THE BIOLOGY OF THE COD Gadus morhua (L.)) OF THE NORTHEAST COAST OF NEWFOUNDLAND

RICHARD WELLS

ABSTRACT

The biology of the cod of the northeast coast of Newfoundland is analyzed from observations made in various years in the period 1940-65 but mostly in the 1960's. Age and length distributions indicate that numbers of older and larger fish have declined over this period. Year-class dominance, not present at the beginning of the period, is now evident. The growth rate and total mortality rates have increased. The changes listed above have been attributed primarily to an increase in fishing effort. Age at sexual maturity is lower for males than for females but the range of ages over which sexual maturity takes place is the same. There are indications that the stock is made up of more or less distinct inshore and offshore substocks.

THE BIOLOGY OF THE COD (Gadus morhua (L.)) OF THE NORTHEAST COAST OF NEWFOUNDLAND

by

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CONTENTS

I. INTRODUCTION

There is a continuing need for biological information about fish stocks. In areas where stocks undergo fishing pressure, data such as growth rates, mortality rates and age and length compositions are necessary for an understanding of changes in the fishery and the formulation of appropriate regulations. Hodder (1964) used such information in his assessment of the fisheries of the Northwest Atlantic.

In the present study results of cod investigations conducted off the northeast coast of Newfoundland from 1940 to 1965, but mainly in the 1960's, are analyzed. The area under consideration is Division 3K, (Fig. 1) one of the areas delineated by the International Commission for the Northwest Atlantic Fisheries (ICNAF).

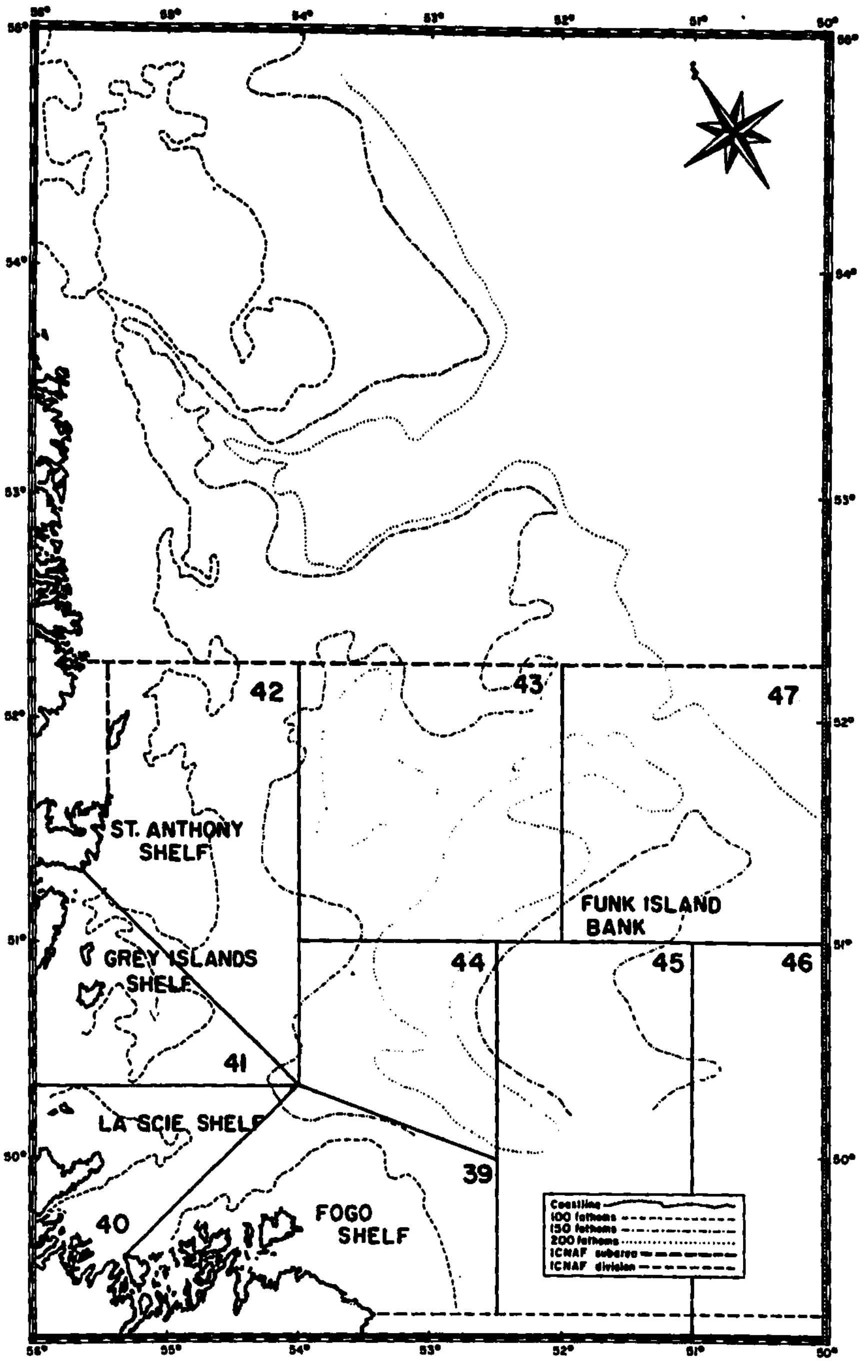

Fig. I. Area map showing ICNAF Division 3K and Subdivisions 39-47.

II. THE FISHERY

The cod fishery off the northeast coast of Newfoundland had been prosecuted by European fishermen as early as the first part of the sixteenth century (Innis, 1954). Detailed statistics of catches and fishing effort expended are not available prior to 1954 but since that time appear in the yearly Statistical Bulletins of ICNAF. It is likely that the fishery in the early 1950's was primarily "inshore", that is, carried on by shore-based Newfoundland fishermen using small open boats usually within 1-2 miles of the land. In the period 1954-57, landings by offshore vessels using otter trawls accounted for about 20-25% of the total catch (Fig. 2). Since 1957, 55-75% of the total catch has been taken offshore. During 1954-65, about 9% of the cod landings of the northwest Atlantic were taken from this area. The inshore portion of the catch, taken exclusively by Newfoundland fishermen, has decreased both absolutely and in relation to the total cod catch in the ICNAF area by Newfoundland fishermen (Fig. 2 and 3).

Hodder (1965) discussed the trends in this fishery during the period 1954-62. The statistics for 1963-65 were added to his series and the data reworked in the same way. For the offshore fishery, the Portuguese otter-trawl hour was again selected as the standard unit of effort. Monthly Spanish otter-trawl effort data were plotted against corresponding data from the Portuguese fleet (Fig. 4). A line passing through the origin was fitted to these data and a slope of 0.924 was derived. Spanish effort data were then multiplied by this factor. Spanish landings and converted effort were added to the Portuguese landings and effort by month. The average catch per standard (Portuguese) hour was calculated for each month and when the catch per standard hour was divided into the total landings for that month, the total monthly effort was obtained. Figure 5 shows that while the total effort and landings in the otter-trawl fishery have increased sharply since 1957, the catch per standard hour has remained fairly stable.

From statistics obtained from the Department of Fisheries (Canada) at St. John's, Newfoundland, it was apparent that the number

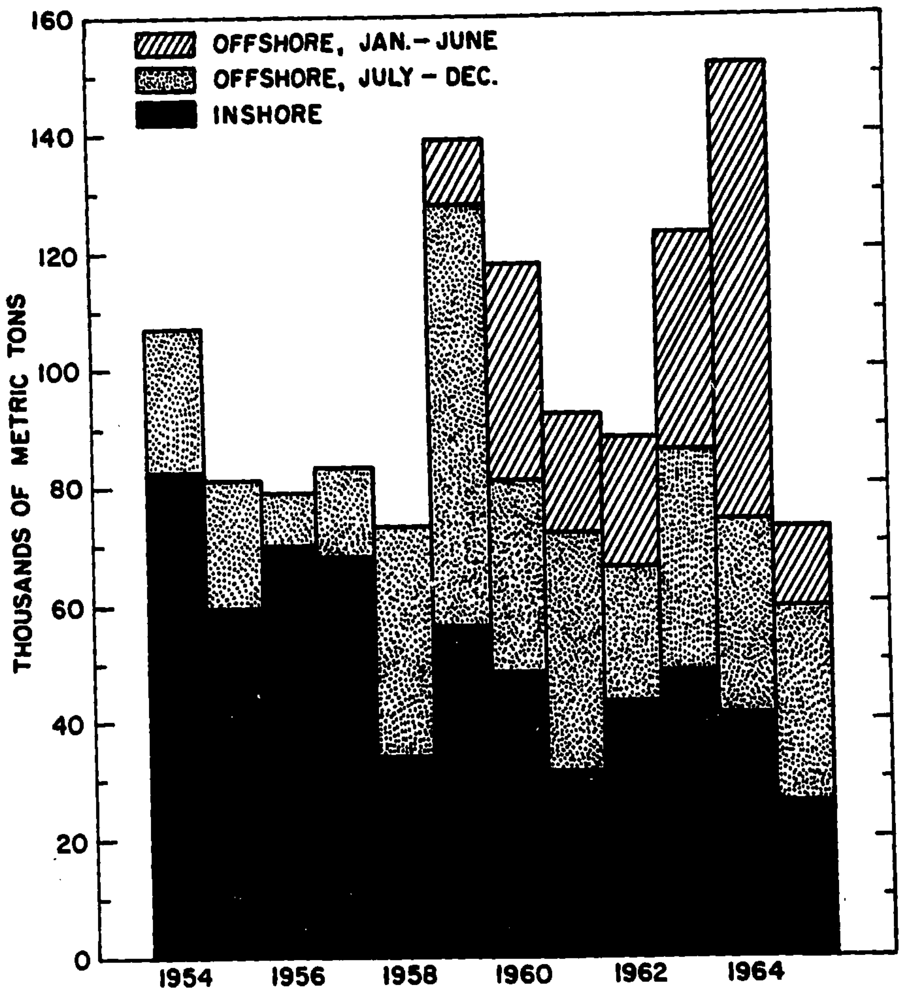

Fig. 2. Cod landings from inshore and offshore areas in Division 3K, 1954-65. Landings from offshore areas are shown in half-yearly portions.

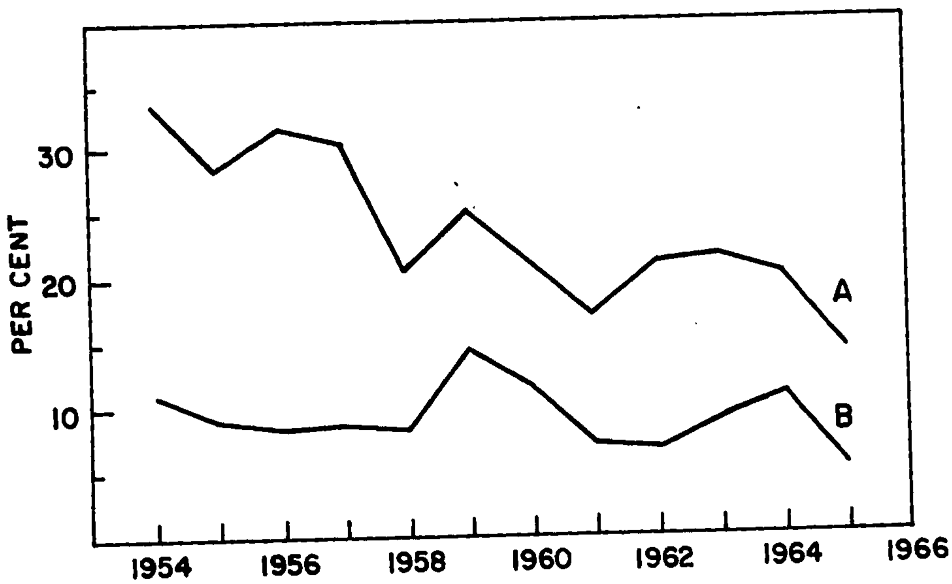

Fig. 3. Relative contribution, 1954-65, of (A) Division 3K cod landings by Newfoundland to total ICNAF area cod landings by Newfoundland and (B) Division 3K cod landings to total ICNAF area cod landings.

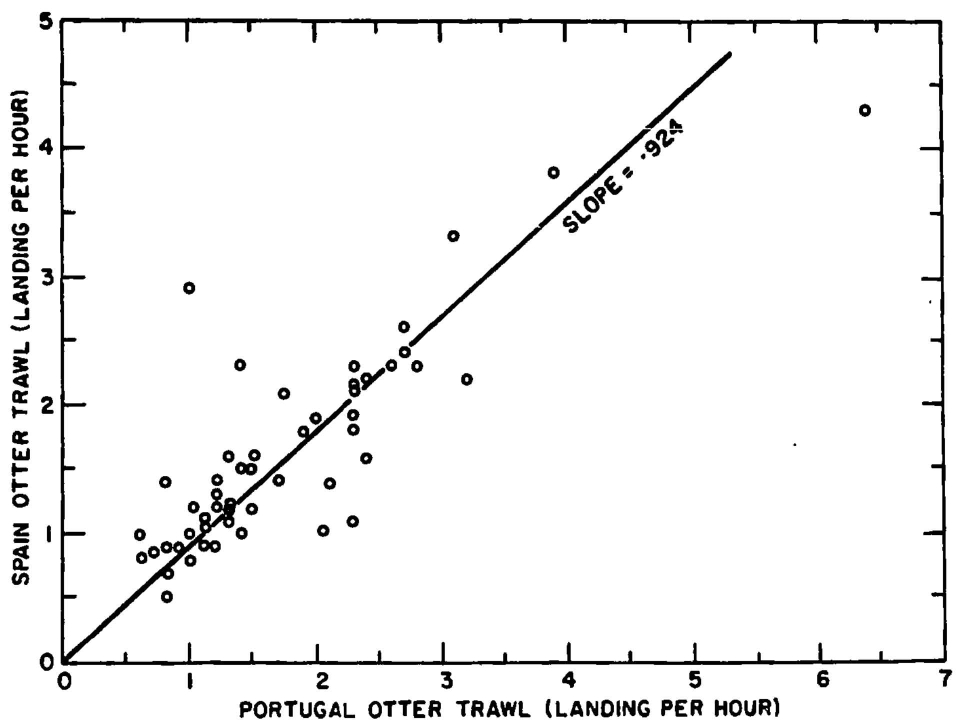

Fig. 4. Landings per otter-trawl hour (metric tons) fished by Spanish trawlers plotted against corresponding landings per hour for Portuguese otter trawlers for the period 1954-65.

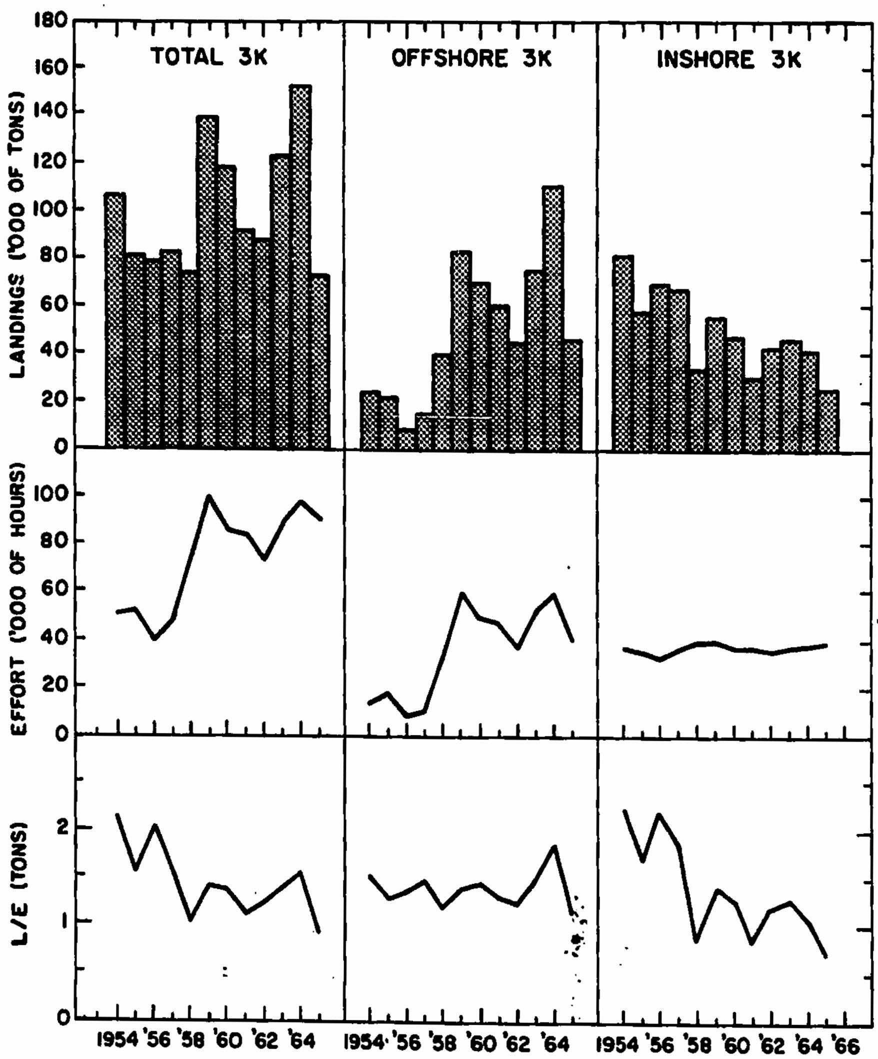

Fig. 5. Landings, effort, and landings per standard trawler hour of cod from Division 3K, 1954-65.

of men engaged in the inshore fishery each year in the area has been rather constant over the period 1954-65. The inshore effort data (number of fishermen) were converted to standard otter-trawl hours by multiplying by a factor of 8.96. This factor equals the slope of a line passing through the origin and fitting arbitrarily a plot of annual catch per man against annual catch per standard hour (Fig. 6). In Fig. 5 both the landings and catch per standard hour in the inshore fishery show a decline.

To obtain an overall view of the fishery, the effort, in standard hours, was combined for the otter-trawl and inshore fisheries by year and a yearly catch per standard hour calculated. For the fishery as a whole, landings have shown no appreciable trend (Fig. 5). Effort expended has gone up. The catch per standard hour has decreased from a level of about 1.8 tons per hour in the period 1954-57 and appears to have stablized at about 1.3 tons per standard hour since 1958.

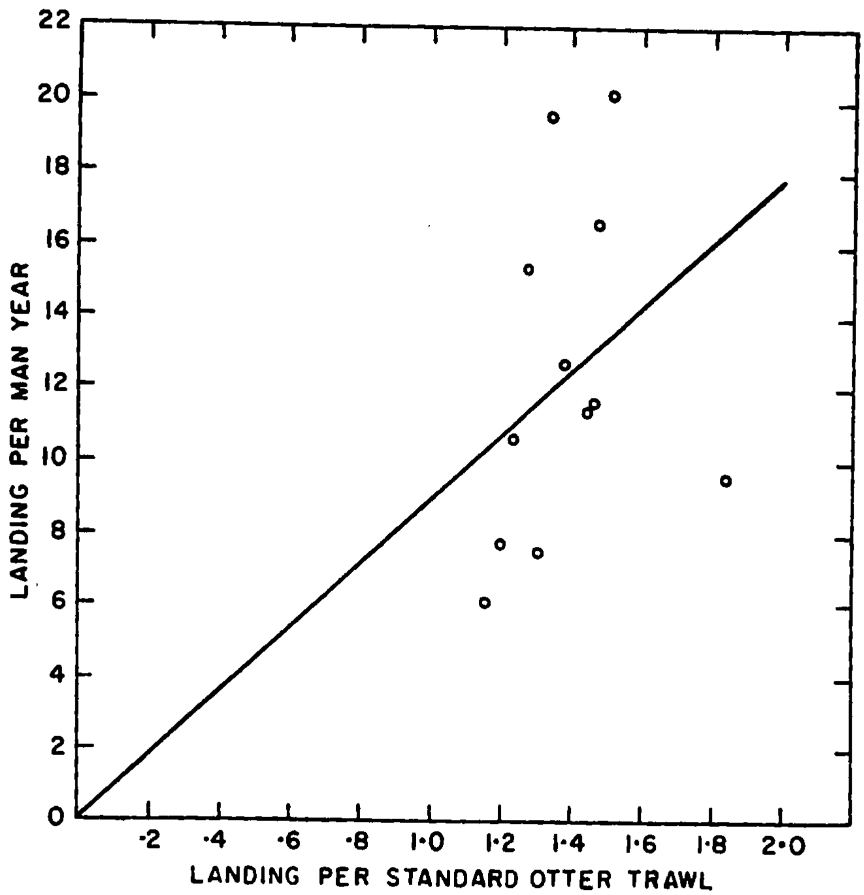

Fig. 6. Landings per man-year (metric tons) in inshore areas plotted against corresponding landings per standard hour in the offshore areas for the period I954-65 in Division 3K.

III. MATERIALS AND METHODS

A. DATA COLLECTIONS

The materials used formed part of data collected from the commercial inshore fishery and from research vessel otter-trawl surveys. Figure 1 shows the general locations from which the samples were taken and Tables 1 and 2 list the localities and dates of collection. For convenience in comparison Division 3K has been divided into 9 Subdivisions, 39-47. Inshore collections from various gears were obtained in Subdivisions 39,40,41 and 42 and offshore collections by otter trawl in all Subdivisions except 40.

Otter-trawl samples were collected from catches by the *Investigator II* and *A.T. Cameron*, research vessels operated by the Fisheries Research Board of Canada at St. John's. In most cases the codend of the trawl was either lined or covered with small-meshed netting to ensure the retention of small fish. The inshore samples were taken from the catches, before discarding, of commercial fishermen at various fishing communities in the area.

B. LENGTH MEASUREMENTS

Length measurements were taken at random from the catches. Fork length to the nearest cm was invariably obtained. In the inshore sampling an attempt was made to measure fish from the major gears operating at the time of sampling and to sample from as many different boats as possible. The length frequencies for each gear were then combined and a total obtained for each 3-cm-group. Each otter trawl frequency was adjusted to the catch of the tow from which it was selected. The adjusted frequencies were added in 3-cm groups to arrive at a total for the particular area concerned.

C. AGE DETERMINATIONS

Random subsamples were taken of the measured fish for scales and otoliths. The otter-trawl otolith samples usually contained a large random sample and a smaller "category" sample taken from fish of sizes not well represented in the random sample. Since 1962, the inshore otolith samples consisted of smaller random samples and larger "category" samples.

The otoliths of some 15,000 cod were examined to determine age following the method outlined by Keir (MS, 1960). Occasionally scale readings were used to confirm the age reading obtained from an otolith. In all cases, the age distributions were adjusted to the number measured by means of age-length keys.

D. GROWTH

The average length at age was determined from the otolith ages. Bertalanffy growth curves were fitted using an adaptation of Ricker's (1958) "trial L_∞" method. This growth curve is of the form

$$l_t = L_\infty\{1-e^{-k(t-t_o)}\}$$

where l_t is the length at age t years, L_∞ is the asymptotic length for the fish population, k is a constant determining rate of change in length increment and t_o , the theoretical age at zero length, is the point at which the extrapolated curve intersects the length axis.

The constants L_∞, k and t_o are calculated by fitting least squares straight lines to the following (Ricker, 1958):

(1) l_{t+1} against l_t

(2) $\ln(L_\infty - l_t)$ against t.

The slope and intercept obtained from (1) are e^{-k} and L_∞ $(1-e^{-k})$ respectively, from which values of L_∞ and k can be derived. The second equation has a slope of -k and intercept ($\ln L_\infty + k\ t_o$) from which a second estimate of k and a value of t are found. A worksheet for calculation these constants makes up Table 2.

Ricker suggests (p.196) that a plot of ln $(L_\infty - l_t)$ against t should be straight and that a few trial plots will soon show the L_∞ which gives the straightest line - which can usually be selected sufficiently well by eye. He further suggests that only points be used which fit this line. The plot of ln $(L_\infty - l_t)$ against t is therefore useful in determining the range of ages it is desirable to use.

Having decided on an L_∞ by this inspection method, the remaining parameters were calculated and the Bertalanffy curve constructed. Further curves were constructed using L_∞'s 3 cm above and/or below the first L_∞ chosen and the sum of squares of the deviations of the observed points from the fitted curves was calculated for each curve constructed. The process was continued until the curve having the least sum of squares was determined. This curve was judged to be the curve best fitting the data.

Average lengths at age based on less than 10 fish have been used sparingly in constructing the curves.

Length-weight curves were based on weighings to the nearest ounce of both round and gutted-head-on fish (gills in).

E. SEXUAL MATURITY

Maturity stages used were those developed by the Fisheries Research Board's Biological Station, St. John's. Males with testes very narrow and with a narrow thin-walled vas deferens were classed as immature. Males maturing to spawn in the year they were caught had thick and white testes. After spawning is completed residual milt may remain in the testes and vasa deferentia for a short time but at the edge of the testes the milt has disappeared and new grey or pink tissue appears.

Immature females had small, pinkish ovaries with thin-walled ovarian membranes. Females were considered mature when eggs were visible to the naked eye. After spawning, the ovaries had thick walls, were bluish-grey or whitish-grey in colour, and often had residual white or clear eggs.

Late in the spawning season and afterwards, both males and females may have gonads which appear to be developing for spawning in the next spawning season. When the observer cannot tell if such a fish has spawned in the year of observation, the gonad is classed simply as "maturing for spawning next year". Whether such a fish is mature or immature in the year of observation is doubtful.

IV. LENGTH AND AGE COMPOSITIONS

In Division 3K, the fishing gear which takes the largest part of the inshore catch is the trap. Pinhorn *et al* (1966) show that in 1964 about 50% of the inshore catch was taken by trap and that line gears and gillnets were also important.

Because of differences in selectivity, sizes and ages of fish caught may differ from gear to gear. A similar result would occur if the fish were to separate into size and age groups because of temperature, depth, food or other preferences. Almost all gillnet-caught fish are greater than 55 cm in length and 6 years in age, but fish of that size and age and below usually make up the bulk of the trap samples. Age compositions by 5-year groups are shown in Table 3.

A. TRAP

In 1949 the catch in Subdivision 39 was composed of a wide range of ages (Fig. 7 and Table 3) and about 1/4 of the catch were 11-15 years old at the time of capture. From 1963 on, only about 1% of the catch has been in this age group. A similar trend is noted in Subdivisions 40 and 42 (Fig. 8 and 9 and Table 3). Catches in the 1960's were composed of fish with a narrower range of ages than those caught in 1954. The single trap sample from Subdivision 41 (Fig. 10 and Table 3) consisted mainly of fish 5-8 years of age.

The 1965 age and length compositions from Subdivisions 41 and 42 appear to be fairly similar. The principal mode was at 49 cm and the 1960 year-class (5-year-olds) was dominant. In Subdivision 40, however, the 1959 year-class was dominant and the principal mode was at 58 cm. In Subdivision 39 the mode was at 43 cm and the 1960 and 1961 year-classes were of about the same size and constituted over 60% of the total catch.

B. GILLNET

In Subdivision 42, gillnet samples for 1964 and 1965 (Fig. 11 and Table 3) indicate that a large range of ages are represented in the catches. The 1955 year-class was predominant in each year. In Subdivision 39 the 1955 year-class was very strongly represented in the catches from 1962-65. As in the case of the trap, age and length compositions for

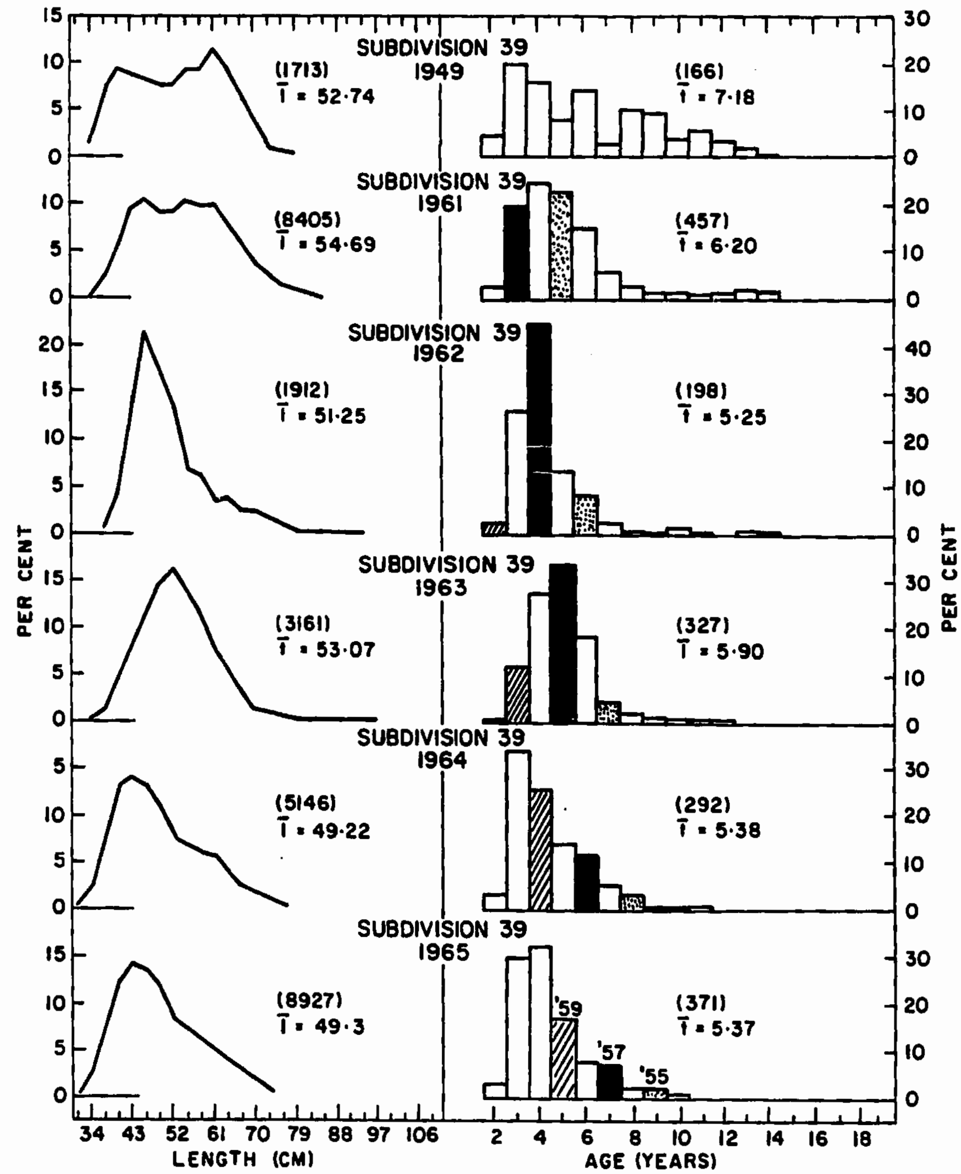

Fig. 7. Age and length distributions of cod caught by trap in Subdivision 39 during 1949-65. Numbers of fish are in brackets. $\bar{l}$ and $\bar{t}$ are the average lengths and ages respectively.

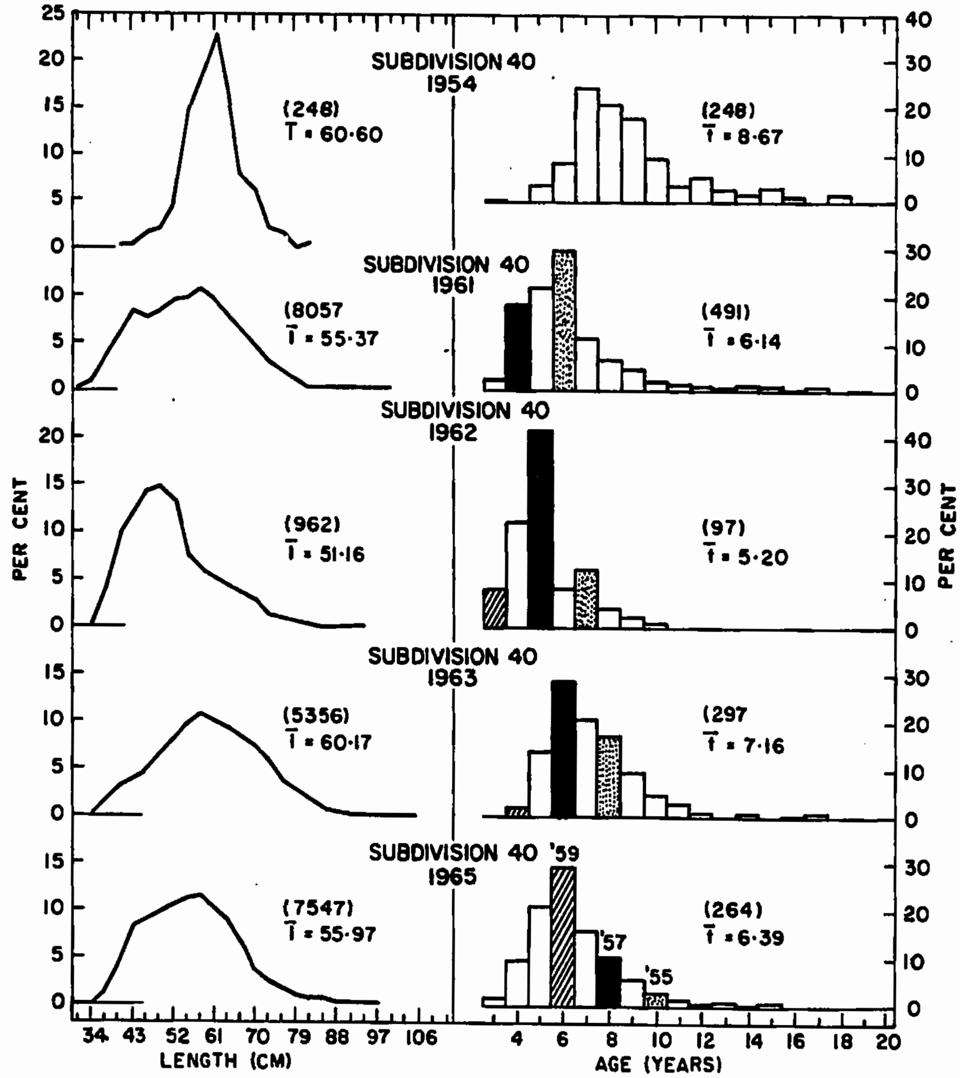

Fig. 8. Age and length distributions of cod caught by trap in Subdivision 40 during 1954-65. Numbers of fish are in brackets. $\bar{l}$ and $\bar{t}$ are the average lengths and ages respectively.

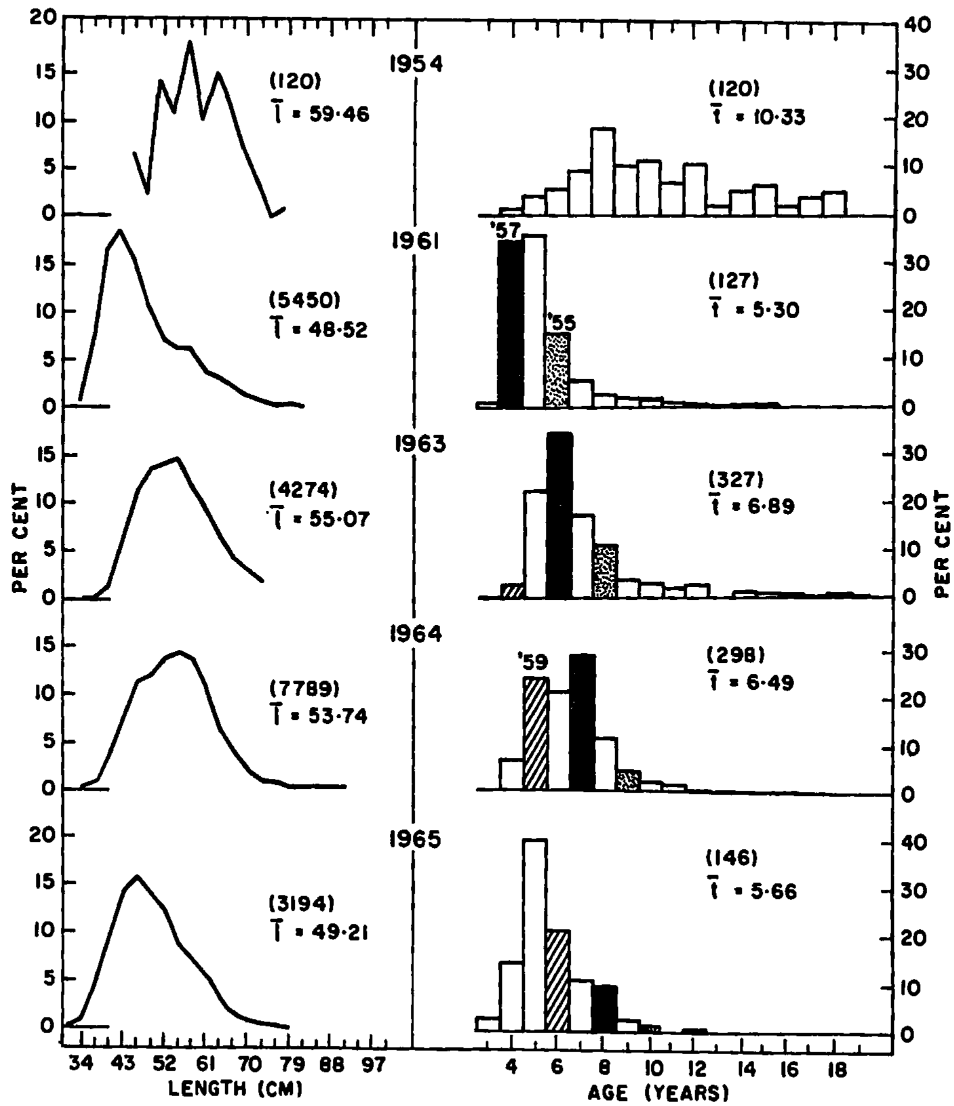

Fig. 9. Age and length distributions of cod caught by trap in Subdivision 42 during I954-65. Numbers of fish are in brackets. $\bar{l}$ and $\bar{t}$ are the average lengths and ages respectively.

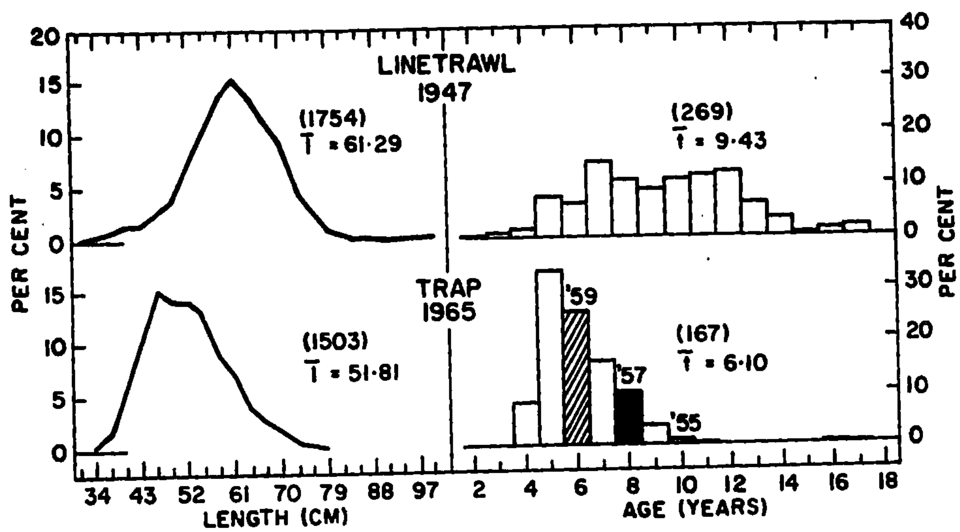

Fig. IO. Age and length distributions of cod caught in Subdivision 4I by linetrawl in 1947 and by trap in 1965. Numbers of fish are in brackets. $\bar{l}$ and $\bar{t}$ are the average lengths and ages respectively.

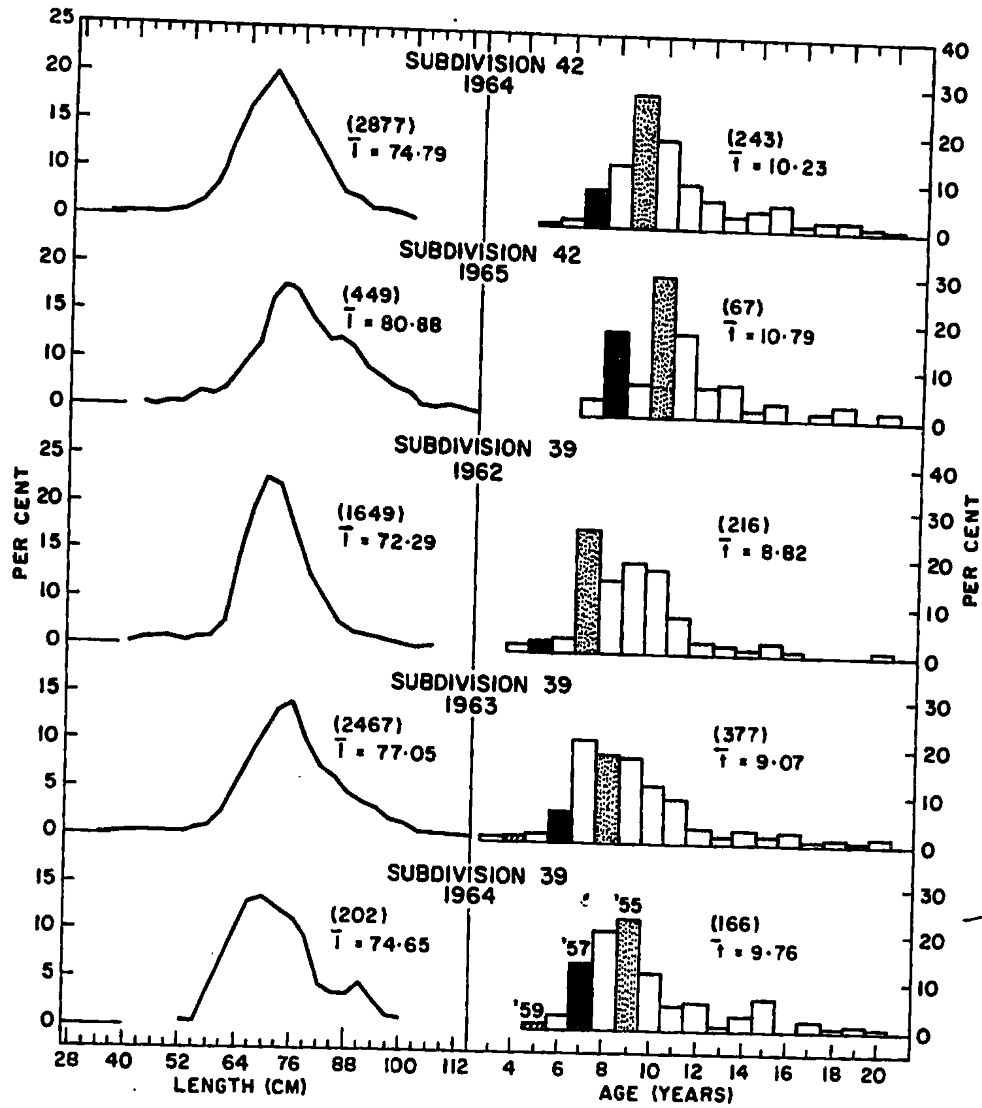

Fig. II. Age and length distributions of cod caught by gillnet in 1964-65 in Subdivision 42 and 1962-64 in Subdivision 39. Numbers of fish are in brackets. $\bar{l}$ and $\bar{t}$ are the average lengths and ages respectively.

these 2 Subdivisions are different.

C. LINE-GEARS

In the deep water longline fishery in Subdivision 39, a wide range of ages and lengths was taken (Fig. 12 and Table 3) from 1962-65. Older and larger fish were considerably reduced in the 1965 sample as compared to the 1962-64 samples. The shallow water longline (linetrawl) sample of Subdivision 39 was composed of smaller and younger fish than those from the deep water (Fig. 12 and Table 3). It was quite similar to the 1963 trap sample (Fig. 7) taken from the same Subdivision.

Only one line-gear sample was available from area 41 (Fig. 10 and Table 3). This sample, collected in 1947, was from depths of 50-80 fm and was composed of fish of a wide range of lengths and ages. In Subdivision 42, longline samples (Fig. 13) were generally similar to the samples taken from deep water in Subdivision 39 in containing many large and old fish.

D. HANDLINE

Samples from this gear were few. The catches were generally composed of young and small fish (Fig. 14 and Table 3).

E. JIGGER

Figure 15 and Table 3 suggested that jigger catches in 1940 contained relatively more older fish than those of the 1960's.

F. OTTER TRAWL

Because most of the samples from this gear came from otter trawls having a small-meshed liner or cover on the codend (Table 1), fish as young as age 1 were present. In 1950-51 no single year-class dominated the catch and fish of a wide range of ages were present (Fig. 16). In 1952, however, the 1947 year-class (5-year-olds) was dominant. The 1946 and 1945 year-classes were also strongly represented. There were still good proportions of older fish in the catch in 1960 and 1962 (Fig. 17 and Table 3), but by 1963 and 1964 the proportion of fish over 10 years of age was quite small.

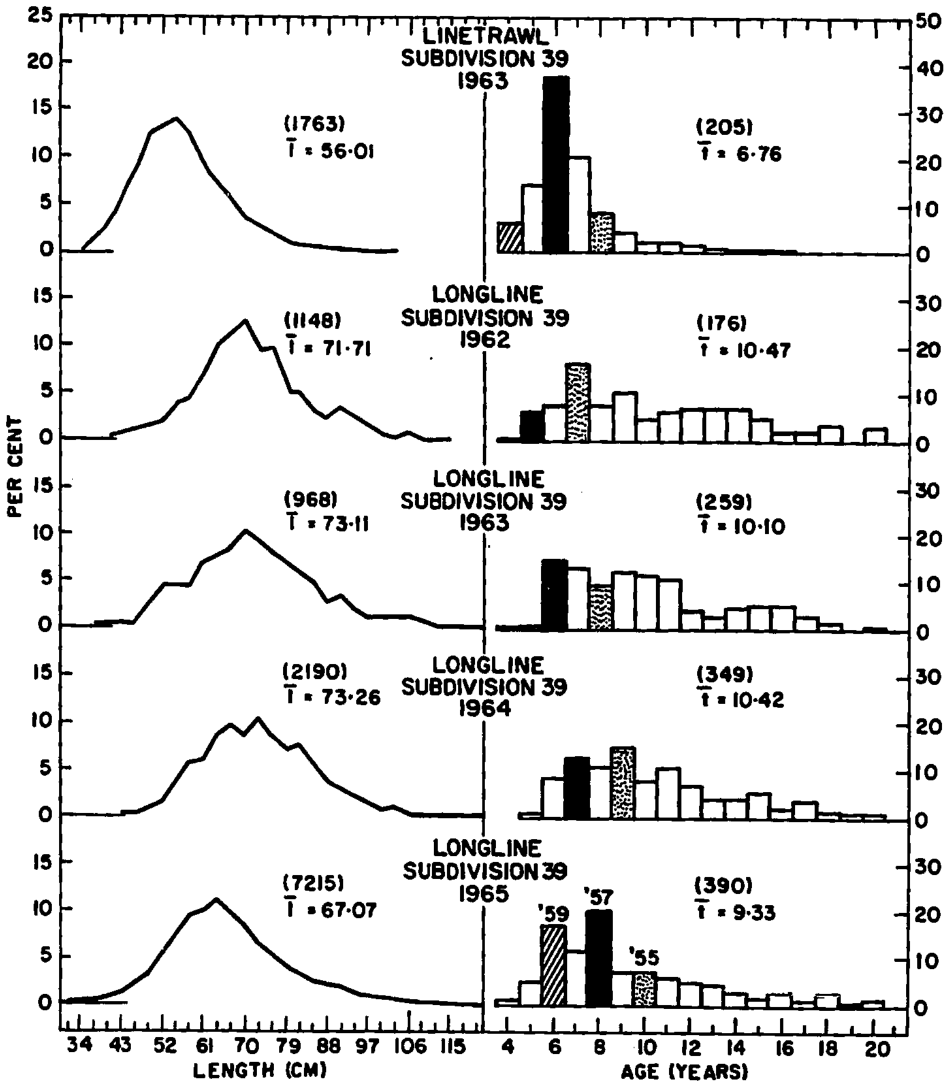

Fig. I2. Age and length distributions of cod caught by linetrawl in I963 and by longline in I962-65 in Subdivision 39. Numbers of fish are in brackets. $\bar{l}$ and $\bar{t}$ are the average lengths and ages respectively.

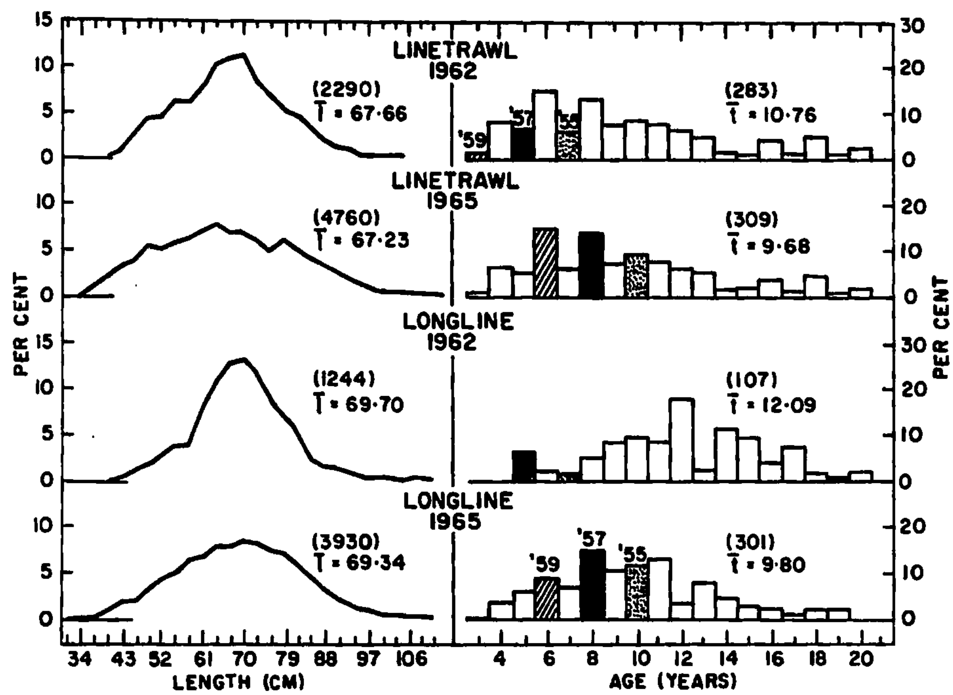

Fig. I3. Age and length distributions of cod caught by linetrawl and longline in I962 and I965 in Subdivision 42. Numbers of fish are in brackets. $\bar{l}$ and $\bar{t}$ are the average lengths and ages respectively.

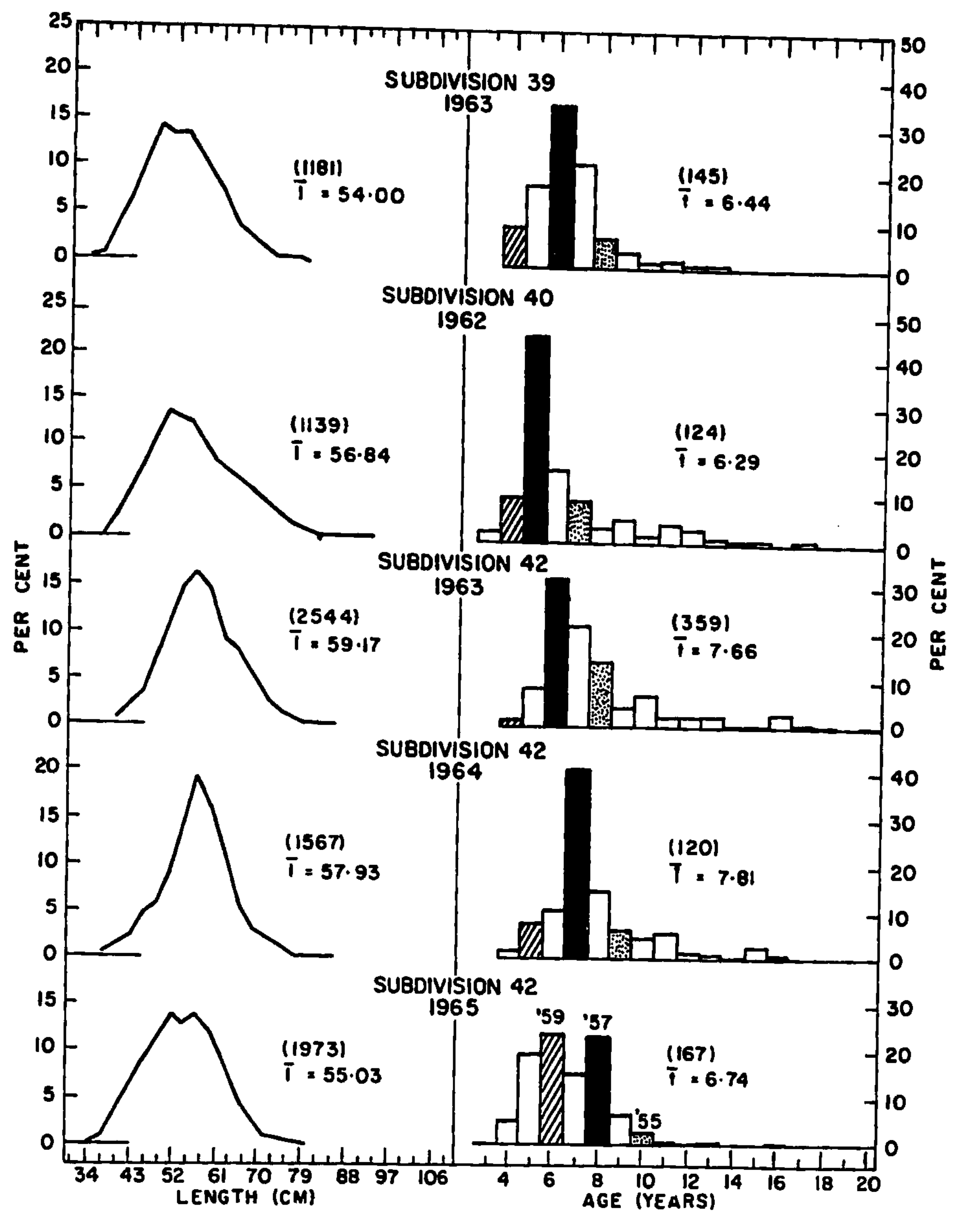

Fig. I4. Age and length distributions of cod caught by handline in I963 in Subdivision 39, in I962 in Subdivision 40, and in I963-65 in Subdivision 42. Numbers of fish are in brackets. $\bar{l}$ and $\bar{t}$ are the average lengths and ages respectively.

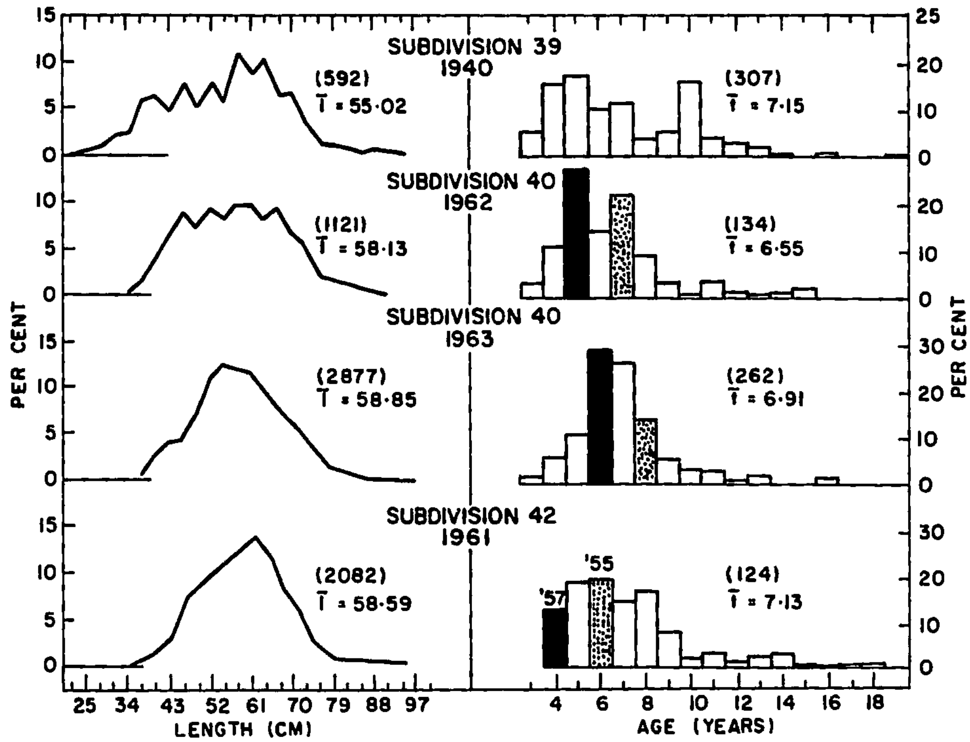

Fig. I5. Age and length distributions of cod caught by jigger in I940 in Subdivision 39, in I962-63 in Subdivision 40 and in I96I in Subdivision 42. Numbers of fish are in brackets. $\bar{l}$ and $\bar{t}$ are the average lengths and ages respectively.

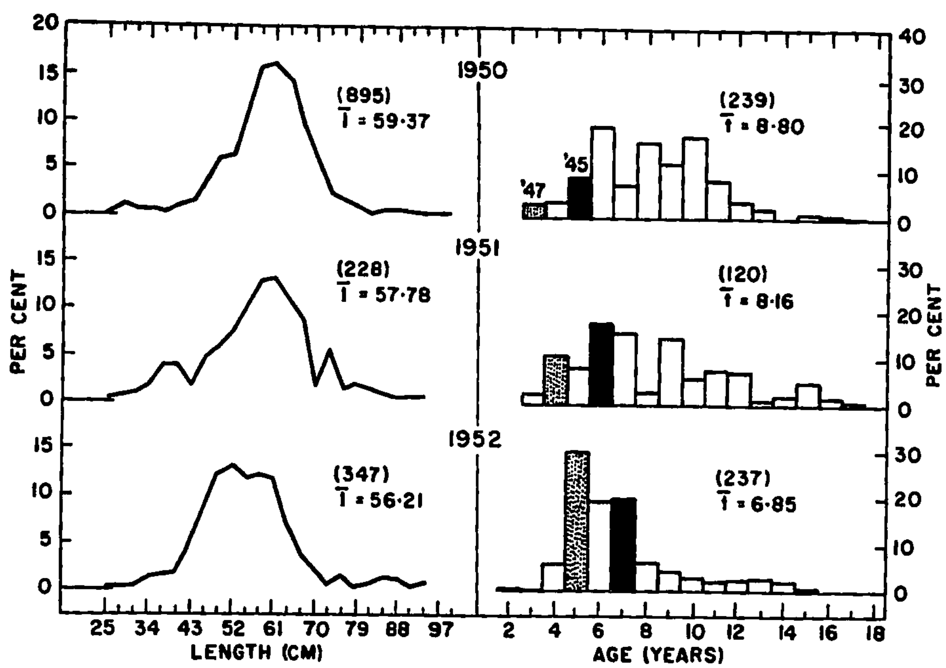

Fig. I6. Age and length distributions of cod caught by research otter trawl in I950-52 in Division 3K. Numbers of fish are in brackets. $\bar{l}$ and $\bar{t}$ are the average lengths and ages respectively.

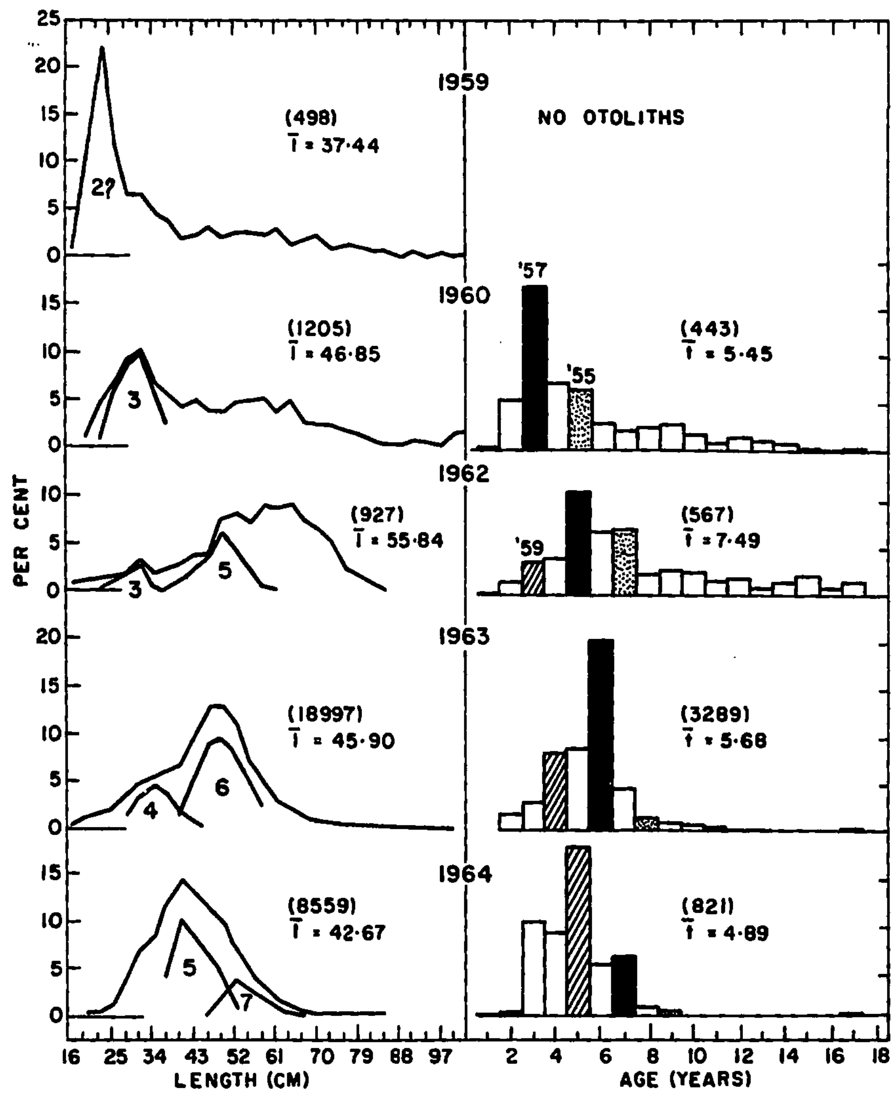

Fig. I7. Age and length distributions of cod caught by research otter trawl in I959-60 and I962-64 in Division 3K. Numbers of fish are in brackets. $\bar{l}$ and $\bar{t}$ are the average lengths and ages respectively. Length distributions of the I957 and I959 year-classes have been superimposed on the length distributions.

In 1963 samples were taken from all Subdivisions except 46. Age and length compositions (Fig. 18 and Table 3) showed that the 1957 year-class (6-year-olds) was by far the most abundant one except in Subdivision 42 where the 1959 year-class was apparently stronger. The seaward Subdivisions, 43, 45 and 47 contained fewer small and young fish than the more landward Subdivisions.

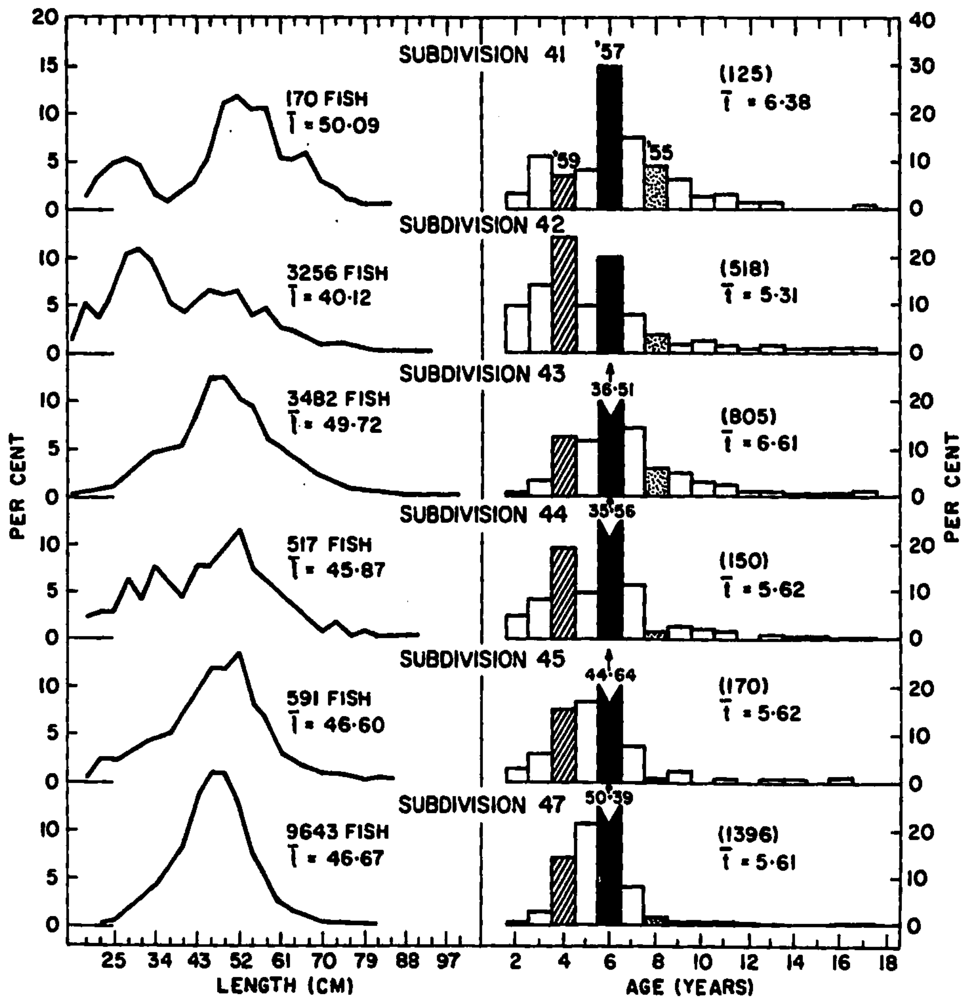

Fig. I8. Age and length distributions of cod caught by research otter trawl in I963 in various subdivisions. Numbers of fish are in brackets. $\bar{l}$ and $\bar{t}$ are the average lengths and ages respectively.

V. VALIDATION OF OTOLITH AGES

May (1965) has pointed out the need for validation of otolith ages for different localities. Such studies have been done in the Newfoundland area by May (1965 and 1967) Fleming (1960), Williamson (MS 1965) and Wiles (MS 1967).

Otoliths from Subdivision 3K very often exhibit secondary rings or "checks", particularly in the early years. Moreover, annual rings may be split or indistinct. Determination of the age from the otolith requires interpretation of the various zones and is therefore open to errors of judgement. If the age structure of the catch could be determined by a method other than by means of the otoliths, a useful check would be available. Parrish (1956) suggests that a modification of Petersen's method provides such a check against other ageing methods. It consists of tracing an abundant year-class which shows a peak in the length frequencies through the fishery from year to year. Petersen's method is appropriate where the distribution of lengths of a year-class is normally distributed, and with a mean length sufficiently different from the neighbouring year-classes such that it forms a distinct mode in the length frequency of the catch. Growth in Division 3K proceeds at a low rate (May et al 1964) and therefore only younger ages could be validated in this manner.

In Fig. 17, the distributions of the 1957 and 1959 year-classes have been shown on the length frequencies for the years in which they occur. The 1957 year-class, 3 years old in 1960, occupied practically all the mode at 31 cm. No sample was collected in 1961, but in 1962, this year-class, as 5-year-olds, had advanced to a peak at 49 cm. In the following year, the peak was still at 49 cm. There was apparently little growth from August-September 1962 to April-May 1963 in this year-class. As 7-year-olds, this year-class displayed a peak in the length frequency at 52 cm in 1964.

Although no otolith sample was taken in 1959, the length frequency, with a strong mode at 22 cm, suggests that the 1957 year-class was dominant in the catch (Fig. 17).

The 1959 year-class can be followed through the length frequencies of 1962-64 as 3-4- and 5-year-old fish.

VI. GROWTH

A. GROWTH IN LENGTH

The offshore data were insufficient to derive growth curves for a comparison of growth by Subdivision. It was possible, however, to obtain reasonably close-fitting curves for certain combinations of years (Fig. 19) for Division 3K as a whole. For the combined September sample from the early 1950's the curve had a high k value and low L_∞. The curves for April-May 1963-64 and October 1964 had the same L_∞ but k values which differed considerably. The August-September 1960's curve was derived mainly from material of 1960 and 1962 (Table 1). It was practically identical with a curve derived from the 1960-62 data by May et al (1964). K and L_∞ values of this curve were intermediate between those of the early 1950's and April-May and October 1963-64.

A comparison of the offshore curves is shown in Fig. 20. It is clear that the growth rate has increased from the 1950's to the 1960's. If one considers the August-September 1960's curve as being representative of the early 1960's, the growth rate has increased from the early 1950's (September) to the early 1960's (August-September) and again to the middle 1960's (April-May). In the middle 1960's, the October curve lay well above that of April-May except at the extremities.

From the inshore data, growth curves have been derived from a variety of years. From a preliminary inspection of the length-at-age data it was decided that all 1960's samples could be combined except for line-gear samples from Subdivision 42. In Figure 21, trap curves are shown for Subdivisions 39-42. In Subdivisions 39 and 40, the growth rate in the 1960's showed a definite increase over that of 1949 and 1954 respectively. No curves were fitted to the 1954 data for Subdivison 40 or 42 because the resultant L_∞'s were unreasonably high. There was an increase in growth rate in Subdivision 42 from 1954 to the 1960's. The increase was apparently not as great as that experienced in Subdivisions 39 and 40. Only one sample was obtained from Subdivision 41. Curves for Subdivisions 39, 40 and 41 in the 1960's were similar as to L_∞. Subdivisions 39 and 41 had similar k values but that for Subdivision 40 was higher. Subdivision 42 had the lowest L_∞ and highest k of all.

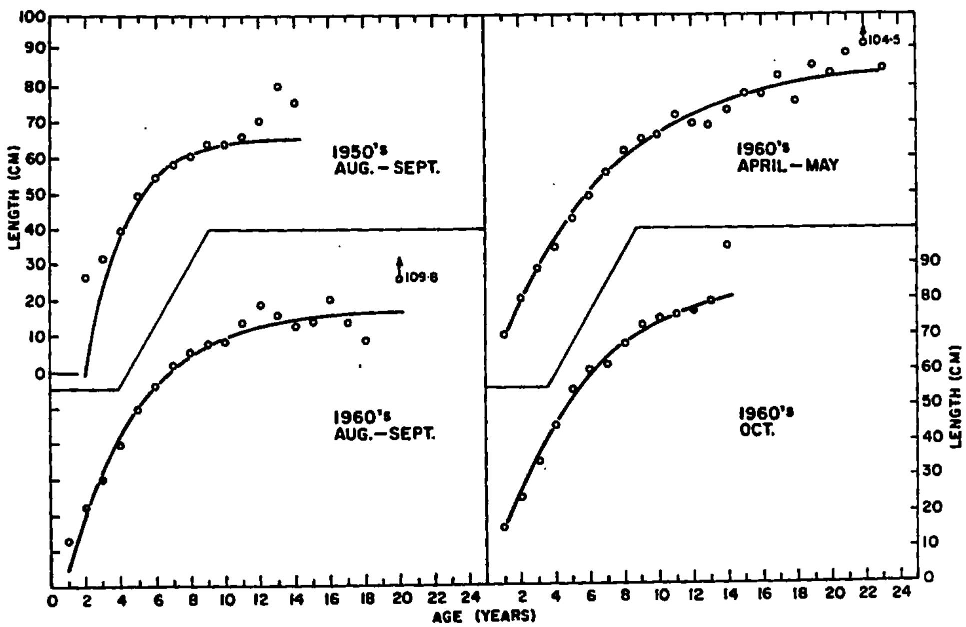

Fig. I9. Average length at age and fitted growth curves of otter-trawl caught cod in Division 3K in various years.

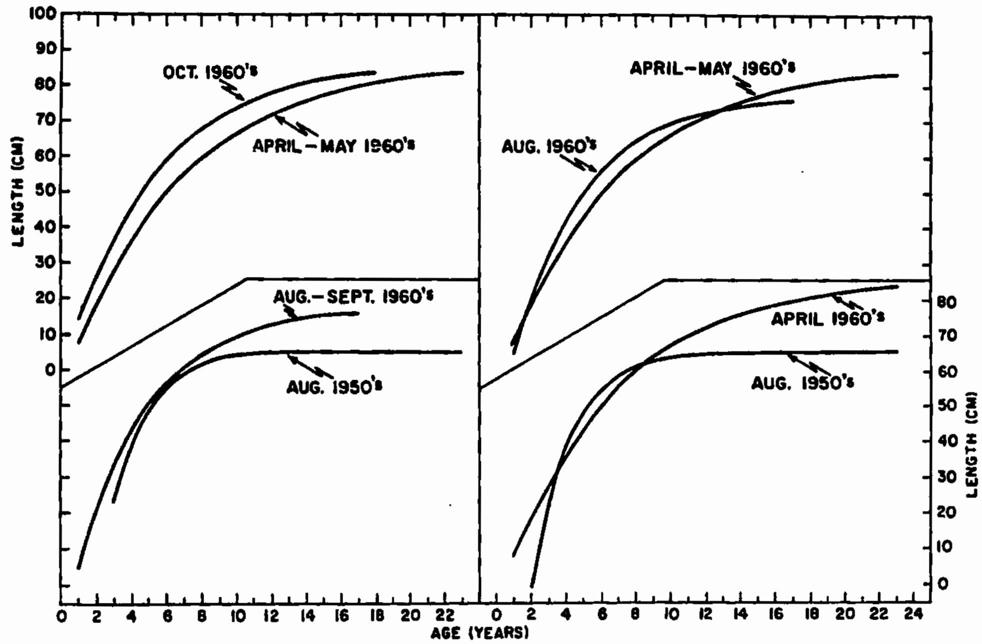

Fig. 20. Comparision of fitted growth curves of otter-trawl caught cod in Division 3K.

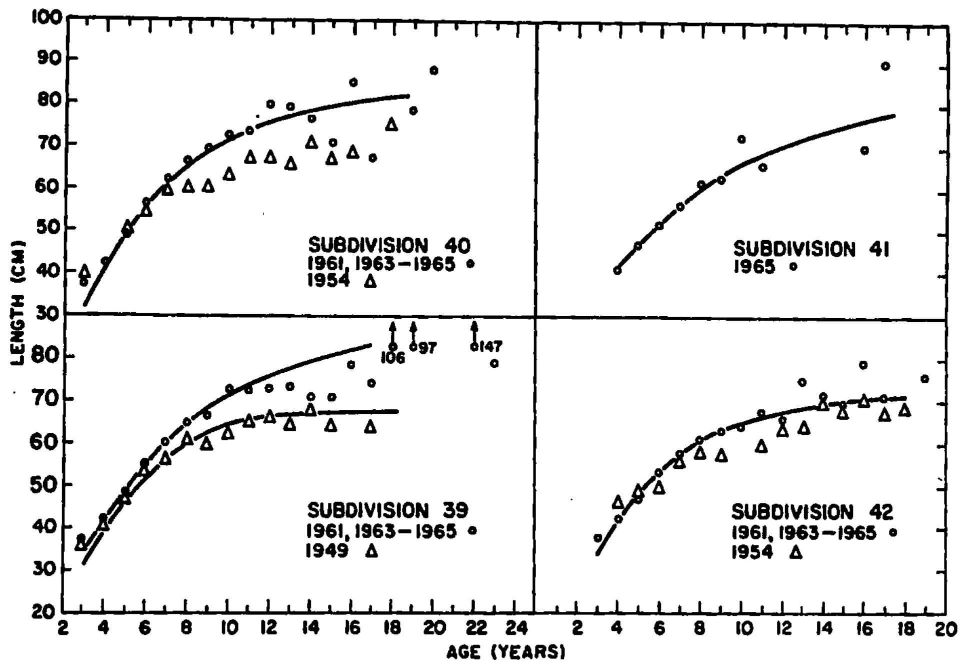

Fig. 2I. Average length at age and fitted growth curves of trap-caught cod in various subdivisions and years in Division 3K.

A comparison of the fitted curves (Fig. 22) showed that those of Subdivisions 39 and 40 were similar, that of Subdivision 41 had a somewhat lower, and Subdivision 42 a decidedly lower, growth rate. The 1954 length-at-age data for Subdivisions 40 and 42 did not appear to be much different from those of the fitted curve for 1949 from Subdivision 39.

In Figure 23, the growth curve for jigger 1940 had an L_∞ and k of about the same magnitude as the trap 1949 sample (Fig. 21). The jigger curve for Subdivision 42 in 1961 had a low L_∞ and high k. The growth rate was much lower than for the Subdivision 40 jigger sample of 1963. The gillnet sample for Subdivision 42 displayed a lower rate of growth than that of Subdivision 39. The handline samples for the same two Subdivisions virtually overlap.

Growth curves for line-gear samples are shown in Fig. 24. In Subdivision 42 longline samples were taken mostly from the Belle Isle area. Longline samples taken by small open boats close to shore were termed linetrawl samples in all Subdivisions. In Subdivision 39, the longline samples are those from deep water.

Linetrawl samples from Subdivison 41 in 1947 and from Subdivision 42 in 1962 were similar. The longline samples for Subdivision 39 in the 1960's and the linetrawl and longline samples of Subdivision 42 in 1965 have high L_∞'s and low k's. The L_∞ for Subdivision 42 longline in 1962 is intermediate between the other longline samples and the linetrawl sample for 1965.

B. LENGTH-WEIGHT RELATIONSHIP

From inshore samples from Subdivisions 39 and 42 in June-July 1963, 803 round and 1279 gutted (head-on, gills-in) cod were weighed to the nearest ounce. Length-weight curves were constructed by fitting least squares lines to the log-log transformations of the data.

It was found that the whole range of data could not be described adequately by one straight line fitted to the log-log transformations. In both the round and gutted fish an increase in slope was apparent after the fish had reached about 70 cm. Two curves were therefore fitted in each case (Fig. 25). The equations are:

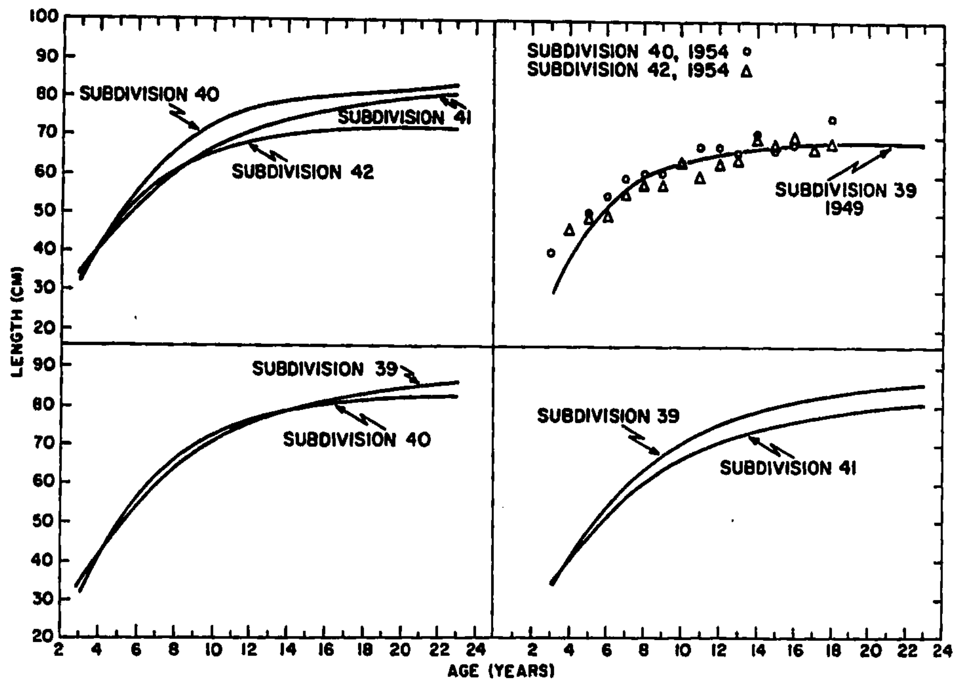

Fig. 22. Comparision of fitted growth curves of trap-caught cod in various subdivisions in Division 3K.

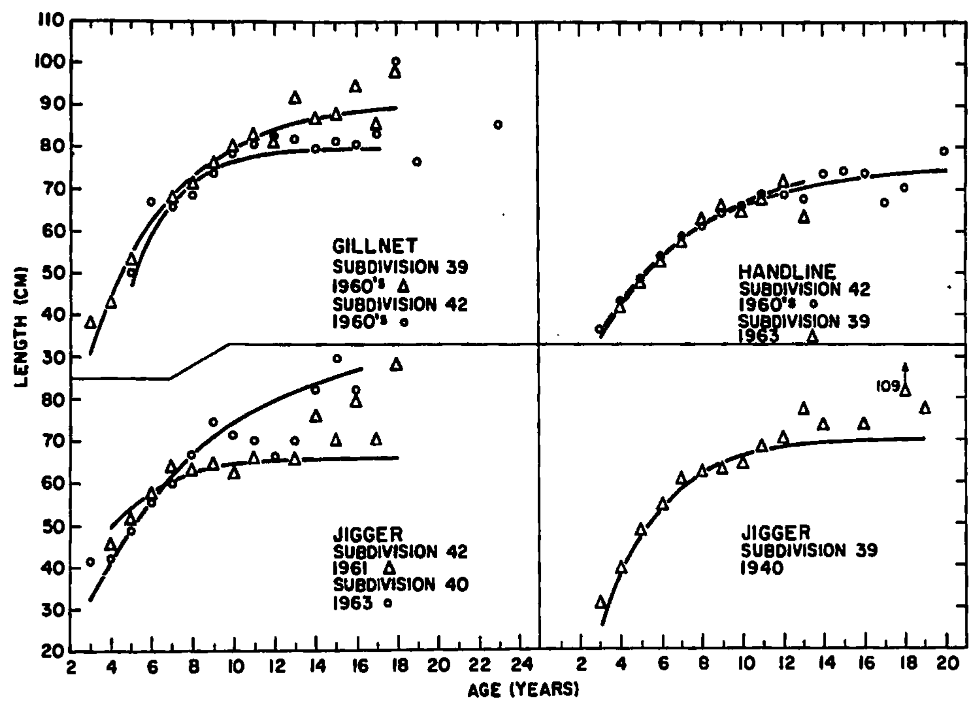

Fig. 23. Average length at age and fitted growth curves of cod caught by various gears and in various subdivisions and years in Division 3K.

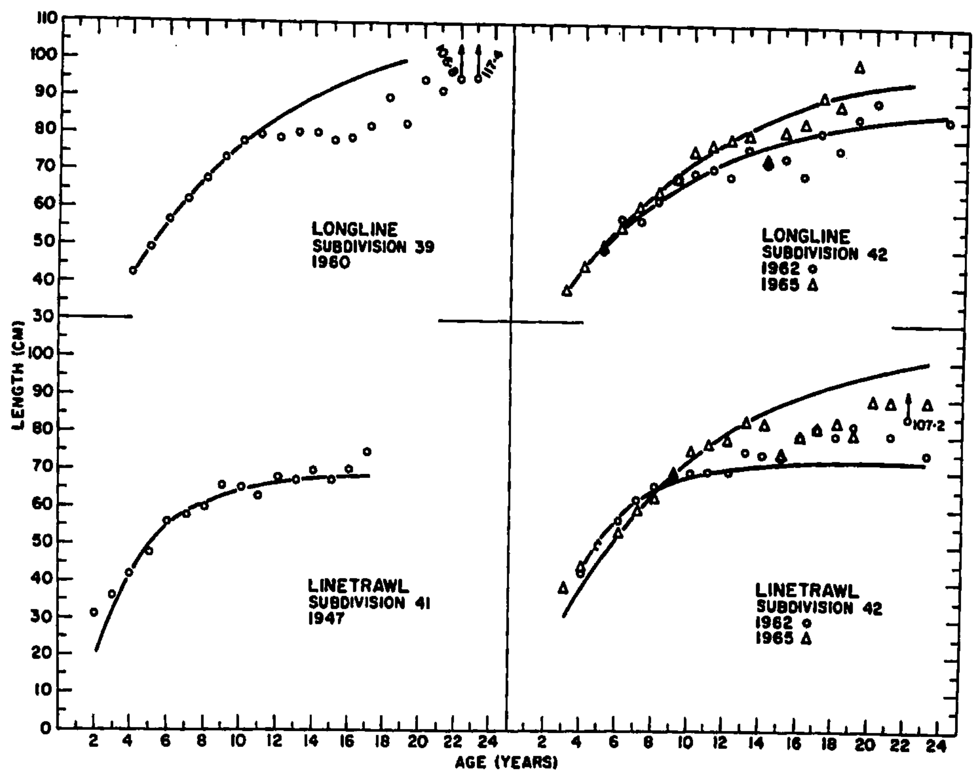

Fig. 24. Average length at age and fitted growth curves of cod caught by linetrawl and longline in various years and in various subdivisions in Division 3K.

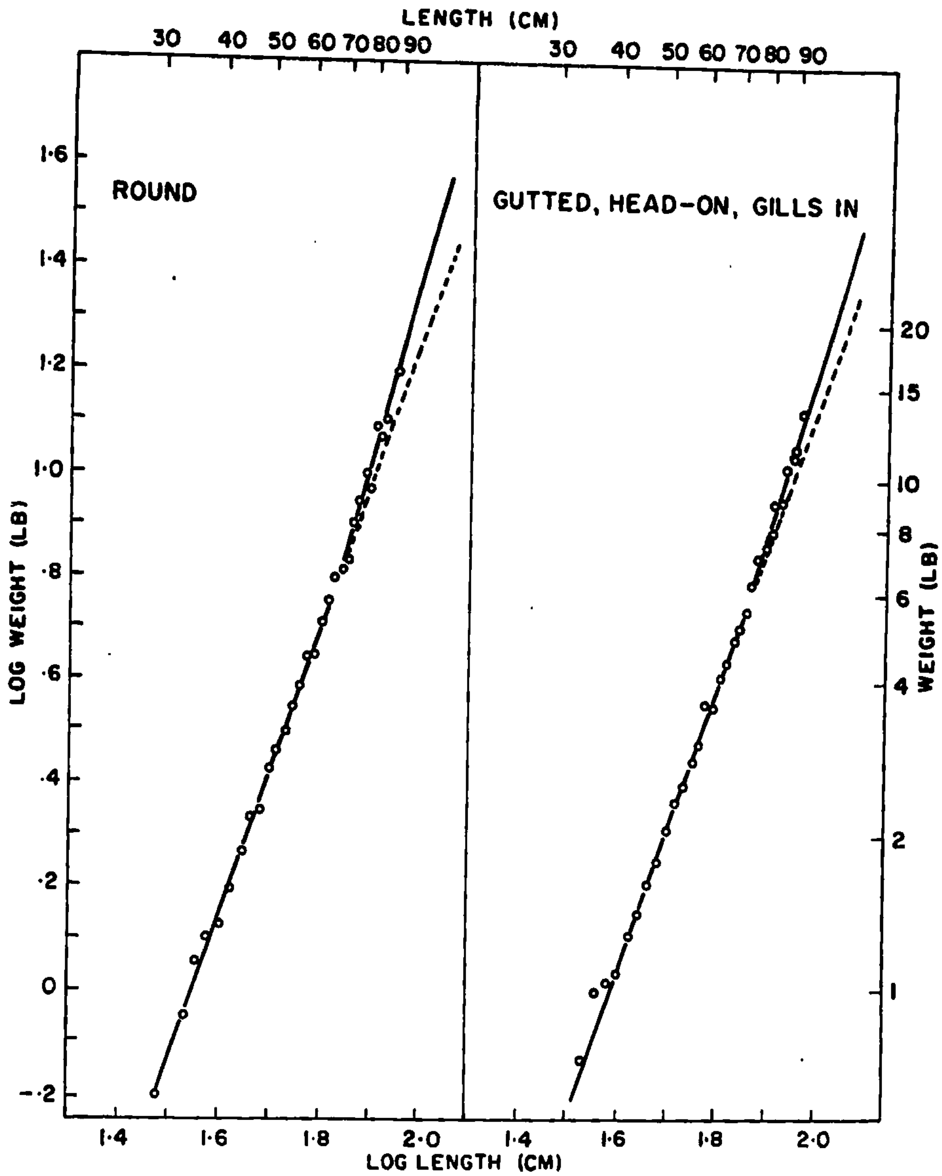

Fig. 25. Relationship of length to round and gutted (head-on, gills-in) weight of cod caught in June-July in Division 3K.

gutted weight (to 70 cm) $= .00005611 \ l^{2.69}$

(over 70 cm) $= .0000009718 \ l^{3.63}$

round weight (to 70 cm) $= .00005436 \ l^{2.75}$

(over 70 cm) $= .0000004759 \ l^{3.86}$

VII. DELINEATION OF STOCKS

Templeman (1962) concluded that data from tagging, migration and meristic studies were not inconsistent with the existence of one large stock of cod on the east coasts of Labrador and Newfoundland and to the north of the Grand Bank. He thought it likely, however, that further research might indicate the presence of sub-stocks which did not intermingle greatly or which separated out at certain seasons. The present data include observations on the degree of infestation of the gills by *Lernaeocera* and on the number of vertebrae, excluding the urostylar half-vertebra, in the backbone.

A. *LERNAEOCERA* INFESTATION

The degree of infestation differed from place to place and gear to gear (Table 4). In the inshore areas, infestation of longline and gillnet fish was generally much lower than that of trap fish. The infestation of trap fish in Subdivision 41 was very high. In Division 3K, trap-caught fish have traditionally accounted for the major portion of the inshore landings. In 1963, for example, 60% of the inshore landings were taken by trap (Pinhorn and Wells, 1965). χ^2 tests of total infestation of trap samples in the 1961-65 period from Subdivisions 39-42 showed that Subdivision 41 cod were significantly (5% level) more infested with *Lernaeocera* than were any of the other Subdivisions. The rate of infestation in Subdivisions 39 and 42 were significantly different from each other, but neither was different from that of Subdivision 40. In Subdivisions 39 and 40, where trap samples from a good range of years had been examined for *Lernaeocera* no significant difference in *Lernaeocera* infestation was found between years within either Subdivision.

As a general rule, the degree of infestation by this parasite decreased with age (Table 5). In the inshore samples, no fish older than 13 years was infested and infestation decreased sharply after a fish reached 7 years. The rate of infestation at ages 8-13 was high in the Subdivision 41 sample but this sample was quite small.

In Subdivision 39, χ^2 tests carried out on the samples listed in Table 4 indicated that there was no significant difference in degree of infestation between trap, handline and linetrawl samples at any age. Longline samples had infestation rates which were not significantly different at any age from those of handline and linetrawl samples but were on the borderline of significant difference with those of trap at ages 3-6. The observed χ^2 was 3.85 (5% significance level - 3.84). Gillnet samples had significantly lower infestation at the younger ages than those from all other gears.

In Subdivision 40, there was no significant difference in Lernaeocera infestation at any age between the trap, linetrawl, jigger and handline samples. In Subdivision 41 there was a significant difference between the linetrawl and trap samples at ages 6-8 but not at ages 3-5.

Trap, linetrawl, handline and jigger samples in Subdivision 42 were not significantly different from one another. Longline and gillnet samples were not large enough to compare by small groups with each other or the other gears, but in both gears infestation of the total samples was significantly lower than that occuring in the other gears.

Infestation rates between Subdivisions were compared. In each Subdivision samples were combined for which no significant difference had been demonstrated. Longline and gillnet samples were excluded from the Subdivision 39 and 42 totals, the 1965 trap sample only was used for Subdivision 41 (Table 5). χ^2 tests revealed that Subdivision 41 was different from the other areas for the various age groups. The difference between rates of infestation by age groups was not significant between Subdivision 40 and 42. Only fish at age 7 showed any significant difference among samples from Subdivision 39, 40 and 42. The age 7 fish from Subdivision 39 were significantly more infested.

Otter-trawl samples for April-May, 1963-64, showed lower rates of infestation than the inshore gears. Total infestation rates for Subdivisions 41 and 42 were not significantly different from each other but were significantly higher than all other areas. Subdivision 43 infestation was significantly higher than that of Subdivision 47. Differences in rates of infestation among Subdivisions 43, 44 and 45 were not significant, nor were rates between Subdivisions 43, 44 and 47.

No χ^2 tests were done between age groups in the otter-trawl samples because the numbers of infested fish were too small.

B. VERTEBRAL NUMBER

A list of the inshore samples from which the average number of vertebrae (excluding the urostylar half-vertebra) and the standard error of the mean have been calculated is shown in Table 6. In analyzing the data, samples were considered to be statistically different if the ranges of their mean ± 2 standard errors did not overlap. In Subdivision 42 the average vertebral numbers of trap and handline samples were not significantly different from each other but were different from that of the gillnet sample. The vertebral average of a linetrawl sample taken in 1947 in Subdivision 41 was significantly higher than that of a trap sample collected in 1965. In Subdivision 40, there was no significant difference between vertebral averages of fish from the trap and jigger samples of 1963, but the 1954 trap vertebral average was significantly higher than these. The vertebral average of the gillnet sample from Subdivision 39 was different from those of other gears in the area. The vertebral averages from longline, trap and handline samples collected in the 1960's were not significantly different and so were combined. The trap sample of 1949 had a very small degree of overlap with the handline and trap samples of the 1960's and no overlap with the combined sample. It is therefore considered to be different from these samples. A linetrawl sample collected in 1963 had a vertebral average significantly higher than those of other samples collected in this Subdivision in the 1960's but was not significantly different from the 1949 trap sample.

In comparing the vertebral average of the 1965 trap sample of Subdivision 41 with those of the combined samples of Subdivisions

42, 40 and 39 (Table 6), it was found that the average of Subdivision 42 was higher than all the others. Averages from Subdivisions 41 and 40 were similar but the average of Subdivision 39 was different from that of Subdivision 41 and was on the borderline of significance with that of Subdivision 40. The vertebral averages from samples taken previous to 1961 in the inshore-areas were not statistically different from each other.

Vertebral averages from otter-trawl samples ranged from 54.2 to 54.5 (Table 6). Samples collected in the early 1950's were statistically similar to each other in all Subdivisions. While the averages of samples collected in the 1960's were statistically similar to each other, averages from Subdivisions 42, 43 and 47 were significantly lower than averages of samples collected in the 1950's from Subdivisions 42 and 44.

A comparison of vertebral averages from inshore and offshore samples collected in the 1940's and 1950's showed general similarity except that the average from the offshore sample from Subdivision 42 was statistically higher than that of the inshore linetrawl sample collected in 1947 in Subdivision 41. The inshore combined samples of the 1960's from Subdivision 39, 40 and 41 had averages statistically lower than any of the offshore (1960's) samples. The average for Subdivision 42 for the 1960's was no different from the offshore samples. Figures 26 and 27 show the vertebral averages with their respective standard errors.

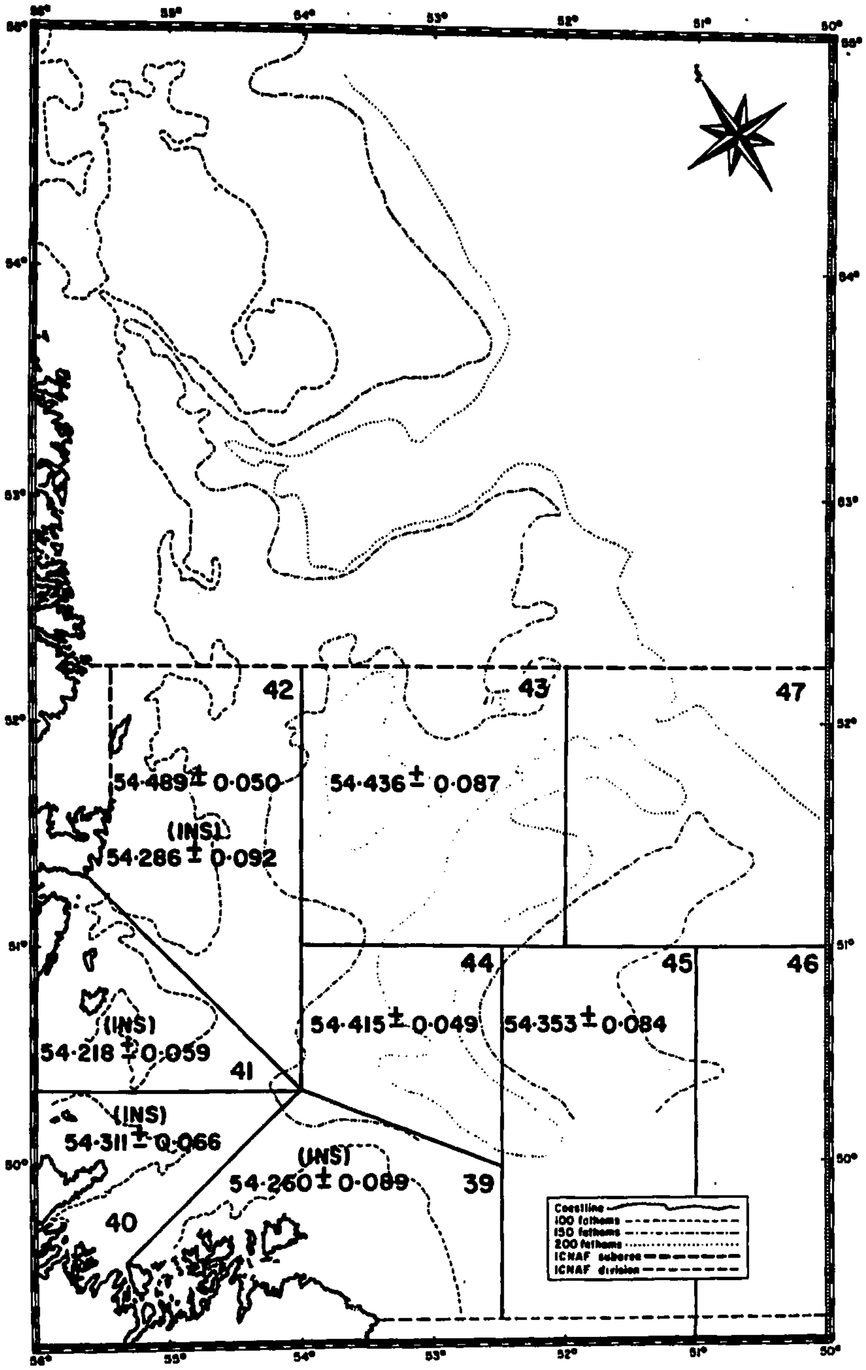

Fig. 26. Vertebral average and standard error by subdivision of cod caught in Division 3K in the 1950's.

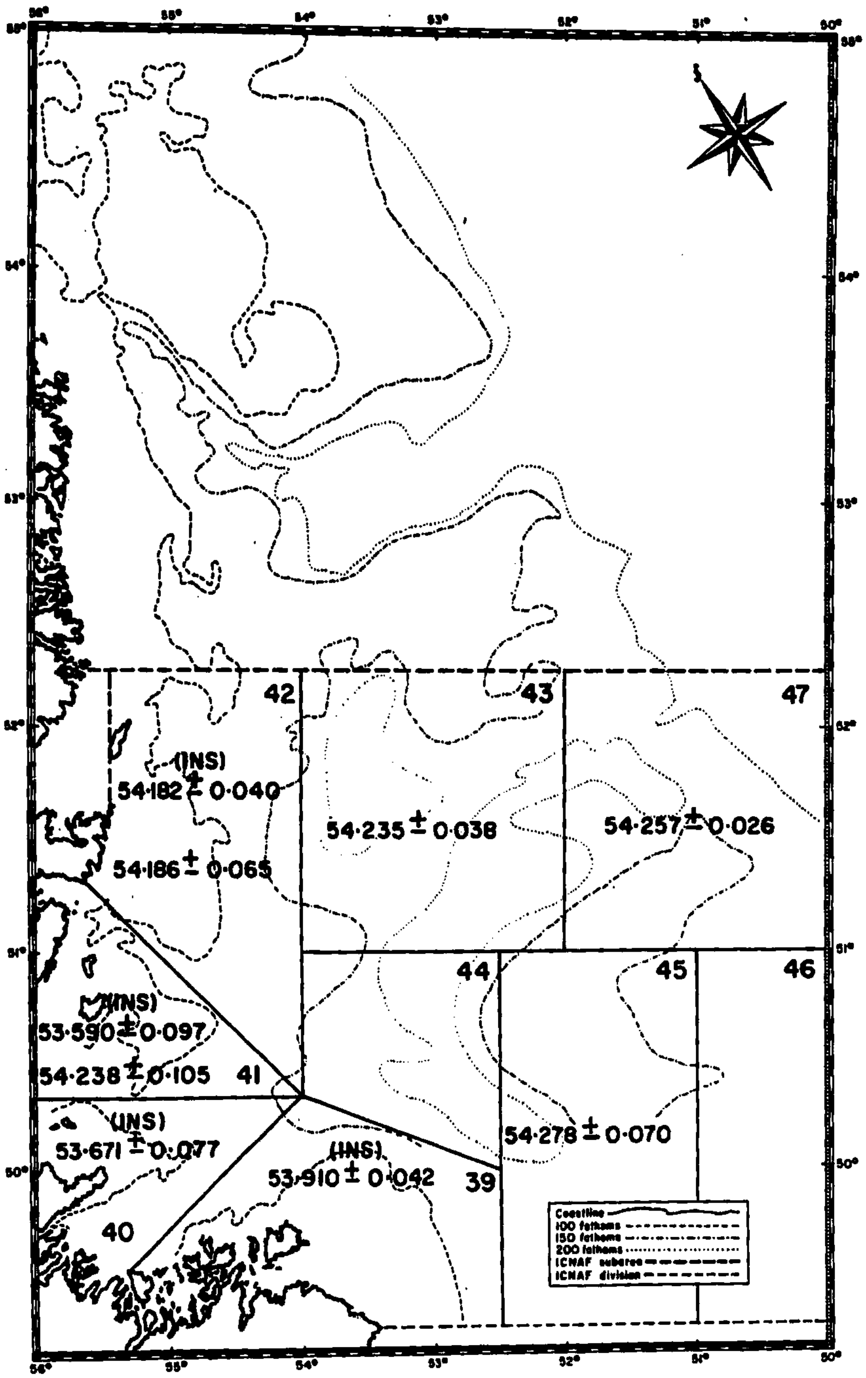

Fig. 27. Vertebral average and standard error by subdivision of cod caught in Division 3K in the 1960's.

VIII. SEXUAL MATURITY

A. SEXUAL CYCLE

Table 7 shows the percentages of immature and mature cod present in combined samples taken during the period 1960-65. The June-July sample consists of trap-caught fish while all other samples are from otter trawl. Of the mature fish, the percentages of post-spawning fish and of pre-spawning and spawning fish combined are shown in Table 8. It is apparent that spawning is completed by the end of July and is probably at its peak in April or even earlier.

B. SEX RATIO

In all the combined samples analyzed, the number of females was greater than that of males (Table 9). In only one case, the October sample, was the number of males and females statistically similar according to χ^2 tests at the 5% level.

C. AGE AT SEXUAL MATURITY

In the combined otter trawl sample collected in April-May in 1963-64, all cod, male or female, of age 4 and below were immature, while all those of 9 years and above were mature. The percentages of mature males within this range were consistently higher than those of mature females (Table 10).

The ages at which 50% of the males, 50% of the females, and 50% of the combined males and females, were mature (M_{50}) were calculated according to the method of Fleming (1960). This method, the "LD_{50}" procedure (Bliss 1935 a,b, 1952; Mather 1946) was adopted by Fleming from Stanley and Slatis (1955). Fleming (1960) demonstrated the method by means of a worked example. Table 11 shows the relevant statistics and Fig. 28 the fitted curves. M_{50} for males was significantly different from that of the females, but the slopes were similar.

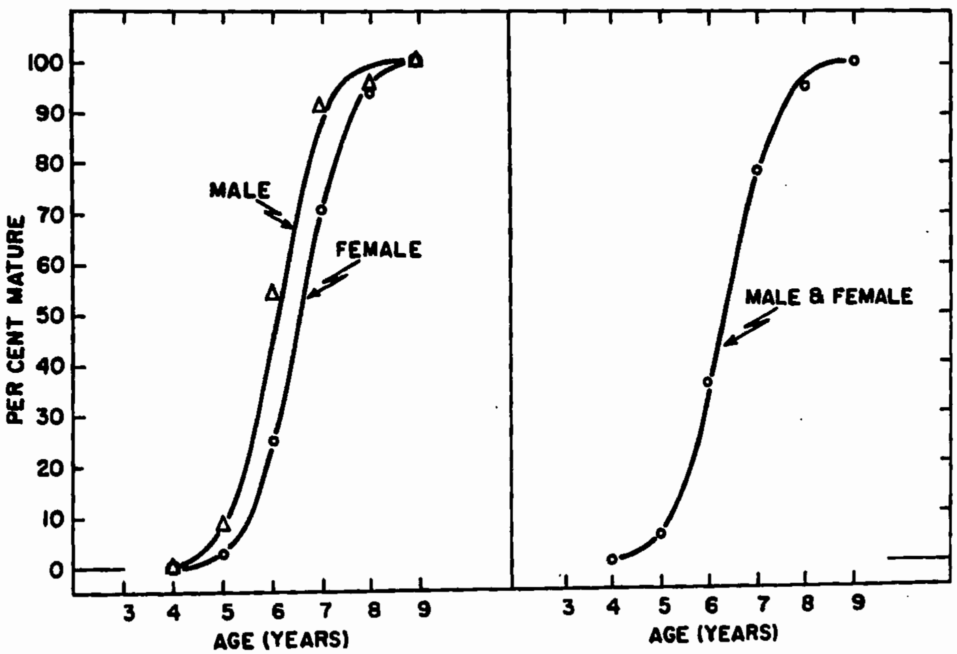

Fig. 28. Percentage mature at age for cod caught in April-May, 1963-64 in Division 3K. Males and females and combined male and females are shown separately.

IX. MORTALITY

Estimates of total mortality were obtained from least squares regressions fitted to the descending right limb of catch curves based on percentage age distributions. Only otter-trawl catches were used as these were felt to sample the population more randomly than the inshore gears. Percentage age frequencies were combined for 1950-52, 1960-62 and 1963-64 (Fig. 29). The data for 1950-52 and 1960-62 followed fairly closely the fitted straight lines over the whole range of ages used, namely 5-17 years. The instantaneous total mortalities derived from these curves were 0.32 and 0.25 respectively, indicating little change in total mortality over this period. The data for 1963-64 for the same range of ages assumed a concave shape and were not adequately fitted by a single straight line. Accordingly, two lines were fitted, one to ages 5-12 and the other to ages 10-17. The respective total mortalities were 0.73 and 0.25.

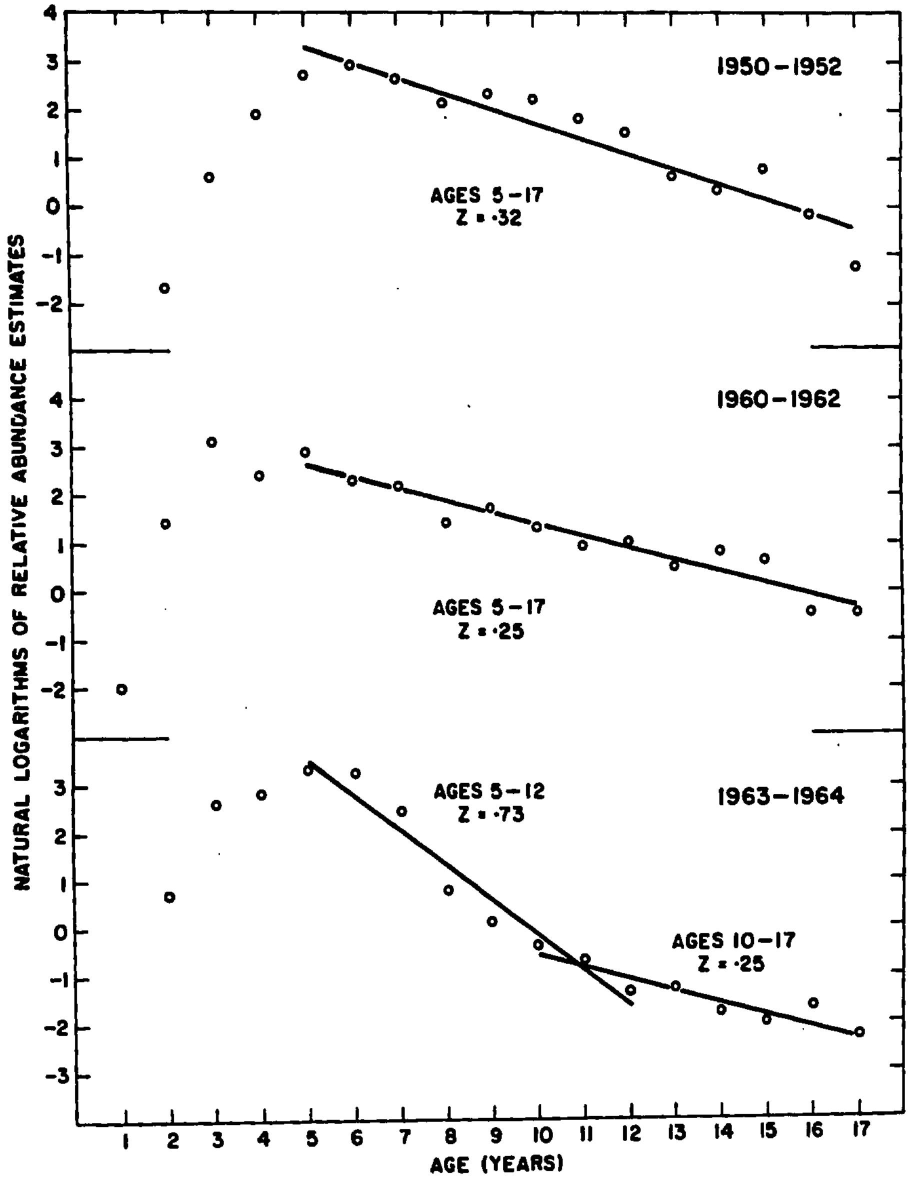

Fig. 29. Mortality curves fitted to the descending limb of the catch curves of otter trawls for various periods. Instantaneous mortality rates (Z) and ages on which the curves are based are shown.

X. DISCUSSION AND CONCLUSIONS

A. THE FISHERY

Up to the early 1950's the fishery off the northeast coast of Newfoundland (ICNAF Division 3K) was primarily an inshore one carried on by Newfoundland fishermen in small open boats near the shoreline and using a variety of gears. In 1958-59 the number of hours fished yearly by foreign otter trawlers fishing offshore increased to a level about four times as great as that of 1954-57 and remained at this high level for the period 1958-65. The otter-trawl fishery accounted for 20-25% of the total landings in 1954-57 but 55-75% in 1958-65. The catch per unit effort for the otter-trawl fishery has remained fairly constant over the whole period. The landings for the inshore fishery have decreased both absolutely and relative to the total cod catch in the ICNAF area by Newfoundland fishermen.

B. AGE AND LENGTH COMPOSITIONS

The inshore fishery in Division 3K usually begins in June with the arrival in shoal water of schools of cod which have pursued the capelin from deeper water towards the land. The fishery in the early part of the season is carried out mainly by traps - large, boxlike devices of netting which may take up to 10,000 pounds or more of cod in a single haul.

Traps are usually set in depths of more than 7 and less than 20 fathoms. The catches in recent years have been comprised of fish of average size between 49 and 55 cm and of ages 4-8 years. Differences in the size and age compositions are apparent in samples taken from different parts of the division in the same years. As the season progresses, the cod move out of the range of depths at which traps are effective and are fished by other gears, including hand-lines, longlines, gillnets and jigger. These gears usually take somewhat larger and older fish than the traps. In the southern part of the Division deep water is available relatively close to shore, and longlines set in depths greater than 100 fathoms take fish of a much greater average size and age than the other gears mentioned. These data indicate that cod in their spring feeding migrate towards land, tend to distribute themselves by depth such that proportionately more large cod are to be found as the depth increases. Furthermore it would seem that many of the largest cod living in water of depths greater than about 100 fathoms do not make the inshore migration at all. Templeman and Fleming (1956) have found this to be the case in fishing areas further south in Newfoundland. It may well be that these large fish have feeding habits and capabilities which enable them to make use of the food available in the deep water in the spring at the time when smaller cod are pursuing capelin towards the land.

Catches by trap in 1949 and 1954 contained large numbers of old fish. Since 1961, however, fish above 8 years of age are much more poorly represented in catches by this gear. Catches by jigger in 1940 and shallow water linetrawl in 1947 also contained large numbers of older fish.

Year-class dominance was not evident in samples taken from 1947-50 from coastal areas of Labrador and Newfoundland by Fleming (1960). The samples of 1949 trap and 1947 linetrawl catches analyzed by Fleming (1960) have been re-examined for age in the present study and this conclusion is confirmed. However, in more recent years dominant year-classes appear in most of the inshore gears. Exceptions are fish caught by deep-water longline in Subdivision 39 and by longline in the northern part of Subdivision 42. Gillnet samples usually showed a predominance of 3 or 4 year-classes in the 7-10 year-old range. The year-classes of 1955, 1957 and 1959 were strong in samples from all inshore gears.

The appearance of dominant year-classes in recent years indicates that the stock of older and larger fish has been so depleted that the strength of a new year-class entering the fishery can have an immediate effect on the landings. In the majority of inshore gears, where the range of ages taken is low, a strong year-class may mean the difference between a successful or unsuccessful fishing season. In those line-gear fisheries where there is still a wide range of ages, the success of the fishery is not now dependent on the strength of a single year-class entering the fishery. Presumably the success of a year-class is due mainly to mortality during the egg and larval stages when the fish are particularly vulnerable to predation and unsuitable environmental conditions.

Hermann, Hansen and Horsted (1965) show a positive correlation between temperature and survival of cod larvae off West Greenland. Martin and Kohler (1965) on the other hand, found that recruitment of cod of the southern ICNAF area is negatively correlated with sea surface temperatures. It is interesting to note that 1957 and 1959, years in which there was good year-class survival in the Division, were unusually cold years (Templeman, 1965). It is likely that many cod eggs and larvae are carried to the northeast coast of Newfoundland from spawning grounds on the slopes of Hamilton Inlet Bank, Labrador. Large numbers of spawning and post-spawning cod were found in this area in otter-trawl surveys in April-May 1963 (Templeman and May, 1965). The general current system in the area is a southward one (Smith, Soule and Mosby, 1937) and larvae from this northward spawning probably settle to the bottom all along the east coast of Newfoundland.

Research otter-trawl cod catches in 1950 and 1951 had a wide spread of ages similar to that encountered in the inshore gears prior to 1960. The 1952 sample, however, contained a dominant year-class, that of 1947. This year-class was well represented in the trap sample of 1954 from Subdivision 40, but not as strongly as might have been expected in the 1954 trap sample of Subdivision 42. This may have been an anomaly due to the smallness of the sample (120 fish) in Subdivision 42.

In the otter-trawl samples of the 1960's the 1957 and 1959 year-classes were outstanding and may be traced in the length frequencies as distinct peaks for a number of years. In 1960, the 1957 year-class was very strong as 3-year-olds and in the following year, as 4-year-old fish, it dominated the otter-trawl catch and was very strongly represented in the trap catches of that year. It was predominant in the 1962 otter-trawl catch and in the trap, jigger and handline catches inshore. It continued to be strong in 1963, being predominant in the otter-trawl catches, and in the trap, jigger and handline catches in all Subdivisions. In 1963 the 1959 year-class was also fairly strong in the otter trawl but of minor importance inshore. In 1964 the 1959 year-class was predominant in the otter-trawl catches while the 1957 year-class was of reduced importance. The 1957 year-class was still predominant in Subdivision 42 and the 1959 year-class was next in importance. In the south, in Subdivision 39, the 1959 year-class was second in importance to that of 1960 and the 1957 year-class was considerably reduced. The 1957 year-class accounted for better than 40% of the handline catch in 1964 in Subdivision 42.

It is apparent that otter-trawl samples are generally representative of the fish which are taken inshore, except that the otter-trawl catches may contain large numbers of 3-year-olds which are seldom represented in the commercial gears operating inshore. Two-year-old fish may be quite well-represented as in the 1959 otter-trawl length frequency. One-year-olds are seldom taken in large quantities.

The age distributions of 1960 and 1962 contain proportionately more older fish than those 1963-64. As noted previously, the samples of the 1950-51 period contained a good range of older fish. The 1952 sample was, however, dominated by the 1945-57 year classes. It is likely that the 1952 age frequency represents not a diminution of the older age groups, but a great influx of a successful 1947 year-class. This year-class was abundant in the West and East Greenland areas (Templeman, 1965) and in Labrador (May, 1959). The decrease in numbers of older fish from 1950-52 to 1960-62 and again to 1963-64 is indicative of the increased fishing mortality consequent on a great increase in fishing effort after 1957.

Otter-trawl age and length compositions for the different Subdivisions in May, 1963 were similar but there was a tendency for relatively more younger and smaller fish to occur in the more landward Subdivisions. This is apparently a reflection of the beginning of the inshore migration with size differentation by depth as previously noted.

C. GROWTH

The results suggest that the growth rate of cod taken by otter trawl has increased progressively from 1950-52 to 1960-62 and to 1963-64. The fitted curves were:

September, 1950-52	$l_t = 65\ (1-e^{-.46(t-2.03)})$.
August-September, 1960-62	$l_t = 77\ (1-e^{-.24(t-.74)})$.
April-May, 1963-64	$l_t = 86\ (1-e^{-.15(t-.38)})$.

L_∞ increased while k and t_o values decreased over the period. In fitted curves shown in Fig. 23, the curve for October, 1964 is higher than that for April, May 1963-64 except at the extremities and the L_∞'s are both 86 cm. The April, May curve describes the growth characteristics of cod during spawning. In October the increase in length may be considered to be almost complete for the year.

It should be noted that generally the length at age t in the October sample is greater than that of age t+1 in the April-May samples. This indicates that the growth of cod during the growing season of 1964 was greater than that of the previous 2 years incorporated in the April-May 1963-64 curve. The trend towards increase in length at age evident from 1950-64 may therefore well be continuing.

The overlap of the curves for August-September 1960 and September 1950-52 with that of April-May 1963-64 is probably due mostly to seasonal increment of length. It is nevertheless apparent that the increase in growth has occurred mainly in fish of ages 8-10 and above.

In the major inshore gear, trap, growth rates in the 1960's from Subdivisions 39 and 40 have increased considerably over those from samples taken in 1949 and 1954 respectively. There was a less pronounced increase in growth rate in Subdivision 42, from 1954-65. The differences in age-at-length are most apparent in fish of 7 years and older.

A jigger sample collected in 1940 in Subdivision 39 and a linetrawl sample collected in 1947 in Subdivision 41 were practically identical to each other and to the trap samples taken in 1949 in Subdivision 39. It has already been noted that the 1949 trap growth curve fitted reasonably well the length-at-age data for the 1954 collections from Subdivisions 40 and 42.

The growth curve for Subdivision 42 in the 1960's was much lower than those of the Subdivisions further south. For Subdivisions 39-41 some of the differences in growth rate were not large but the curve for Subdivision 39 was somewhat higher than that of Subdivision 41.

In samples taken in the 1960's from jigger and gillnet growth rates in Subdivision 42 were lower than those of Subdivisions 40 and 39. However, growth rates in Subdivisions 42 and 39 were very similar for a handline sample taken in Subdivision 39 in 1963 and the combined sample of 1963-65 for Subdivision 42.

Longline and linetrawl samples from Subdivision 42 and longline samples from Subdivision 39 were similar in having L_∞'s in the 90-113 cm range and k values of 0.10 to 0.13. These curves lie far above those of the other inshore gears and of otter trawl, and may be artificially high because of hook selection favoring the capture of larger fish. However, the 1947 linetrawl curve for Subdivision 41 was practically the same as curves for samples collected from other inshore gears at about the same time.

It is reasonable to suppose, then, that an inshore growth curve for the Division based on any one of the samples taken in 1940, 1947, 1949 and 1954 would be representative of this early period for the whole Division. The curve for the 1949 trap sample was $l_t = 69 (1-e^{-.29(t-1.05)})$. The trap curves for the period 1961-65 show a decided difference between the northernmost and southernmost Subdivisions so that both the curves are listed below:

Subdivision 39 $l_t = 88\ (1-e^{-.16(t-0)})$

Subdivision 42 $l_t = 73\ (1-e^{-.24(t-.41)})$.

The otter-trawl curve for 1950-52 is not greatly different from that of the inshore curve for 1949. The inshore curve for Subdivision 39 is very similar to the 1963-64 offshore curve. The curve for Subdivision 42, however, is most like the 1960-62 offshore curve.

The difference in growth rate in cod of the northern part of the Division from that of cod in the southern part may perhaps be due to environmental conditions. Growth of cod may be modified by external factors and is different in cod from different areas. Studies on cod growth are numerous (Wise, 1963) and recent studies relating cod growth to environmental conditions have been published by Taylor (1958), Kohler (1964), Dementyeva and Mankevich (1965), Hermann and Hansen (1965), Jonsson (1965), May et al (1965), Williamson (MS 1965), May (1966), and Wiles (1967). The study by May et al (1965) showed that for cod in the Newfoundland area, von Bertalanffy growth curves had highest values of k and least values of L in the cooler waters to the north. The present differences in the inshore curves between Subdivisions 39 and 42 in the samples of the 1960's are related in a manner similar to the curves of May et al (1965). Their observations of the hydrography of the area were that there were increasing surface temperatures and decreasing volume of cold water (less than 0°C) from north to south.

Hermann and Hansen (1965) report a positive correlation between cod growth and temperature changes in the West Greenland area. Jonsson (1965) found that immature cod in Icelandic waters provided a good example of a strong positive correlation between temperature and growth. As noted above a positive correlation between L_∞ and increasing latitude was shown by May et al (1965). On the other hand Taylor (1958), after constructing von Bertalanffy growth curves for widely separated areas of the North Atlantic and relating these areas to available mean sea surface temperature data, found that L_∞ and life span decreased with increasing surface temperature. Holt (1959) proposes that, on theoretical grounds, L_∞ should decrease slowly with increasing temperature.

On the basis of opposite findings such as those shown above, it may be inferred that temperature may not be the major factor influencing growth. In any event, the influence of temperature on fish growth is usually taken to be partly an indirect one, through its effects on the feeding actions of the predator and the distribution of predator and prey. Kohler (1964) found correlations between temperature and food consumption and between food consumption and growth, but could not demonstrate a direct temperature-growth correlation.

The difference in growth rates between northern and southern extremities of the Division is therefore provisionally attributed to temperature differences between those areas. Results indicate lower L_∞ and higher k with increasing latitude. Cod in the higher latitudes (cooler water) reach a lower average maximum size than those from the lower latitudes (warmer water). Furthermore, cod in the higher latitudes approach their maximum size more rapidly than do those to the south.

The increase in growth rate between 1949-54, 1960-62 and 1963-64 may not be due to temperature changes over the whole area. Sea temperatures for the area should have been increasing over this period in order for an increase in growth to be apparent. Comparative hydrographical information is scarce but Templeman (1967) reports a series of temperature data for Hydrographic Station 27, situated about 2 nautical miles from St. John's. The correlation between mean sea temperatures, especially at the surface, and air temperatures in the same year at Torbay-St. John's was extremely good. In the absence of a good series of hydrographic data from the Division under study, the trends shown by Templeman (1967) for Station 27 are taken as indications of what occurred in the Division. Mean annual air temperatures on the basis of 5-year means, have decreased since the early 1950's. For the period between 1950-62, there was a slight downward trend in the water temperatures. It is therefore unlikely that increases in growth rate during this period were due to temperature increases.

Coincident with the observed growth changes was a large increase in fishing effort for the fishery as a whole. This increase was due to increased otter-trawl fishing by the foreign offshore fleet starting in 1958. It is hypothesized that the reduced density of older fish provided relatively more food per fish and was a major factor causing the increased growth rate. Kohler (1964) postulates that changes in the growth rate of cod in the western Gulf of St. Lawrence were due both to changes in abundance and availability of food, and to changes in competition for food resulting from density changes due to fishing. Williamson (MS 1965) attributed increased growth rate of cod of the southern Grand Bank partly to increased fishing. For the northern Gulf of St. Lawrence, Wiles (MS 1967) reports increased growth rate coincident with well defined reductions in larger and older cod in the commercial landings. May (MS 1966) considers it most unlikely that observed changes in growth rate of Labrador cod were due to temperature and attributes the change to increased fishing. Evidence in this case is not completely conclusive but change in growth is attributed primarily to increased fishing.

The change in the rate of increase in weight at about length 70 cm occurs in both round and gutted fish. This implies a change in body proportions. Data are not now available to explain this interesting phenomenon. It may be due to change in the type of food eaten. Moreover, as the fish reach a sufficiently large size, activity may be lessened because they are not very liable to predation and are themselves capable predators of a wider range of sizes of prey.

D. DELINEATION OF STOCKS

Templeman and Fleming (1963), in a study of the distribution of *Lernaeocera* in the Newfoundland area, found that infestation declined approximately in proportion to the distance from shore. The otter-trawl samples of the present study confirm these findings for Division 3K. Templeman and Fleming report that cod infestation takes place mainly inshore from mid-summer to early autumn on the east coast of Newfoundland. During this time the intermediate host, the lumpfish, Cyclopterus lumpus L. is common in inshore Newfoundland waters, and cod which have come inshore during the spring migration are liable to infestation by Lernaeocera larvae which infest the gills of the lumpfish. Since, as has been noted previously, cod exhibit a depth preference according to size during this migration, it is to be expected that younger and smaller fish be more heavily infested with Lernaeocera.

Rates of infestation by Lernaeocera may be misleading when only entire samples are compared. In the inshore samples, the infestation in Subdivision 41 was significantly higher than in Subdivisions 39, 40 and 42. Infestation in Subdivisions 39 and 42 was significantly different. An analysis by age groups indicated that while the infestation in Subdivision 41 was indeed higher, there was no significant difference in infestation among the samples from Subdivisions 39, 40 and 42 except for a difference in infestation of 7-year-olds in Subdivisions 39 and 42. Offshore collections were not infested heavily enough to compare infestation by age groups.

That infestation of younger and smaller fish is heaviest, and taking into account that lumpfish with gills highly infested with Lernaeocera larvae have been found only near the shore, confirms the differential in cod sizes with depth during the spring migration in Division 3K. Differences in numbers of cod infested by inshore gears is related to the sizes of cod taken by these gears. It may also be concluded from the inshore data that cod taken in Subdivision 41 at least, form more or less a distinct substock which does not intermingle fully with cod of other parts of the Division. The heavy rate of infestation in Subdivision 41 also suggests a large concentration of lumpfish in that Subdivision.

A comparison of vertebral averages showed that significant differences in a vertebral average may occur between Subdivisions and within Subdivisions, between different gears and even within the same gear. When samples displayed similar averages, they were combined. The vertebral averages for samples taken previous to 1961 in the inshore area were not statistically different from each other. In addition, offshore averages for that period were statistically similar to each other and in general were similar to those of the inshore samples, except that the offshore average for Subdivision 42 was higher than that of the inshore linetrawl sample collected in 1947 in Subdivision 41.

The inshore samples collected in the 1960's in Subdivisions 39, 40 and 41 had vertebral averages significantly lower than those of the offshore samples. The inshore average for Subdivision 42 was not different from the averages of the offshore samples.

The average vertebral number in this Division seems, in general, to have declined over the period studied. While the averages, both inshore and offshore, were essentially the same throughout the Division in the 40's and early 50's there is a tendency in the 1960's for the inshore averages to be lower than those of offshore.

Templeman (1967) showed a general increase since about 1925 to the early 1950's in air temperatures based on 5-year running means. Since then to the early 1960's there has been a decline in air temperatures and in sea surface temperatures. Early studies showed that temperature and meristic characters are negatively correlated (Schmidt 1919, Motley 1934, 1937; Taning 1944, 1945). Templeman (1962) states that, in the North Atlantic, high temperatures produce low vertebral numbers and low temperatures high vertebral numbers. If the upward trend since 1925 in air temperatures at Torbay is indicative of the trend in the surface waters of Division 3K during the same years, the general decrease in vertebral numbers is easily understood.

The differences between the inshore and offshore samples in the 1960's samples are not so easily explained. The offshore samples had, in general, higher vertebral averages than the inshore samples.

The difference may be due to differences in the year-class structure of the samples taken. Since the vertebral number depends on the temperature, year to year variations in vertebral averages can be expected to occur. While the possibility of random sampling error cannot be overlooked, it is not considered to be the likely answer. According to Templeman (1962), cod of vertebral averages lower than 53.0 are to be found in the Gulf of St. Lawrence, and averages mainly below 53.0 on the southern Grand Bank. A coastwise migration from either of these areas into the Division would have the effect of lowering the vertebral average. Such migrations are considered to be a remote possibility in light of Templeman's (1962) conclusions.

If higher vertebral numbers in the offshore samples of the 1960's as compared to the inshore samples are not an artefact of the year-class distribution of the various gears, or of sampling error, or of migration into the Division from other areas, it must be concluded that the inshore and offshore stocks are relatively distinct. In that case since the number of vertebrae is fixed in the early stages (Taning, 1952), spawning would have to take place in different areas or in the same areas at different times. An analysis of the distribution of spawning cod was not undertaken in this study.

E. SEXUAL MATURITY

Templeman (1965) lists the spawning periods for a number of cod stocks:

West Greenland cod	March-April-May
East Greenland cod	April-May
Icelandic cod	Mid-March-mid-April
Arcto-Norwegian cod	late February-March-mid-April

Thompson (1943) gives the maximum spawning period on the Grand Bank as early June. However, recent unpublished information on file at the St. John's Biological Station indicates that the peak of spawning takes place in April-May. May (1966) reports the time of maximum spawning in southern Labrador to be March. The peak of spawning in the southern Gulf of St. Lawrence is in June (Powles, 1958).

In Division 3K, the peak of spawning is probably in March but continues into April and May. In inshore catches there are usually a number of pre-spawning and spawning individuals, especially among the larger fish, up to August and September.

Fleming (1960) shows a decline in the size at first maturity and in general, a decrease in M_{50} and increase in slope (range of ages over which maturity takes place) between the cold eastern and northern areas and the warmer southern and western areas. The M_{50} and slope for the combined sample in the present study were 6.34 and 1.16 respectively. The M_{50} is not statistically different from that derived by Fleming (1960) but the slopes are different at the 5 per cent level. That the slope is higher is consistent with a warming trend over the interval. In recent years cod matured over a narrower range of ages than formerly.

The slope for females was not different from that of males but the M_{50} was significantly different, ($t= 6.98$, p .01). Males mature earlier than females. It is not inconceivable that the predominance of females in nearly all samples is due in part to their increased age at sexual maturity. Spawning concentrations in the north are heavily fished, (May, MS 1964) and mature males are taken at an earlier age. The difference between M_{50} of females and males is taken to be a genetic one.

F. MORTALITY

Ricker (1958) describes the method whereby mortality rates can be obtained from analyses of catch curves based on age distributions. The ascending limb of the catch curve reflects the selectivity of the gear towards smaller fish and/or the unavailability of younger fish to the gear. It is not a reliable indication of the abundance of these groups. The dome of the curve is taken to be the age at which the fish are fully recruited to the gear. The descending right limb of the curve is an indication of the action of total mortality. Straightness of the right limb or any part of it is usually interpreted in the manner of

Baranov (1918) which involves the following conditions:

(1) Mortality rate at each age is the same.

(2) Sampling is random.

(3) Recruitment is constant, that is, age groups are equal in number at the time they entered the fishery.

(4) There is no change in mortality rate over the period.

The effects of an increase in mortality rate is not immediately apparent in the catch curve (Ricker, 1958). After a number of years have elapsed, a concavity appears. The older ages may still reflect the original mortality rate. A fairly good estimate of both the new and the old mortality rates may be obtained by calculating the greatest and least slopes of the right limb. Such a curve was obtained for the 1963-64 otter-trawl data. The fit for the older ages is fairly good and the total instantaneous mortality estimate of 0.25 is in excellent agreement with that obtained from the 1960-62 curve and in good agreement with that of the 1950-52 curve.

The fit for the younger ages for the 1963-64 curve is not so good. There is considerable fluctuation about the line with a slope indicating a total instanteneous mortality of 0.73. This estimate is therefore taken to be a minimum.

A method of estimating natural mortality proposed by Silliman (1943) is applicable when (1) there have been in the history of the fishery 2 different levels of fairly uniform fishing effort, (2) natural mortality has remained the same for the two periods, (3) fishing mortality is proportional to the fishing effort expended.

These conditions appear to have been met in the Division 3K otter-trawl fishery for the periods 1954-57 and 1958-65. Otter-trawl effort increased by a factor of about 4. Instantaneous fishing mortality, F, and natural mortality, M, are additive and their sum equals Z, the total mortality.

Thus $F + M = 0.25$ for the early period.

$4F + M = 0.73$ for the later period.

The solution of this equation gives estimates of M = 0.09, F = 0.16 for the early period and 0.64 in the later period. If the total mortality rate derived from the 1950-52 data is used, the values are M = 0.13, F = 0.12 for the early period and 0.60 for the later period.

The estimate of M = 0.09 is probably rather low. The natural mortality rate is certainly not greater than 0.25, the total mortality for the 1960-62 period. Estimates of fishing mortality of 0.60 and 0.64 are probably not representative of the true fishing mortality of the most recent years. A line of much steeper slope and consequently greater total mortality could be fitted to ages 7-8. The fishing mortality estimates for recent years are therefore considered to be minimum.

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XII. REFERENCES

Baranov, F.I. 1918. (On the question of the biological basis of fisheries.) Nauchnyi issledovatelskii ikhtiologicheskii Institut, Iyvestiia, 1(1): 81-128.

Bliss, C.I. 1935a. The calculation of the dosage-mortality curve. Ann. Appl. Biol., 22(1): 134-167.

1935b. The comparison of dosage mortality data. Ann. Appl. Biol., 22(2): 307-333.

Dementyeva, T.F. and E.M. Mankevich. 1965. Changes in the growth rate of the Barents Sea cod as affected by environmental factors. Int. Comm. NW Atlant. Fish., Spec. Publ. No. 6, pp. 571-578.

Fleming, A.M. 1960. Age, growth and sexual maturity of cod (Gadus morhua L.) in the Newfoundland area, 1947-1950. J. Fish. Res. Bd. Canada, 17(6): 775-807.

Hermann, F. and P.M. Hansen. 1965. Possible influence of water temperature on the growth of the West Greenland cod. Int. Comm. NW Atlantic Fish., Spec. Publ. No. 6, pp. 557-564.

Hermann, F., P.M. Hansen and Sv. Aa. Horsted. 1965. The effect of temperature on the distribution and survival of cod larvae at West Greenland. Int. Comm. NW Atlantic Fish. Spec. Publ. No. 6, pp. 389-396.

Hodder, V.M. 1964. Assessments of the effects of fishing and of increases in the mesh size of trawls on the major commercial fisheries of the Newfoundland area (ICNAF Subarea 3). Fish. Res. Bd. Canada, MS Rept. Biol. No. 801, 116 pp.

1965. Trends in the cod fishery off the east coast of Newfoundland and Labrador. Int. Comm. NW Atlantic Fisheries, Res. Bull., No. 2, pp. 31-41.

Holt, S.J. 1959. Water temperature and cod growth rate. J. Cons. Expl. Mer., Rapp. et Proces-Verb., 24(2): 374-376.

ICNAF, 1954-65. Statistical Bulletins, Int. Comm. NW Atlantic Fish., Vols. 4-15.

Innis, H.A. 1954. The cod fisheries. The history of an international economy. Revised edition. Univ. Toronto Press, 522 pp.

Jonsson, J. 1965. Temperature and growth of cod in Icelandic waters. Int. Comm. NW Atlantic Fish., Spec. Publ. No. 6, pp. 537-540.

Keir, R.S. MS, 1960. Techniques for reading otoliths. Ann. Meet. int. Comm. NW Atlantic Fish., 1960, Doc. No. 4.

Kohler, A.C. 1964. Variations in the growth of Atlantic cod. J. Fish. Res. Bd. Canada, 21(1): 57-100.

Mather, K. 1946. Statistical analysis in biology. Methuen, London, 2nd ed., 267 pp.

May, A.W. 1959. Cod investigations in Subarea 2 - Labrador, 1950 to 1958. Int. Comm. NW Atlantic Fish., Ann. Proc. No. 9, pp. 103-105.

1964. New cod fishing grounds off Labrador and the northeast coast of Newfoundland. Can. Dept. Fish., Trade News, 16(12): 3-6.

1965. The validity of otolith ages of southern Grand Bank cod. Int. Comm. NW Atlantic Fish., Res. Bull. No. 2, pp. 19-24.

MS, 1966. Increase in growth of Labrador cod. Ann. Meet. Int. Comm. NW Atlantic Fish., 1966, Doc. No. 66-24, Serial No. 1632, 10 pp.

1967. Otolith age validation in Labrador cod. Int. Comm. NW Atlantic Fish., Res. Bull. No. 4, pp. 116-120.

May, A.W., A.T. Pinhorn, R. Wells and A.M. Fleming. 1965. Cod growth and temperature in the Newfoundland area. Int. Comm. NW Atlantic Fish., Spec. Publ. No. 6, pp. 545-555.

Martin, W.R. and A.C. Kohler. 1965. Variation in recruitment of cod (*Gadus morhua* L.) in southern ICNAF waters, as related to environmental changes. Int. Comm. NW Atlantic Fish., Spec. Publ. No. 6, pp. 833-846.

Mottley, C. McC. 1934. The effect of temperature during development on the number of scales in the Kamloops trout, *Salmo kamloops* Jordan. Contr. Can. Biol. Fish., Ser. A, 8(41): 254-263.

1937. The number of vertebrae in trout (Salmo). J. Biol. Bd. Canada, 3: 169-176.

Parrish, B.B. 1956. The cod, haddock and hake. In Sea Fisheries. Their Investigation in the United Kingdom, pp. 251-331. Edited by M. Graham. Edward Arnold (Publishers) Ltd., London, 487 pp.

Pinhorn, A.T., R. Wells and E. Dunne. 1966. Breakdown of catch by type of gear in the Newfoundland inshore cod fishery, 1964. Fish. Res. Bd. Canada, MS Rept. Biol. No. 879, 8 pp.

Pinhorn A.T. and R. Wells, MS, 1965. Breakdown of catch by type of gear in the Newfoundland inshore cod fishery in 1963. Fish. Res. Bd. Canada, MS Rept. Biol. No. 816, 7 pp.

Powles, P.M. 1958. Studies on reproduction and feeding of Atlantic cod (Gadus callarias L.) in the southwestern Gulf of St. Lawrence. J. Fish. Res. Bd. Canada, 15(6): 1383-1402.

Ricker, W.E. 1958. Handbook of computations for biological statistics of fish populations. Bull. Fish. Res. Bd. Canada, 119: 1-300.

Schmidt, J. 1919. Experiments with Lebistes reticulatus Peters. Compte-Rend. Trav. Lab. Carlsberg, 14(5): 1-7.

Smith, E.H., F.M. Soule and O. Mosby, 1937. The Marion and General Greene expeditions to Davis Strait and the Labrador Sea, 1928. 35. Scientific Results. Part 2. Physical Oceanography. U.S. Treas. Dept. Coast Guard Bull., No. 19, vi + 259 pp.

Stanley, J. and H.M. Slatis. 1955. Studies from the autotrephon, III. A black mutation of Tribolium confusum composed with the normal reddish-brown strain. Ecology, 36(3): 473-485.

Taning, A.V. 1944. Experiments on meristic and other characters in fishes. I. On the influence of temperature on some meristic characters in sea trout and the fixation period of these characters. Medd. Komm. Havunders., Ser. Fisk., 11(3): 66 pp.

1952. Experimental study of meristic characters in fishes. Biol. Rev., 27: 169-193.

Taylor, C.C. 1958. Cod growth and temperature. J. Cons. Expl. Mer., 23(3): 366-370.

Templeman, W. 1962. Divisions of cod stocks in the Northwest Atlantic. Int. Comm. NW Atlantic Fish., Redbook, 1962. Part 3, pp. 73-123.

1965. Relation of periods of successful year-classes of haddock on the Grand Bank to periods of success of year-classes for cod, haddock and herring in areas to the north and east. Int. Comm. NW Atlantic Fish., Spec. Publ. No. 6, pp. 523-534.

1967. Anomalies of sea temperature at Station 27 off Cape Spear and of air temperature at Torbay-St. John's. Int. Comm. NW Atlantic Fish., Redbook, 1967. Part 4, pp. 69-75.

Templeman, W. and A.M. Fleming. 1956. The Bonavista longlining experiment, 1950-53. Bull. Fish. Res. Bd. Canada, 109: 55 pp.

1963. Distribution of Lernaeocera branchialis (L.) on cod as an indicator of cod movements in the Newfoundland area. Int. Comm. NW Atlantic Fish., Spec. Publ. No. 4, pp. 318-322.

Templeman, W. and A.W. May. 1965. Research vessel catches of cod in the Hamilton Inlet Bank area in relation to depth and temperature. Int. Comm. NW Atlantic Fish., Spec. Publ. No. 6, pp. 149-166.

Wiles, M. MS, 1967. Otolith age validation in cod from the northeastern Gulf of St. Lawrence. Ann. Meet. Int. Comm. NW Atlantic. Fish., 1967. Doc. No. 67/87. Serial No. 1883. 8 pp.

Wiles, M. MS, 1967. Changes in the growth rate of cod from the northeastern Gulf of St. Lawrence (ICNAF Divisions 4R and 4S) during 1947-66. Ann. Meet. Int. Comm. NW Atlantic Fish., 1967. Doc. No. 67/80, Serial No. 1876. 10 pp.

Williamson, G.R. MS, 1965. Age, growth, sexual maturity and mortality of cod on the Grand Bank of Newfoundland and St. Pierre Bank during 1946-62. London University, Ph.D. thesis, 140 pp.

Wise, J.P. 1963. Bibliography on the biology of the cod, Gadus morhua, and related species. U.S. Dept. Int., Fish and Wildl. Serv., Fish. Bull., 62(215): 483-538.

The following references were inadvertently omitted from the preceding bibliography:

Thompson, H. 1943. A biological and economic study of cod (*Gadus callarias* L.) in the Newfoundland area, including Labrador. Nfld. Dept. Nat. Resources, Fish. Res. Bull., No. 14, 160 pp.

Silliman, R.P. 1943. Studies on the Pacific pilchard or sardine (*Sardinops caerulea*). 5. A method of computing mortalities and replacements. U.S. Dept. Int., Fish and Wildl. Serv., Spec. Sci. Rept., No. 24, 10 pp.

APPENDIX I - LIST OF FIGURES

APPENDIX II - TABLES

Table 1. List of samples used in constructing age-length keys.

Month	Year	Area	Gear	Depth	Otoliths	Measured
			Otter trawl			
VII	1950	45	Unlined	166	120	195
IX	1950	42	Unlined	122	119	700
IX	1951	42	Lined	113	120	228
IX	1952	44	Lined	165	237	347
VIII	1960	39,44-46	Lined	127-258	325	944
VIII	1960	43,47	Lined	159-278	118	261
VIII	1962	41	Cover	90-125	170	170
VIII	1962	42	Cover	78-99	270	630
IX	1962	42	Unlined	99	127	127
V	1963	41	Lined	115	125	170
V	1963	42	Lined	107-114	97	386
V	1963	42	Lined	98-157	421	2870
V	1963	43	Lined	125-175	347	1558
V	1963	43	Lined	123-200	458	1924
V	1963	44	Lined	148-176	149	517
V	1963	45	Lined	122-170	170	591
IV	1963	47	Lined	125-167	557	564
V	1963	47	Lined	123-182	396	5265
V	1963	47	Lined	126-250	441	3814
IX	1963	47	Lined	144-203	128	1338
IV	1964	47	Lined	122-201	214	233
V	1964	47	Unlined	120	208	7825
X	1964	47	Lined	120-200	166	268
X	1964	42,43	Lined	74-177	233	233
VI	1949	39	Trap	11-14	165	1713
VII	1961	39	Trap	7-21	457	8404
VIII	1962	39	Trap	14-17	198	1912
VI	1963	39	Trap	12-17	327	3161
VII	1964	39	Trap	8-17	292	5146
VII	1965	39	Trap	11-17	371	8927
VIII	1954	40	Trap	17-18	248	248
VII	1961	40	Trap	14-20	491	8057
VIII	1962	40	Trap	16	97	962
VII	1963	40	Trap	10-16	297	5356
VII	1965	40	Trap	12-15	264	7547
VI	1965	41	Trap	14-18	167	1503
VIII	1954	42	Trap	16	120	120
VII	1961	42	Trap	14-25	276	5450
VII	1963	42	Trap	8-13	372	4274
VII	1964	42	Trap	10-19	298	7789
VII	1965	42	Trap	10-12	146	3194

Table 1. (continued)

Month	Year	Area	Gear	Depth	Otoliths	Measured
VIII	1962	39	Gillnet	16-40	216	1649
IX	1963	39	Gillnet	33-55	376	2466
IX	1964	39	Gillnet	25-30	163	202
VII	1964	42	Gillnet	18-50	243	2875
VII	1965	42	Gillnet	35-40	67	449
VIII	1962	29	Longline	138-145	176	1148
VI	1963	39	Longline	135-140	258	967
VII	1964	39	Longline	150-170	348	2190
VII	1965	39	Longline	135-150	389	7215
VIII	1962	42	Longline	35	107	1244
VII	1965	42	Longline	25	100	1164
IX	1965	42	Longline	17-30	201	2766
VI	1963	39	Linetrawl	5-35	205	1763
IX	1947	41	Linetrawl	40-60	269	1754
VIII	1962	42	Linetrawl	28-48	282	2290
VII	1965	42	Linetrawl	22-50	121	818
IX	1965	42	Linetrawl	30-55	207	3942
VI	1963	39	Handline	11	145	1181
VIII	1962	40	Handline	12-25	124	1139
VII	1963	42	Handline	3-15	359	2544
VII	1964	42	Handline	3-12	120	1567
VII	1965	42	Handline	5-10	167	1973
VIII	1940	39	Jigger	11-38	307	594
VIII	1962	40	Jigger	16-25	134	1121
VII	1963	40	Jigger	7-18	262	2877
VII	1961	42	Jigger	20-26	124	2082

Table 2. Worksheet for von Bertalanffy growth curves.

I	II	III	IV	V	VI	VII	VIII	IX
t	l_t	l_{t+1}	$L_\infty - l_t$	$\ln(L_\infty - l_t)$	$t - t_o$	$K(t-t_o)$	$1-e^{-k(t-t_o)}$	$l_t = L_\infty(\text{VIII})$

Calculations for L_∞

1. $\Sigma\left[l_t(l_{t+1})\right]$
2. $\bar{l}_t$
3. $\Sigma\, l_{t+1}$
4. (2)x(3)
5. (1)-(4)
6. $\Sigma\, l_t{}^2$
7. $\Sigma\, l_t$
8. (2)x(7)
9. (6)-(8)
10. (5)-(9)
11. 1-(10)
12. k(tables)
13. $\bar{l}_{t+1}$
14. (10)x(2)
15. (13)-(14)
16. (15)-(11)=L_∞
17. ln(16)

Calculations for k and t_o

1. $\Sigma\left[t(\ln L_\infty - l_t)\right]$
2. $\bar{t}$
3. $\Sigma\left[\ln(L_\infty - l_t)\right]$
4. (2)x(3)
5. (1)-(4)
6. $\Sigma\, t^2$
7. $\Sigma\, t$
8. (2)x(7)
9. (6)-(8)
10. (5)-(9)
11. -(10)=k
12. $\overline{\ln(L_\infty - l_t)}$
13. (10)x(2)
14. (12)-(13)
15. $\ln L_\infty$ (See prev.#7)
16. (14)-(15)
17. (16)-(11)=t_o

Table 3. Average lengths, average ages and age compositions by gear for the various Subdivisions.

Sub-division	Month	Year	Gear	Average length	Average age	Per cent compositions by age groups 1-5	6-10	11-15	16-20	21-25
39	June	1949	trap	52.74	7.18	40	35	25	-	-
39	July	1961	trap	54.69	6.20	46	47	6	1	-
39	Aug.	1962	trap	51.25	5.25	74	24	2	-	-
39	June	1963	trap	53.07	5.90	40	59	1	-	-
39	July	1964	trap	49.22	5.38	63	35	1	-	-
39	July	1965	trap	49.39	5.37	65	34	1	-	-
40	Aug.	1954	trap	60.60	8.76	4	79	15	2	-
40	July	1961	trap	55.37	6.14	42	53	4	1	-
40	Aug.	1962	trap	51.16	5.20	72	28	-	-	-
40	July	1963	trap	60.17	7.16	16	79	4	1	-
40	July	1965	trap	55.97	6.39	33	64	3	-	-
41	June	1965	trap	51.81	6.10	42	57	1	-	-
42	Aug.	1954	trap	59.46	10.33	5	55	30	10	-
42	July	1961	trap	48.52	5.30	71	26	2	-	-
42	July	1963	trap	55.07	6.89	25	68	6	1	-
42	July	1964	trap	53.74	6.49	30	68	2	-	-
42	July	1965	trap	49.21	5.66	56	43	-	-	-
39	Aug.	1962	net	72.29	8.82	4	80	15	1	-
39	Sept.	1963	net	77.05	9.07	3	75	18	4	-
39	Sept.	1964	net	74.65	9.76	1	73	21	4	-
42	July	1964	net	74.79	10.23	1	68	26	5	-
42	July	1965	net	80.88	10.79	-	58	36	4	2
39	Aug.	1962	longline	71.71	10.47	7	47	34	9	2
39	June	1963	longline	73.11	10.10	2	61	27	10	-
39	July	1964	longline	73.26	10.42	1	57	32	10	1
39	July	1965	longline	67.07	9.33	7	64	21	8	1
42	Aug.	1962	longline	69.70	12.09	6	27	50	15	1
42	Jul.,Sept.	1965	longline	69.34	9.80	10	52	31	7	-
39	June	1963	linetrawl	56.01	6.76	21	72	6	1	-
41	Sept.	1947	linetrawl	61.29	9.43	10	52	35	3	-
42	Aug.	1962	linetrawl	67.66	10.76	13	40	31	14	2
42	Jul.,Sept.	1965	linetrawl	67.23	9.68	13	52	23	12	1
39	June	1963	handline	54.00	6.44	26	69	5	-	-
40	Aug.	1962	handline	56.84	6.29	56	34	9	1	-
42	July	1963	handline	59.17	7.66	10	78	8	4	-
42	July	1964	handline	57.93	7.81	10	77	12	1	-
42	July	1965	handline	55.03	6.74	25	73	2	-	-
39	Aug.	1940	jigger	55.02	7.15	40	48	11	1	-
40	Aug.	1962	jigger	58.13	6.55	41	49	9	-	-
40	July	1963	jigger	58.85	6.91	17	77	6	-	-
42	July	1961	jigger	58.59	7.13	30	59	10	1	-
45	July	1950	otter trawl	54.63	6.28	42	50	7	-	-

Table 3 (continued)

Sub-division	Month	Year	Gear	Average length	Average age	Per cent compositions by age groups				
						1-5	6-10	11-15	16-20	21-25
42	Sept.	1950	otter trawl	60.70	8.62	6	77	16	1	-
42,45	comb.	1950	otter trawl	59.37	8.08	14	71	14	1	-
42	Sept.	1951	otter trawl	57.78	8.16	20	56	22	2	-
44	Sept.	1952	otter trawl	56.21	6.85	37	52	11	-	-
46,47	Oct.	1959	otter trawl	37.44	-	-	-	-	-	-
39, 43-47	Aug.	1960	otter trawl	46.85	5.45	67	24	9	-	-
41	Aug.	1962	otter trawl	58.49	8.54	28	46	18	8	1
42	Aug.	1962	otter trawl	54.22	7.02	44	40	12	3	-
42	Sept.	1962	otter trawl	60.29	8.45	28	43	25	-	-
41,42	comb.	1962	otter trawl	55.84	7.49	38	42	15	4	-
41	May	1963	otter trawl	50.09	6.38	30	63	6	1	-
42	May	1963	otter trawl	40.12	5.26	58	36	5	1	-
43	May	1963	otter trawl	49.72	6.60	28	64	6	2	-
44	May	1963	otter trawl	45.87	5.62	43	54	3	-	-
45	May	1963	otter trawl	46.60	5.61	42	55	2	1	-
47	Apr. May	1963	otter trawl	46.67	5.57	38	61	1	-	-
47	Sept.	1963	otter trawl	42.95	4.55	67	32	-	-	-
41-45, 47	comb.	1963	otter trawl	45.90	5.68	42	55	2	1	-
47	Apr.-May	1964	otter trawl	42.28	4.87	75	25	-	-	-
47	Oct.	1964	otter trawl	53.70	5.50	53	42	4	1	-
47	comb.	1964	otter trawl	42.67	4.89	74	26	-	-	-

Table 4. Percentages of cod infested by Lernaeocera.

Subdivision	Year	Months	Gear	Number of fish	% Infested
39	1949	June-July	Trap	165	10.9
39	1962	Aug.	Trap	170	7.1
39	1961,63-65	June-July	Trap	766	11.2
39	1962,64	Aug.-Sept.	Net	321	2.2
39	1962	Aug.	Longline	113	1.8
39	1963-65	June-July	Longline	494	3.4
39	1949	July	Linetrawl	55	9.1
39	1963	June	Linetrawl	119	9.2
39	1963-65	June-July	Handline	276	7.6
40	1962	July-Aug.	Trap	96	8.3
40	1961,63,65	June-July	Trap	529	9.6
40	1962	Aug.	Linetrawl	52	0.0
40	1962	Aug.	Handline	103	2.9
40	1962	Aug.	Jigger	114	7.9
41	1965	June-July	Trap	125	21.6
41	1947	Aug.-Sept.	Linetrawl	220	6.4
42	1961,63-65	July-Aug.	Trap	662	7.4
42	1964-65	July	Net	185	1.1
42	1965	July,Sept.	Linetrawl	241	5.0
42	1965	July-Sept.	Longline	219	0.5
42	1963-65	June-July	Handline	499	5.4
42	1961,65	June-July	Jigger	135	3.0
41	1963	Apr.-May	Otter trawl	125	7.2
42	1950-51	Sept.	Otter trawl	240	2.2
42	1963	Apr.-May	Otter trawl	305	6.9
43	1963	Apr.-May	Otter trawl	794	3.3
44	1952	Sept.	Otter trawl	237	3.4
44	1963	Apr.-May	Otter trawl	120	1.7
45	1950	July	Otter trawl	120	0.8
45	1963	Apr.-May	Otter trawl	165	1.8
47	1963-64	Apr.-May	Otter trawl	1908	1.5
47	1963-64	Apr.-May	Otter trawl	1645	1.6

Table 5. Numbers and percentages by age group of cod infested by Lernaeocera.

Sub-Division	3-4 No.	3-4 %	5 No.	5 %	6 No.	6 %	7 No.	7 %	8-13 No.	8-13 %
39	295	10.5	346	12.7	334	10.5	241	12.0	315	4.4
40	162	12.4	233	8.6	217	9.6	119	5.0	148	4.1
41	8	0	44	29.6	35	31.4	21	4.8	16	12.5
42	142	6.3	292	9.3	328	8.5	247	5.7	470	3.1

Table 6. Vertebral averages and standard errors of the mean of cod samples collected in Division 3K from various gears and in various years during the period 1947-1965.

Gear	Sub-division	Year	No.	$\bar{X}$	$S_{\bar{x}}$	$\bar{X}+2S_{\bar{x}}$	$\bar{X}-2S_{\bar{x}}$
Otter trawl	41	1963	105	54.238	.105	54.448	54.028
Otter trawl	42	1962,63	264	54.186	.065	54.316	54.056
Otter trawl	45	1963	115	54.278	.070	54.418	54.138
Otter trawl	43	1963	565	54.235	.038	54.311	54.159
Otter trawl	45	1950	116	54.353	.084	54.522	54.185
Otter trawl	47	1963,64	1076	54.257	.026	54.309	54.205
Otter trawl	42	1951	96	54.417	.089	54.595	54.239
Otter trawl	44	1952	222	54.360	.058	54.477	54.244
Otter trawl	43	1952	117	54.436	.087	54.610	54.262
Otter trawl	42	1950	116	54.491	.090	54.671	54.312
Otter trawl	44	1952	103	54.534	.087	54.708	54.360
Otter trawl	42	1951	95	54.526	.078	54.682	54.370
Net	42	1964-65	110	53.055	.097	53.249	52.861
Net	39	1964	114	53.417	.106	53.629	53.205
Trap	40	1963	104	53.615	.115	53.845	53.385
Trap	41	1965	117	53.590	.097	53.784	53.396
Jigger	40	1963	109	53.725	.104	53.933	53.517
Longline	39	1963-65	223	53.857	.072	54.001	53.713
Trap	39	1961-65	212	53.929	.076	54.083	53.775
Handline	39	1963-65	200	53.950	.070	54.090	53.810
Trap	42	1961-65	250	54.072	.064	54.200	53.944
Linetrawl	39	1949	52	54.250	.131	54.512	53.988
Trap	39	1949	146	54.260	.089	54.438	54.082
Linetrawl	41	1947	211	54.218	.059	54.336	54.100
Trap	42	1954	105	54.286	.092	54.470	54.102
Handline	42	1963-65	234	54.252	.060	54.372	54.132
Linetrawl	39	1963	110	54.327	.086	54.499	54.155
Trap	40	1964	219	54.311	.066	54.443	54.179
*	39	1960's	635	53.910	.042	53.994	53.826
*	40	1960's	213	53.671	.077	53.825	53.517
*	42	1960's	589	54.182	.040	54.261	54.102

* Combinations of various gears. See text.

Table 7. Percentages of mature and immature cod by sex for various time periods. The June-July sample is from inshore gears, but all other samples are from otter trawls.

Month	Males			Females		
	Number Examined	% Mature	Doubtful this year will spawn next year	Number Examined	% Mature	Doubtful this year will spawn next year
Apr.-May	1344	35	10	1814	29	-
June-July	1018	52	9	1132	46	-
Aug.-Sept.	507	36	17	607	47	1
Oct.	186	52	12	199	21	31

Table 8. Percentages by sex of mature cod spawning and pre-spawning and with spawning completed. The June-July sample is from inshore gears but all samples are from otter trawls.

Month	Males		Females	
	% Spawning & Prespawning	% Spawning Completed	% Spawning & Prespawning	% Spawning Completed
Apr.-May	25	75	16	84
June-July	13	87	17	83
Aug.-Sept.	3	97	1	99
Oct.	-	100	-	100

Table 9. Percentages of male cod, observed ^{2}, and expected ^{2} at the 5% level for various times periods. The June-July sample is from inshore gears but all other samples are from otter trawls.

Month	Number Males	% Males	Observed χ^2	χ^2 .05, =1
Apr.-May	1344	43	69.95	3.84
June-July	1018	47	6.04	3.84
Aug.-Sept.	507	46	8.98	3.84
Oct.	186	48	.44	3.84
Total	3055	45	71.37	3.84

Table 10. Percentages by sex of mature cod over the range of ages in which they mature.

Age	Mature Males	Mature Females
4	0	0
5	8.61	2.33
6	54.43	24.83
7	91.15	70.05
8	95.65	93.75
9	100.00	100.00

Table 11. The age at 50% maturity (M_{50}), the slope (m), the standard error ($S_{\bar{x}}$), and the chi-square for the computed lines representing the incidence of sexually mature male, female, and male and female combined cod in Division 3K.

Sex	Number Examined ages 4-9	M_{50}	$S_{\bar{x}}$ (M_{50})	m	$S_{\bar{x}}$ (m)	Observed$_2$	D.F.	χ^2(.05)
Male	1120	6.08	.040	1.263	.110	5.412	2	5.991
Female	1525	6.47	.039	1.213	.025	.273	2	5.991
Total	2645	6.34	.029	1.164	.038	1.925	3	7.815

APPENDIX III - BRIEF DESCRIPTION OF INSHORE GEARS

Trap - See Ronayne (1956) in Canada Department of Fisheries, Trade News, 9(4): 3-7 for a description.

Gillnet - This is a rectangular nylon fishing net in which the fish is caught around the gill covers or other parts of the body. In Division 3K it is usually 50 fathoms long and 2 fathoms deep and can be set on the bottom or at the surface.

Longline - This consists of a long main line to which are attached, at intervals of about 6 feet, short lines(gangings) 2-3 feet in length which are equipped with baited hooks. The main line is usually set along the bottom, and may extend for several miles. Such a long main line requires a fairly large boat (25 tons or more) equipped with a mechanical hauler.

Linetrawl - Really the same type of gear as longline but fished from a small boat and hauled by hand.

Handline - A single line equipped with one or two baited hooks and hauled by hand.

Jigger - A single line fitted with a double unbaited hook and hauled by hand.

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