishery and the potential for its expansion taking into account the annual abundance of the delimited exploitable stocks. This is important since smelt stocks tend to be localised, being limited to individual bays or river systems. McKenzie (1964) states that tagging and marking studies in the Miramichi "support the opinion that smelt stocks are are restricted in range so that recruitment from one river system to another is restricted. This means that each river system, and even tributaries, should be considered individually for management. It also means that quantitative observations derived for the Miramichi system apply only to it although it is belived that qualitative conclusions apply generally throughout the Maritimes region".

Finally, it is in order at this juncture, to stress the importance of obstructions in spawning brooks to the mortality of adult smelt and their eggs. As indicated earlier, large concentrations of spawning smelt and spawn were observed below road culverts. Because of the swift flow of water resulting from the difference in level between the culvert and the stream bed downstream, smelt were prevented from going further upstream where they could have found suitable spawning sites. This would reduce crowding of eggs and increase larval production as it has been observed that reduced crowding of eggs increases survival of larvae up to 100 times (McKenzie 1947, 1964). It would be of great help to the smelt populations if grades through culverts were made to conform to the slope of the original stream bed and that the bottom of the culvert at the outflow should be level with or lower than the stream bed. This would facilitate passage of smelt to spawning grounds upstream and this would contribute to increasing the survival of larva and in the final analysis, increase or maintain the abundance of smelt stocks.

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LIST OF TABLES

TABLE 1: Landings of smelt in Newfoundland during 1936-1968

Year	Weight (000' lbs)	Value (000'$)
1936	270.1	*
1937	457.9	*
1938	278.9	*
1939	431.2	*
1940	305.7	*
1941	170.3	*
1942	265.5	*
1943	110.1	*
1944	241.4	*
1945	185.2	24.5
1946	264.5	40.1
1947	143	23.8
1948	225.9	46.8
1949	*	*
1950	*	*
1951	*	*
1952	54	5.5
1953	105	11
1954	34	3.4
1955	118	14.3
1956	95	11.5
1957	55	6.2
1958	12	1.1
1959	23	2.1
1960	109	12.3
1961	95	9.1
1962	55	5.5

TABLE 1: (continued)

Year	Wt (000'lbs)	Value (000'$)
1963	49	5
1964	28	1
1965	20	2
1966	35	4
1967	51	5
1968	17	2

Sources 1936-48: Newfoundland Government Economic Bulletins - Export figures only

1952-68: Dominion Bureau of Statistics; Fisheries statistics of Canada.

* Indicates no figures available.

Table 2: Areas in Newfoundland where smelt were collected

Date	Place	Locality	Period collected	No. collected
1971				
April 22-27	Norris Arm	Bottom Brook	End of spawning season	264
May 27-June 21	Piccadilly	Smelt Brook	Early & late spawning season	342
May 29-June 23	Port au Port	Smelt Brook	Early, mid & late spawning season	1982
June 8	Fox Island River.	Little River	Only one day sample obtained	56

Table 2A. Summary of comparisons of the mean sizes of fish in the fresh condition and after preservation in isopropylcohol.

Comprison of weights(grams)		
No. of fish in the sample		100
Mean size in fresh condition		31.12
Mean size after preservation		33.14
Standard deviation of mean		10.43
	t =	1.95*
Comparison of lengths(cm)		
No. of fish in the sample		100
Mean size in fresh condition		18.23
Standard deviation of mean		1.89
Mean size after preservation		18.07
Standard deviation of mean		1.83
	t =	1.00 n.s.

*Significant difference at 5% level

n.s.= No Significant difference at 5% level.

TABLE 3: Average total lengths of fish at each scale radius interval of 0.05mm for Norris Arm smelt. Numbers of fish in brackets

Scale radius (mm)	Total length (cm)
1.30	18.70 (1)
1.65	17.55 (2)
1.70	19.70 (3)
1.75	19.20 (2)
1.80	19.59 (11)
1.85	19.79 (15)
1.90	19.50 (13)
1.95	20.10 (16)
2.00	20.50 (17)
2.05	20.30 (18)
2.10	20.27 (17)
2.15	20.77 (22)
2.20	20.86 (19)
2.25	21.94 (16)
2.30	22.07 (11)
2.35	22.23 (12)
2.40	22.70 (16)
2.45	23.06 (11)
2.50	23.04 (7)
2.55	24.37 (3)
2.60	23.78 (6)
2.65	25.13 (3)
2.70	25.10 (6)
2.75	- -
2.80	25.05 (4)
2.85	26.75 (2)
2.90	- -
2.95	26.36 (3)
3.00	25.20 (2)
3.50	31.10 (1)
Total numbers of fish	259

TABLE 4: Average total lengths of fish at each scale radius interval of 0.05mm for early spawning Port au Port smelt. Numbers of fish are in brackets.

Scale radius (mm)	Total length (cm)	
	Males	Females
1.20	14.60 (1)	-
1.25	14.43 (3)	15.10 (2)
1.30	14.87 (7)	15.03 (3)
1.35	14.71 (7)	14.45 (2)
1.40	15.48 (11)	15.28 (5)
1.45	14.84 (5)	15.45 (4)
1.50	15.88 (10)	15.76 (5)
1.55	16.14 (5)	16.10 (3)
1.60	17.37 (3)	17.17 (3)
1.65	17.11 (7)	16.30 (2)
1.70	18.25 (4)	17.63 (3)
1.75	18.42 (11)	18.95 (2)
1.80	18.35 (8)	19.30 (1)
1.85	19.50 (11)	20.10 (2)
1.90	19.45 (12)	19.87 (6)
1.95	19.99 (11)	19.90 (3)
2.00	20.15 (8)	20.59 (7)
2.05	19.90 (4)	20.56 (5)
2.10	20.50 (3)	21.03 (4)
2.15	21.27 (3)	22.25 (2)
2.20	21.26 (5)	21.48 (4)
2.25	-	-
2.30	-	-
2.35	-	-
2.40	-	22.10 (1)
Numbers of fish	140	70

TABLE 5: Average total length of fish at each scale radius interval of 0.05mm for mid-season spawning Port au Port smelt. Numbers of fish in brackets.

Scale radius (mm)	Total length (cm) Males	Total length (cm) Females
1.20	13.50 (1)	-
1.25	14.23 (4)	14.50 (2)
1.30	14.65 (4)	-
1.35	14.65 (6)	15.20 (1)
1.40	14.92 (9)	15.30 (4)
1.45	15.45 (14)	15.05 (2)
1.50	16.18 (13)	15.80 (2)
1.55	16.85 (4)	15.48 (4)
1.60	16.71 (8)	14.40 (1)
1.65	17.08 (8)	17.90 (3)
1.70	18.16 (9)	16.97 (3)
1.75	18.50 (5)	18.40 (1)
1.80	18.98 (7)	18.60 (2)
1.85	18.95 (6)	19.57 (3)
1.90	19.24 (11)	19.40 (2)
1.95	19.90 (8)	19.55 (4)
2.00	20.29 (7)	19.98 (4)
2.05	20.20 (8)	19.73 (3)
2.10	21.10 (2)	21.35 (2)
2.15	21.00 (2)	21.10 (1)
2.20	21.00 (1)	-
2.25	-	-
2.30	19.40 (1)	-
Total Numbers of fish	135	44

TABLE 6: Average total lengths of fish at each scale radius interval of 0.05mm for late spawning Port au Port smelt. Numbers of fish in brackets.

Scale radius (mm)	Total lenth (cm) Males	Females
1.10	13.20	-
1.15	13.35 (2)	-
1.20	14.17 (3)	13.50 (1)
1.25	-	13.87 (3)
1.30	14.20 (6)	14.51 (7)
1.35	14.40 (7)	14.79 (7)
1.40	14.96 (11)	14.76 (11)
1.45	15.28 (9)	14.82 (13)
1.50	15.98 (12)	15.44 (5)
1.55	15.28 (6)	15.20 (1)
1.60	17.48 (6)	17.23 (4)
1.65	16.99 (7)	17.63 (3)
1.70	17.40 (10)	19.45 (4)
1.75	17.85 (8)	18.98 (4)
1.85	18.72 (5)	19.43 (8)
1.90	19.82 (9)	19.15 (11)
1.95	19.46 (9)	18.77 (3)
2.00	20.02 (9)	19.73 (6)
2.05	20.50 (1)	20.43 (4)
2.10	20.80 (1)	20.15 (2)
2.15	20.45 (2)	21.00 (1)
2.20	21.40 (1)	21.50 (1)
2.25	19.90 (2)	-
2.30	20.75 (2)	-
2.35	-	-
Total Numbers of fish	140	108

TABLE 7: Average total lengths of fish at each scale radius interval of 0.05mm for early spawning Piccadilly smelt. Numbers of fish in brackets.

Scale radius (mm)	Total length (cm) Male		Total length (cm) Female	
1.30	-		15.30	(1)
1.35	15.25	(1)	-	
1.40	15.25	(6)	16.10	(2)
1.45	15.10	(3)	16.90	(1)
1.50	16.20	(2)	-	
1.55	16.10	(2)	16.60	(1)
1.60	17.23	(3)	-	
1.65	17.50	(2)	17.80	(2)
1.70	18.10	(1)	-	
1.75	19.83	(3)	18.60	(1)
1.80	19.41	(9)	21.00	(2)
1.85	19.66	(8)	21.05	(2)
1.90	19.85	(6)	20.96	(5)
1.95	19.87	(7)	20.84	(12)
2.00	20.51	(14)	21.08	(10)
2.05	20.67	(9)	21.45	(11)
2.10	21.26	(7)	21.76	(10)
2.15	20.66	(2)	21.88	(5)
2.20	21.75	(2)	22.57	(7)
2.25	20.50	(1)	22.30	(4)
2.30	-		23.00	(1)
2.35	21.70	(1)	22.90	(1)
2.40	-		23.40	(1)
2.45	-		-	
2.50	-		24.30	(1)
Total Numbers of Fish	89		80	

TABLE 8: Average total lengths of fish at each scale radius interval of 0.05mm for late spawning Piccadilly smelt. Numbers of fish in brackets.

Scale radius (mm)	Total length (cm)	
	Male	Female
1.20	-	-
1.25	14.90 (1)	-
1.30	-	15.30 (1)
1.35	14.70 (1)	14.20 (1)
1.40	14.50 (1)	-
1.45	16.40 (1)	-
1.50	17.60 (1)	-
1.55	-	-
1.60	16.80 (1)	-
1.65	18.90 (3)	-
1.70	18.95 (2)	-
1.75	18.50 (3)	18.20 (1)
1.80	20.10 (1)	-
1.85	18.93 (7)	20.78 (4)
1.90	18.55 (2)	-
1.95	19.90 (2)	20.07 (3)
2.00	20.60 (1)	20.50 (1)
2.05	-	24.00 (1)
2.10	-	-
2.15	-	-
2.20	-	22.35 (2)
Numbers of fish	27	14

TABLE 9: Average total lengths of fish at each scale radius interval of 0.05mm for Fox Island River smelt. Numbers of fish are in brackets.

Scale radius (mm)	Total length (cm) Male	Female
1.20	-	Nil
1.25	-	
1.30	15.87 (3)	
1.35	-	
1.40	15.30 (1)	
1.45	15.20 (1)	
1.50	-	
1.55	-	
1.60	16.90 (2)	
1.65	17.90 (1)	
1.70	19.80 (1)	
1.75	19.40 (2)	
1.80	18.93 (3)	
1.85	19.43 (4)	
1.90	19.20 (1)	
1.95	20.70 (1)	
2.00	20.30 (1)	
2.05	19.45 (2)	
2.10	20.60 (1)	
2.15	20.50 (1)	
2.20	-	
2.25	21.10 (2)	
Numbers of fish	27	

TABLE 10A: Comparison of regressions of total length of fish on scale radius by analysis of covariance for male and female smelt from Norris Arm and Port au Port.

Test	Source of Variation	Errors of Estimate Degrees of freedom	Sum of Squares	Mean Square	F
Between sexes, Norris Arm (Bottom Brook)	Within Samples	253	320.08	1.27	
	Regression Coefficients	1	4.70	4.70	3.71*
	Common Regression	254	324.77	1.28	
	Adjusted Means	1	37.01	37.01	28.95*
	Total	255	361.79		

* Significant difference at 1% level (Pearson & Hartley 1956)

Table 10B:

Test	Source of Variation	Errors of Estimate Degrees of freedom	Sum of Squares	Mean Square	F
Between Sexes, Port au Port (Smelt Brook)	Within Samples	205	174.72	0.85	
	Regression Coefficients	1	0.66	0.66	0.78 n.s
	Common Regression	206	175.39	0.85	
	Adjusted Means	1	0.58	0.58	0.68 n.s.
	Total	207	175.97		

n.s. = No significant difference at 1% or 5% level

TABLE 11: Regression equations of total length (L) on scale radius (S) for Newfoundland smelt. L and S are in centimetres.

Place	Sex	No. of fish	Equations
Norris Arm	Male	259	L = 8.6784 + 57.750S
	Female	18	L = 6.4152 + 74.351S
Port au Port	Male	140	L = 4.5174 + 77.796S
(Early spawners)	Female	70	L = 5.9031 + 81.955S
Port au Port	Male	135	L = 4.1595 + 79.515S
(Mid-season spawners)	Female	44	L = 3.5898 + 81.922S
Port au Port	Male	140	L = 4.2688 + 77.584S
(Late spawners)	Female	140	L = 3.3900 + 83.321S
Piccadilly	Male	89	L = 4.6317 + 78.798S
(Early spawners)	Female	80	L = 6.6607 + 71.977S
Piccadilly	Male	27	L = 6.0263 + 71.328S
(Late spawners)	Female	14	L = 2.9700 + 91.425S
Fox Island	Male	27	L = 7.7825 + 61.112S
River	Female	-	-

TABLE 12: Length distribution of the age-groups of Norris Arm smelt.

M = Male F = Female

AGE-GROUP AND SEX

Length Intervals	3	4		5		6		7		Total		
		M	F	M	F	M	F	M	F	M	F	M + F
17.0-17.4		1								1		1
17.5-17.9												
18.0-18.4		3								3		3
18.5-18.9	3	8	2							11	2	13
19.0-19.4	1	11								12		12
19.5-19.9		38								38		38
20.0-20.4		36	1							36	1	37
20.5-20.9		30		1						31		31
21.0-21.4		20	1	1						21	1	22
21.5-21.9		20	3	2						22	3	25
22.0-22.4		10	2	2		1				13	2	15
22.5-22.9	1	7	2	1						9	2	11
23.0-23.4		8	1	2		1				11	1	12
23.5-23.9		1		3						4		4
24.0-24.4		2		5		5				12		12
24.5-24.9		1		4						5		5
25.0-25.4			1	1	2	1				2	3	5
25.5-25.9				3			1			3	1	4
26.0-26.4				5		1	1			6	1	7
26.5-26.9												
27.0-27.4			1	1			1			1	2	3
27.5-27.9												
28.5-28.9					1						1	1
31.0-31.4									1		1	1
Total No. of fish	5	196	14	31	3	9	3		1	241	21	262
Percentage	1.9	74.5	5.3	11.8	1.1	3.4	1.1		0.4	91.6	8.4	100

TABLE 15: Length distribution of the age groups of early spawning Port au Port smelt.

M = Male F = Female

Length Intervals (cm)	Age-group and Sex: 2 M	2 F	3 M	3 F	4 M	4 F	5 M	5 F	6 M	6 F	Total M	Total F	Total M + F
13.0-13.4		1										1	1
13.5-13.9	1										1	-	1
14.0-14.4	8	2									8	2	10
14.5-14.9	17	4									17	4	21
15.0-15.4	31	4									31	4	35
15.5-15.9	31	7		1							31	8	39
16.0-16.4	18	6									18	6	24
16.5-16.9	2	3	1	1							3	4	7
17.0-17.4	3		1		1						5	-	5
17.5-17.9	1		12								13	-	13
18.0-18.4			20	1	5						25	1	26
18.5-18.9			21	3	20	1					41	4	45
19.0-19.4			28	5	27	1					55	6	61
19.5-19.9				3	45	3					45	6	51
20.0-20.4				3	30	3					30	6	36
20.5-20.9				1	12	1	1				13	2	15
21.0-21.4			1		7	6					8	6	14
21.5-21.9			1		4	3			1		6	3	9
22.0-22.4						5					-	5	5
22.5-22.9						1					-	1	1
23.0-23.4						1					-	1	1
Total No. of fish	112	27	85	18	151	25	1	-	1	-	350	70	420
Percentage	26.7	6.4	20.2	4.3	36.0	6.0	0.2	-	0.2	-	83.3	16.7	100

TABLE 14: Length distribution of the age groups of mid-season spawning Port au Port smelt.

M = Male F = Female

Age-group and Sex

Length Intervals ( )	2		3		4		5		6	Total		
	M	F	M	F	M							+
13.0-13.4												
13.5-13.9	2	1								2	1	3
14.0-14.4	29	2								29	2	31
14.5-14.9	61	2								61	2	63
15.0-15.4	106	10								106	10	116
15.5-15.9	69	11								69	11	80
16.0-16.4	30	9								30	9	39
16.5-16.9	4	5	15							19	5	24
17.0-17.4			10							10	-	10
17.5-17.9			23		3					26	-	26
18.0-18.4			53	3	13					66	3	69
18.5-18.9			86	9	21					107	9	116
19.0-19.4			57	13	56					113	13	126
19.5-19.9			19	9	45					64	9	73
20.0-20.4			14	16	32		5			51	16	67
20.5-20.9					16	10				16	10	26
21.0-21.4			3		7	9				10	9	19
21.5-21.9					5	3				5	3	8
22.0-22.4					1					1	-	1
22.5-22.9												
Total No. of fish	301	40	280	50	199	22	5	-	-	785	112	897
Percentage	33.6	4.5	31.2	5.6	22.2	2.5	0.6			87.5	12.5	100

TABLE 15: Length distribution of the age groups of late spawning Port au Port smelt.

M = Male F = Female

Aged-groups and Sex

Length Interval (cm)	2 M	2 F	3 M	3 F	4 M	4 F	5 M	5 F	6 M	6 F	Total M	Total F	Total M + F
13.0–13.4	2										2	-	2
13.5–13.9	10	6									10	6	16
14.0–14.4	52	7									52	7	59
14.5–14.9	64	19									64	19	83
15.0–15.4	37	10									37	10	47
15.5–15.9	22	5									22	5	27
16.0–16.4	6	2									6	2	8
16.5–16.9	1		4								5	-	5
17.0–17.4			25	2							25	2	27
17.5–17.9			33	4	8						41	4	45
18.0–18.4			68	9	8	1					76	10	86
18.5–18.9			58	10	15	1					73	11	84
19.0–19.4			40	13	20		6				66	13	79
19.5–19.9			27	7	18	2					45	9	54
20.0–20.4			2	1	19	1					21	2	23
20.5–20.9				1	5	2			1		6	3	9
21.0–21.4					1	4	2				3	4	7
21.5–21.9						1	1	1			1	2	3
22.0–22.4						1					-	1	1
22.5–22.9													
Total No. of fish	194	49	257	47	94	13	9	1	1	-	555	110	665
Percentage	29.2	7.4	38.7	6.9	14.1	2.0	1.4	0.2	0.2		83.5	16.5	100

TABLE 16: Length distribution of the age groups of all Port au Port smelt.

M = Male F = Female

Length Interval (cm)	Age-group and Sex 2 M	2 F	3 M	3 F	4 M	4 F	5 M	5 F	6 M	6 F	Total M	Total F	Total M + F
13.0-13.4	2	1									2	1	3
13.5-13.9	13	7									13	7	20
14.0-14.4	89	11									89	11	100
14.5-14.9	142	25									142	25	167
15.0-15.4	174	24									174	24	198
15.5-15.9	122	23		1							122	24	146
16.0-16.4	54	17									54	17	71
16.5-16.9	7	8	20	1							27	9	36
17.0-17.4	3	-	36	2	1						40	2	42
17.5-17.9	1	-	68	4	11						80	4	84
18.0-18.4			141	13	26	1					167	14	181
18.5-18.9			165	22	56	2					221	24	245
19.0-19.4			125	31	103	1	6				234	32	266
19.5-19.9			46	19	108	5					154	24	178
20.0-20.4			16	20	81	4	5				102	24	126
20.5-20.9				2	33	13	1	-	1	-	35	15	50
21.0-21.4			4	-	15	19	2				21	19	40
21.5-21.9			1	-	9	7	1	1	1	-	12	8	20
22.0-22.4					1	6					1	6	7
22.5-22.9						1					-	1	1
23.0-23.4						1					-	1	1
Total No. of fish	607	116	622	115	444	60	15	1	2	-	1690	292	1982
Percentage	30.6	5.9	31.4	5.8	22.4	3.0	0.8	0.1	0.1		85.4	14.6	100

TABLE 17: Length distribution of the age groups of early spawning Piccadilly smelt.

M = Male F = Female

Length Intervals (cm)	Age-group and Sex: 2 M	2 F	3 M	3 F	4 M	4 F	5 M	5 F	6 M	6 F	Total M	Total F	Total M + F
13.0-13.4													
13.5-13.9													
14.0-14.4	1										1	-	1
14.5-14.9													
15.0-15.4	6	2									6	2	8
15.5-15.9	5	2									5	2	7
16.0-16.4	4	1									4	1	5
16.5-16.9	2	3									2	3	5
17.0-17.4													
17.5-17.9													
18.0-18.4			2	-	1						3	-	3
18.5-18.9			7	2	11						18	2	20
19.0-19.4			11	1	27						38	1	39
19.5-19.9			6	3	25						31	3	34
20.0-20.4				2	38	7					38	9	47
20.5-20.9				1	34	13					34	14	48
21.0-21.4				2	12	19		1			12	22	34
21.5-21.9					7	12	1				8	12	20
22.0-22.4					1	10					1	10	11
22.5-22.9						11					-	11	11
23.0-23.4						2	1				1	2	3
23.5-23.9						1	-				-	1	1
24.0-24.4								1			-	1	1
Total No. of fish	18	8	26	11	156	75	2	2			202	96	298
Percentage	6.0	2.7	8.7	3.7	52.3	25.2	0.7	0.7			67.8	32.2	100

TABLE 18: Length distribution of the age groups of late spawning Piccadilly smelt.

M = Male F = Female

Length Intervals (cm)	Age-group and Sex: 2 M	2 F	3 M	3 F	4 M	4 F	5 M	5 F	6 M	6 F	Total M	Total F	Total M + F
13.0-13.4													
13.5-13.9													
14.0-14.4		1									-	1	1
14.5-14.9	3										3	-	3
15.0-15.4		1									-	1	1
15.5-15.9													
16.0-16.4	1										1	-	1
16.5-16.9			1								1	-	1
17.0-17.4			1								1	-	1
17.5-17.9			3								3	-	3
18.0-18.4			2	1	2						4	1	5
18.5-18.9					3						3	-	3
19.0-19.4			1	1	4						5	1	6
19.5-19.9					5	1					5	1	6
20.0-20.4					2	2					2	2	4
20.5-20.9				1	2	1					2	2	4
21.0-21.4						2					-	2	2
21.5-21.9													
22.0-22.4						1					-	1	1
22.5-22.9													
23.0-23.4													
23.5-23.9								1			-	1	1
24.0-24.4								1			-	1	1
Total No. of fish	4	2	8	3	18	7	-	2	-	-	30	14	44
Percentage	9.1	4.6	18.2	6.8	40.9	15.9	-	4.6			68.2	31.8	100

TABLE 19: Length distribution of the age groups of all Piccadilly smelt.

M = Male F = Female

Length Intervals (cm)	Age-group and Sex 2 M	2 F	3 M	3 F	4 M	4 F	5 M	5 F	6 M	6 F	Total M	Total F	Total M + F
13.0-13.4													
13.5-13.9													
14.0-14.4	1	1									1	1	2
14.5-14.9	3										3	-	3
15.0-15.4	6	3									6	3	9
15.5-15.9	5	2									5	2	7
16.0-16.4	5	1									5	1	6
16.5-16.9	2	3	1								3	3	6
17.0-17.4			1								1	-	1
17.5-17.9			3								3	-	3
18.0-18.4			4	1	3						7	1	8
18.5-18.9			7	2	14						21	2	23
19.0-19.4			12	2	31						43	2	45
19.5-19.9			6	3	30	1					36	4	40
20.0-20.4				2	40	9					40	11	51
20.5-20.9				2	36	14					36	16	52
21.0-21.4				2	12	21		1			12	24	36
21.5-21.9					7	12	1				8	12	20
22.0-22.4					1	11					1	11	12
22.5-22.9						11					-	11	11
23.0-23.4						2	1				1	2	3
23.5-23.9						1		1			-	2	2
24.0-24.4								2			-	2	2
Total No. of fish	22	10	34	14	174	82	2	4	-	-	232	110	342
Percentage	6.4	2.9	9.9	4.1	50.9	24.0	0.6	1.2			67.8	32.2	100

TABLE 20: Length distribution of the age groups of Fox Island River smelt

M = Male F = Female

Length Intervals (cm)	Age-group and Sex 2 M	2 F	[illegible] M	[illegible] F	4 M	4 F	5 M	5 F	6 M	6 F	Total M	Total F	+
13.0-13.4													
13.5-13.9													
14.0-14.4													
14.5-14.9													
15.0-15.4	9										9	-	9
15.5-15.9	3										3	-	3
16.0-16.4	1										1	-	1
16.5-16.9	3										3	-	3
17.0-17.4			1								1	-	1
17.5-17.9			2								2	-	2
18.0-18.4			4								4	-	4
18.5-18.9			6								6	-	6
19.0-19.4			5								5	-	5
19.5-19.9			5		2						7	-	7
20.0-20.4					6						6	-	6
20.5-20.9					6		1				7	-	7
21.0-21.4					1						1	-	1
21.5-21.9					1						1	-	1
Total No. of fish	16	-	23	-	16	-	1	-	-	-	56	-	56
Percentage	28.6	-	41.0	-	28.6	-	1.8	-	-	-	100	-	100

TABLE 21: Percentage length composition of smelt from Newfoundland.

M = Male F = Female

Length Interval (cm)	Norris Arm			Port au Port			Piccadilly			Fox Island River		
	M	F	Total	M	F	Total	M	F	Total	M	F	Total
13.0–13.4				0.16	0.05	0.21	–	–	–	–	–	–
13.5–13.9				0.68	0.37	1.05	–	–	–	–	–	–
14.0–14.4				4.58	0.63	5.21	0.29	0.29	0.58	–	–	–
15.0–15.4				8.57	1.42	9.99	1.75	0.88	2.63	16.07	–	16.07
15.5–15.9				6.42	1.21	7.63	1.46	0.58	2.05	5.36	–	5.36
16.0–16.4				2.79	0.84	3.63	1.46	0.29	1.75	1.79	–	1.79
16.5–16.9				1.21	0.42	1.63	0.88	0.88	1.76	5.36	–	5.36
17.0–17.4	0.38	–	0.38	2.21	0.11	2.31	0.29	–	0.29	1.79	–	1.79
17.5–17.9	–	–	–	4.05	0.26	4.31	0.88	–	0.88	3.53	–	3.57
18.0–18.4	1.15	–	1.15	8.31	0.79	9.10	2.05	0.29	2.34	7.14	–	7.14
18.5–18.9	4.20	0.76	4.96	10.57	1.37	11.94	6.14	0.58	6.72	10.71	–	10.71
19.0–19.4	4.58	–	4.58	11.41	1.42	12.83	12.57	0.58	13.15	8.93	–	8.93
19.5–19.9	14.50	–	14.50	7.94	1.21	9.15	10.52	1.17	11.69	12.50	–	12.50
20.0–20.4	13.74	0.38	14.12	5.15	1.00	6.15	11.70	3.22	14.92	10.71	–	10.71
20.5–20.9	11.83	–	11.83	1.84	0.68	2.52	10.52	4.68	15.20	12.50	–	12.50

TABLE 21: (Continued)

Length Interval (cm)	Norris Arm M	F	Total	Port au Port M	F	Total	Piccadilly M	F	Total	Fox Island River M	F	Total
21.0–21.4	8.02	0.38	8.40	1.10	1.05	2.16	3.51	7.02	10.53	1.79	–	1.79
21.5–21.9	8.40	1.15	9.55	0.53	0.42	0.95	2.34	3.51	5.85	1.79	–	1.79
22.0–22.4	4.96	0.76	5.72	0.11	0.47	0.58	0.29	3.22	3.51			
22.5–22.9	3.44	0.76	4.20	–	0.16	0.16	–	3.22	3.22			
23.0–23.4	4.20	0.38	4.58	–	0.05	0.05	0.29	0.58	0.88			
23.5–23.9	1.53	–	1.53				–	0.58	0.58			
24.0–24.4	4.58	–	4.58				–	0.58	0.58			
24.5–24.9	1.91	–	1.91									
25.0–25.4	0.76	1.15	1.91									
25.5–25.9	1.15	0.38	1.52									
26.0–26.4	2.29	0.38	2.67									
26.5–26.9	–	–	–									
27.0–27.4	0.38	0.76	1.14									
27.5–27.9	–	–	–									
28.0–28.4	–	–	–									
28.5–28.9	–	0.38	0.38									
31.0–31.4	–	0.38	0.38									
Total No. of fish	241	21	262	1690	292	1982	232	110	342	56	–	56

TABLE 22: Percentage age composition of smelt from Newfoundland. Numbers of fish in brackets.

Locality	Sex	Age-groups 2	3	4	5	6	7	Total
Norris Arm	Male	-	1.9(5)	74.5(196)	11.8(31)	3.4(9)	-	91.6(241)
	Female	-	-	5.3(14)	1.1(3)	1.1(3)	0.4(1)	8.4(21)
Port au Port	Male	30.6(607)	31.6(622)	22.4(444)	0.8(15)	0.1(2)	-	85.4(1690)
	Female	5.9(116)	5.8(115)	3.0(60)	0.1(1)	-	-	14.6(292)
Piccadilly	Male	6.4(22)	9.9(34)	50.9(174)	0.6(2)	-	-	67.8(232)
	Female	2.9(10)	4.1(14)	24.0(82)	1.2(4)	-	-	32.2(110)
Fox Island River	Male	28.6(16)	41.0(23)	28.6(16)	1.8(1)	-	-	100(56)
	Female	-	-	-	-	-	-	0

TABLE 23: Average Back-calculated lengths at age for Norris Arm smelt. Numbers of fish are shown in brackets.

Year Class	Sex	Back-calculated average lengths at Age in cm. L_1	L_2	L_3	L_4	L_5	L_6	L_7
1968	Male	13.66(5)	17.43(5)	19.60(5)				
	Female	-	-	-				
1967	Male	13.05(192)	16.99(192)	19.24(192)	20.64(192)			
	Female	11.78(14)	17.05(14)	20.42(14)	22.34(14)			
1966	Male	12.06(32)	17.37(32)	21.36(32)	23.14(32)	24.25(32)		
	Female	11.69(2)	17.32(2)	21.86(2)	24.41(2)	26.95(2)		
1965	Male	12.08(10)	17.31(10)	21.12(10)	22.63(10)	23.56(10)	24.37(10)	
	Female	10.01(2)	17.02(2)	20.62(2)	23.46(2)	25.35(2)	26.3(2)	
	Male	-	-	-	-	-	-	-
	Female	12.41(1)	18.41(1)	20.52(1)	25.11(1)	27.57(1)	29.34(1)	31.1
Means	Male	12.71	17.27	20.33	22.13	23.91	24.37	
	Female	11.47	17.45	20.86	23.83	26.63	27.82	31.1
EMPIRICAL	Male	-	-	19.6(5)	20.67(192)	24.25(32)	24.37(10)	-
MEANS	Female	-	-	-	22.34(14)	26.95(2)	26.3(2)	31.1 (1)

TABLE 24: Average back-calculated lengths at age for early spawning Port au Port smelt. Numbers of fish are shown in brackets.

Year-Class	Sex	Back-calculated average lengths at age in cm.					
		L_1	L_2	L_3	L_4	L_5	L_6
1969	Male	8.58(55)	15.44(55)				
	Female	8.20(27)	15.49(27)				
1968	Male	7.97(31)	14.54(31)	18.4(31)			
	Female	7.65(18)	14.75(18)	19.11(18)			
1967	Male	8.94(53)	15.42(53)	18.71(53)	20.06(53)		
	Female	8.46(25)	15.37(25)	19.13(25)	21.08(25)		
1966	Male	8.22(1)	15.62(1)	18.95(1)	19.69(1)	20.80(1)	
	Female	-	-	-	-	-	
1965	Male	7.29(1)	14.22(1)	18.03(1)	19.42(1)	20.12(1)	21.50(1)
	Female	-	-	-	-	-	-
Means	Male	8.20(141)	15.05(141)	18.52(86)	19.72(55)	20.46(2)	21.50(1)
	Female	8.10(70)	15.20(70)	19.12(43)	21.08(25)		
EMPIRICAL means	Male	-	15.44(55)	18.4(31)	20.06(53)	20.80(1)	21.50(1)
	Female	-	15.49(27)	19.11(18)	21.08(25)	-	-

TABLE 25: Average back-calculated lengths at age for mid-season spawning Port au Port smelt. Numbers of fish are shown in brackets.

Back-calculated average lengths at age in cm.

Year-Class	Sex	L_1	L_2	L_3	L_4	L_5	L_6
1969	Male	8.15(54)	15.16(54)				
	Female	7.74(19)	15.36(19)				
1968	Male	7.93(47)	14.34(47)	18.30(47)			
	Female	7.25(20)	14.67(20)	19.26(20)			
1967	Male	8.59(33)	15.21(33)	18.34(33)	19.90(33)		
	Female	8.50(5)	14.94(5)	18.41(5)	21.04(5)		
1966	Male	7.07(1)	13.32(1)	18.34(1)	19.57(1)	20.40(1)	
	Female	-	-	-	-	-	
Means	Male	7.94(135)	14.51(135)	18.32(81)	19.73(34)	20.40(1)	
	Female	7.83(44)	14.99(44)	18.83(25)	21.04(5)	-	
IMPIRICAL means	Male	-	15.16(54)	18.30(47)	19.90(33)	20.40(1)	
	Female	-	15.36(19)	19.26(20)	21.04(5)	-	

TABLE 26: Average back-calculated lengths at age for late-spawning Port au Port smelt. Numbers of fish are shown in brackets.

		Back-calculated average length at age in cm.					
Year-Class	Sex	L_1	L_2	L_3	L_4	L_5	L_6
1969	Male	7.85(56)	14.80(56)				
	Female	7.15(48)	14.75(48)				
1968	Male	7.68(48)	14.15(48)	18.26(48)			
	Female	6.84(42)	14.04(42)	18.85(42)			
1967	Male	8.16(26)	14.59(26)	18.14(26)	19.78(26		
	Female	7.22(12)	14.74(12)	18.58(12)	20.65(12)		
1966	Male	7.25(4)	14.40(4)	18.57(4)	19.66(4)	20.85(4)	
	Female	6.02(1)	13.91(1)	19.17(1)	20.92(1)	21.80(1)	
1965	Male	7.11(1)	12.79(1)	17.05(1)	18.47(1)	19.53(1)	20.60(1)
	Female	-	-	-	-	-	-
Means	Male	7.61(135)	14.15(135)	18.00(79)	19.30(31)	20.19(5)	20.60(1)
	Female	6.81(103)	14.36(103)	18.87(55)	20.79(13)	21.80(1)	-
EMPIRICAL	Male	-	14.79(56)	18.26(48)	19.78(26)	20.85(4)	20.6(1)
Means	Female	-	14.75(48)	18.85(42)	20.65(12)	21.80(1)	-

TABLE 27A: Summary of average back-calculated length at age one (L_1) in cm for Port au Port smelt.

Year-Class	Age	Males Early	Males Mid	Males Late	Females Early	Females Mid	Females Late
1969	2	8.58	8.15	7.85	8.20	7.74	7.15
1968	3	7.97	7.93	7.68	7.65	7.25	6.84
1967	4	8.94	8.59	8.16	8.46	8.50	7.22
1966	5	8.22	7.07	7.25	-	-	6.02
1965	6	7.29	-	7.11	-	-	-

TABLE 27B: Summary of empirical average length at age (in cm) of Port au Port smelt.

M = Male F = Female

Year-class and Age-group

Spawning Season	1969		1968		1967		1966		1965		
	2								6		
				F	M		M				
Early	15.55	15.49	8.40	19.11	0.06	21.08	20.80	-	21.50	-	
Mid-	15.16	15.36	18.30	19.26	19.90	21.04	20.40	-	-	-	
Late	14.79	4.75	18.26	18.85	19.78	20.65	20.85	21.80	20.60	-	
Average	15.13	5.20	8.32	19.07	9.91	20.92	20.68	21.80	21.05	-	

TABLE 28: Average back-calcuated lengths at age for early spawning Piccadilly smelt. Numbers of fish are shown in brackets

Back-calculated average length at age in cm.

Year-Class	Sex	L_1	L_2	L_3	L_4	L_5	L_6
1969	Male	8.86(17)	15.61(17)				
	Female	10.24(6)	16.30(6)				
1968	Male	8.39(10)	15.15(10)	18.95(10			
	Female	10.32(8)	16.23(8)	19.90(8)			
1967	Male	9.15(60)	15.61(60)	18.72(60)	20.21(60)		
	Female	10.86(64)	16.81(64)	19.95(64)	21.66(64)		
1966	Male	7.78(2)	15.74(2)	19.10(2)	20.77(2)	22.45(2)	
	Female	10.66(2)	16.66(2)	20.48(2)	21.98(2)	22.66(2)	
Means	Male	8.54(89)	15.53(89)	18.92(72)	20.49(62)	22.45(2)	
	Female	10.52(80)	16.50(80)	20.11(74)	21.82(66)	22.66(2)	
Empirical Means	Male	-	15.61(17)	18.95(10)	20.31(60)	22.45(2)	
	Female	-	16.3(6)	19.9(8)	21.66(64)	22.66(2)	

TABLE 29: Average back-calculated lengths at age for late spawning Piccadilly smelt. Numbers of fish are shown in brackets.

Year-Class	Sex	Back-calculated average length at age in cm L_1	L_2	L_3	L_4	L_5	L_6
1969	Male	8.95(4)	15.12(4)				
	Female	7.19(2)	14.75(2)				
1968	Male	8.71(8)	14.47(8)	17.85(8)			
	Female	6.66(3)	14.05(3)	19.37(3)			
1967	Male	9.20(15)	15.21(15)	18.33(15)	19.45(15)		
	Female	7.91(7)	14.93(7)	18.83(7)	20.71(7)		
1966	Male	-	-	-	-		
	Female	6.65(2)	14.49(2)	19.88(2)	21.35(2)	23.80(2)	
Means	Male	8.95(27)	14.93(27)	18.09(23)	19.45(15)		
	Female	7.10(14)	14.55(14)	19.36(12)	21.03(9)	23.80(2)	
Empirical Means	Male	-	15.13(4)	17.85(8)	19.45(15)	-	
	Female	-	14.75(2)	19.37(3)	20.71(7)	23.80(2)	

TABLE 30A: Summary of average back-calculated length at age one (L_1) for Piccadilly smelt. Length in cm.

		Males		Females	
Year class	Age	Early	Late	Early	Late
1969	2	8.86	8.95	10.24	7.19
1968	3	8.39	8.71	10.32	6.66
1967	4	9.15	9.20	10.86	7.91
1966	5	7.78	-	10.66	6.65

TABLE 30B: Summary of empirical average length at age (in cm) of Piccadilly smelt.

M = Male F = Female

Year-class and Age-group

	1969		1968		1967		1966		1965	
	2		3				5		6	
Spawning Season	M	F	M	F	M	F	M	F		F
Early	15.61	16.30	18.95	19.90	20.31	21.66	22.45	22.66	-	-
Late	15.13	14.75	17.85	19.37	19.45	20.71	-	23.80	-	-
Average	15.37	15.53	18.40	19.64	19.88	21.19	22.45	23.23	-	-

TABLE 31: Average back-calculated lengths at age for Fox Island River smelt. Numbers of fish are shown in brackets.

Year class	Sex	Back-calculated average lengths at age (in cm) L_1	L_2	L_3	L_4	L_5	L_6
1969	Male	10.75(6)	15.78(6)				
	Female	-	-				
1968	Male	10.60(12)	15.78(12)	18.81(12)			
	Female	-	-	-			
1967	Male	11.23(8)	16.66(8)	19.44(8)	20.52(8)		
	Female	-	-	-	-		
1966	Male	10.76(1)	16.06(1)	19.38(1)	20.04(1)	20.70(1)	
	Female	-	-	-	-	-	
Means	Male	10.83(27)	16.07(27)	19.21(21)	20.28(9)	20.70(1)	
	Female	-	-	-	-	-	
Empirical	Male	-	15.78(6)	18.81(12)	20.53(8)	20.70(1)	
	Female	-	-	-	-	-	

TABLE 32: Comparison of smelt growth in Newfoundland and Michigan (USA) from back-calculated data.

A. Males

Area & source	Average length at age in cm					
	L_1	L_2	L_3	L_4	L_5	L_6
Norris Arm	12.71	17.27	20.33	22.13	23.91	24.37
Port au Port	7.91	14.57	18.28	19.58	20.23	21.05
Piccadilly	8.74	15.50	18.65	19.86	20.70	
Fox Island River	10.83	16.07	19.21	20.28	20.70	
Gull Lake Michigan (Burbidge) 1969	14.86	16.25	17.48	18.80	18.00	

B. Females

Area & source	L_1	L_2	L_3	L_4	L_5	L_6	L_7
Norris Arm	11.47	17.45	20.86	23.83	26.63	27.82	31.10
Port au Port	7.58	14.85	18.94	20.97	21.80	-	-
Piccadilly	8.81	15.52	19.73	21.42	23.23	-	-
Fox Island River	-	-	-	-	-	-	-
Gull Lake Michigan (Burbidge 1969)	15.06	16.39	19.27	20.16	19.30	-	-

TABLE 33: Summary of empirical lengths-at-age of Newfoundland smelt.

Area	Sex	Average lengths at age (cm)					
		2	3	4	5	6	7
Norris Arm	Male	-	19.60	20.67	24.25	24.37	-
	Female	-	-	22.34	26.95	26.30	31.10
Port au Port	Male	15.13	18.32	19.91	20.68	21.05	-
	Female	15.20	19.07	20.92	21.80	-	-
Piccadilly	Male	15.37	18.40	19.88	22.45	-	-
	Female	15.53	19.64	21.19	23.23	-	-
Fox Island River	Male	15.78	18.81	20.53	20.70	-	-
	Female	-	-	-	-	-	-

TABLE 34: Comparison of growth parameters for Newfoundland smelt.
L_∞, K and t_0 defined in section 3.4.2. Z = total mortality coefficient.
Tmax = maximum age (years) recorded in samples.

MALES

Locality	Mean L_∞ (cm)	95% Confidence limits of L_∞ (cm)	Mean K	95% Confidence limits of K	Z	Tmax	Mean t_0 (yr)	95% Confidence limits of t_0 (yr)	Mean L_∞ (cm
Norris Arm	26.1034	26.0439–26.1628	0.4152	0.4118–0.4186	1.5404	6	-0.6090	-0.6185 to -0.5995	31.5900
Port au Port (Early)	21.3554	21.2841–1.4268	0.6913	0.6839–0.6987		6	0.3972	0.3918 to 0.4027	23.5310
Port au Port (Mid)	22.0131	21.9158 to 22.1104	0.6416	0.6331 to 0.6500	1.8624	5	0.3050	0.2981 to 0.3120	23.7322
Port au Port (Late)	21.5263	21.4208 to 1.6318	0.6510	0.6413 to 0.6606		6	0.3326	0.3248 to 0.3404	23.7437
Piccadilly (Early)	22.0934	22.0429 to 2.1440	0.7236	0.7174 to 0.7299	4.4660	5	0.3240	0.3189 to 0.3292	24.2730
Piccadilly (Late)	21.0404	20.9712 to 21.1095	0.6911	0.6825 to 0.6997		4	0.1991	0.1909 to 0.2073	24.8764
Fox Island River	22.0289	21.8204 to 22.2373	0.6535	0.6287 to 0.6782	1.5677	5	-0.0323	-0.0622 to -0.0024	-

ity Coefficient.

FEMALES

Mean t_0(yr)	95% Confidence limits of t_0(yr)	Mean L∞ (cm)	95% Confidence limits of L∞ (cm)	Mean K	95% Confidence limits of K	Z	(yr)	Mean t_0(yr)	95% Confidence limits of t_0(yr)
0.6090	-0.6185 to -0.5995	31.5900	31.4016-31.9401	0.3421	0.3318-0.3490	0.7702	7	-0.2947	-0.3191 to -0.2910
0.3972	0.3918 to 0.4027	23.5310-	23.4986-23.5634	0.5195	0.6170 to 0.6221		4	0.3190	0.3160 to 0.3212
0.3050	0.2981 to 0.3120	23.7322	23.6488 to 23.8157	0.6162	0.6105 to 0.6218	2.3725	4	0.3737	0.3697 to 0.3776
0.3326	0.3248 to 0.3404	23.7437	23.6345 to 23.8530	0.5945	0.5876 to 0.6013		5	0.4113	0.4065 to 0.4161
0.3240	0.3189 to 0.3292	24.2730	24.2065 t 24.3395	0.5829	0.5770 to 0.5887	3.0204	5	0.0274	0.0197 to 0.0351
0.1991	0.1909 to 0.2073	24.8764	24.2840 to 25.4689	0.5556	0.5177 to 0.5935		5	0.3966	0.3601 to 0.4331
0.0323	-0.0622 to -0.0024	-	-	-	-	-	-	-	-

[redacted]

TABLE / 35: Length-weight equations of smelt

W = wt in gms. L = total length in cm.

	Norris Arm	Port au Port	Piccadilly	Fox Island River
Males	log W = 2.7742 logL-1.9438	log W = 3.2106 logL-2.5395	log W = 3.2796 logL-2.6239	log W = 3.2510 logL-2.5954
Correlation Coefficient (r)	0.9546	0.9846	0.9770	0.9852
Number of fish (N)	245	318	103	56
Females	log W = 2.7036 logL-1.8090	log W = 3.3081 logL-2.6637	log W = 3.1003 logL-2.3909	—
Correlation Coefficient (r)	0.9331	0.9728	0.9420	—
Number of fish (N)	19	67	61	—

Table 35A: Comparison of regressions of the logarithms of total lengths on the logarithm of weight by analysis of covariance for male and female smelt from Norris Arm, Port au Port and Piccadilly.

Test	Source of Variation	Errors of Estimate Degrees of freedom	Sum of Squares	Mean Square	F
Between sexes, Norris Arm	Within Samples	260	0.3256	12.52	
	Regression Coefficient	1	272.25	272.25	0.22n.s.
	Common Regression	261	0.3258	12.48	
	Adjusted Means	1	2.486	2.486	19.92*
	Total	262	0.3507		
Between sexes, (Smelt Brook) Port au Port	Within Samples	381	0.4002	10.51	
	Regression Coefficient	1	17.19	17.19	1.64n.s.
	Common Regression	382	0.4020	10.52	
	Adjusted Means	1	2092.4	2092.4	0.02n.s.
	Total	383	0.4020		
Between sexes, Piccadilly (Smelt Brook)	Within Samples	160	0.2307	14.42	
	Regression Coefficient	1	21.66	21.66	1.50n.s.
	Common Regression	161	0.2338	14.46	
	Adjusted means	1	7857.93	7857.93	0.05n.s.
	Total	162	0.2329		

n.s. = No significant difference at 1% or 5% level

* = Significant difference at 1% level

(Pearson & Hartley 1956)

TABLE 36: Percentage sex ratio of smelt on one spawning bed in smelt brook, Port au Port, at different times of the night during different quarters of the spawning season (Numbers of fish shown in brackets).

Newfoundland Standard time	1st quarter		2nd quarter		3rd quarter		4th quarter		Seasonal Average	
	M	F	M	F	M	F	M	F	M	F
0700	-	-	-	-	-	-	-	-		
0800	-	-	85(33)	15(6)	-	-	83(55)	17(11)	84	16
0900	88(30)	12(4)	-	-	73(77)	27(29)	-	-	76	24
1000	-	-	65(26)	35(14)	-	-	-	-	65	35
1100	-	-	-	-	-	-	-	-	-	-
1200	90(51)	10(6)	-	-	-	-	-	-	90	10
1300	-	-	91(39)	9(4)	-	-	78(36)	22(10)	84	16
1400	-	-	-	-	76(99)	24(32)	-	-	76	24
1500	80(39)	20(10)	-	-	-	-	-	-	80	20
1600	-	-	78(31	22(9)	-	-	71(34)	24(14)	72	28
1700	-	-	-	-	-	-	-	-	-	-
1800	89(16)	11(2)	-	-	69(52)	31(23)	-	-	73	27
1900	-	-	78(31)	22(9)	64(55)	36(31)	74(58)	26(18)	71	29
2000	60(60)	40(40)	-	-	80(92)	20(23)	83(38)	17(8)	73	27
2100	-	-	90(27)	10(3)	78(64)	22(18)	-	-	81	19
2200	-	-	84(59)	16(11)	70(76)	30(33)	-	-	75	25

TABLE 36 (continued)

Newfoundland Standard	I st quarter M	F	2nd quarter M	F	3rd quarter M	F	4th er M	F	Seasonal Ave e M	F
2300	-	-	-	-	77(68)	23(20)	90(51)	10(5)	83	17
2400	89(25)	11(3)	89(56)	11(7)	66(42)	34(22)	75(54)	25(18)	78	22
0100	89(31)	11(4)	-	-	66(48)	34(25)	83(58)	17(12)	77	23
0200	-	-	98(53)	2(1)	78(91)	22(26)	86(75)	14(12)	85	15
0300	-	-	-	-	64(63)	36(35)	-	-	64	36
0400	84(47)	16(9)	-	-	79(73)	21(19)	-	-	81	19
0500	-	-	94(66)	6(4)	73(72)	27(27)	85(46)	15(8)	83	17
0600	81(48)	19(11)	81(58)	19(14)	78(78)	22(22)	86(54)	14(9)	81	19
Seasonal Average	85(347)	15(89)	85(479)	15(82)	74(1086)	26(385)	82(559)	18(125)	78	22

M = Male   F = Female

TABLE 37: Percentage comparison of sex ratios of the year-classes during the 1971 spawning run at Smelt Brook, Port au Port (Numbers of fish in brackets).

M = Male F = Female

Year-class	Age	Early spawning season		Mid - Season		Late - Season		T O T A L		% Age Comp.
		M	F	M	F	M	F	M	F	M + F
1969	2	81(112)	19(27)	88(301)	12(40)	80(194)	20(49)	84(607)	16(116)	37(723)
1968	3	83(85)	17(18)	85(280)	15(50)	85(257)	15(47)	84(622)	16(115)	37(737)
1967	4	86(151)	14(25)	54(119)	46(22)	88(94)	12(13)	88(444)	12(60)	25(504)
1966	5	100(1)	0(0)	100(5)	0(0)	90(9)	10(1)	94(15)	6(1)	0.8(16)
1965	6	100(1)	0(0)	-	-	100(1)	0(0)	100(2)	0(0)	0.1(2)
Seasonal Average		83(350)	17(70)	88(785)	12(112)	83(555)	17(110)	85(1690)	15(292)	99.9(1982)

TABLE 38: Percentage comparison of sex ratios of the year-classes during the 1971 spawning run at smelt brook, Piccadilly. (Numbers of fish in brackets)

M = Male F = Female

Year class	Age	Early Spawning		Late Spawning		T O T A L		% Age Comp.
		M	F	M	F	M	F	M + F
1969	2	69(18)	31(8)	67(4)	33(2)	69(22)	31(10	9(32)
1968	3	70(26)	30(11)	73(8)	27(3)	71(34)	29(14)	4(48)
1967	4	68(156)	32(75)	72(18)	28(7)	68(174)	32(82)	5(256)
1966	5	50(2)	50(2)	0(0)	100(2)	33(2)	67(4)	2(6)
Seasonal Average		68(202)	32(96)	68(30)	32(14)	68(232)	32(110)	

TABLE 39: Percentage comparison of sex ratios of the year-classes during the 1971 spawning run - Bottom Brook Norris Arm (Numbers of fish in brackets).

M = Male F = Female

Year-class	Age	M	F	% Age composition M + F
1968	3	100(5)	0(0)	2(5)
1967	4	93(196)	7(14)	80(210)
1966	5	91(31)	9(3)	13(34)
1965	6	75(9)	25(3)	5(12)
1964	7	0(0)	100(1)	1(1)
Average		92(241)	8(21)	100(262)

TABLE 40: Average back-calculated length-at-age for all Port au Port smelt. Numbers of fish in brackets.

Year-class	Sex	1	2	3	4	5	6
		Back-calculated average length at age (cm)					
1969	Male	8.19(165)	15.13(165)				
	Female	7.69(94)	15.20(94)				
1968	Male	7.86(126)	14.34(126)	18.32(126)			
	Female	7.25(80)	14.29(80)	19.07(80)			
1967	Male	8.56(112)	15.07(112)	18.40(112)	19.91(112)		
	Female	8.06(42)	15.01(42)	18.71(42)	20.92(42)		
1966	Male	7.51(6)	14.45(6)	18.62(6)	19.64(6)	20.68(6)	
	Female	6.02(1)	13.91(1)	19.17(1)	20.92(1)	21.80(1)	
1965	Male	7.20(2)	13.51(2)	17.54(2)	18.95(2)	19.83(2)	21.05(2)
	Female	-	-	-	-	-	-

TABLE 41: Average back-calculated length-at-age for all Piccadilly smelt. Numbers of fish in brackets.

Back-calculated length at age (cm)

Year-class	Sex	L_1	L_2	L_3	L_4	L_5	L_6
1969	Male	8.91(21)	15.37(21)				
	Female	8.72(8)	15.53(8)				
1968	Male	8.55(18)	14.81(18)	18.40(18)			
	Female	8.49(11)	15.14(11)	19.64(11)			
1967	Male	9.18(75)	15.41(75)	18.53(75)	19.83(75)		
	Female	9.39(71)	15.87(71)	19.39(71)	21.19(71)		
1966	Male	7.78(2)	15.74(2)	19.10(2)	20.77(2)	22.45(2)	
	Female	8.66(4)	15.58(4)	20.18(4)	21.67(4)	23.23(4)	
Mean	Male	8.61(116)	15.33(116)	18.68(95)	20.30(77)	22.45(2)	
	Female	8.82(116)	15.53(94)	19.74(86)	21.43(75)	23.23(4)	