THE BIOLOGY AND FISHERY OF THE GREENLAND HALIBUT (REINHARDTIUS HIPPOGLOSSOIDES (WALBAUM)) IN THE NEWFOUNDLAND AREA

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The biology and fishery of the Greenland halibut (*Reinhardtius hippoglossoides* (Walbaum)) in the Newfoundland area

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ABSTRACT

Various aspects of the biology of the Greenland halibut stock in the Newfoundland-Labrador area were investigated. The distribution of Greenland halibut in relation to depth and temperature is described for several areas. The largest concentrations were found to be in depths of 150 and 325 fathoms and temperatures from 1° to 3°C.

The food of Greenland halibut is discussed in relation to half-monthly periods, depth and fish length. Capelin is the major food of Greenland halibut larger than 20 cm with euphausiids being the major food below 20 cm.

The age and growth patterns, and length-weight relationships for several areas are described as well as evidence supporting the validity of the otolith ageing technique. The growth rate of Greenland halibut decreases from south to north possibly because of the cold Labrador Current in the northern areas. The growth rate of Greenland halibut in Trinity Bay has increased since 1953 possibly because of an increase in temperature in this area and also because of a decrease in numbers resulting from the high fishing intensity in Trinity Bay during 1964-68.

Estimates of total and annual mortality rates are calculated for each area under consideration. Sufficient time had not elapsed since the increase in effort in Trinity Bay for the expected increase in total mortality to be reflected in the catch curves at the time of sampling.

CONTENTS

INTRODUCTION

The range of the Greenland halibut (<u>Reinhardtius hippoglossoides</u> (Walbaum)) in the Northwestern Atlantic extends from the Arctic regions of the Atlantic southwards to the Grand Banks off Newfoundland (Norman, 1934). Leim and Scott (1966), quoting Breder (1929), extend the range southwards to the deep waters off New Jersey but this is an error since Breder (1929) referred to Atlantic halibut and not Greenland halibut. Schroeder (1953) reports that 20 Greenland halibut were caught on Georges Bank and 1 off La Have Bank, the former being the most westerly record. The depth range was 305-530 fathoms, the size from 13 to 36 inches long. However, it has been reported as an occasional stray in the Gulf of Maine (Boyar, 1964), four specimens being captured in 35-55 fathoms, when the water temperatures in the area of capture were 1.5° to 2.5°C. lower than in the previous three years. Barrett (1968) reported an occurrence of Greenland halibut in the Bay of Fundy when the bottom temperature in the month of capture was 0.8°C.; this was the lowest recorded since 1959 and prior to that since 1948. He attributed the occurrence in the Bay of Fundy to the low temperatures, higher and stable salinities and large concentrations of food during this period. Dunbar and Hildebrand (1952) report that 29 small Greenland halibut were taken from stomachs of Atlantic cod at Port Burwell, Ungava Bay in August 1947. Templeman and Squires (MS, 1960) report that Greenland halibut was the dominant fish occurring in otter-trawl catches between Cape Dyer and Cape Mercy, Baffin Island. Catches up to 500 lb per half-hour's drag were usually obtained at 300 fathoms and bottom temperatures between 1° and 2°C.

Greenland halibut prefer cold, deep water and are generally found in depths from 100 to 600 fathoms. The best commercial catches in the Newfoundland area are taken between 150 and 270 fathoms and bottom temperatures between 1.2° and 2.5°C.

The aim of this study is to describe in detail the biology of Greenland halibut in the Newfoundland area with respect to distribution, food and feeding, age and growth and mortality.

The common name, Greenland halibut, as recommended and adopted by the American Fisheries Society and as accepted by the International Commission for the Northwest Atlantic Fisheries (ICNAF), International Commission for the Exploration of the Sea (ICES), International North Pacific Fishery Commission (INPFC), and the Food and Agricultural Organization of the United Nations (FAO), will be used throughout this study when referring to *Reinhardtius hippoglossoides*.

HISTORY OF THE FISHERY

Introduction

No account of Greenland halibut being caught in Newfoundland is given by early historians such as Anspach (1827), Tocque (1878), Hatton and Harvey (1883) or Prowse (1896). Bonnycastle (1842) states that, "turbot (P. maximus) is very rare, but the halibut (the *hyppoglassus vulgaris* of Cuvier) is common enough to embarrass the fishermen who detest it for the trouble it gives". The turbot referred to here is an European species of the subfamily Scophthalminae and only inhabits the coasts of Europe, from Scandinavia to the Mediterranean; and Iceland, (Norman, 1934), and is not the locally called turbot or Greenland halibut found in the

Newfoundland area. There is no record of Greenland halibut occurring as incidental catches in the codfishery in these earlier years. However, they probably were caught in the deeper bays when the fishermen set their lines in deeper water in the autumn as the cod moved offshore. As a consequence there must have been some local consumption of Greenland halibut.

Trends in Landings and Values (1857-1968)

The first record of Greenland halibut being sold appears in the customs returns for 1857 in which year 2 barrels and 8 kegs (1800 pounds, round fresh), valued at $18 were exported (Table 1). The quantity and the value of Greenland halibut exported remained very low until 1916 when 1.3 million pounds were exported at a value of $31,424. The landings from 1916 until 1964 fluctuated between 500 thousand and 2 million pounds. The Greenland halibut fishery was a traditional line one using capelin, squid and herring for bait. The chief areas of operation were Trinity, Green, Fortune and White bays. The Fortune Bay fishery was mainly a winter-spring fishery (Templeman, 1966).

The fish were salted in barrels and exported mainly to logging camps in Quebec and the Maritimes with smaller quantities going to the United States, British West Indies and St. Pierre. This method of curing had a great disadvantage since the fish is very fatty and does not keep well in warm weather, thus limiting the fishery to the cooler seasons.

In 1901 the first shipment of fresh Greenland halibut was exported to the United States. These fish were packed in barrels in chopped ice. Small quantities of Greenland halibut were smoked and exported mainly to the United States and Canada.

In 1964 the catch of Greenland halibut increased from the usual 1-2 million pounds to 4 million pounds. Part of the reason for this increase was the utilization of Greenland halibut for fresh frozen fillets and fish blocks, most of which were exported to the United States with small quantities being sent to Europe. At present there is a fair quantity of the larger-size Greenland halibut (4.4 pounds and over) which are gutted, trimmed and frozen and exported to Germany where they are smoked.

Only a small part of the catch is now salted, the main area for this operation being in Green Bay.

The landings of Greenland halibut kept increasing from the 1964 level until 1967 when they reached 36.6 million pounds (Fig. 2) with a landed value of 1 million dollars (Fig. 3).

Introduction of Gillnets

The introduction of synthetic gillnets by the Industrial Development Service of the Department of Fisheries of Canada and the Newfoundland Fishery Development Authority of the Department of Fisheries of Newfoundland in an experimental venture in 1960 (Fleming, 1964) caused many fishermen to become interested in obtaining synthetic nets. With the increased use of these nets in Trinity Bay from 1963 onwards, the use of longlines decreased until by late 1967 they were completely phased out by Greenland halibut fishermen. The Green Bay fishery, however, still uses longlines. The gillnets which were first used were 6", 6½" and 7" mesh (stretched) ulstron but as the smaller fish became scarcer, larger mesh sizes of 8" and 9" were introduced in 1967 so

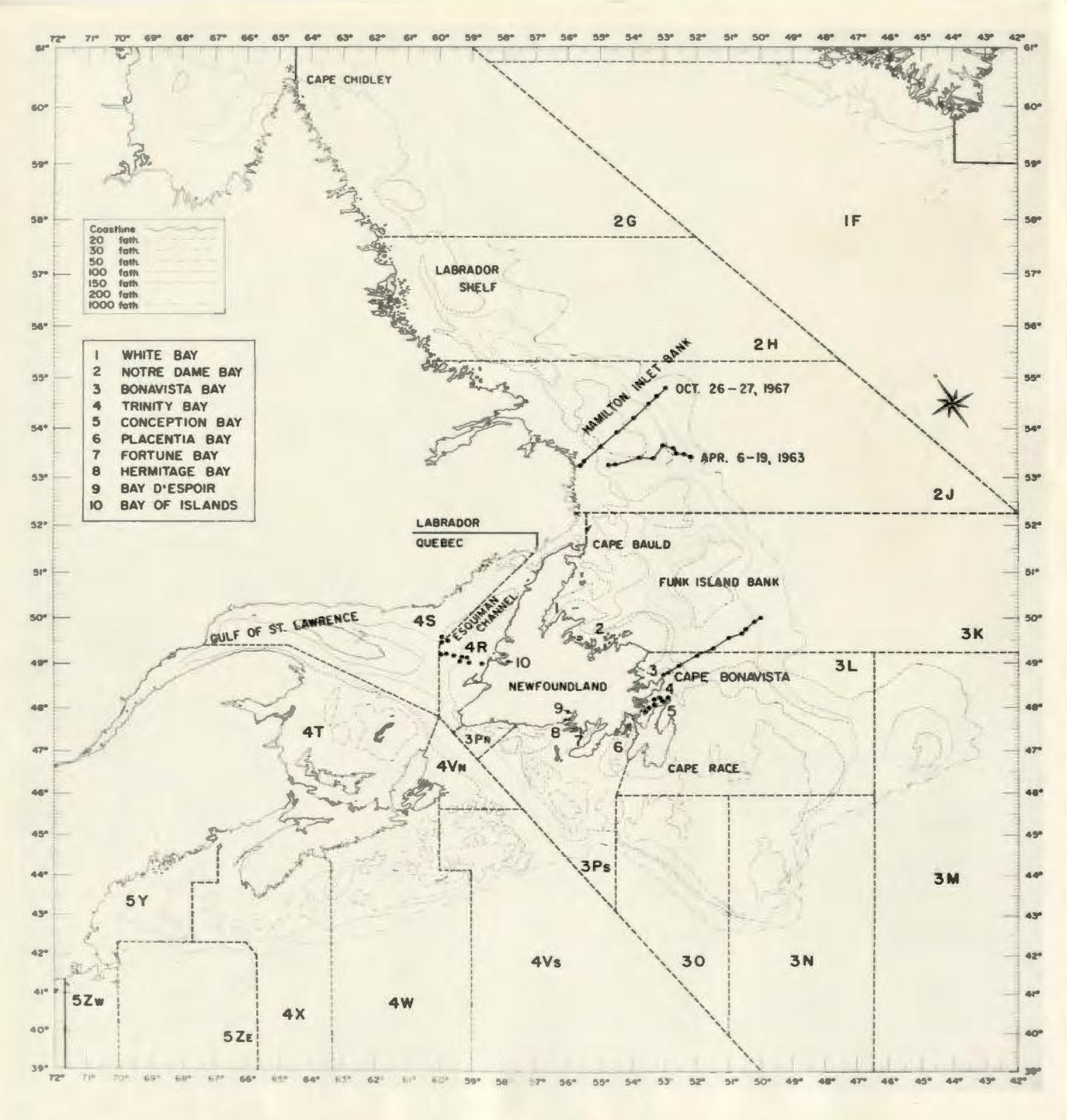

Fig. 1. Area map showing ICNAF subareas and divisions, hydrographic stations (black dots) and place names mentioned in the text.

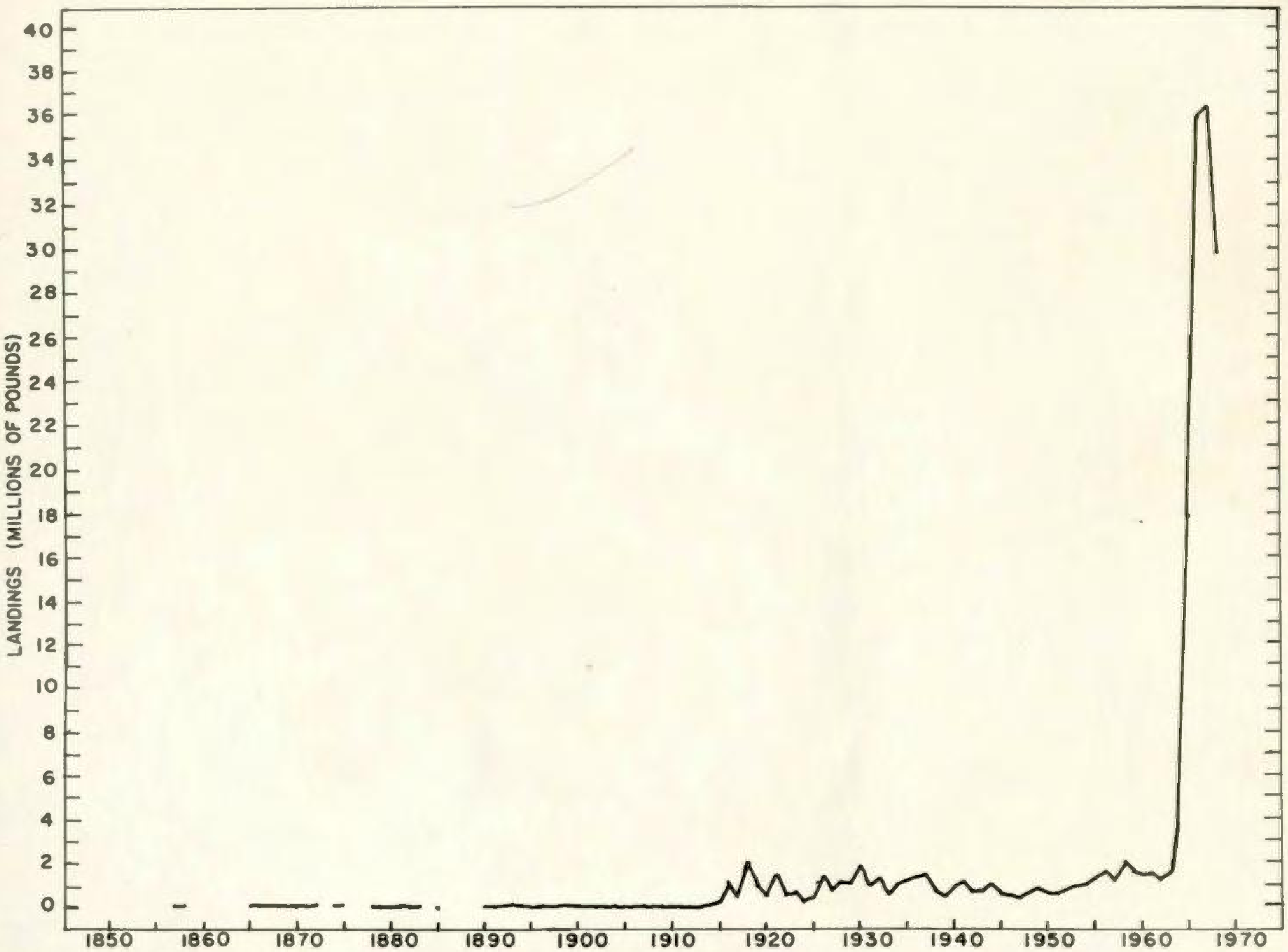

Fig. 2. Annual landings of Greenland halibut from the Newfoundland area during 1857-1968.

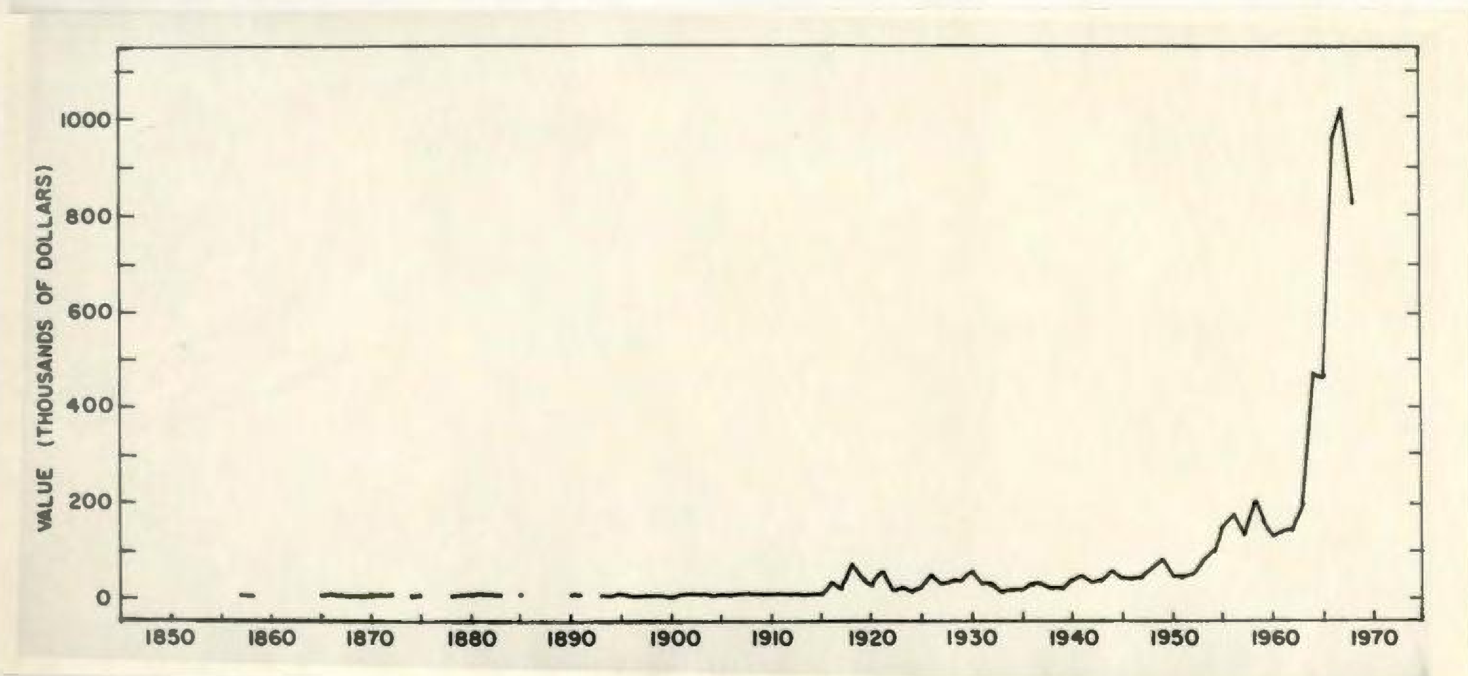

Fig. 3. Annual values of Greenland halibut landed in the Newfoundland area during 1857-1968.

that by 1968 these larger mesh nets were predominant.

Monofilament nylon nets were introduced in 1966 and by late 1967 the ulstron nets were largely replaced by monofilament. The fishery in Trinity, Bonavista and Notre Dame bays now uses 7"-9" monofilament nylon gillnets. There has recently been a trend towards use of smaller mesh nets as the larger Greenland halibut are less abundant and also because of increased fishing intensity on flounder and cod.

Catch per unit effort in Trinity Bay (1966-69)

There has been a considerable decrease in the catch per unit effort in Trinity Bay since the increased fishing intensity began in 1965. The average catch per 50-fathom gillnet decreased from 348 pounds (round weight) in 1966 to 150 pounds in 1967 and to 51 pounds in 1969 (Fig. 4). The average catch per 50-fathom line (50 hooks) decreased from 53 pounds (round weight) in 1966 to 44 pounds in 1967 (Fig. 5). There is a seasonal fluctuation in catch per effort with good catches in the early part of the year

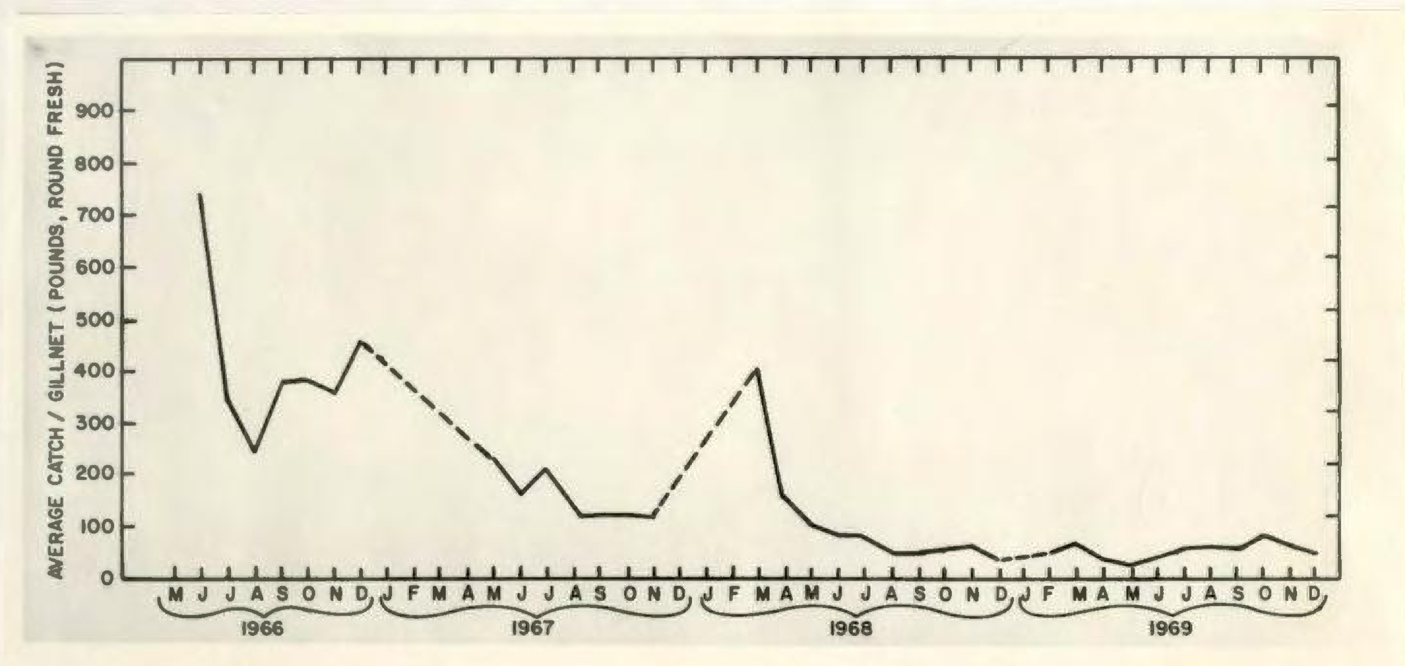

Fig. 4. Average catch of Greenland halibut per 50-fathom gillnet by monthly periods in Trinity Bay during 1966-69.

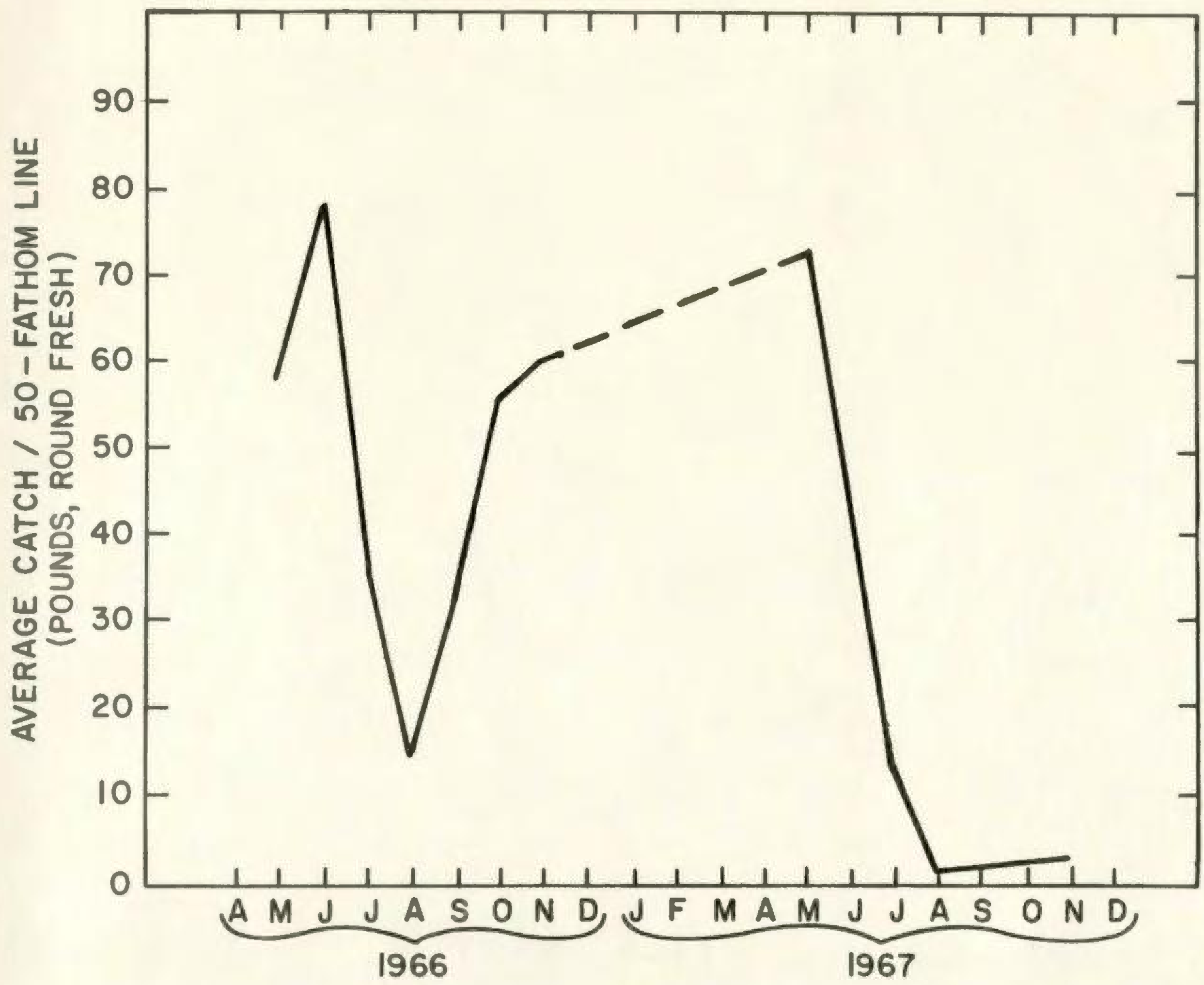

Fig. 5. Average catch of Greenland halibut per 50-fathom line by monthly periods in Trinity Bay during 1966-67.

probably due to decreased fishing intensity in the winter months and the congregation of the fish in deeper warmer water during the winter months.

As a result of reduced catches in Trinity Bay the Trinity Bay boats began fishing for Greenland halibut in Bonavista Bay in 1967 and Notre Dame Bay and White Bay in 1968. Good catches were obtained in Bonavista Bay during 1967 and early 1968, in Notre Dame Bay and White Bay during 1968 and 1969. The catches in Bonavista Bay and White Bay decreased in late 1968 and 1969 respectively.

Landings from the ICNAF Area by Country

The landings of Greenland halibut from ICNAF Subareas 1, 2, 3 and 4 (Fig. 1) for the period 1961 to 1968 are shown in Fig. 6 and Table 2. Newfoundland landings, almost all from east coast bays, mainly Trinity Bay, comprised 42-77% of the total in 1965-68. The Danish landings were mainly from longlines in West Greenland fjords with the Polish landings being from otter trawlers fishing in ICNAF Division 3K (mainly from Funk Island Bank (Chrzan, 1967)) and ICNAF Divisions 2H and 2J, off Northern Labrador and on Hamilton Inlet Bank, respectively. In 1968 Newfoundland's

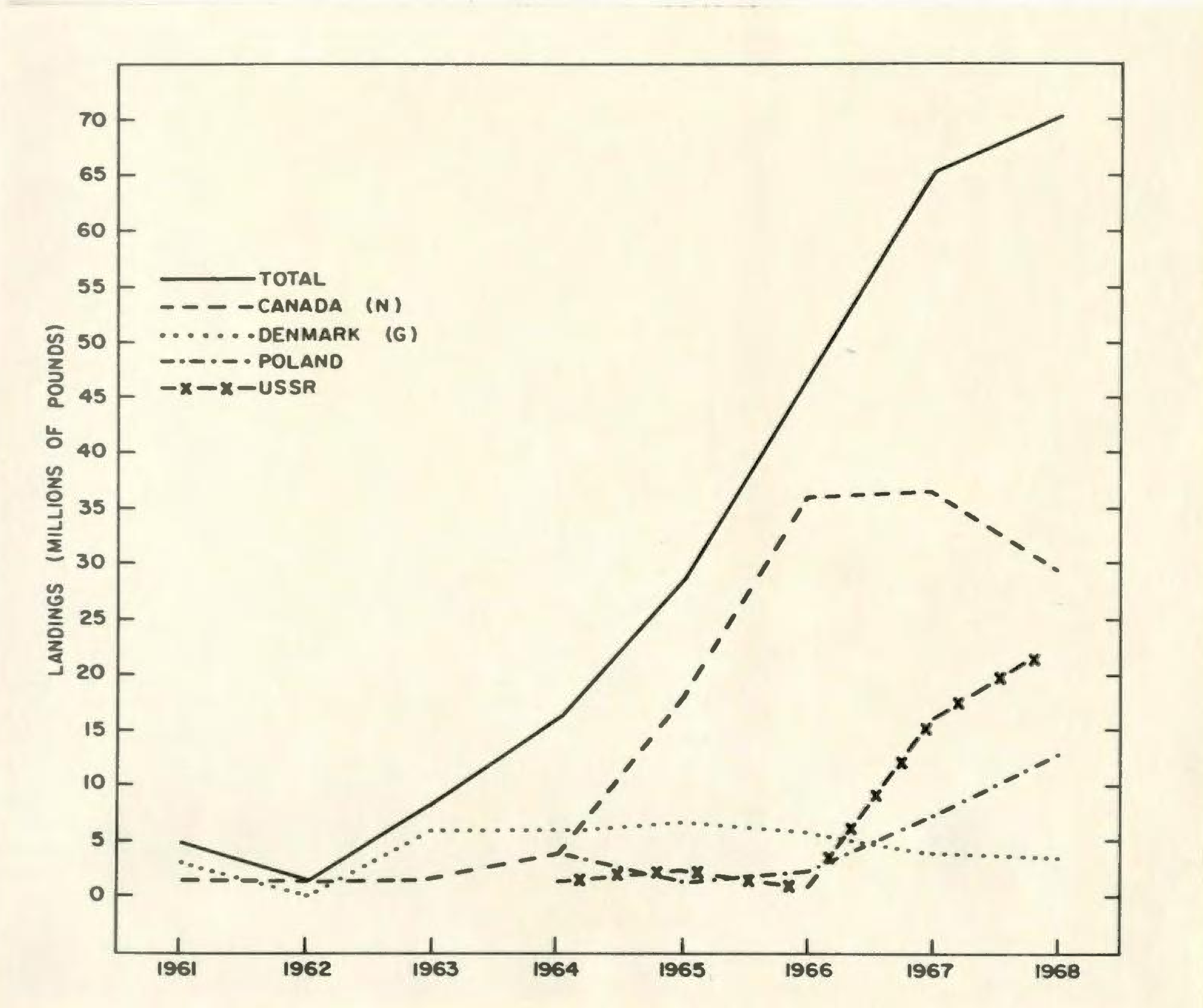

Fig. 6. Annual landings of Greenland halibut from ICNAF Subareas 1, 2, 3 and 4 by country during 1961-68.

landings dropped while those of Poland increased.

Large catches of Greenland halibut were evidently also made by the U.S.S.R. However, the U.S.S.R. landings of Greenland halibut and Atlantic halibut are included in the preliminary ICNAF statistics as halibut. The Polish landings of Greenland halibut during the period 1964-68 inclusive averaged 93% of the combined halibut landings. The Polish and Russian ships were fishing in the deeper waters and in the same areas. The Russian landings of Greenland halibut from 1964 to 1968 have been estimated by applying the Polish percentage to the Russian halibut landings. Previous to 1964 landings of halibut by both countries were very small. The Russian landings of Greenland halibut increased from 1.6 million pounds in 1964 to 15.9 million pounds in 1967. In 1968, including the 3.2 million pounds caught near Baffin Island the Russian landings were 22.7 million pounds (Table 2, Fig. 6).

METHODS AND MATERIALS

Distribution in the Newfoundland Area

The data on the distribution of Greenland halibut in Newfoundland were collected by gillnet and longline surveys by the M.V. Marinus during 1966-69 and by otter-trawl surveys by the A.T. Cameron during 1966-68.

On the longline surveys 32 lines of No. 18 tarred nylon, each 50 fathoms long were used in each set. No. 6/0 Pflueger hooks were attached by No. 4 tarred nylon gangings every 6 feet giving a total of 1600 hooks per longline. The hooks were baited with capelin except for five sets when they were baited with capelin and squid. The lines were allowed to lie on the bottom for approximately 2 hours before being hauled back. The fish were measured in baskets and the weight of the catch was determined by multiplying the number of baskets of Greenland halibut by 95 pounds. The unit of effort for longlines is in terms of catch in pounds/32 lines/hour.

The gillnets used in the survey were 6", 7" and 8" mesh monofilament nylon. These were 50 fathoms long and 25 meshes deep. The headline was braided nylon rope with torpedo or cylindrical style polystyrene plastic floats spaced every 2½ fathoms. The footrope was composed of a core of lead covered with interwoven, braided nylon. Two sizes of mesh were used during each 1966-68 trip while three sizes were used on the south coast trip during September 1969, with the nets of different mesh sizes being strung together alternately. The nets were set and hauled the following day if circumstances permitted. The fish from each mesh size were kept separate, measured in baskets and weights determined as above. The gillnet unit of effort is in terms of catch in pounds/gillnet/24 hours. The A.T. Cameron surveys used a No. 41.5 standard otter trawl with a 1 1/8" nylon liner. The drags were of 30 minutes duration. The catch per effort in relation to depth and temperature is in terms of catch in pounds/ one-hour drag.

Food and Feeding

The stomach samples were collected from Trinity Bay (Division 3L) during the otter trawl, gillnet and longline surveys and from the commercial catches. The stomachs were collected on the cruises at every depth fished. Where possible, up to five stomachs were collected from each 10-centimetre length group at each depth. The stomachs from the commercial catch were collected during the commercial fishery but in many cases the depths were not known and these are not included in the percentage volume or occurrence versus depth data. The stomachs were tied off at the oesophagus, tagged and preserved in 10% formalin solution. The volume of each type of food in the stomach was measured at the Biological Station by using a graduated cylinder.

The volume of a particular food type was expressed as a percentage of the total volume of food at a particular length group, depth range or half-monthly period.

The occurrences of a type of food were expressed as percentages of the total number of fish with food in the stomach at each length group, depth range or half-monthly period.

Temperature

The temperature cross sections of Hamilton Inlet Bank, Trinity Bay and the Gulf of St. Lawrence were prepared from data collected on survey cruises on the FRB research vessels Marinus and A.T. Cameron.

The positive and negative temperature anomalies on the Cape Bonavista hydrographic section (from Templeman (unpublished data)) were calculated for each year from 1950 to 1965 and are based on the average temperature for the period 1951-65.

Age and Growth

The materials used in this study were collected during survey cruises of the A.T. Cameron from 1966 to 1968, except one sample for 1953 which was collected in Trinity Bay (Division 3L) by the Investigator II. The A.T. Cameron used a No. 41.5 standard otter trawl with a 1 1/8" nylon liner while the Investigator used a No. 36 otter trawl when the 1953 sample was collected. The fish were measured randomly to the nearest centimetre from snout to mid-fork of the caudal fin, sexed and subsampled for otoliths, sexual maturity, and where possible for whole and gutted weights.

Collections ranged over all months of the year except February, September and December. To compensate for seasonal growth differences and avoid an error of 1 year being made in ages in September-December, the presence of opaque or translucent bands in the otolith edges was recorded and January 1 regarded as the "birthday of the fish". Since all of the samples from Subarea 2 were caught in October, the otolith ages are in error by ¾ years. To compensate for seasonal differences of this type, in preparing the growth figures ¼ year has been added to the calculated otolith age for each quarter year beyond January-March. This was necessary to make the growth curves for different areas comparable.

For Division 3K, since the number of fish was less than 100, the fish of age 9 and older from the 8" mesh gillnets were included in the 3K growth curve since at this age 100% of the fish were completely vulnerable to the gear. Selecting only those fish age 9 and over would remove the bias caused by the faster growing fish being selected.

Since the females live longer and grow larger than the males, the growth curves of both sexes are treated separately.

The left sacculus otolith was more suitable for age reading than the right because the rings are spaced more evenly and are more distinct. The otolith was ground on its convex surface by a fine grit, revolving, horizontal carborundrum stone powered by an electric sewing machine motor. The otolith was then placed in a black watch glass containing ethyl alcohol, which made the hyaline zones more distinct. The ages were determined by observing the otolith through a microscope set at a magnification of 10x to 15x. The interpretation of the otolith age was sometimes difficult especially for fish over 10 years old when the hyaline and opaque zones are narrow and very close together and the ages of these older fish may be in error $\pm$ one or two years as a result.

The length compositions of the different areas are combined by 3-cm length groups for each subarea or division under consideration. The age distribution in each subarea or division is presented graphically in percentage values.

Growth was expressed in terms of the von Bertalanffy (1938) growth equation

$$l_t = l_\infty (1-e^{-K(t-t_0)})$$

where l_t is the mean fork length at age t years, l_∞ is the "maximum" or asymptotic length, K is a constant determining the rate of change in length increment and t_0 is the theoretical age at which the fish would be zero years (arbitrary origin of growth curve). Growth curves were fitted using the least-squares method (Allen, 1966).

Length and weight data were collected from survey cruises in Subarea 2 during 1966-67, Division 3L during 1953, 1966-68, Division 3P during 1967-68 and from Subarea 4 during 1968. The weights were obtained to the nearest ounce except for the smaller fish (less than 4 ounces), which were weighed to the nearest gram. All the weights used in the computations of the length-weight curves were converted from pounds and ounces or grams to pounds expressed to the nearest hundredth. The length was measured as fork length to the nearest centimetre. Length-weight keys were used to calculate the length-weight curves. The length-weight relationships were obtained by using the equation

$$W = CL^b$$

where W = weight, L = length, and C and b are constants. The least squares regression of the logarithmic transformation

$$Y = a+bx,$$

in which $Y = \log_{10}W$, $a = \log_{10}C$ and $x = \log_{10}L$, was used for estimating the values of C and b (Snedecor, 1956).

Age Validation

The seasonal changes in the otolith edge deposition were recorded when the ages were read to give an indication of the seasonal growth pattern of the fish. The modal lengths of the otolith ages were compared with the modes in the length distribution to validate the otolith ages from Subarea 2. Also the age distributions for two successive years (1966-67) in Subarea 2 were plotted graphically to illustrate the 1965 year-class dominance in each year. Also 0^+ - age group fish were collected from cod stomachs in Subarea 2 and used as further evidence of otolith age validation. Representative otoliths of age groups 0^+ to 6 years inclusive were photographed to show annual growth zones.

Estimates of Total Mortality (Z)

Estimates of total mortality (Z) for otter-trawl catches for ICNAF Subareas 2 and 4, and Divisions 3K, 3L (Trinity Bay), and 3P for 1966-68 and Division 3L (Trinity Bay) for 1953 were calculated from least squares regressions fitted to the descending limbs of catch curves based on the distribution of the natural logarithm of numbers at age (Ricker, 1958). Trinity Bay samples of 1953 and 1966-68 were compared to determine the change in total mortality during that period. The mortality rates for some of the areas may be in error in view of the small numbers of fish and also the possibility of error in reading the ages of the older fish.

RESULTS

Distribution in the Newfoundland Area

The catches/32 lines/hour for White Bay, Notre Dame Bay and Trinity Bay are shown in Fig. 7. These catches were obtained by the M.V. Marinus during September 6 - December 2, 1966. The largest catches (500-750 pounds) in White Bay were in the northwestern part of the bay in 160-200 fathoms and bottom temperatures of 1.07 to 2.01°C. The largest catch in Notre Dame Bay was 219 pounds in 132-140 fathoms and bottom temperature of 0.68°C. In Trinity Bay the largest catches were 350-400 pounds in 188-310 fathoms and bottom temperatures of 2.67 to 2.81°C.

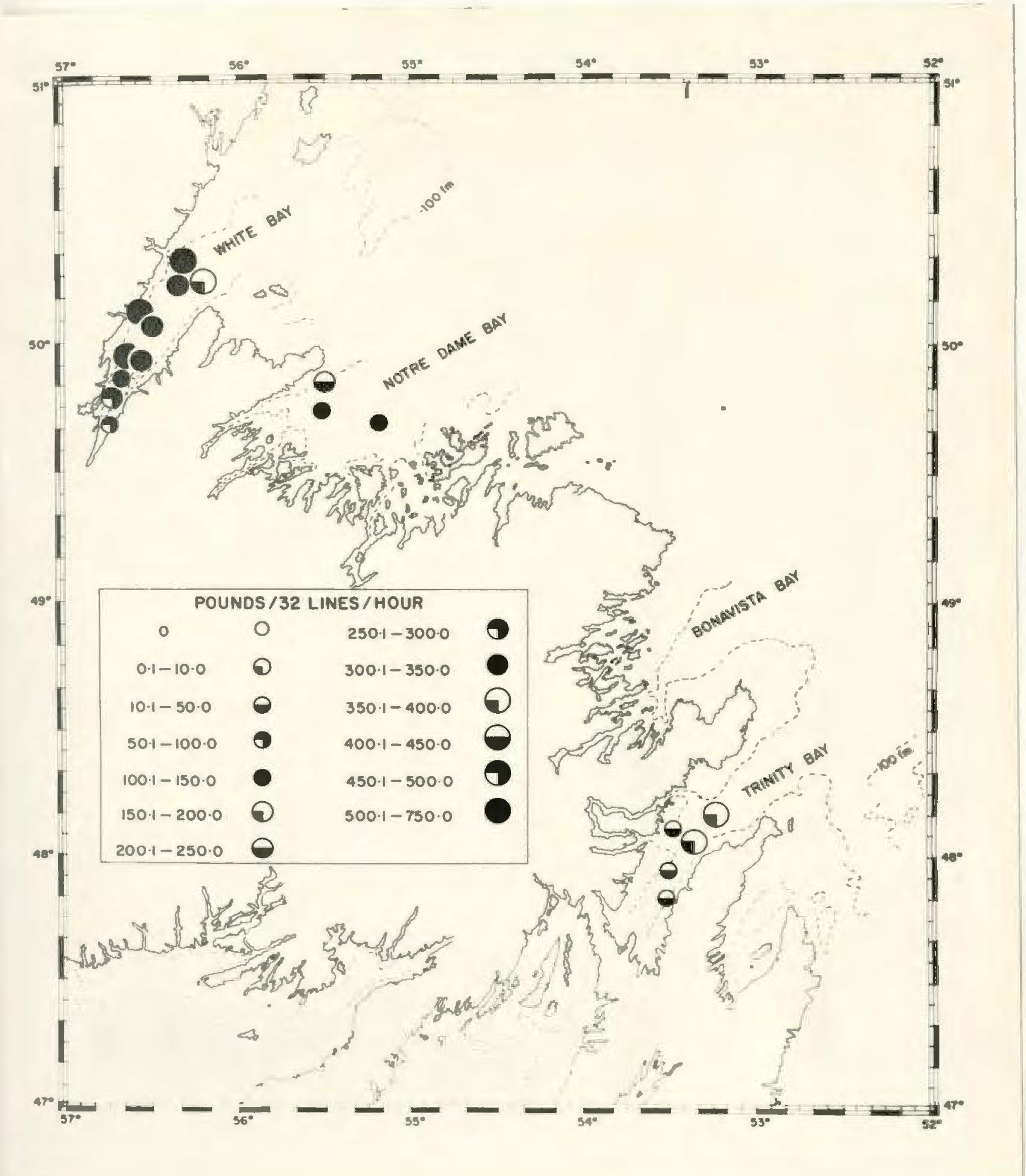

Fig. 7. Average catch of Greenland halibut per 32 lines per hour in White, Notre Dame and Trinity bays during 1966.

The catches per 6" gillnet in 24 hours for Trinity Bay during November 2 - December 6, 1966, Notre Dame Bay and Bonavista Bay during September 25 - October 17, 1968 and Fortune and Hermitage bays during September 15-30, 1969 are shown in Fig. 8. The largest catch (47 pounds) in Bonavista Bay occurred in a depth of 144-147 fathoms and bottom temperature of 0.27°C. The largest catches in Notre Dame Bay were 100-150 pounds in depths of 140-178 fathoms and bottom temperatures of -0.31° to -0.34°C. The largest catch in Trinity Bay was 260 pounds in 128-136 fathoms and bottom temperature of 2.13°C. The largest catch in Fortune Bay was 38 pounds in a depth of 262-268 fathoms and bottom temperature of 0.60°C. The largest catch in Hermitage Bay was 19 pounds in a depth of 200-235 fathoms and bottom temperature of 4.92°C.

The catches per 7" gillnet in 24 hours for Trinity Bay during November 2 - December 10, 1966, Notre Dame Bay during September 26 - October 5, 1967 and Fortune and Hermitage bays during September 15-30, 1969 are shown in Fig. 9. The largest catches in Notre Dame Bay were 466 and 398 pounds in depths of 165-171 and 185-190 fathoms

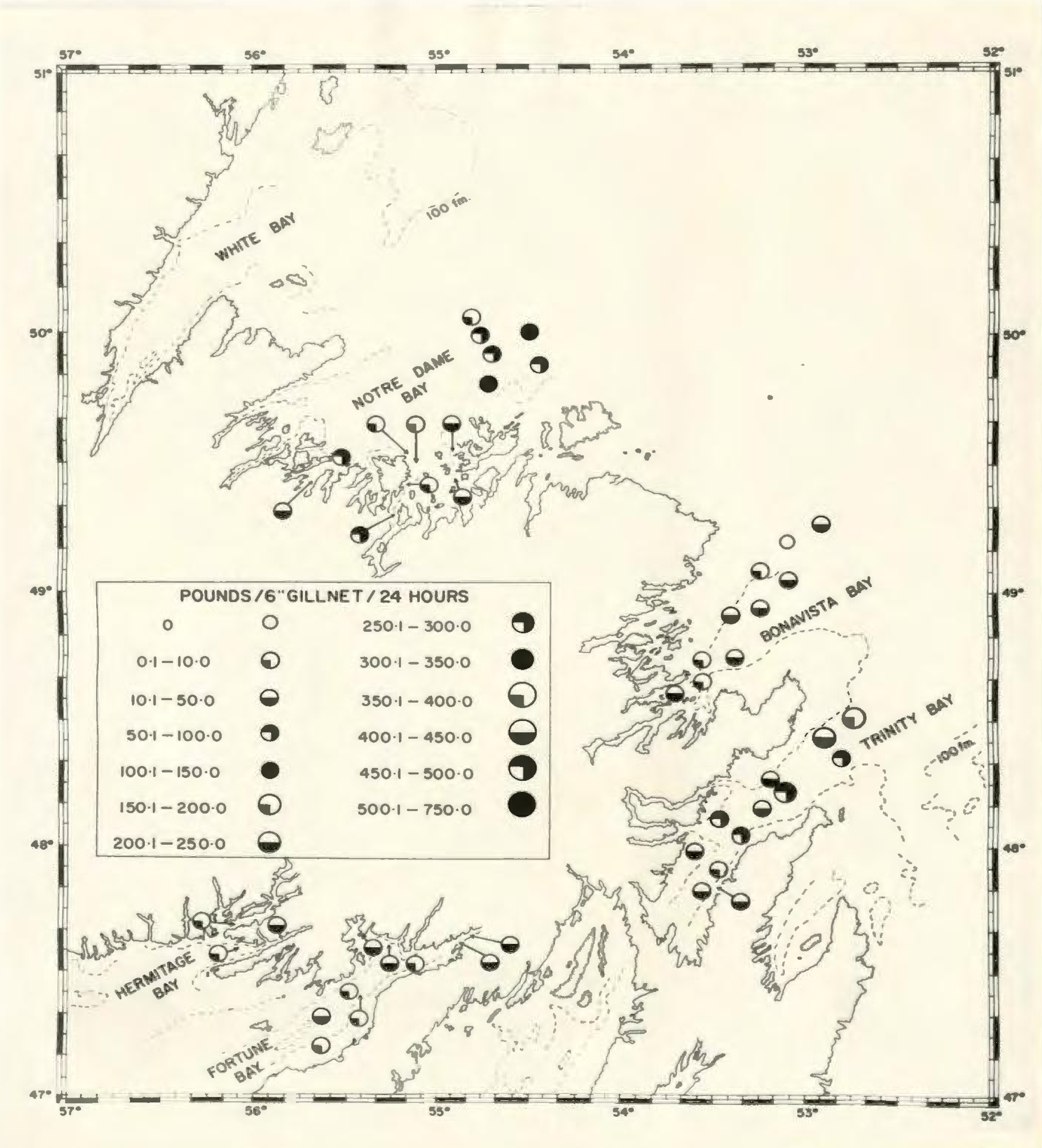

Fig. 8. Average catch of Greenland halibut per 50-fathom 6" gillnet in Notre Dame, Bonavista, Trinity, Fortune and Hermitage bays during 1966-69.

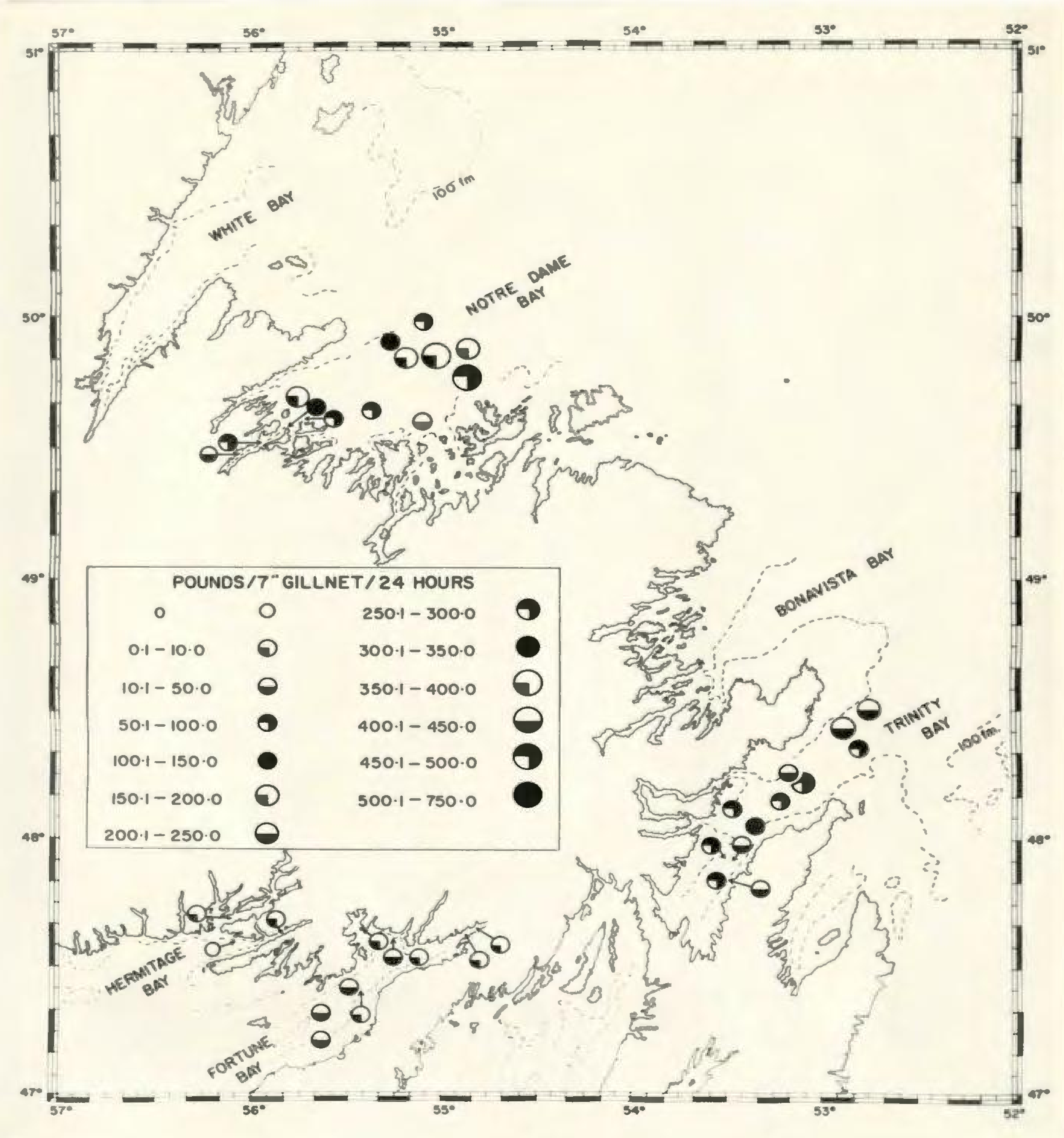

Fig. 9. Average catch of Greenland halibut per 50-fathom 7" gillnet in Notre Dame, Trinity, Fortune and Hermitage bays during 1966-69.

respectively and bottom temperature of 2.01°C. These good catches were obtained in the centre of the bay where the bottom contour slopes from 160 fathoms down to 200 fathoms. In Trinity Bay the largest catches were 294, 243 and 213 pounds in depths of 128-136, 140-145 and 150-152 fathoms and bottom temperatures of 2.13, 2.04 and 2.18°C. respectively. The largest catch in Fortune Bay was 38 pounds in a bottom depth of 262-268 fathoms and a bottom temperature of 0.60°C. In Hermitage Bay the largest catch (8 pounds) occurred in a depth of 200-235 fathoms and a bottom temperature of 4.92°C.

The catches per 8" gillnet in 24 hours for Notre Dame Bay during September 25 - October 2, 1968, Bonavista Bay during October 4-17, 1968 and for Fortune and Hermitage bays during September 15-30, 1969 are shown in Fig. 10. The largest catches in Notre Dame Bay were 204 and 154 pounds in depths of 178 and 200-228 fathoms and bottom temperatures of -0.34° and 1.85°C. respectively. The largest catch in Bonavista Bay was 35 pounds in 186-189 fathoms and bottom temperature of 0.25°C. The largest catch in Fortune Bay was 38 pounds in 262-268 fathoms

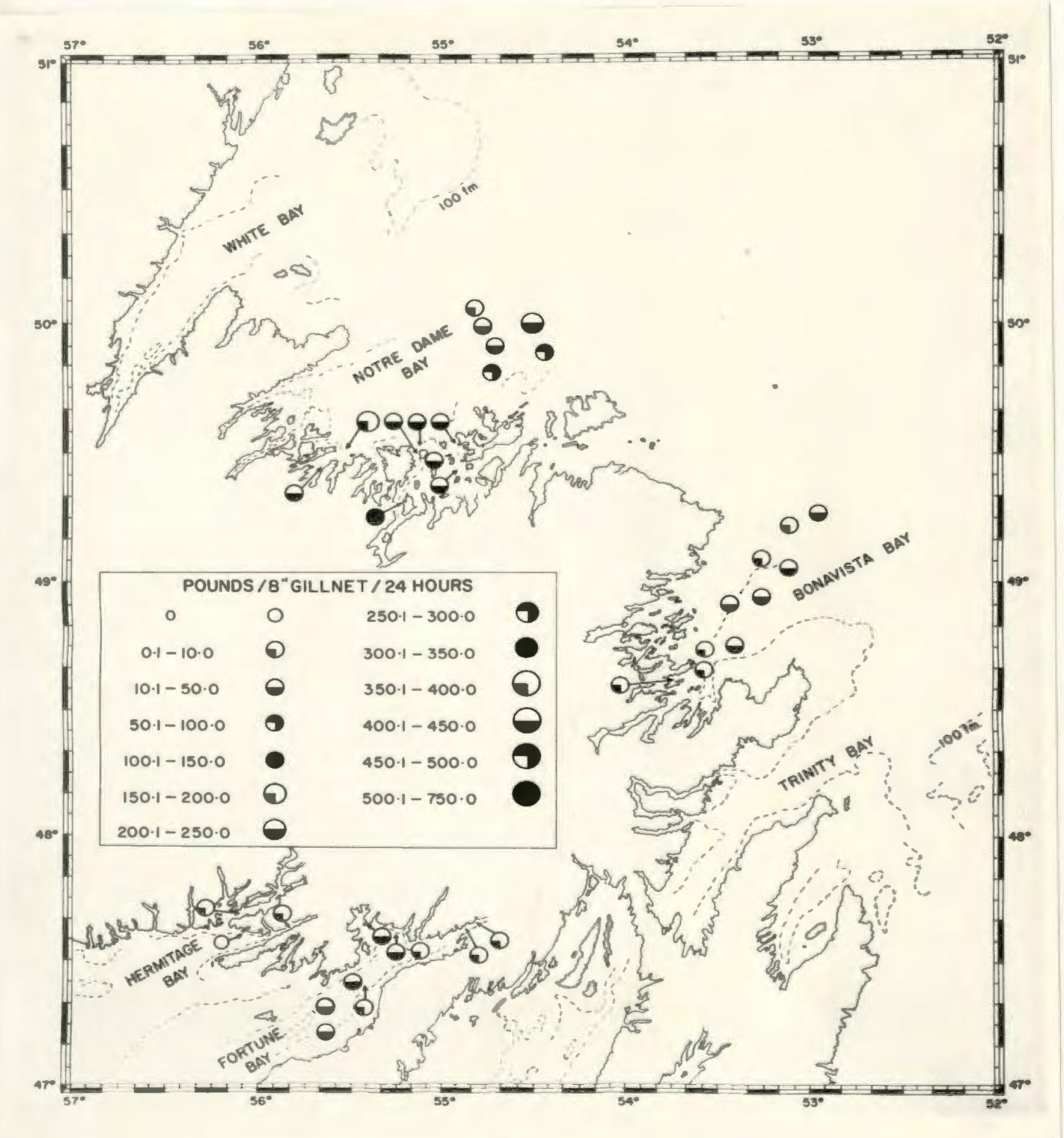

Fig. 10. Average catch of Greenland halibut per 50-fathom 8" gillnet in Notre Dame, Bonavista, Fortune and Hermitage bays during 1968-69.

and bottom temperature of 0.60°C. The catches in Hermitage Bay were 0.0 and 0.5 pounds for the 8" mesh gillnet.

One set, made in Bay d'Espoir, caught only 6 fish from 9 gillnets, 3 each of 6", 7" and 8" mesh in 240-305 fathoms and bottom temperature of 5.11°C.

The catches per 6" and 7" gillnet in 24 hours for Trinity Bay during 1966 and 1968 are shown in Fig. 11 and 12 respectively. The largest catches in 1968 were all below 50 pounds/gillnet/24 hours which compares with the 92 pounds/gillnet from commercial catches which are taken over a period of more than 24 hours, usually 2 to 6 days. The depths fished ranged from 122 to 320 fathoms and temperatures ranged from 0.24° to 2.31°C. During 1966 the largest catches were 277, 241 and 187 pounds/gillnet/ 24 hours in depths of 128-136, 140-145 and 150-152 fathoms and bottom temperatures of 2.13°, 2.04° and 2.18°C. respectively. The 1966 figures are for November 2 - December 10, and those of 1968 are for May 29 - June 6. Some of the differences may be seasonal but since the greatest catch per effort occurred at the beginning of the fishing season (Fig. 4), the figures for May-June, 1968 show very markedly the decrease in catch per unit effort

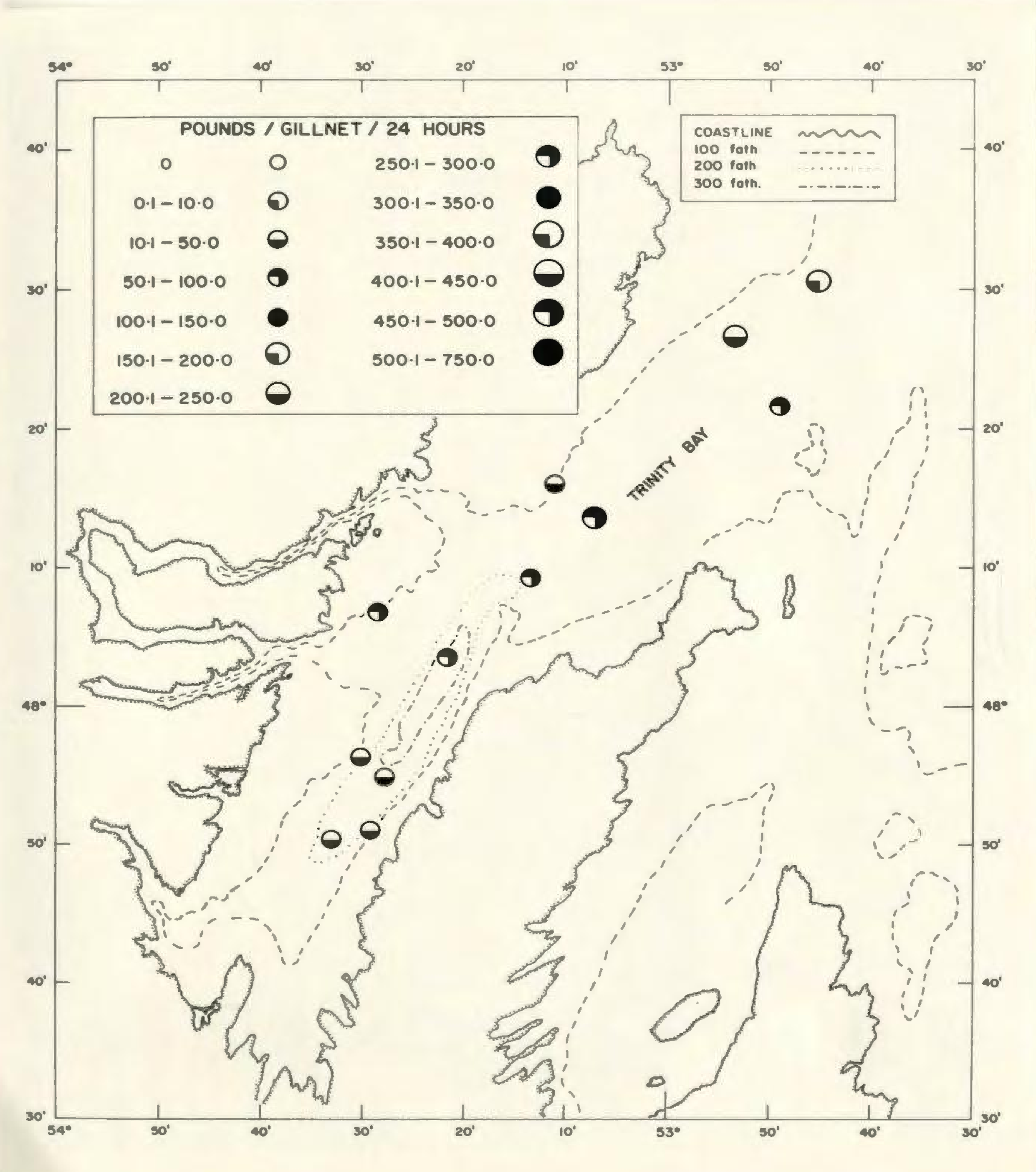

Fig. 11. Average catch of Greenland halibut per 50-fathom gillnet (6" and 7" combined) in Trinity Bay during November 2 - December 10, 1966.

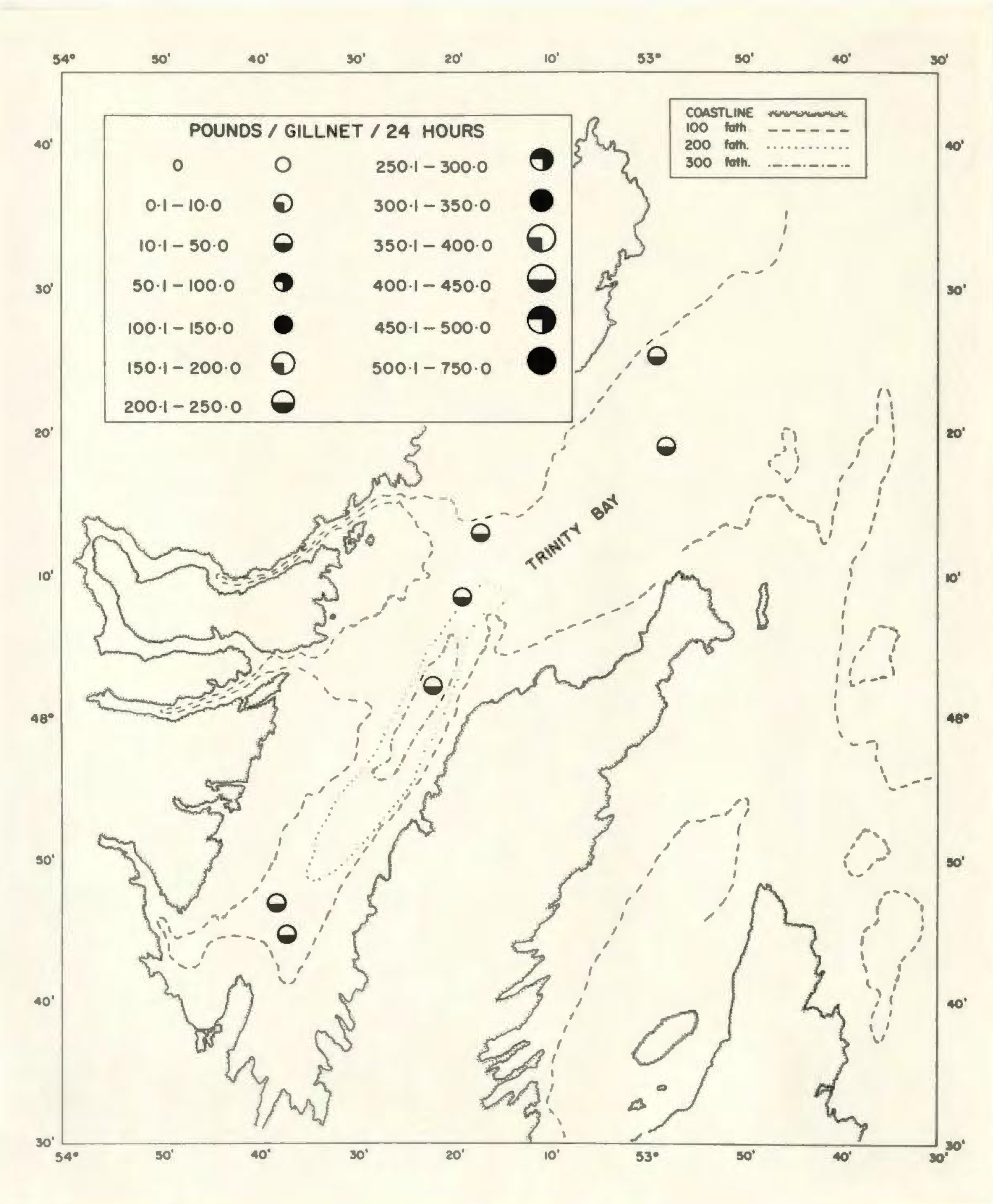

Fig. 12. Average catch of Greenland halibut per 50-fathom gillnet (6" and 7" combined) in Trinity Bay during May 29 - June 6, 1968.

in Trinity Bay.

The catches/hour's drag for A.T. Cameron Trip No. 129, March 2-6, 1967 in Trinity Bay are shown in Fig. 13. The largest catches were 4088, 3896, 3620, 3200 and 2504 pounds/hour in mean depths of 183, 240, 264, 212 and 167 fathoms and bottom temperatures 1.71°, 2.68°, 2.63°, 2.77° and 1.14°C. respectively.

The catches/hour's drag for A.T. Cameron Trip No. 129, March 2-6, 1967 and Trip No. 140, January 16, 1968 in Trinity Bay plotted against depth and temperature (Fig. 14) show that the largest catches occurred in depths of 150 to 325 fathoms where bottom temperatures ranged from 1° to 3°C.

The average catches/hour's drag for A.T. Cameron Trip No. 124, October 11-19, 1966 and Trip No. 138, October 10-27, 1967 for the Labrador Shelf and Hamilton Inlet Bank (Subarea 2) plotted against depth and temperature (Fig. 14) gives a clear picture of the distribution of Greenland halibut in depths less than 175 fathoms. Since these were primarily cod surveys, the deeper water was not surveyed. The largest catch of 396 pounds was in 155 fathoms

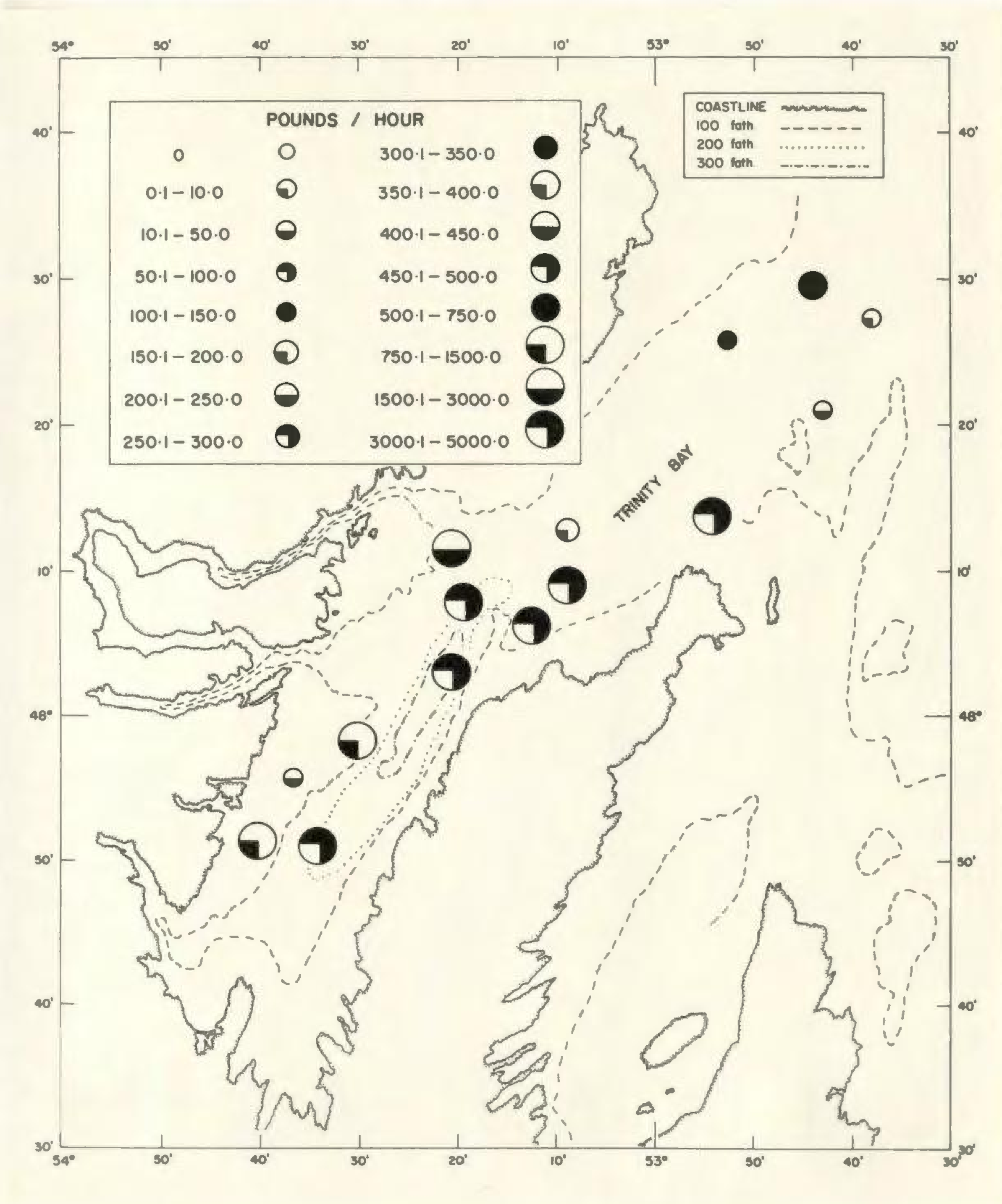

Fig. 13. Average catch of Greenland halibut per 1-hour drag of the A.T. Cameron in Trinity Bay during March 2-6, 1967.

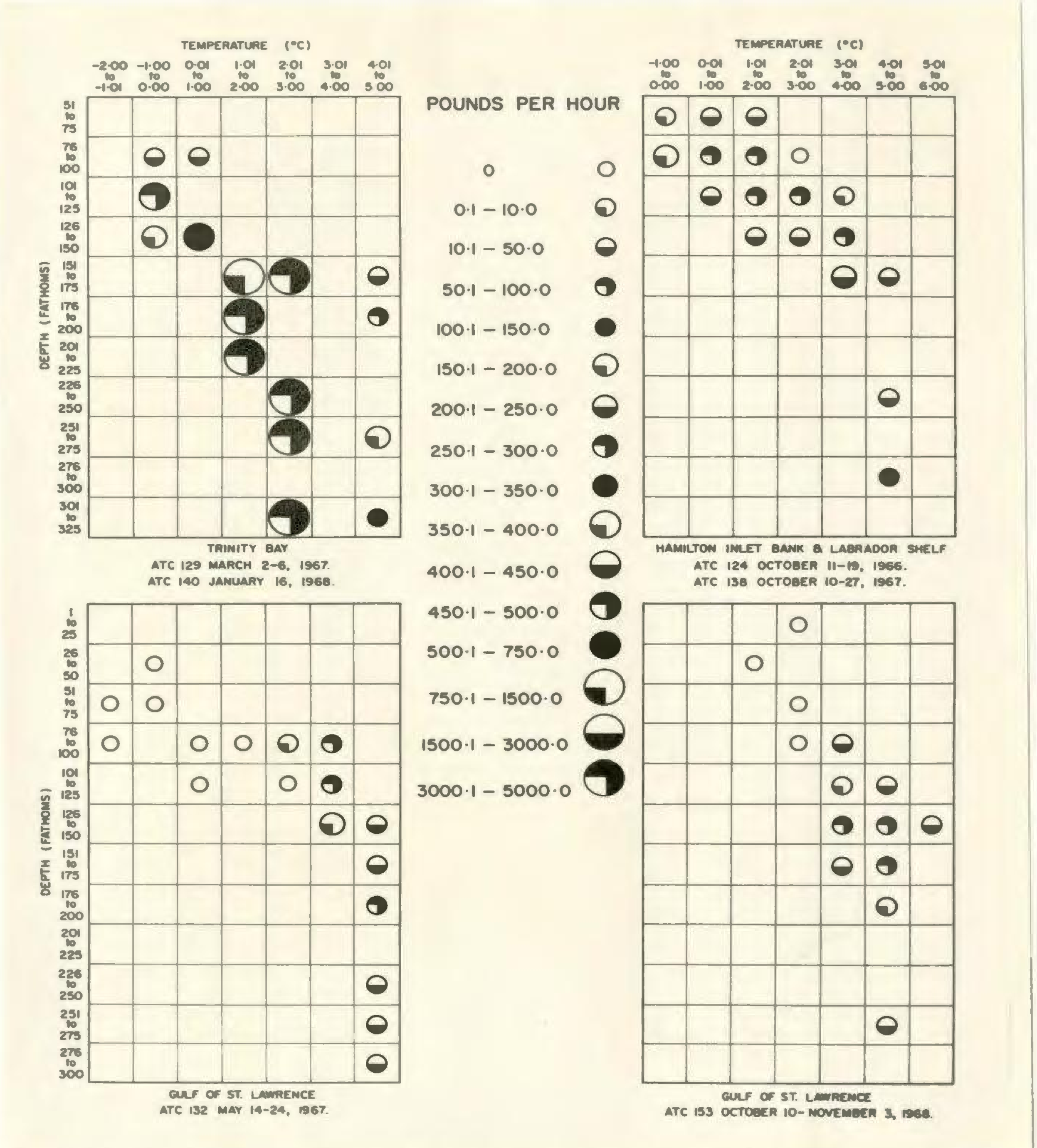

Fig. 14. Average catch of Greenland halibut per 1-hour drag plotted against depth and temperature for Trinity Bay during March 2-6, 1967 and January 16, 1968; Hamilton Inlet Bank and Labrador Shelf during October 11-19, 1966 and October 10-27, 1967; Gulf of St. Lawrence during May 14-24, 1967, and Gulf of St. Lawrence during October 10 - November 3, 1968.

where the bottom temperature was 3.70°C. In Subarea 2, the Greenland halibut in depths from 51-150 fathoms were distributed fairly evenly over a wide range of temperatures from -1.00° to 4.00°C. There was a catch of 200 pounds in 98 fathoms and bottom temperature of -0.03°C.

The average catches/hour plotted against depth and temperature for A.T. Cameron Trip 132, May 14-24, 1967 in the Gulf of St. Lawrence (Subarea 4) are shown in Fig. 14. No Greenland halibut were caught where bottom temperatures were less than 2°C. The largest catch of 328 pounds occurred in 178 fathoms and a bottom temperature of 4.08°C. A similar survey was made in the same area by the A.T. Cameron during October 10 - November 3, 1967 and similar results were obtained as in May, 1967. The Greenland halibut were found in depths greater than 100 fathoms and within a temperature range of 3° to 5°C. No Greenland halibut were found in depths less than 75 fathoms or temperatures less than 3°C. with only small quantities being found in depths less than 100 fathoms.

Food and Feeding

The percentage volume and occurrence versus length for all depths and all seasons (Fig. 15) shows that for the smaller Greenland halibut (11-20 cm) euphausiids form the major part of the diet and capelin a very minor part. Greenland halibut in the size range 21-80 cm feed almost exclusively on capelin. This is not biased in favor of season since it will be seen later that the Greenland halibut feed on capelin during the period March to November. Greenland halibut larger than 80 cm eat fairly large quantities of their own species. Shrimp, mainly pandalids, account for only a small part of the volume of food eaten by all sizes of Greenland halibut but occur quite frequently in larger fish. The percentage of euphausiids in the diet decreases both in volume and occurrence as the fish grow larger. Other items (Table 3) contribute very small amounts in terms of volume or occurrence in the diet of Greenland halibut.

The percentage volume and occurrence of various food items versus depth when all lengths and seasons

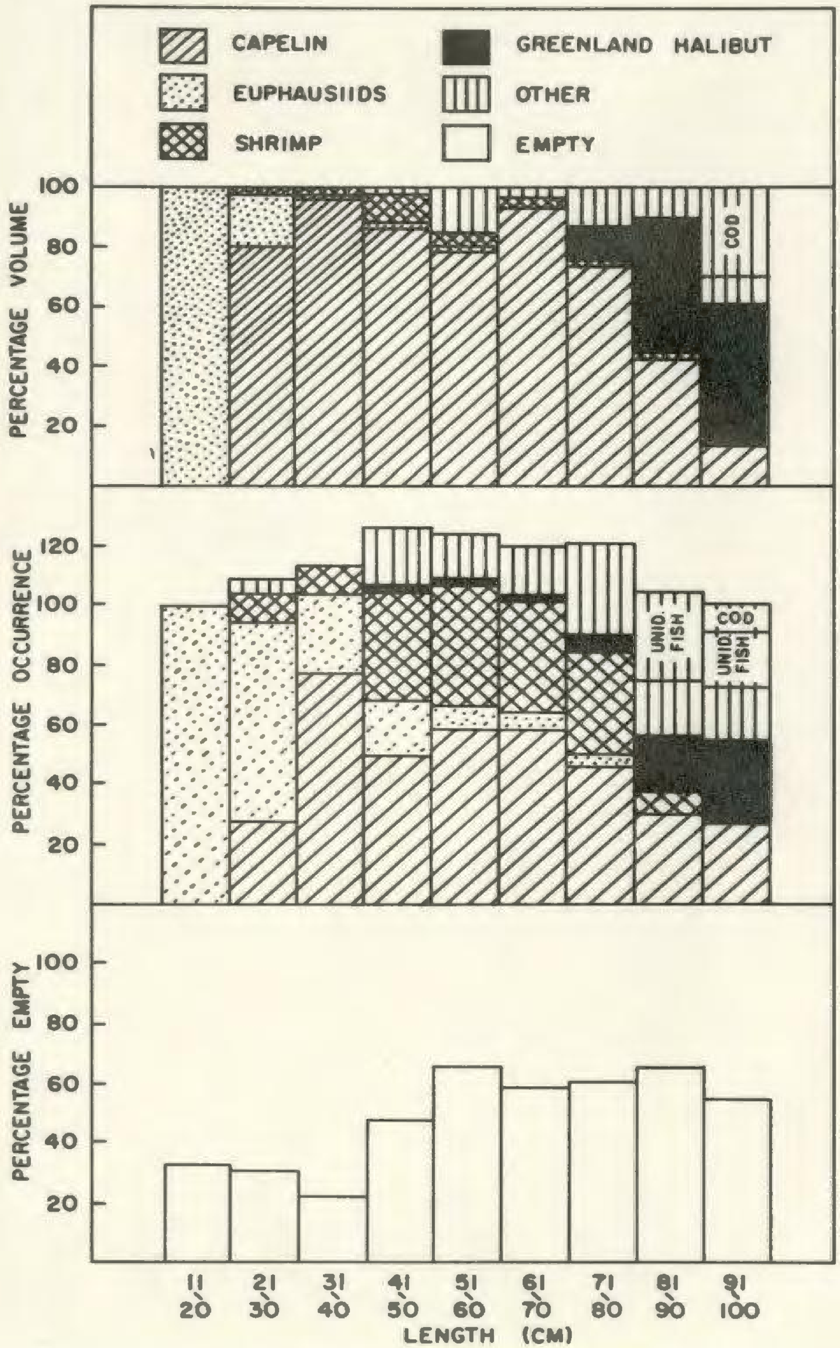

Fig. 15. Percentage volume and occurrence of various food items in the stomachs of Greenland halibut in Trinity Bay in 10-cm length groups.

are combined are shown in Fig. 16. Capelin comprised a major part of the volume of food at all depths except at 201-225 and 251-275 fathoms. No fish were sampled in 276-300 fathoms. At 201-225 and 251-275 fathoms the major food item in terms of volume was Greenland halibut. Shrimp were found to be of minor importance with regard to volume but occurred quite frequently in all depths with the highest occurrence being at 201-250 fathoms. Euphausiids also contributed very little in terms of volume at any one depth except at 76-100 fathoms but occurred quite frequently, especially at shallower depths (76-100 fathoms).

The percentage volume and occurrence of food items in half-monthly periods with all lengths and depths combined are shown in Fig. 17. Capelin comprised a large percentage of the volume of food eaten in all periods except May 1-15, August 16 - September 15, and November 16-30. The volume of capelin eaten in the period June 1 - July 15, is only about 50% of that for May 16-31, and July 16-31. The percentage occurrence of capelin follows a similar pattern except for May 1-15, which shows a 42%

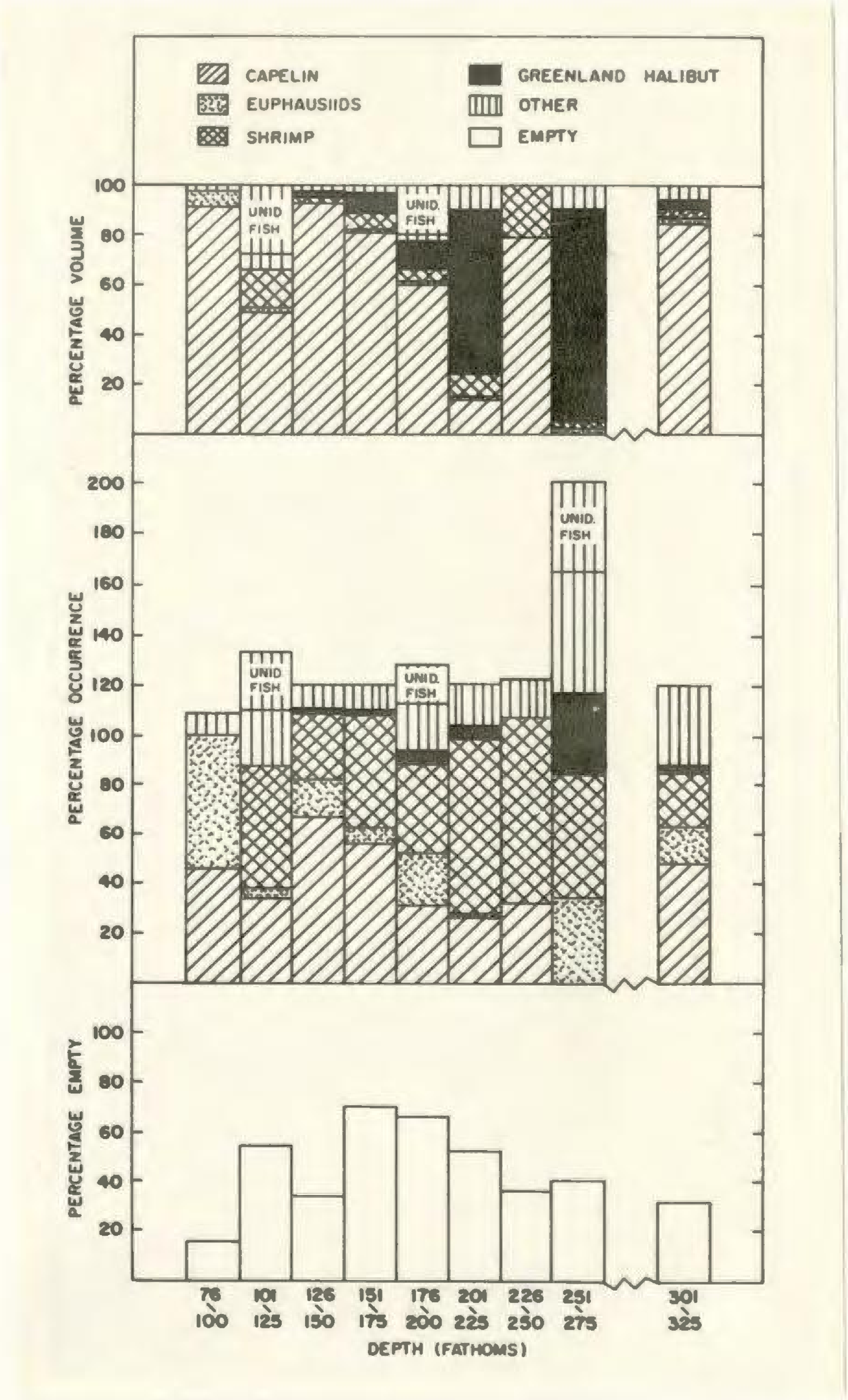

Fig. 16. Percentage volume and occurrence of various food items in the stomachs of Greenland halibut in Trinity Bay in 25-fathom depth intervals.

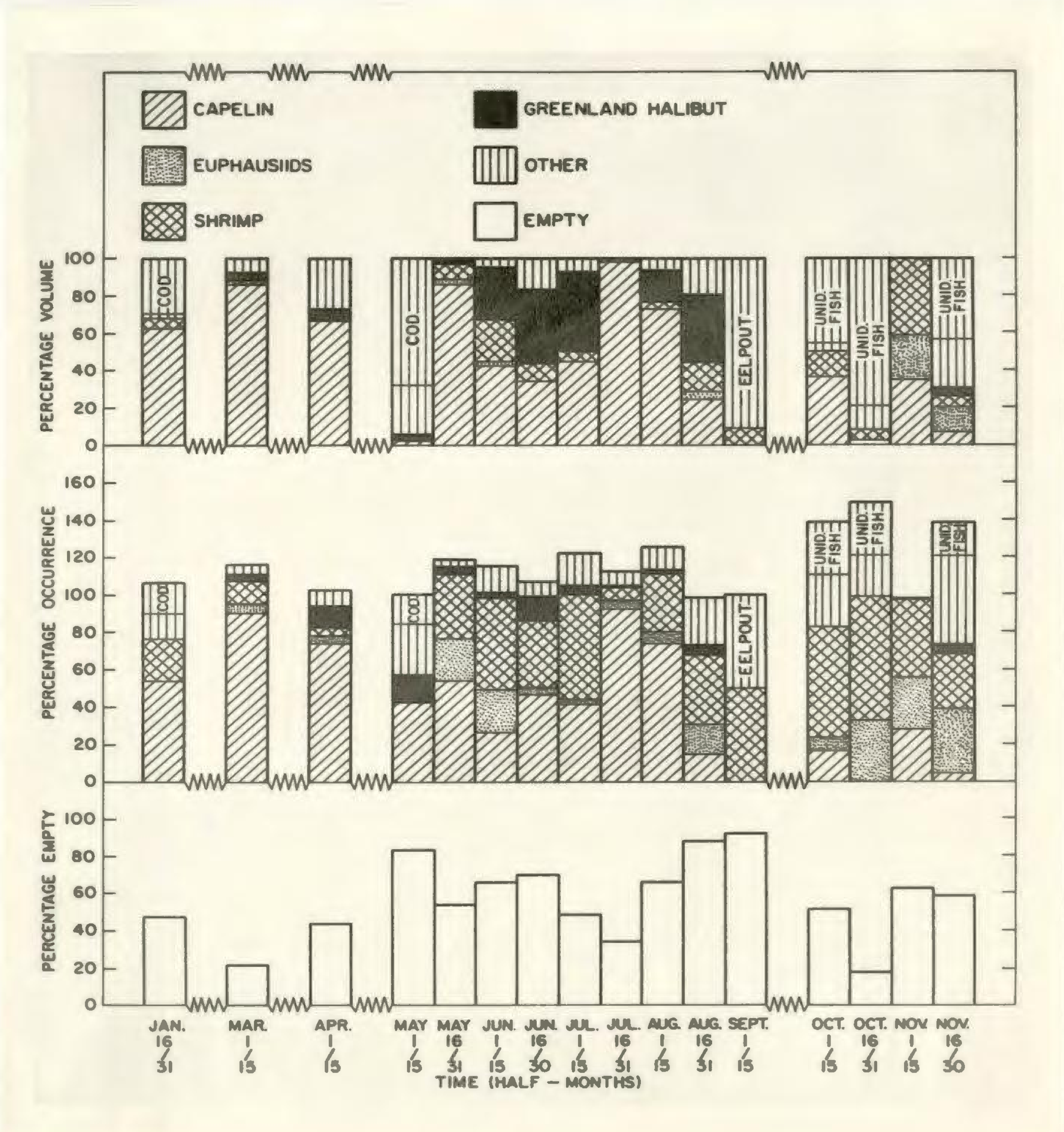

Fig. 17. Percentage volume and occurrence of various food items in the stomachs of Greenland halibut in Trinity Bay in half-monthly periods.

level compared to 2% by volume. Shrimp were low in volume but occurred quite frequently in the periods May 16 - July 15, and August 1 - November 30. Euphausiids were low in volume but occurred fairly often especially during October 16 - November 30, when they occurred in 38-45% of the fish with stomach contents. Greenland halibut accounted for 28-42% of the volume during June 1 - July 15, but on the whole the percentage occurrence was low, the highest being 14% during May 1-15. Other items accounted for from 1-94% by volume. The high percentages of cod and eel-pout are anomalies probably due to a small number of stomachs sampled during days when capelin were unavailable. Unidentified fish material comprised 44-78% of the volume during October 1 - November 30. There is an inverse relationship between the percentage of capelin and that of other items in the stomachs, which again may be a reflection of the availability of capelin. The percentage of empty stomachs during each half-month period is very high from May 15 - June 30, and from August 1 - September 15.

The percentage volume and occurrence of various food items versus length for the depth intervals 126-150, 176-200 and 301-325 fathoms are shown in Fig. 18, 19 and 20 respectively. Capelin comprised a major part of the diet of Greenland halibut in terms of volume for all lengths above 30 cm for the depth interval 126-150 fathoms and for all above 20 cm for the depth intervals 176-200 and 301-325 fathoms. For the 126-150 fathom interval, capelin occurred most frequently in the length group (41-70 cm) while in the 301-325 fathom depth interval the percentage occurrence of capelin decreased as the fish increased in length above 40 cm. In the three depth intervals shrimp accounted for only a small percentage by volume but occurred very frequently in the intermediate sizes. In the 126-150 fathom interval, euphausiids comprised 100 and 88% of the volume at 11-20 and 21-30 cm length groups respectively. The percentage of euphausiids decreased very rapidly as the fish length increased beyond 30 cm. There is also an inverse relationship between fish length and euphausiid occurrence at this depth. At 176-200 fathoms there is a similar

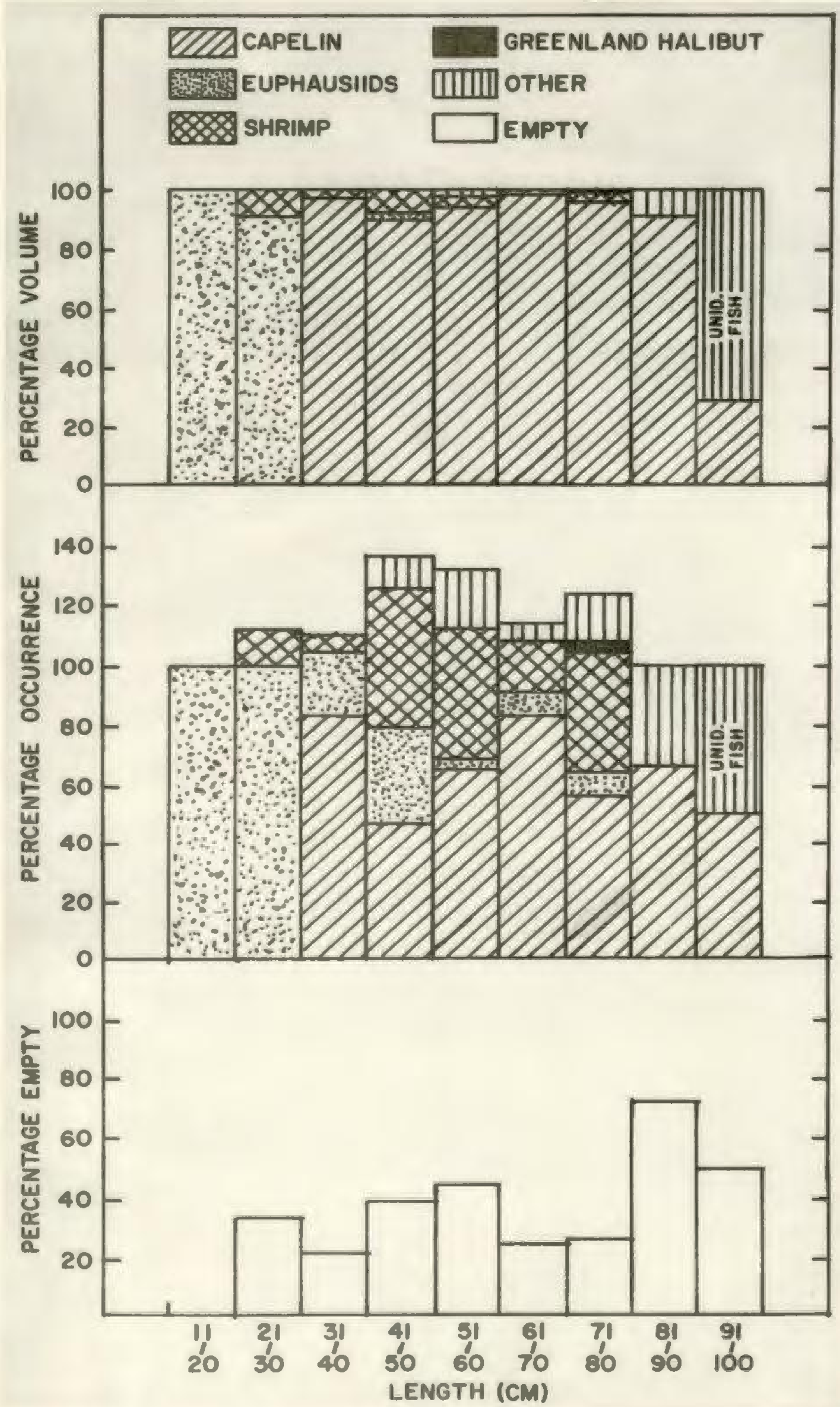

Fig. 18. Percentage volume and occurrence of various food items in the stomachs of Greenland halibut in Trinity Bay in 10-cm length groups for the 126-150 fathom depth interval.

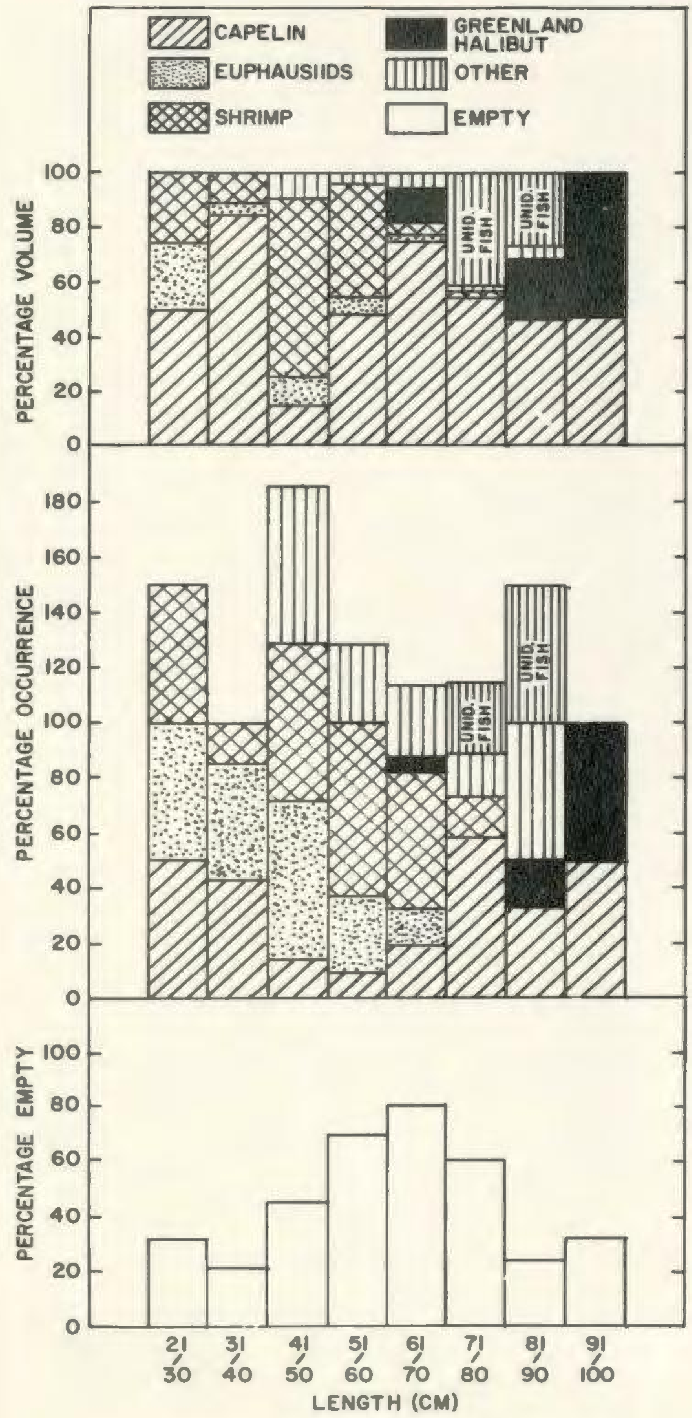

Fig. 19. Percentage volume and occurrence of various food items in the stomachs of Greenland halibut in Trinity Bay in 10-cm length groups for the 176-200 fathom depth interval.

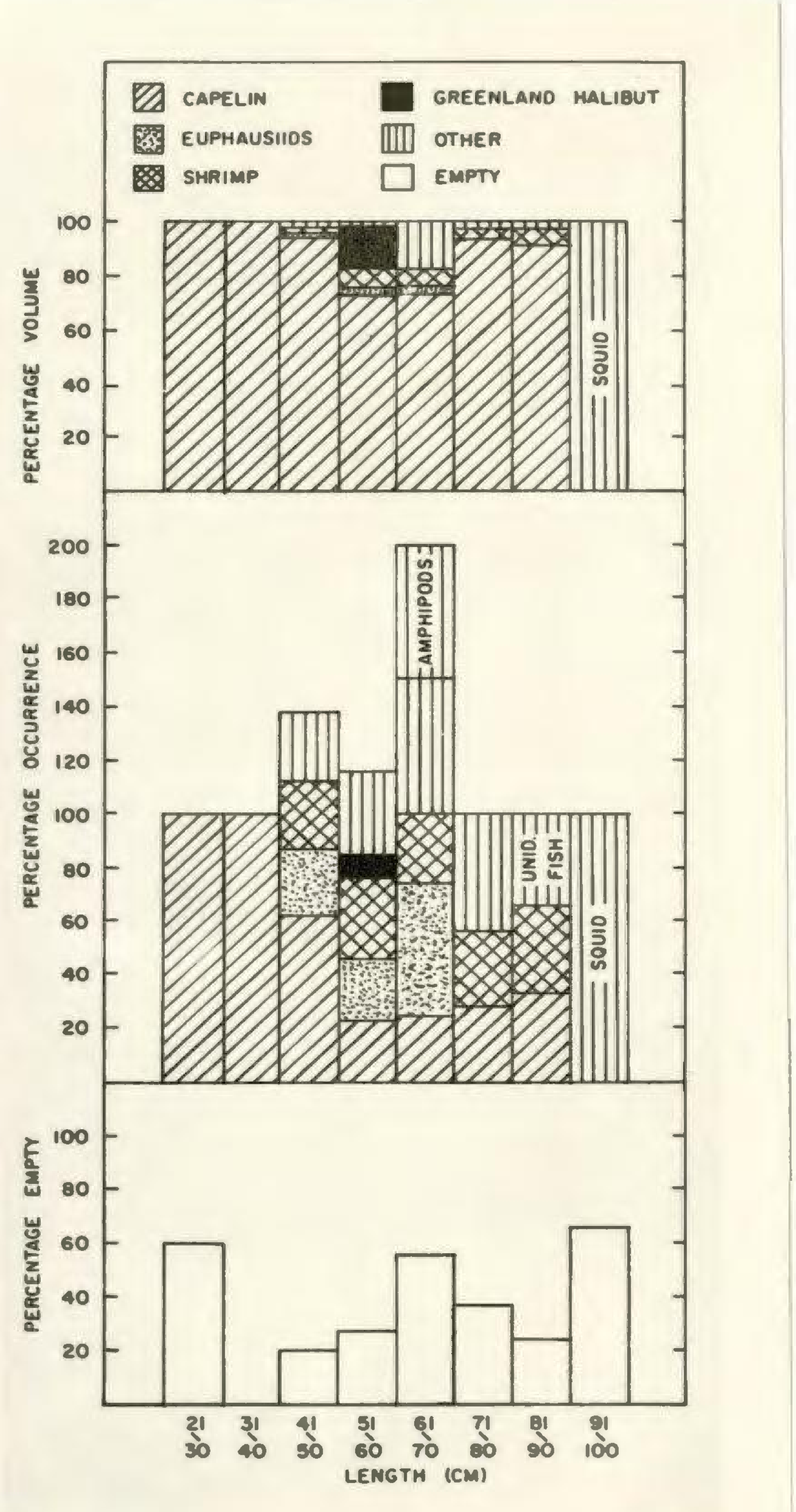

Fig. 20. Percentage volume and occurrence of various food items in the stomachs of Greenland halibut in Trinity Bay in 10-cm length groups for the 301-325 fathom depth interval.

relationship between length of fish and euphausiid volume except the percentage for 21-30 cm was lower (26%). The frequency of occurrence above 30 cm was higher for the 176-200 fathom interval than for the 126-150 fathom interval but there was a similar decrease with length. Euphausiids comprised a very small percentage of the volume at 301-325 fathoms but they occurred quite frequently in the 41-70 cm length range.

Greenland halibut was of very minor significance in the 126-150 and 301-325 fathom depth intervals but in the 176-200 fathom interval it accounted for 13% at 61-70 cm and 20-52% of the volume at the 81-100 cm length range. Other items accounted for only very small percentages of the volume of food of fish below 70 cm in the three depth intervals. Unidentified fish comprised almost all of the volume of other items in fish larger than 80 cm in the 126-150 fathom interval and above 70 cm in the 176-200 fathom interval. In the 301-325 fathom interval, invertebrate materials comprised the major part of the volume of the other items.

The percentage volume of fish and invertebrate food versus half-monthly period is shown in Fig. 21A. The percentage of invertebrate material was lowest during March 1 - May 15, and highest during November being 64% during the period November 1-15.

The percentage volume of fish and invertebrate material versus fish length is shown in Fig. 21B. Invertebrate material comprised 100% of the volume of food in the 11-20 cm length group and decreased rapidly as the length of the predator increased with fish material increasing with increasing predator length.

The percentage volume of fish and invertebrate material versus depth is shown in Fig. 21C. The percentage of invertebrates in all depths was very low, the highest being 21% at 226-250 fathoms and the lowest being 2% at 126-150 and 251-275 fathoms.

The percentage volume of various food items in the stomachs of Greenland halibut is shown in Fig. 21D. This includes all samples in Trinity Bay of all fish lengths, at all depths and during the period January 16 - November 30. Capelin comprised 76% of the total volume (27,221cc), Greenland halibut 10%, shrimp 3%,

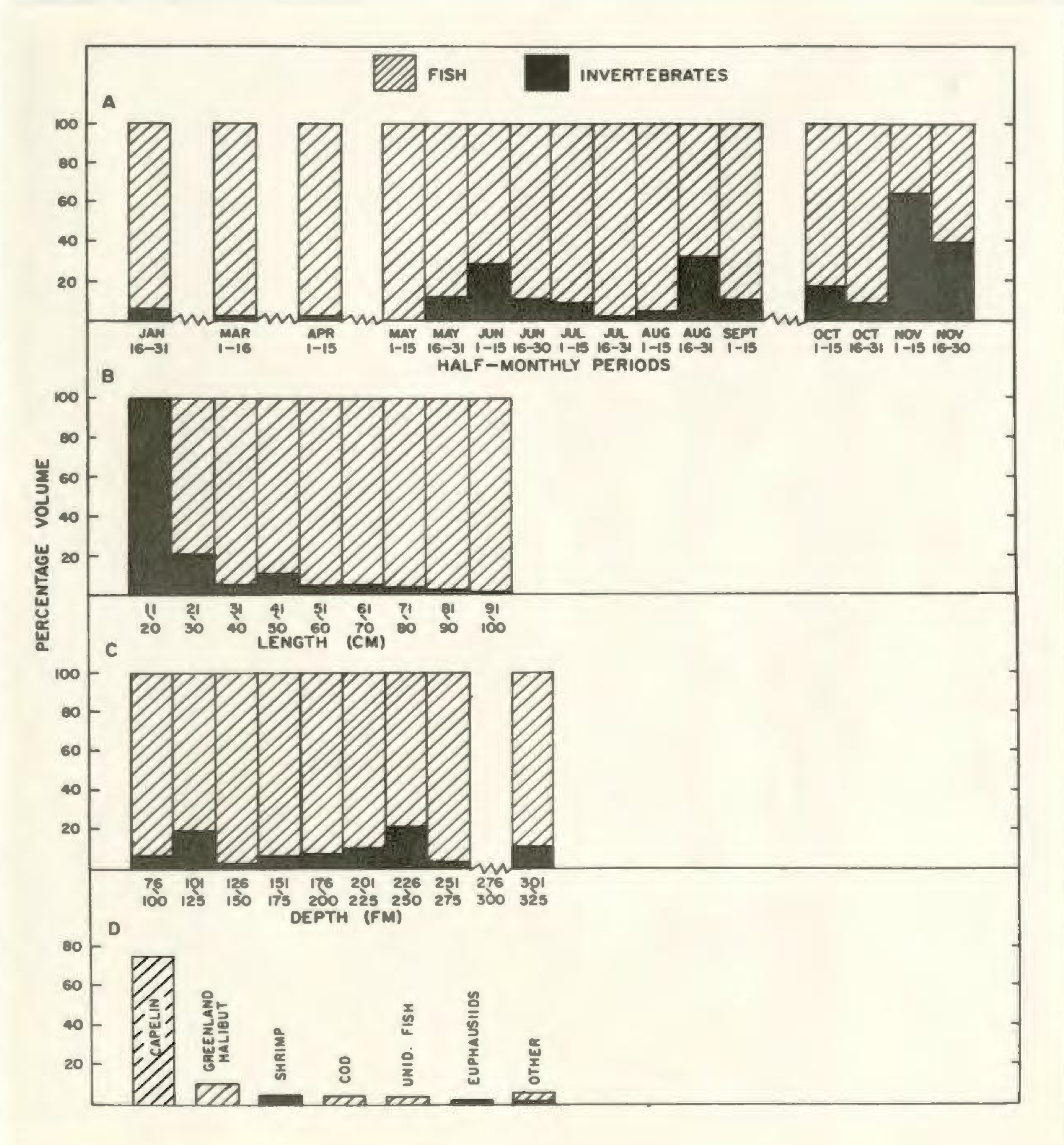

Fig. 21. Percentage volume of fish and invertebrates in the stomachs of Greenland halibut in: A. half-monthly periods; B. 10-cm length groups; C. 25-fathom depth intervals; and D. the percentage volume of various food items for all length groups, depth intervals and monthly periods combined.

cod 3%, unidentified fish 2.5%, euphausiid 1% and other items 4.5%.

Temperatures

The temperature cross sections for three different areas namely Hamilton Inlet Bank (Subarea 2), Trinity Bay (Division 3L) and Gulf of St. Lawrence (Subarea 4) are shown in Fig. 22. The temperature in which the Greenland halibut from Subarea 2 were caught ranged from -0.2° to 4.5°C. but most of the samples were caught in 0°C. to 2°C. In Trinity Bay, the Greenland halibut were caught in temperatures ranging from -0.9° to 4.7°C. but most were caught in temperatures ranging from 1° to 3°C. In the Gulf of St. Lawrence the Greenland halibut were caught in temperatures ranging from 2° to 5.2°C. but most were caught in temperatures ranging from 3° to 5°C.

In Division 3K the Greenland halibut were caught in temperatures ranging from -1.1° to 4.7°C. but most were caught in temperatures ranging from 0° to 2.5°C.

In Division 3P (Placentia and Hermitage Bays) the Greenland halibut were caught in temperatures ranging from 0° to 4.1°C. but most were caught in temperatures ranging

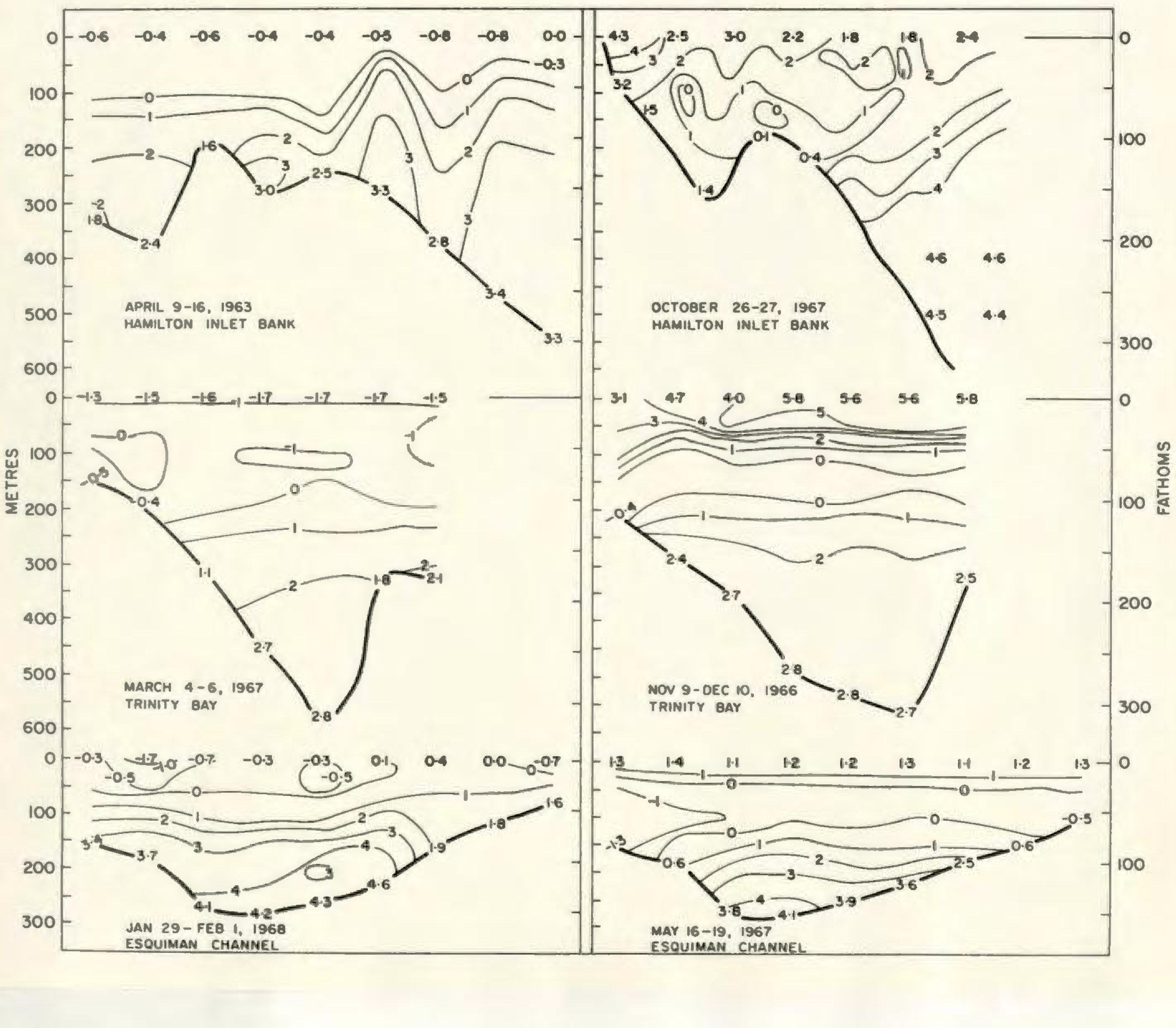

Fig. 22. Temperature profiles for Hamilton Inlet Bank, Trinity Bay and Gulf of St. Lawrence for various times of the year. The station positions are shown in Fig. 1.

from 2° to 4°C.

There has been a trend towards increasing temperature in all depth levels on the Cape Bonavista section during the period 1953 to 1965 (Fig. 23).

Age Validation

The length distributions at the otolith ages superimposed upon the length distributions for Subarea 2 during October 11-17, 1966 and October 21-26, 1967 are shown in Fig. 24. The 0^+ age group in 1967 was taken from cod stomachs. The length modes of each age group up to and including age-2 were quite distinct and corresponded to the modes of the length distributions. The modes of both age and length distributions faded out beyond age-2 with the age-3 length mode being only faintly distinct. The 1965 year-class was very strong in 1966 and was represented fairly strongly in 1967.

Fig. 25A shows the pattern of seasonal deposition of the otolith edge for all areas and all ages and for ages 0^+ to 6 years inclusive (Fig. 25B). Very few fish showed opaque edges as early as March, 25% showed opaque

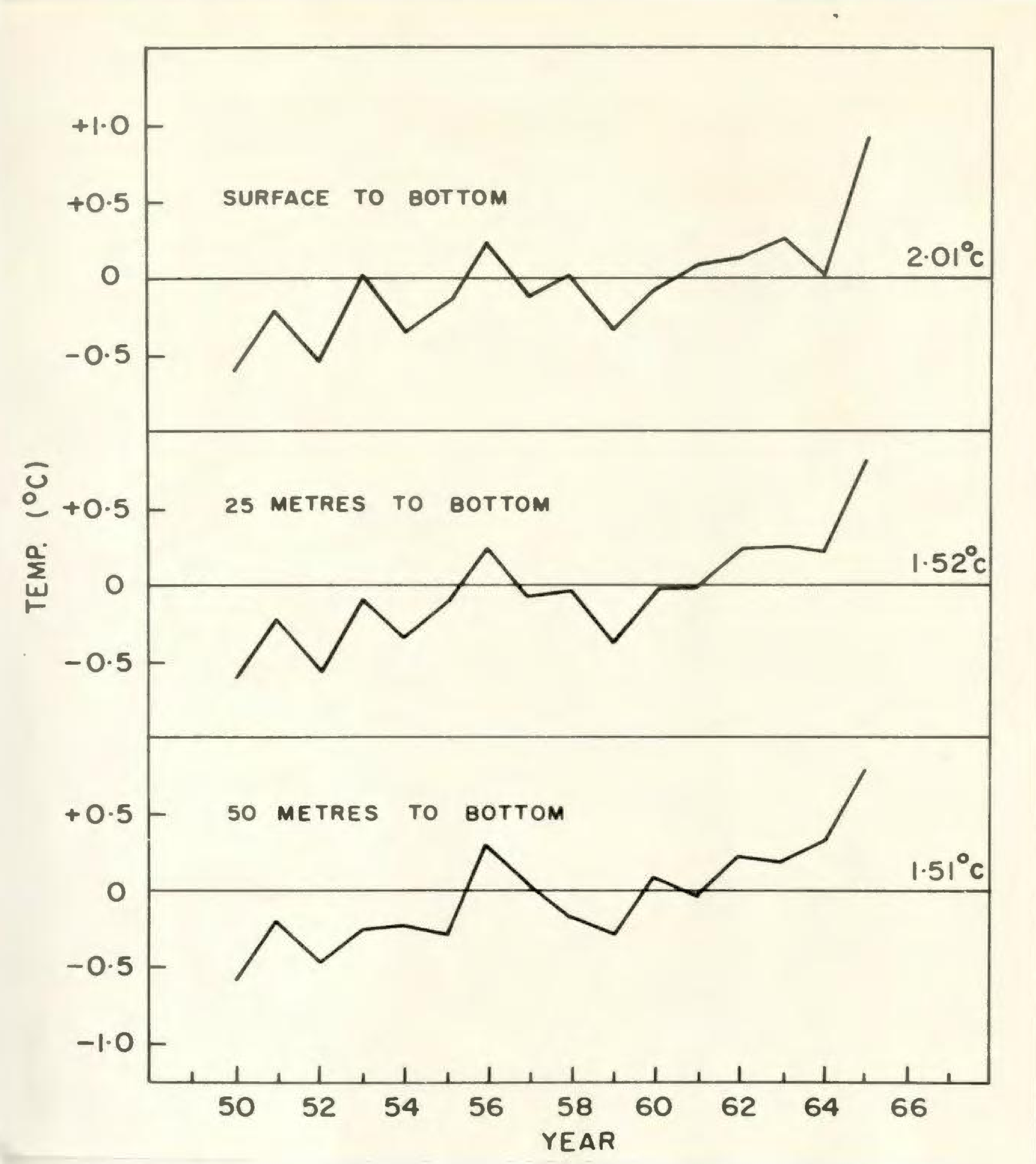

Fig. 23. Positive and negative temperature anomalies on the Cape Bonavista hydrographic section for various years from 1950-66 from averages for 1951-65 (from Templeman (unpublished figure)).

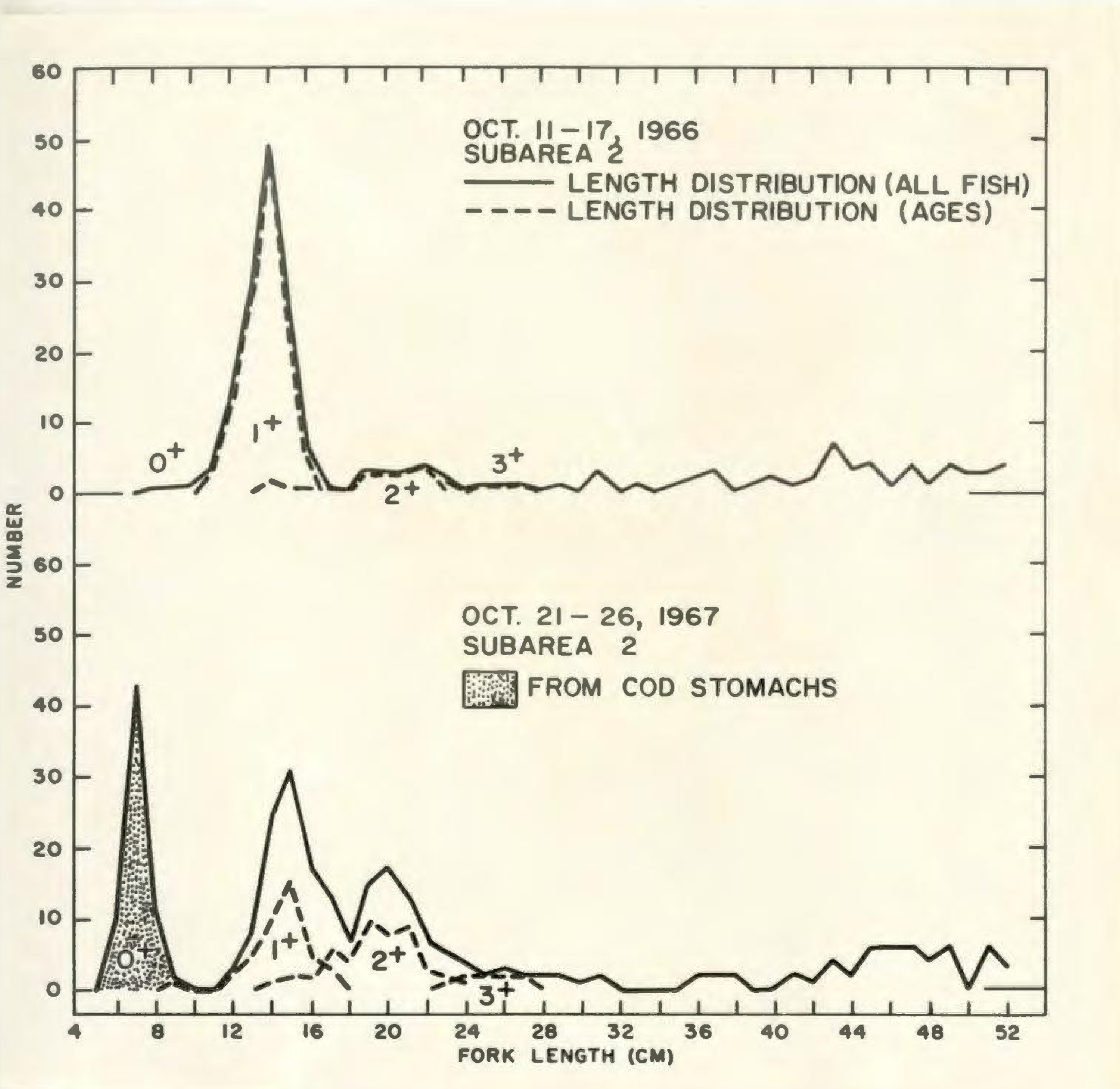

Fig. 24. Length distributions of otolith age groups superimposed upon the length distributions of Greenland halibut from Subarea 2 during October 11-17, 1966 and October 21-26, 1967.

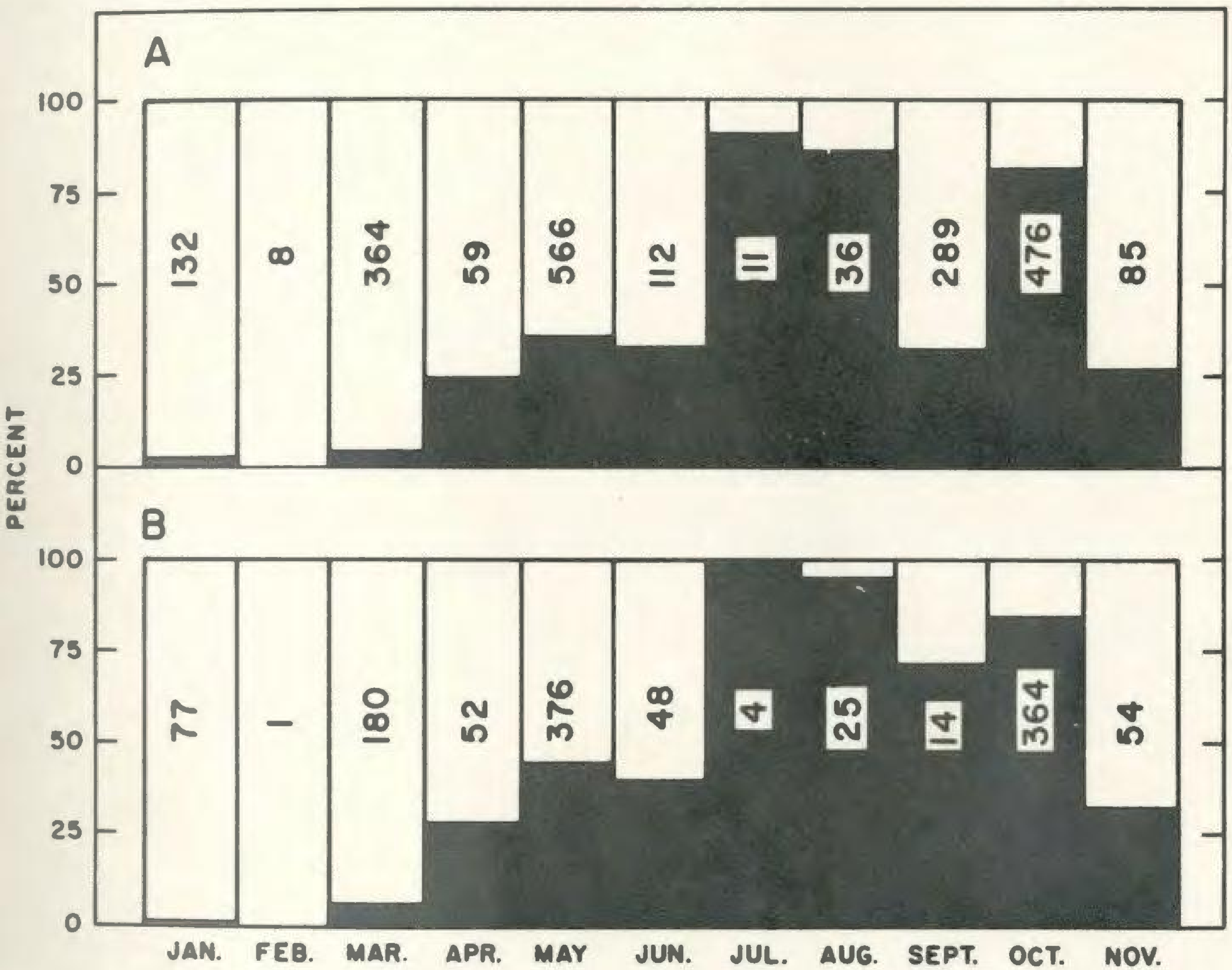

Fig. 25. Monthly incidence of opaque edge deposits from all areas for: A. fish of all ages and; B. fish of age 0^+ to 6 years inclusive. Numbers of fish are shown.

edges in April and they are present in 40-80% from July-November in fish of all ages and from 70-100% in fish aged 0^+ to 6 years.

Fig. 26 shows that opaque edges occurred earlier in young fish than in older fish.

Representative otoliths of the 0^+ to 6 year old Greenland halibut are shown in Fig. 27.

Age and Growth

(a) Length Distributions. In Subarea 2 the smaller length groups (10-22 cm) were predominant in both sexes (Fig. 28). In Divisions 3K and 3L (Trinity Bay) for the period 1966-68, there was a greater proportion of intermediate and larger-sized fish. It is interesting to note that there was a greater proportion of intermediate-sized fish of both sexes in Trinity Bay during 1953 than during 1966-68. It is highly probable that the decrease in intermediate-sized fish has been due to the high fishing intensity exerted during 1965-67. In Division 3P there was a greater proportion of smaller fish than in 3L and 3K with a complete lack of fish over

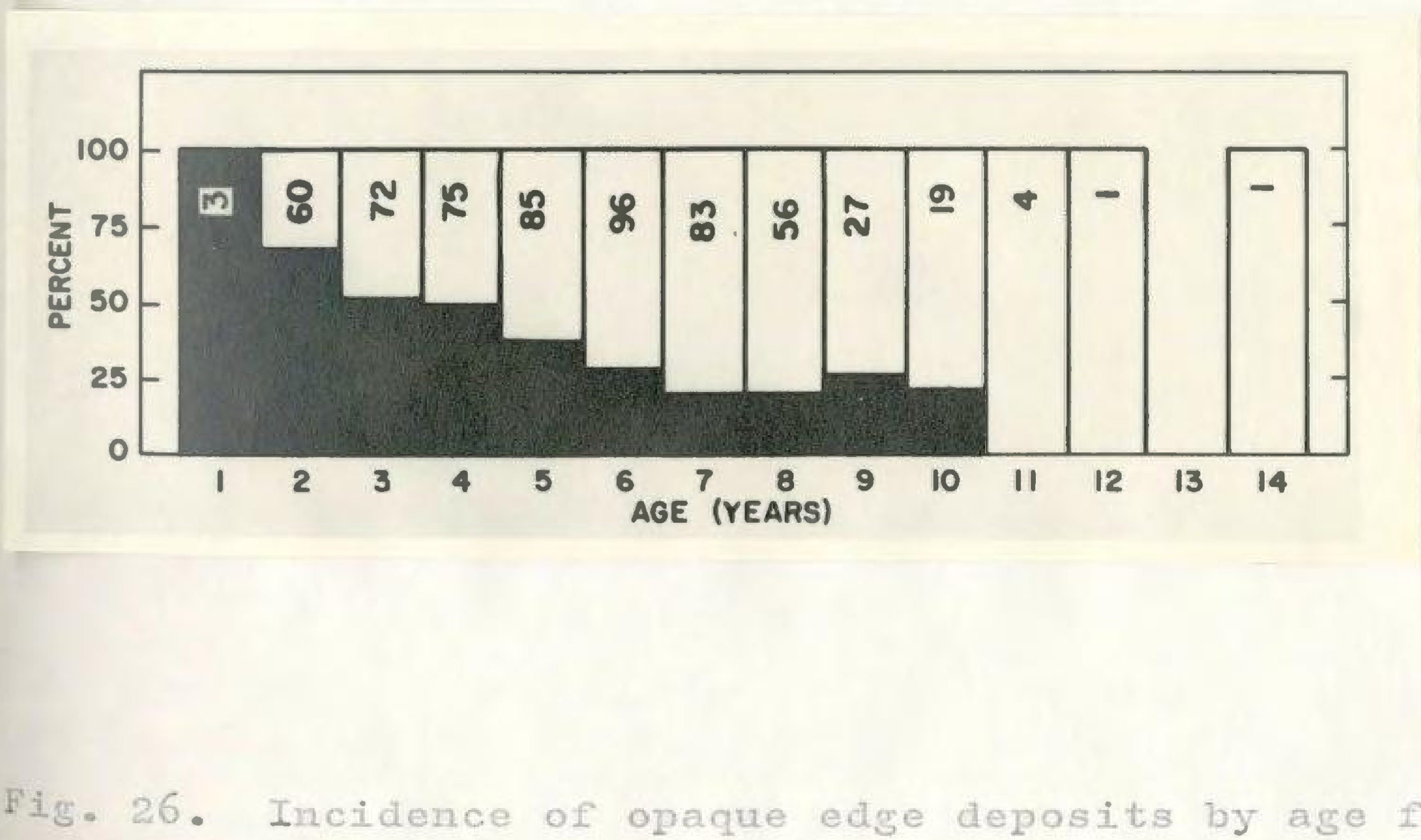

Fig. 26. Incidence of opaque edge deposits by age for May. Numbers of fish are shown.

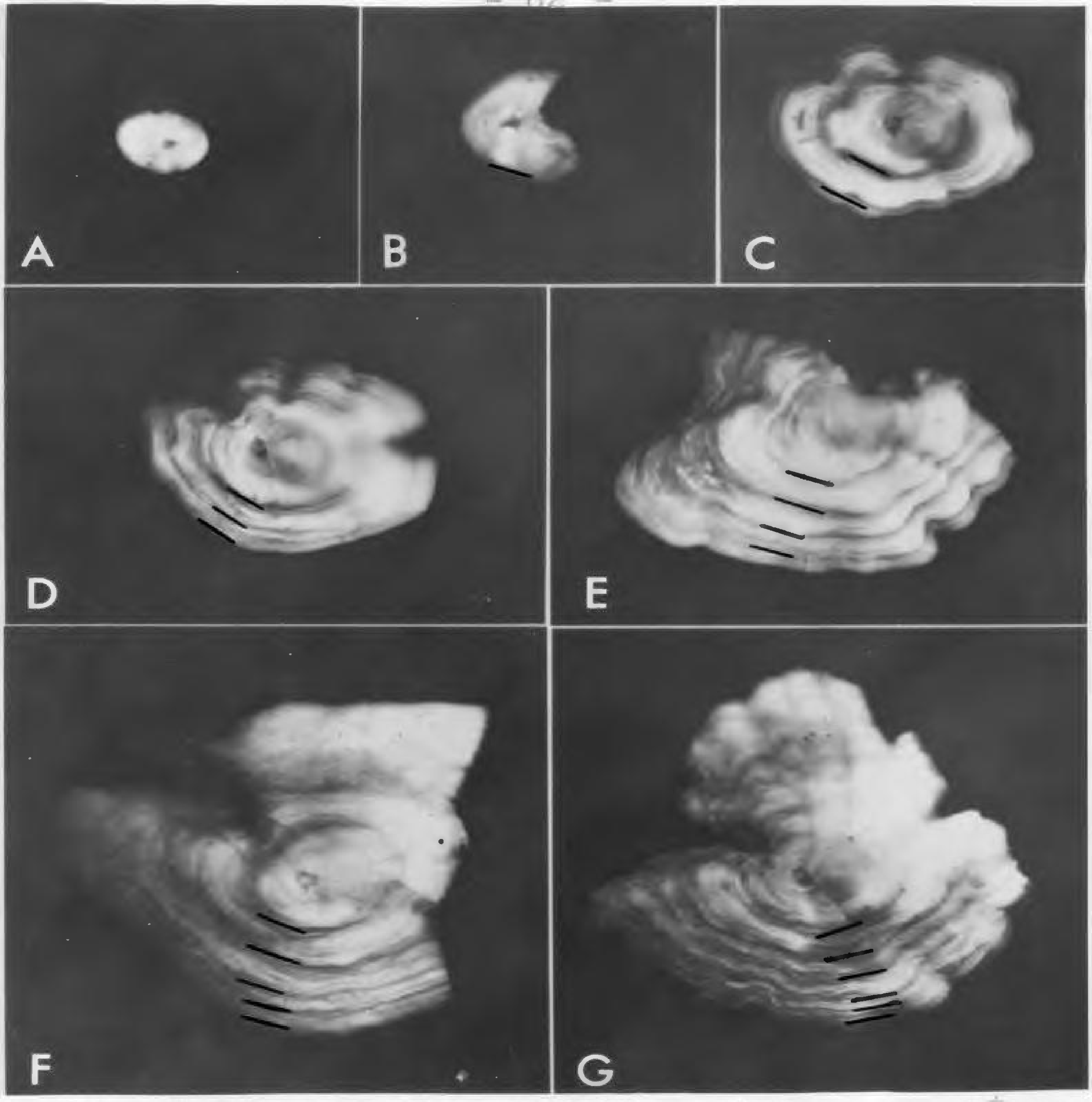

Fig. 27. Representative otoliths of the ages 0^+ to 6 years inclusive (X8). A - age 0^+, 7.1 cm October 21, 1967; B - age 1, 12 cm April 23, 1967; C - age 2, 16 cm October 23, 1967; D - age 3, 21 cm October 23, 1967; E - age 4^+, 33 cm October 30, 1967; F - age 5, 36 cm January 16, 1968; G - age 6, 41 cm January 16, 1968. The marks indicate the centre of the hyaline zone of each annulus. All the otoliths except B are from the left side of the fish.

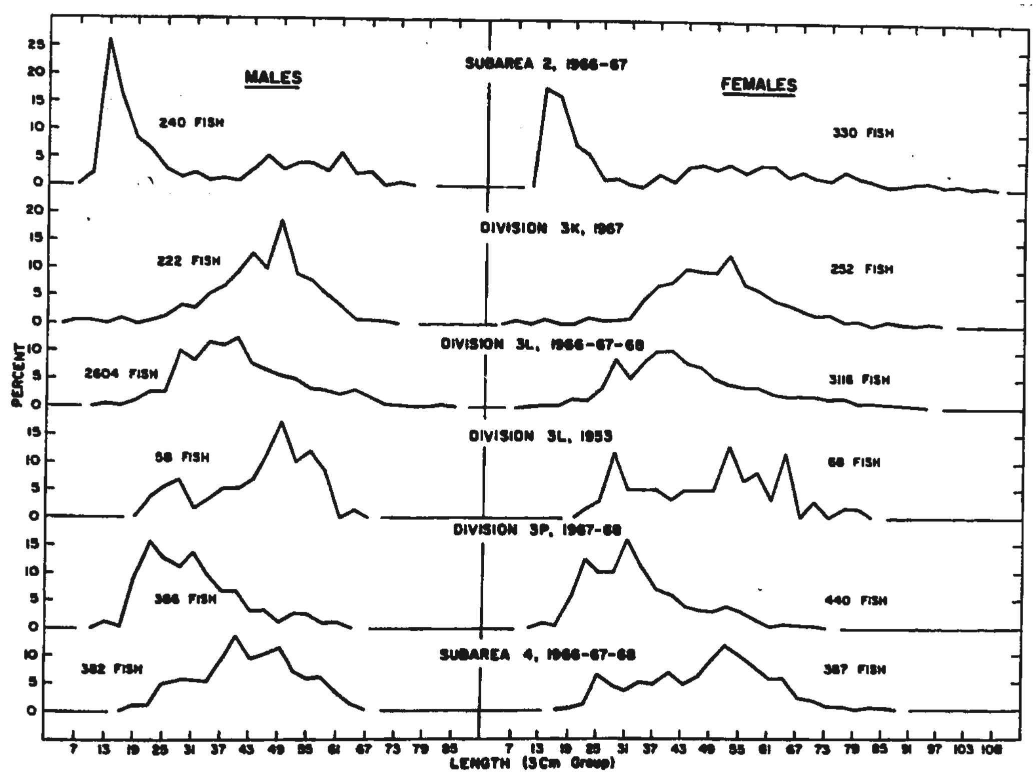

Fig. 28. Length distributions of Greenland halibut (males and females separate) from various areas.

70 cm. In Subarea 4 there was a large proportion of intermediate-sized fish with very few larger fish. In all areas except Subarea 2 there is almost a complete lack of small fish in the size range 10-19 cm.

(b) Age Distributions. Fig. 29 shows the age distributions for the various areas under consideration. In Subarea 2, age-1 was by far the dominant year-class in both sexes with a relatively smaller age-2 year-class. In Division 3K and 3L (Trinity Bay) the intermediate ages (5-8 years) were dominant with very few fish in the age-1 and age-2 year-classes. In Division 3L (Trinity Bay) the proportions of intermediate and older age groups were higher during 1953 than for 1966-68 for both sexes. This is again indicative that the high fishing intensity during the period 1965-67 has cropped off the older fish. In Division 3P there was a predominance of 2-6 year old fish of both sexes. In Subarea 4 the fish of ages 5-8 years were predominant in both sexes. There were relatively fewer older fish in either Division 3P or Subarea 4 than in the other areas; the oldest being 10 years of age except for the Subarea 4 females, a few of which attained an age of 14 years.

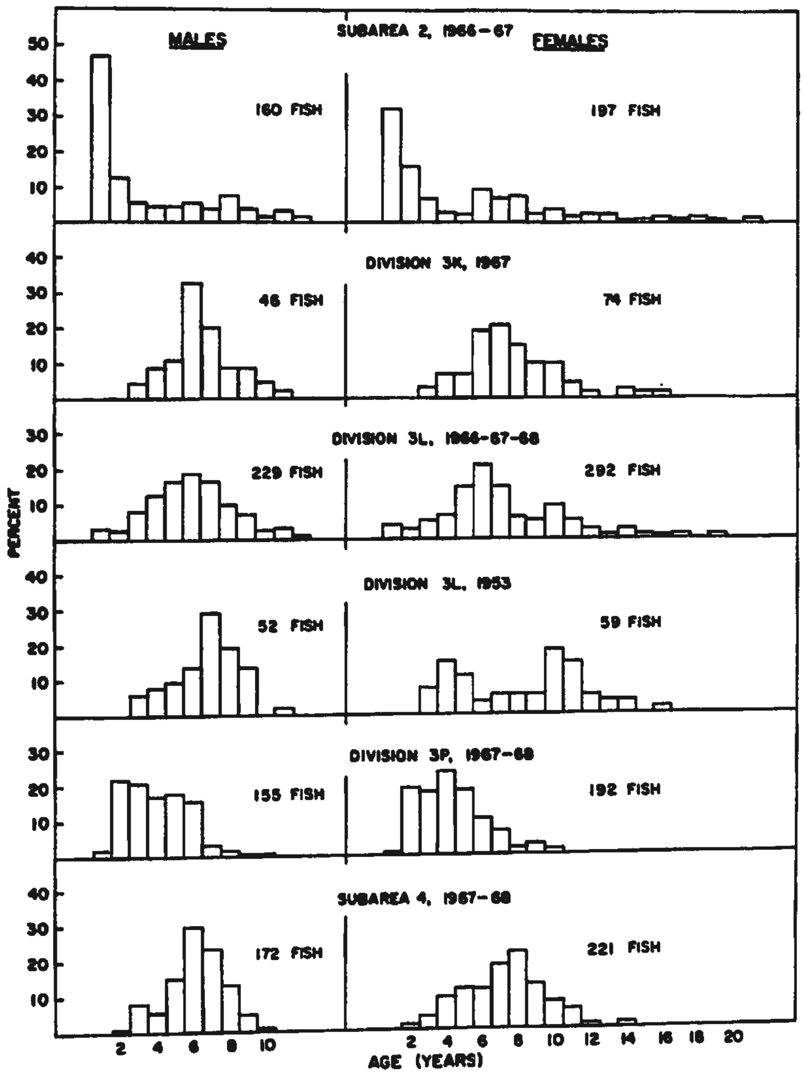

Fig. 29. Age distributions of Greenland halibut (males and females separate) from various areas.

(c) Growth Curves. Fig. 30 shows the growth curves for the various areas under consideration. The growth curves of both sexes for Division 3L (Trinity Bay) during 1966-68 show an increase in average length-at-age since 1953. For the males, the increase was the same for all ages, at least for ages 4 to 12. For the females, the greatest increase was in the older fish. Fig. 31 shows that for the Labrador Shelf to Trinity Bay areas, there was an increase in length-at-age from north to south. The growth curves for Trinity Bay to the Gulf of St. Lawrence areas show that the average length-at-age for Trinity Bay was higher than that for Division 3P and Subarea 4. The growth curves for the Division 3K and Subarea 4 females are similar for the older fish, at least as far as the data extended, up to 14 years.

Except for a low value for the 3P females at age 8, there was a good relationship between average length-at-age of the age-8 and age-14 females and the mid-latitude of each area under consideration; the average length-at-age increasing with decreasing latitude (Fig. 32).

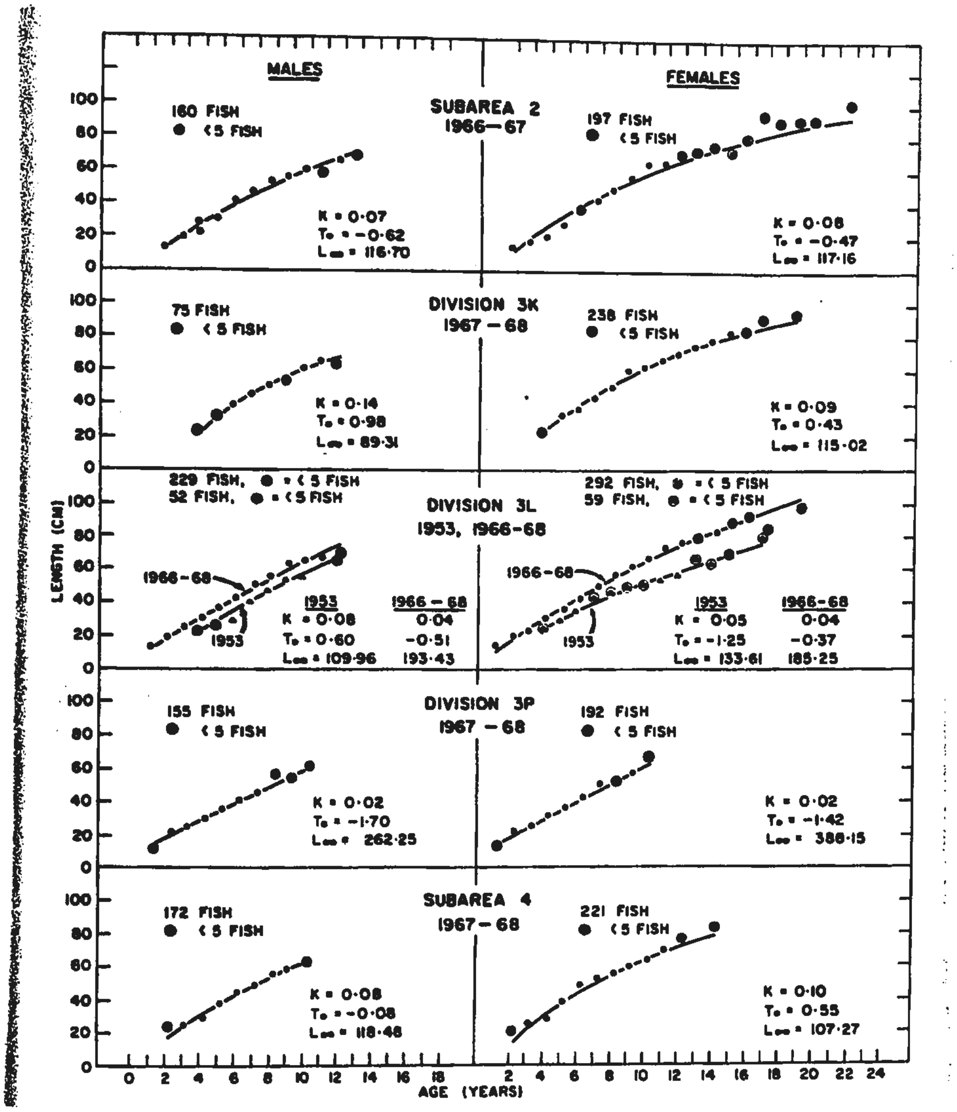

Fig. 30. Growth curves of Greenland halibut from various areas (males and females separate).

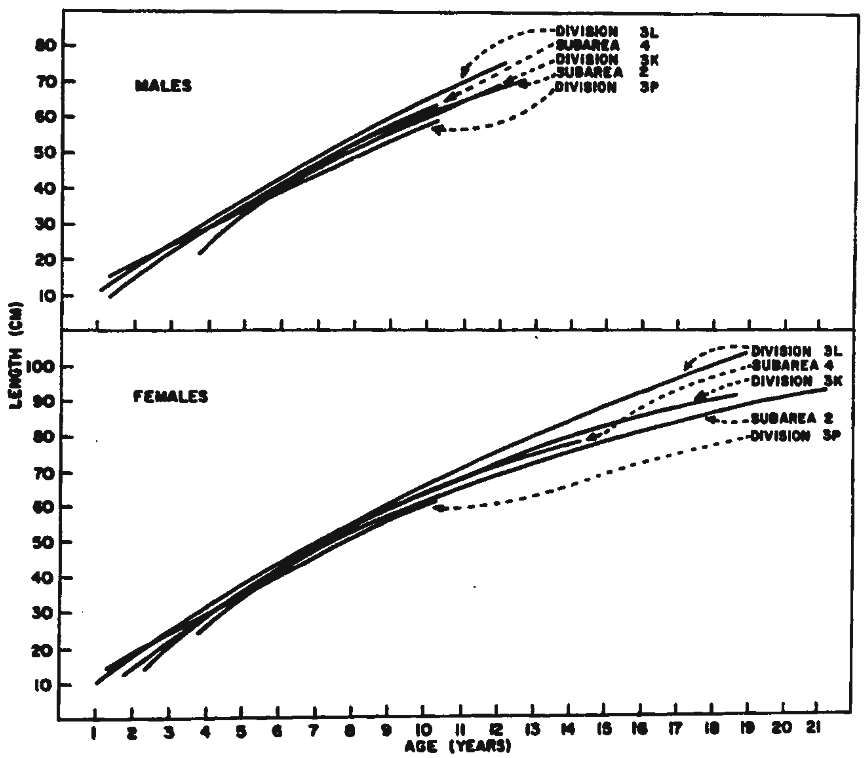

Fig. 31. Comparison of growth curves of male and female Greenland halibut from various areas.

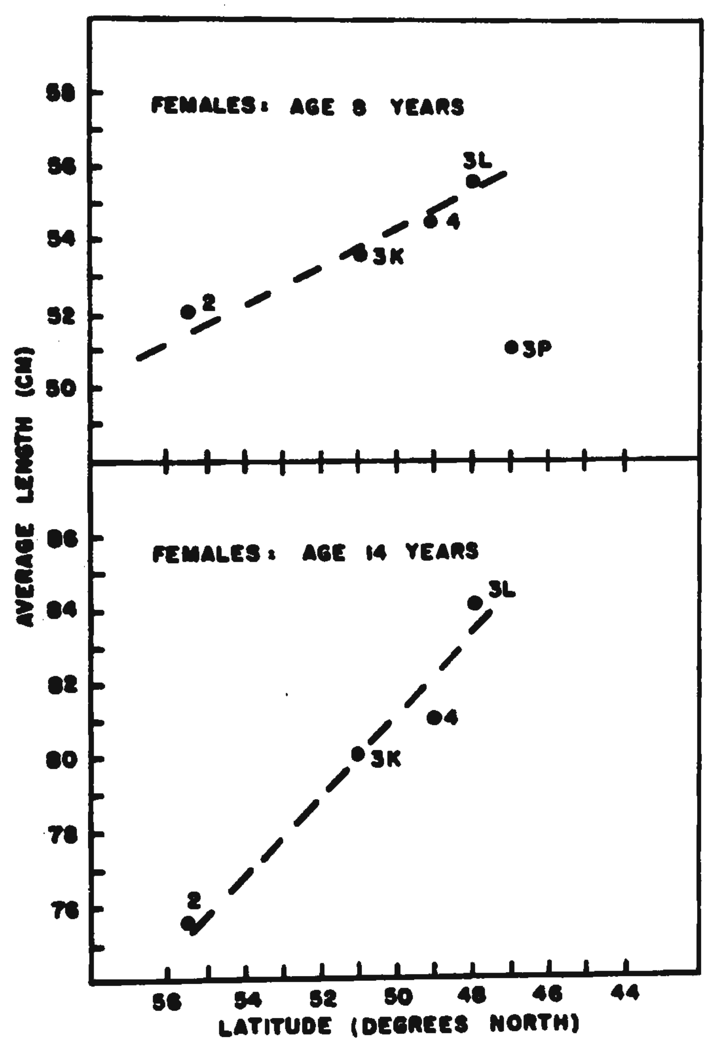

Fig. 32. Average lengths at age of 8-year-old and 14-year-old female Greenland halibut versus mid-latitude of the various areas from which the fish were sampled.

(d) Length-Weight Curves. The length-round weight curves for the various areas under consideration are shown in Fig. 33 and the length-gutted weight curves are shown in Fig. 34.

A comparison is shown in Fig. 35 of the length-weight curves for female Greenland halibut in various areas. From the length-round weight curves, it can be seen that the average weight at length for Subarea 2 females is lower than that for Division 3L, while the average for Division 3K is less than that for the former two areas. Subarea 4 and Division 3P have lower average weights at length than the other three areas. The round weight curves may be biased by the amount of food in the stomachs at the time of capture, especially for the larger fish.

The average gutted weight at length for Division 3K females is greater than that for Division 3L which in turn is greater than that for Subarea 2. Division 3P values are intermediate between Division 3L and Subarea 2 values for the fish up to 66 cm long, with Subarea 4 values again being lower than those for Subarea 2.

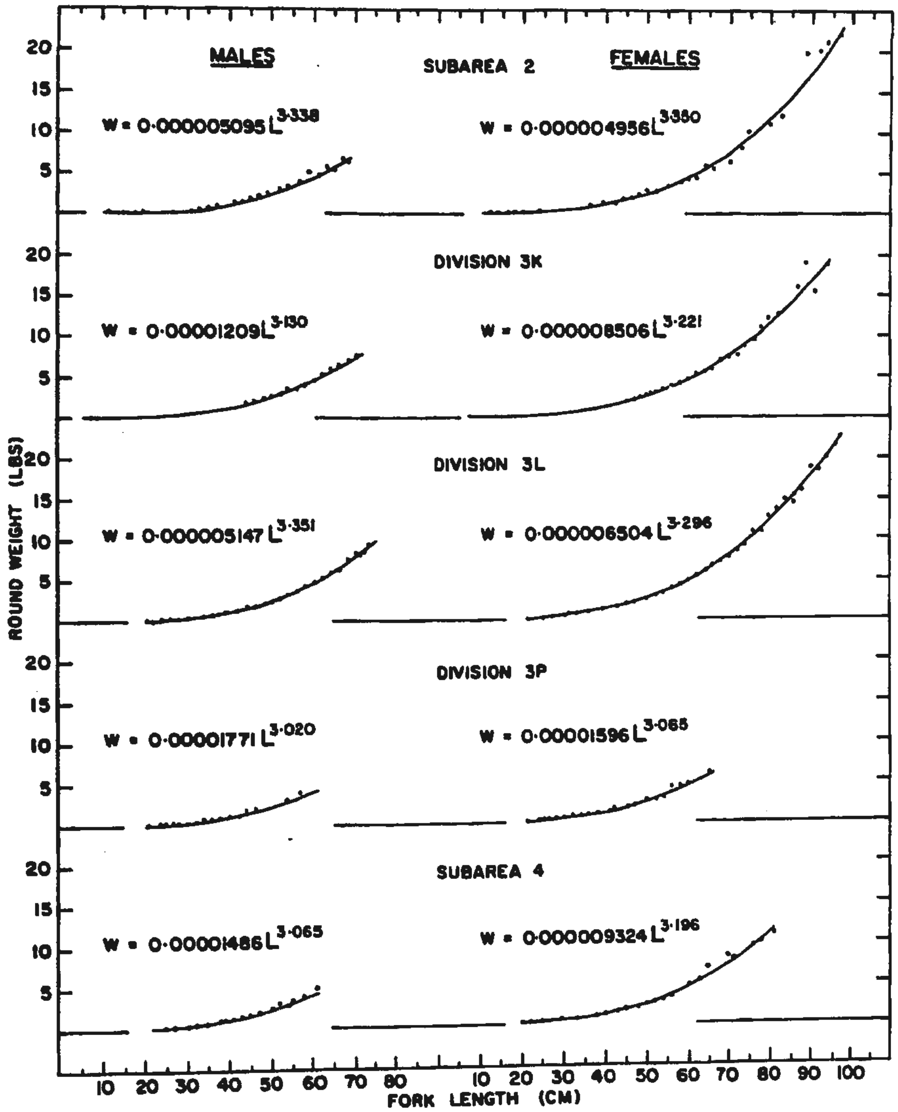

Fig. 33. Length-round weight curves of male and female Greenland halibut from various areas.

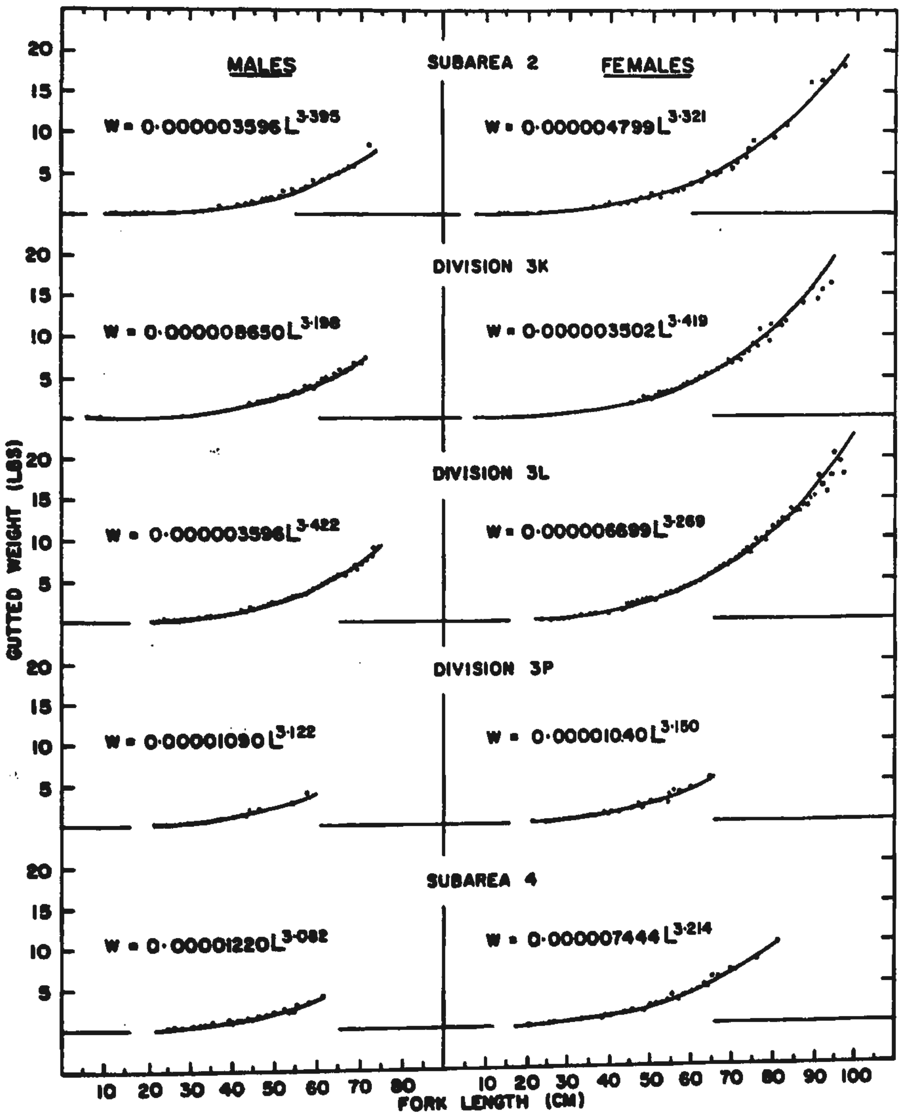

Fig. 34. Length-gutted weight curves of male and female Greenland halibut from various areas.

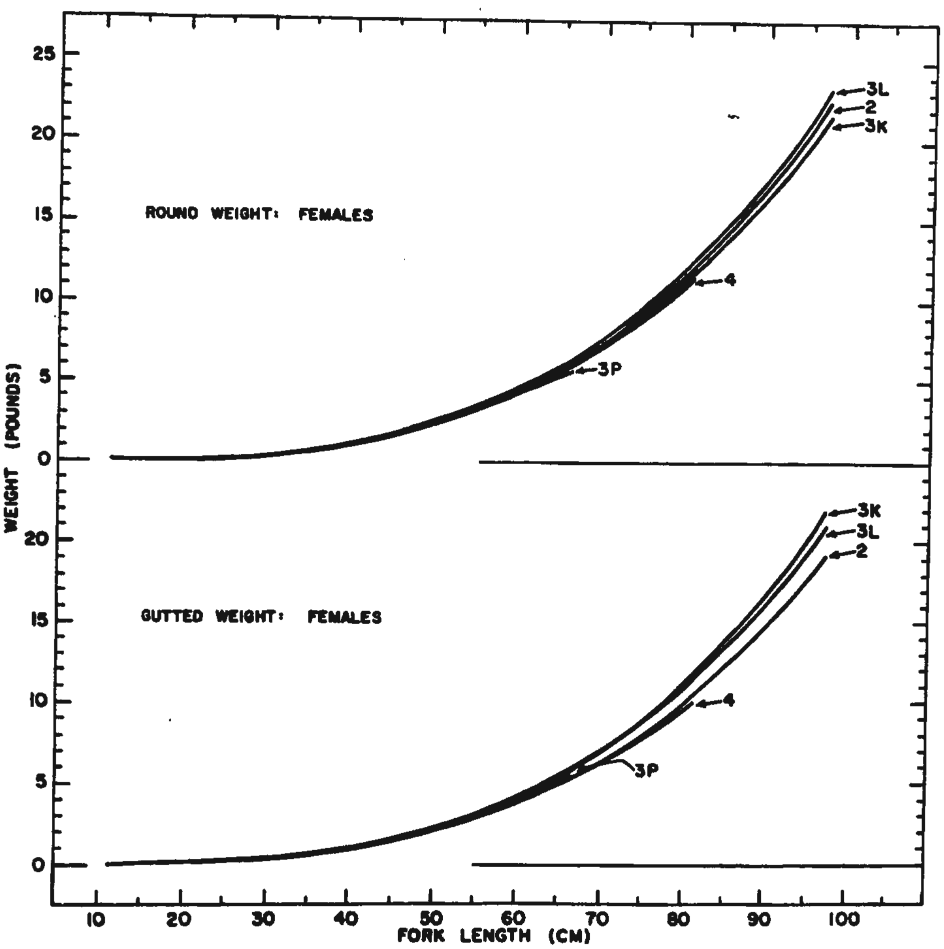

Fig. 35. Comparison of round and gutted weight curves of female Greenland halibut from various areas.

Estimates of Total Mortality (Z)

Fig. 36 shows the estimates of the instantaneous total mortality coefficient (Z) for male and female Greenland halibut for the several areas under consideration. The mortality rates (Z) for Division 3L (Trinity Bay) during the periods 1953 and 1966-68 are shown separately. In all areas the female mortality rate (Z) was lower than for the males, except for Trinity Bay (1953) where they were almost equal (0.39 for females and 0.38 for males). Subarea 2 had a lower mortality rate (Z) than any other area, for both sexes during the period 1966-68, (0.28 for females and 0.38 for males). Division 3K had higher mortality rates (Z) for both sexes, (0.37 for females and 0.52 for males).

Division 3P and Subarea 4 had very high mortality rates (Z) for males (1.05 for Division 3P and 0.47 for Subarea 4).

There has been no great increase in the mortality rates (Z) of both sexes in Division 3L (Trinity Bay) since 1953. The mortality rate (Z) of males increased from 0.38 in 1953 to 0.64 in 1966-68 while the mortality rate of females increased from 0.39 to 0.47 during the same

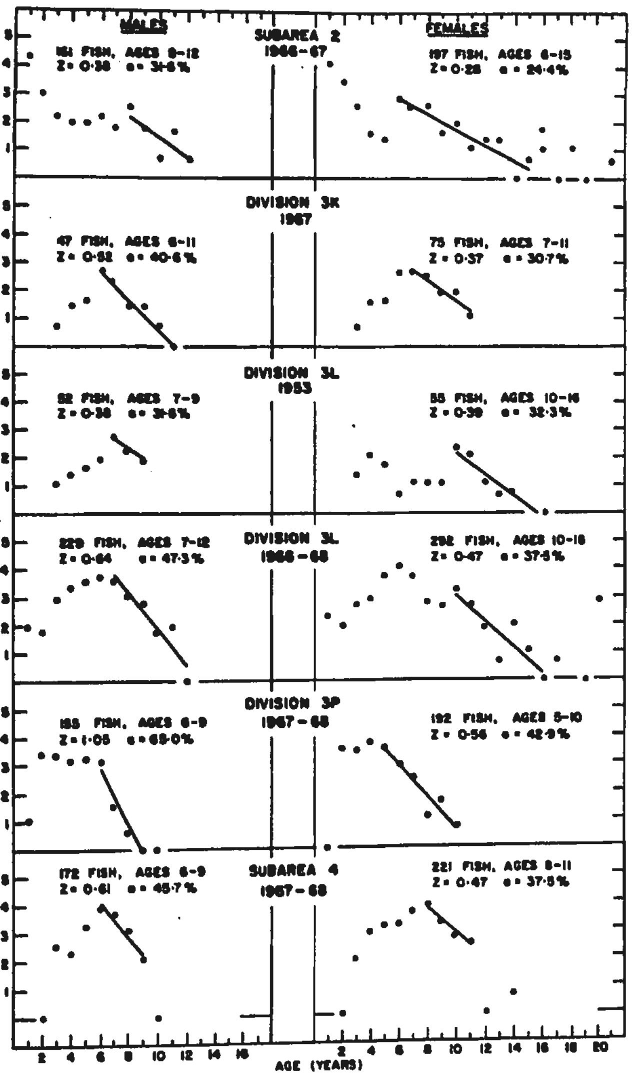

Fig. 36. Catch curves of age distribution of Greenland halibut taken by lined otter trawl showing the calculated total (Z) and annual (a) mortality rates for male and female Greenland halibut in various areas.

period. This only represents an increased annual mortality rate (a) of 16% for males and an increase of only 5% for the females since 1953.

DISCUSSION AND CONCLUSIONS

Distribution in the Newfoundland Area

The average catches (pounds)/32 lines/hour,/50 fathom gillnet/24 hours and /1-hour's drag have been used as indices of distribution and relative abundance in relation to depth and temperature. The best longline catches on the east coast of Newfoundland were taken in depths of 160-310 fathoms and bottom temperatures of 1.1-2.8°C. The longline survey was carried out from September 2 - December 2, 1966 and as such gives only a seasonal index of abundance.

De Groot (MS, 1968) states that in the spring the longline fishery in West Greenland fjords may be a failure whereas during the same period handlines are very profitable. Both types of lines are used in places with a depth of about 300 m (164 fathoms), but longlines lie on the bottom and handline fishermen have only 200 m (109 fathoms) of line out. This suggests that Greenland halibut do not live on the bottom or at least periodically migrate vertically in search of food or because of other undetermined reasons. Further evidence of this vertical migration was obtained when 12 Greenland halibut ranging in size from 21 to 29 cm (average 24.92 cm) were caught in herring nets with the headrope set 6 fathoms from the surface over a depth of 91-110 fathoms in Conception Bay on July 29, 1966. The attachment of floats to Greenland halibut longlines is a common practice of Greenland halibut fishermen in Green Bay. The floats apparently serve two purposes in this case: 1. prolongs the time taken for the lines to sink and thus gives them more fishing time in the mid- and lower depths and also, 2. keeps the bait from sinking into the mud or beneath stones when it eventually reaches bottom. It is possible that the indices of abundance as determined from longlines are underestimated if the Greenland halibut were not all near the bottom at the time when the lines were fishing. Another factor to consider with respect to longline fishing is the availability of food at the time the lines were set. If there were a plentiful supply of food in the area where the lines were set, the indices of abundance would again be underestimated since a smaller proportion of the Greenland halibut would be attracted to the baited hooks.

The relative selectivity of different mesh sizes must be considered when average gillnet catches are used as indices of abundance. In the east coast bays of Newfoundland the 6" mesh gillnet usually catches a greater number of fish than the 8" but the weight of the 6" catch is always less than the catch of the 8" gillnet. In Fortune Bay, where very few large Greenland halibut were found, the weight of fish caught in the 8" mesh nets was approximately the same and in some cases less than that caught by the 6" mesh nets. In view of the foregoing it must be borne in mind that an index of abundance based on the catch for a gillnet of given mesh size is only valid for a particular size range of fish which is selected by the mesh size.

The 1967 and 1968 research vessel catches for Trinity Bay were not included in the averages because it was believed the decrease in catch per unit effort would bias the results and it was considered that it would be preferable to have the results comparable on the basis of equivalent fishing exploitation. The figures for Trinity Bay for 1966 and for Notre Dame Bay for 1967-68 and Bonavista Bay for 1968 were considered to be comparable as these latter bays were being fished to approximately the same degree during 1967-68 as Trinity Bay was up to 1966.

The largest research vessel catch of Greenland halibut on the east coast per 6" mesh gillnet was 260 pounds caught in 128-136 fathoms and bottom temperature of 2.13°C. in Trinity Bay. Very small catches were obtained in Fortune and Hermitage Bays in depths of 99-305 fathoms and temperatures of 0.6° to 4.9°C. The small catches in Bonavista Bay during late 1968 may be because of the high fishing intensity during 1967 and 1968 when large quantities of Greenland halibut were taken.

The largest research vessel catches per 7" gillnet from Notre Dame Bay are for the central part of the bay where the bottom contour slopes gradually from 160 to 200 fathoms and the temperature was around 2.0°C. These catches were higher than those for the 6" gillnets because of the selection of intermediate- and larger-size fish by the 7" mesh. In Trinity Bay the best catches were in 128-152 fathoms and bottom temperatures of 2.0-2.2°C.

The largest research vessel catches per 8" gillnet in Notre Dame Bay were in depths of 178-228 fathoms and temperatures of -0.3° to 1.9°C. The catches in Bonavista Bay were small. Commercial fishermen in Bonavista Bay were also obtaining very small catches at the time the survey was conducted.

The results of the surveys in Trinity Bay during 1966 and 1968 were treated separately to show the effect of the increased fishing intensity on the catch per unit effort. The average catch per gillnet (6" and 7" mesh nets combined) decreased from 96 pounds in 1966 to 23 pounds in 1968. The average catch per commercial gillnet during the same period decreased from 346 pounds in 1966 to 90 pounds in 1968. The commercial catches are higher because the fishermen exploit the largest concentrations whereas the survey was conducted over depths ranging from

110 to 288 fathoms. The best catches in the 1966 survey ranged between 187-277 pounds in depths of 128-152 fathoms and temperatures of 2.0-2.2°C. The best catch in 1968 never reached 50 pounds per gillnet in a survey conducted in depths of 122-320 fathoms and temperatures from 0.2° to 2.3°C. The 1966 figures are for November 2, - December 10, and those of 1968 are for May 29, - June 6. The seasonal difference, if any, should be in favor of the 1968 figures which should be higher since the greatest catch per effort for commercial gillnets occurred at the beginning of the season and decreased markedly as the fishery progressed throughout the rest of the year. This may be due to increased concentration of Greenland halibut during the winter when the fishing intensity ceased, or by the deepening of the thermocline forcing the fish to concentrate in the deep water or by movement of Greenland halibut into Trinity Bay during the winter and spring. It is interesting to note that the catches in late 1969 have increased very markedly in Bonavista Bay. This may be due to the migration of Greenland halibut into the Bay from outside areas and a build up of stocks as a result

of the decreased fishing intensity when the commercial fishermen moved to White and Notre Dame bays. The best catches per 1-hour drag in Trinity Bay during March, 1967 ranged from 2504 to 4088 pounds in depths ranging from 167 to 264 fathoms and temperatures from 1.1° to 2.8°C.

The otter trawl catches for March, 1967 and January 1968 when plotted against temperature show that the largest concentrations of Greenland halibut during this period at least are found in depths ranging from 150-325 fathoms and temperatures from 1° to 3°C.

The information on distribution and abundance of Greenland halibut in ICNAF and other areas is very scanty indeed but the results which are available compare favorably with the foregoing.

Jensen (1925) found that the Greenland halibut were most plentiful in depths of 400-500 m (219-285 fathoms) in Lichtenaufjord in South Greenland.

Novikov (1960) observed that the largest concentrations of Greenland halibut in the Barents Sea occurred most frequently in depths of 350-450 m (191-246 fathoms), ordinarily in depths of 200-500 m (110-

273 fathoms) and only occasionally in depths less than 200 m (110 fathoms). Greenland halibut are capable of descending to greater depths, however, and Jensen (1935) reports a specimen 77 cm long taken at 1600 m (875 fathoms) in Davis Strait. Paschen (1968) states that the best catches of Greenland halibut were taken at depths between 500-600 m (273-328 fathoms) off Northwestern Iceland during April 27 - May 11, 1967. Very few Greenland halibut were taken in two hauls in 400 m (219 fathoms). Smidt (1969) reports that small-sized Greenland halibut (under 20 cm) were most frequent in shallow depths (200-250 m (109-137 fathoms)) while the larger, commercial-size fish have their maximal abundance in depths of 350-600 m (192-328 fathoms).

Mikawa (1963) reports that Greenland halibut were usually caught at depths between 150-500 m (82-273 fathoms) in Hachinohe region of eastern Japan. In the Bering Sea he observed that Greenland halibut were caught in depths between 68-670 m (37-366 fathoms) but are mostly found at depths between 200-500 m (109-273 fathoms).

The largest catch of Greenland halibut in depths less than 175 fathoms was 396 pounds per trawling hour in 155 fathoms and 3.7°C. The catches in depths of 51-150 fathoms were very small even though the temperatures ranged from -1.0° to 4.0°C. In the Gulf of St. Lawrence no Greenland halibut were caught less than 75 fathoms or in temperatures less than 0.0°C. with none being caught in the 76-100 fathom range less than 2.0°C. The largest catch (328 pounds) occurred in 178 fathoms and a bottom temperature of 4.1°C. All catches made during May were in depths of 126-300 fathoms and temperatures of 4° to 5°C.

During October in the same area no Greenland halibut were caught in depths less than 75 fathoms or temperatures less than 3.0°C. The best catches occurred in depths of 126-175 fathoms and temperatures of 3° to 5°C.

These temperature ranges are high for Greenland halibut compared with those for the east coast bays but it also must be noted that the catches in the Gulf are very small compared to those for Trinity Bay or Hamilton Inlet Bank and the Labrador Shelf. Novikov (1960) stated that all the halibuts in the Bering Sea prefer water of low positive temperatures, in the range 3°-4°C. and the Greenland halibut rarely crossed the isotherms of 1° and 5°C. This is true of Greenland halibut in the Gulf of St. Lawrence but on the slopes of Hamilton Inlet Bank, Labrador Shelf and in Trinity Bay good catches were obtained in temperatures ranging from -1.0° to +1.0°C. In Trinity Bay there was a catch of 952 pounds in 98-101 fathoms and a bottom temperature of -0.4°C. In the Gulf of St. Lawrence, except in one instance, no Greenland halibut were caught in temperatures greater than 5.0°C. However, during a gillnet survey 6 Greenland halibut (27 pounds) were caught in 240-305 fathoms and bottom temperature of 5.1° in Bay d'Espoir.

Food and Feeding

Capelin are the major food of Greenland halibut in the length range 21-80 cm. Below 20 cm the major food consists of euphausiids and above 80 cm it consists of Greenland halibut, cod and other fish. An inverse relationship exists between the length of the fish and the percentage volume and occurrence of euphausiids, with a decrease in percentage with increasing length. Smidt (1969) found similar results for small fish below 20 cm in Godthaab Fjord and in the coastal region south of Godthaab.

Shrimp contribute only a minor part of the volume but occur quite frequently in the intermediate and larger size fish (41-80 cm). Smidt (1969) found that the major food item of the large fish in the fjords of West Greenland and in Disko Bay was _Pandalus borealis_ although in some cases this group was found in fish of all sizes above 20 cm. Above 70 cm the Greenland halibut resorted to cannibalism and for fish of length 81-100 cm Greenland halibut comprised 45-47% of the volume and occurred in 29-37% of the stomachs which contained food. Other fish found in the stomachs were cod, rough-headed grenadiers, eelpouts, redfish, sculpins, American plaice, witch, and thorny skate. Invertebrates other than shrimp and euphausiids were squid (_Gonatus fabricii_), amphipods, queen crab, polychaete worms and one squid (_Rossia palpebrosa_).

Novikov (1960) stated that all the species of halibuts in the Bering Sea were active predators, eating such fishes as Alaska pollock, smelt, flounders, sculpins, lycodids and also large crustaceans (spider crab, colt crab, shrimps) and cephalopod molluscs (octopuses, squids).

Mikawa (1963) observed that the Greenland halibut off Japan and in the Bering Sea fed mainly on fishes which comprised 73% of the items by occurrence. The food next largest in quantity found in the stomachs was squid with a frequency ratio of 16%. The crustaceans such as shrimps, euphausiids amounted to 15.5% of the frequency ratio.

Konstantinov (1967) observed that Greenland halibut off Northern Iceland fed mainly on shrimp, cephalopods and fish during July-August and began feeding intensively on sandeels during September.

Jensen (1935) and de Groot (MS, 1968) found that Greenland halibut fed mostly on capelin, polar cod, small redfish and prawns and both attributed the presence of these large amounts of capelin to the vertical migration of Greenland halibut into the upper layers in pursuit of this species. This fact may account for the occurrence of Greenland halibut in the upper surface water of Conception Bay as discussed in the section on distribution.

No information on the food and feeding habits of Greenland halibut in relation to depth has been published to date. The results of the author's study show that capelin are a major item in the diet of Greenland halibut in all depths except the 201-225 and 251-275 fathom intervals where Greenland halibut formed the major item in terms of volume. Shrimp account for from 2 to 20% of the volume in all depths except 76-100 fathoms where euphausiids constitute 7% of the volume. Euphausiids account for very small amounts in the other depths. Shrimp, however, occur quite frequently in all depths except 76-100 fathoms reaching as high as 75% in the 226-250 fathom depth interval. Capelin forms such a major part of the volume and occurs so frequently probably because of the vertical migration of Greenland halibut into the upper layers in pursuit of this species. In this respect the percentage volume and occurrence of capelin in the Greenland halibut stomachs is fairly independent of depth. Templeman (1965) reports that large numbers of Greenland halibut were washed ashore on the eastern side of Trinity Bay on April 8, 1943 and during the week of March 26 - April 2, 1959. It was suggested that the Greenland halibut were moving into the intermediate layers in pursuit of the pelagic capelin and encountered water so cold that they were stunned and lost control of their movements and were finally killed by the cold water or by ice-seeding at the surface.

The seasonal feeding pattern of Greenland halibut shows some fluctuation with respect to the volume and frequency of capelin in the stomachs. The percentage volume and occurrence of capelin in the stomachs were high in the period January 16 - April 15, presumably because the capelin were in large over-wintering concentrations during this period and were readily available to the Greenland halibut (Winters, 1969). During early May the volume and occurrence of capelin in the stomachs were very low possibly because the capelin were in the surface layers (less than 15 fathoms below the surface). The volume of capelin for the period May 16-31, was very high, however. During the period June 1 - July 15, the percentage volume and occurrence of capelin in the stomachs were low presumably because the mature capelin are near the beaches where they spawn. During July 16 - August 15, the percentage volume and occurrence were high as the capelin move offshore during this period and are again available to the Greenland halibut in the warm surface waters. During August 16 - November 30, the percentage volume and occurrence of capelin were low as the schools become dispersed after spawning and the capelin occur in small feeding schools in the warm surface waters and are not so readily available to the Greenland halibut.

The percentage volume and occurrence of shrimp were greatest when the capelin were least available especially during May 16 - July 15, and August 16 - November 30. The proportion of euphausiids in the stomachs of Greenland halibut also increased during these same periods. The percentage volume of Greenland halibut increased also during June 1 - July 15, and August 1-31, when the capelin were unavailable. Cod and American plaice supplemented the diet of Greenland halibut during May 1-15, in the absence of capelin. It seems that Greenland halibut prefer capelin as food when they are available but when these are not readily available, they will take shrimp, euphausiids, smaller Greenland halibut, and other fish to supplement their food supply.

The percentage volume of capelin in the stomachs is similar for the three depth ranges 126-150, 176-200 and 301-325 fathoms, especially for the length ranges 31-90 cm. In the 126-150 fathom range, the smaller fish (11-30 cm) feed almost exclusively on euphausiids while in the 301-325 fathom range the fish (21-30 cm) feed on capelin. The very small percentage of euphausiids and shrimp in the 301-325 fathom depths may be due to smaller relative abundance of these organisms in these depths.

For the 126-150 fathom interval there is an inverse relationship between the percentage volume and occurrence of euphausiids with length. Greenland halibut are not eaten in any volume in this depth probably due to the availability of capelin.

Shrimp and euphausiids are more important in terms of volume and occurrence in the 176-200 fathom interval. Smaller Greenland halibut are eaten by the larger of the species in this interval also possibly because the larger fish are not so active in migrating into the water column as the intermediate-sized fish.

In the 301-325 fathom interval, other items such as squid, queen crab, and amphipods and other invertebrates occur very frequently in the diets of the larger fish (51-90 cm) with a very small frequency of occurrence of capelin and other fish, although the volume of capelin is large compared with the volume of these invertebrates. Smidt (1969) states that pandalids (mainly *Pandalus borealis*) are very important in the diet of Greenland halibut in Disko Bay and Umanak district where these invertebrates are very plentiful. This is not the case in Trinity Bay where shrimp (*Pandalus borealis* and *Pandalus montagui*) are relatively scarce (Squires, 1961).

When the samples for all lengths and all depths are combined, it can be easily seen (Fig. 21D) that in the Newfoundland area Greenland halibut feed mainly on animals from plankton and nekto-benthos with true benthic animals being of very minor importance, the main animals being pelagic capelin, and pelagic crustaceans such as shrimp (Pandalus borealis and Pandalus montagui) and euphausiids. Greenland halibut larger than 20 cm are mainly piscivorous while the smaller fish feed mainly on invertebrates. The seasonal pattern of fish versus invertebrates changes very little except during June 1 - July 15; August 16-31; and November 1-30, when capelin are not readily available and they feed more on invertebrates, although by no means exclusively. When all the seasons and depths are combined it is evident that there is a change in diet as the fish grow larger beyond 11-20 cm when the importance of invertebrates decreases and the percentage volume of fish increases.

There is very little variation in the proportions of fish and invertebrates reflecting the relative independence of feeding on depth between the ranges 76-325 fathoms as the Greenland halibut can migrate vertically into the upper layers in search of food.

Combining all depths, lengths and seasonal patterns, one can conclude that capelin form the major part of the diet (76% of the total volume), followed by Greenland halibut (10%), shrimp (3%), cod (3%), euphausiid (1%), and other items (7%).

Age Validation

Determination of age from skeletal structures usually involves interpretation of the growth zones rather than straightforward counting. The importance of a critical approach to the ageing problem to ensure conformity of methods and results has been pointed out by Graham (1956), May (1965), Pitt (1967), Smidt (1969), and Powles (1966).

Graham (1956) reviewed seven techniques for demonstrating the reliability of otoliths and scales for ageing fish. Two of these have been applied to validate the age of Greenland halibut from otoliths, namely the Petersen method and the seasonal changes in the edge of the otolith.

The Petersen method which makes use of the polymodal nature of the length frequency distributions of samples containing fish of more than one age-group is very useful as a validation technique but it cannot be used to age individual fish. The seasonal change in the otolith does not validate a particular age or age group but provides evidence of the seasonal changes in the otolith edge which produces the annulus or growth ring.

The present study presents evidence in support of the validity of the otolith age method for Greenland halibut in Subarea 2 (Hamilton Inlet Bank and Labrador Shelf) based on the Petersen method. The length distributions of Greenland halibut for October 11-17, 1966 and October 21-26, 1967 are polymodal for the younger ages but overlap in the older fish or are indistinct because of very few fish beyond age 3. The smallest size at which a peak appears for the 1966 length distribution is 12-16 cm. Otoliths of these fish have a typically opaque central area with a narrow translucent band and an outer edge of opaque material which was interpreted as representing 1 full year of growth plus an additional part of another year. This is confirmed by the 1967 length distribution in which is included a sample of small Greenland halibut taken from cod stomachs. The otoliths of fish in the 0+ age group possessed, in some otoliths only, a very wavy translucent ring which was interpreted as a settling ring. The polymodal nature of the length distribution becomes indistinct beyond age 2 probably because of overlapping due to growth of the faster growing fish of one age group overlapping considerably the slower growing fish of another age group. The strong 1 year-class in 1966 is also prominent as 2^+ fish in 1967, whereas the 2^+ year-class of 1966 is barely distinguishable as 3^+ in 1967. In this respect the results of Smidt (1969) for Greenland halibut in West Greenland compare favourably with those of the present author.

Jensen (1935) established that the young larvae of the Greenland halibut were 10-18 mm during April 7 - May 9, in Davis Strait. Around June 20, the pelagic larvae caught measured 17-28 mm, around July 1, they measured 19-30 mm, and around July 7, they measured 25-41 mm. The largest Greenland halibut larvae he obtained were 34-57 mm during August 27-29. He also obtained Greenland halibut larvae in cod stomachs at the beginning of September measuring 60-70 mm. These larvae were fish which had hatched the preceding winter and spring and were in the 0^+ age group. These results agree with the measurements of 65 larvae from cod stomachs from Hamilton Inlet Bank. The larvae in this case which were caught on October 21, 1967 ranged in size from 5.9 cm to 7.7 cm with an average size of 6.9 cm.

The otoliths of a few fish show opaque edges as early as April but the greatest proportion of fish with opaque otoliths occur in July-October. By November otoliths of some fish are beginning to show a narrow hyaline zone at the otolith edge. The otoliths of younger fish (ages 1 to 6 years inclusive) show an opaque zone at the otolith edge earlier than those of older fish. In November the otoliths of younger fish show a greater proportion with hyaline zones than those of older fish. From 50 to 100% of the otoliths of fish of ages 1 to 4 show an opaque zone in the otolith edge in May in Division 3L and 3P and Subarea 4 and the percentage decreases with increasing age. This suggests that the annual period of body growth in old individuals is relatively shorter than for the younger fish (ages 1 to 6 inclusive).

From the seasonal incidence of opaque and hyaline zones of otolith edges it is reasonable to conclude that one hyaline and one opaque zone are deposited each year. However checks may occur between the annual hyaline zones and these may cause difficulty in the interpretation of age. These checks, however, can usually be recognized on the basis that they do not form a complete ring around the central area or because of their being much thinner than the annual hyaline zone.

Age and Growth

(a) Length Distributions. The greatest proportion of small fish (10-19 cm) of both sexes is found on Hamilton Inlet Bank and the Labrador Shelf. The relative lack of small Greenland halibut in Division 3K, and 3L cannot be explained until further research provides evidence on the spawning areas of Greenland halibut.

It may be that the Greenland halibut spawn over the deep warm waters out over Hamilton Inlet Bank and the Labrador Shelf and the larvae settle in the more northern areas first and as they grow they migrate southwards. A great deal of investigation needs to be done to clarify the patterns of spawning and recruitment in the Newfoundland -Labrador area. There are fair quantities of smaller fish in the Gulf of St. Lawrence and Hermitage Bay. Spawning does occur in the Gulf of St. Lawrence but there is very little evidence of spawning in Hermitage or Fortune Bays. Only 11 mature males and 2 mature females were obtained on a recent survey in the area. The greatest proportion of large fish are found in Divisions 3K and 3L with relatively large quantities being found in the Gulf of St. Lawrence and Hamilton Inlet Bank. There has been a reduction in the proportion of larger fish of both sexes in Trinity Bay since 1953 probably due to the large quantities removed since 1964 when the fishing intensity increased far above the previous level.

(b) Age Distributions. A very similar situation exists for the age distributions as does for the length distributions, quite understandably, since length is a function of age. There is a very high percentage (32-45%) of 1-year-olds and a fair percentage (12-16%) of 2-year-olds of both sexes in Subarea 2 with very small percentages of older age groups. In other areas, the 1-year-old group was not found as in Division 3K, or very scarce as in Division 3L. It may be that Hamilton Inlet Bank and the Labrador Shelf act as nursery grounds for the other areas. Division 3P had a fair proportion of 2-year-olds (19-22%). The intermediate sizes were most abundant in Divisions 3K, 3L, 3P, and Subarea 4. Again as in the case of the length distributions the proportions of older fish in Trinity Bay during 1966-68 were less than those for 1953. This was probably due to the cropping off of these older individuals by the high fishing intensity exerted since 1964, since the commercial gillnet catches are composed mostly of fish ranging in age from 8 to 12 years and fish of these ages would necessarily be cropped off first.

(c) Growth. Growth represents the excess of food digested and absorbed over and above that needed for maintenance requirements (Brown, 1957) and in the case of mature individuals for production of genital products. The yearly growth increment depends on the factors influencing availability of food and its assimilation to induce growth in the organism. The factors influencing availability of food for a predator are those which govern the predator-prey relationship and as such are density-dependent to some degree. The degree of assimilation would depend on the rates of digestion and metabolism. Molnár and Tolg (1962) showed that for largemouth bass *Micropterus salmoides* (Lacépède) the rate of digestion more than doubled from 5° to 10°C., with smaller increases above 10°C. Dawes (1930) showed, that for plaice, temperatures appeared to influence growth in that a fall in temperature would induce an inhibition of growth in both length and weight. Kohler (1964) suggested that for cod, temperature was related to growth indirectly by controlling the rate of food consumption.

There has been a considerable increase in growth rate of Greenland halibut in Trinity Bay (Division 3L) since 1953 (Fig. 30). The average length at ages 4-12 years for the males has increased by approximately the same amount (6 cm), from 1953 to 1966-68. The increased length at age for females is not the same for all ages. The female fish at age 4 years showed an increased average in length of 4 cm while the 16-year-old fish showed an average increase in length of 18 cm from 1953 to 1966-68.

The increased growth rate of Greenland halibut in Trinity Bay since 1953 is possibly due in part to a combination of the two factors previously discussed, namely the density-dependent factor of availability of food and the physical factor, temperature, determining the rate of metabolism and the utilization of the available food supply.

First, in terms of availability of food, any decrease in population size would mean greater availability of food to the surviving stock. The very high fishing intensity exerted since 1964 in Trinity Bay by longlines and later by nylon gillnets has decreased the population substantially as is evidenced by the increased total mortality of the older fish and the catch per effort data, which are generally a very good index of relative abundance. Therefore, the amount of food available per fish would have increased and could conceivably have lead to an increased growth rate.

In considering the indirect effect of temperature on the rate of food consumption and its assimilation to form new somatic tissue, it must be borne in mind that there has been a trend of increasing temperatures in all the depth levels on the Bonavista hydrographic section since 1950 (Fig. 23, Templeman, unpublished data). The Bonavista section lies off the mouth of Trinity Bay and as such would be some indication of conditions within the bay since the inshore waters of the Labrador current enter the bay from the Cape Bonavista area (Bailey, MS, 1958). The average temperature values for the 50 m-bottom depths during 1950-53 were all well below the average 1.51°C. for 1951-65. The temperatures during 1960-65 were all well above average except during 1961 when the average temperature was 0.05°C. below the average for 1951-65. Although no temperature data are available before 1950, it can be seen that for 4 years from 1950 to 1953 at least, the Greenland halibut were subjected to lower temperatures than for the period 1962-65. These increasing temperatures might lead to a higher degree of utilization of the increased food supply made available by the decrease in numbers of Greenland halibut in Trinity Bay resulting from the increased fishing intensity. The combination of both of these factors could possibly contribute to the increased growth rate since 1953.

In relating the growth rate to environmental factors such as temperature, it must be pointed out that Greenland halibut may change their habitat frequently especially by vertical migrations in the water column in search of food, especially capelin, where they may encounter temperatures lower than those on the bottom.

The growth rate of Greenland halibut decreases from Division 3L (Trinity Bay) northwards to Subarea 2 (Labrador Shelf and Hamilton Inlet Bank) (Fig. 31). There is a good positive relationship between the average length of females at age 8 and 14 years and decreasing latitude for all areas (except Division 3P) (Fig. 32).

Comparison of the temperature profiles from Hamilton Inlet Bank to the southwestern Grand Banks (Templeman, 1964) shows that the volume of cold water in the Labrador Current decreases from north to south. This is possibly the reason for the decrease in average length from south to north. The fish from Subarea 2 (Labrador Shelf and Hamilton Inlet Bank) are subject to a lower average temperature than those from Division 3K (Notre Dame Bay) or 3L (Trinity Bay) as a result of this. Although the average temperature in which the fish were caught does not always reflect the annual temperature conditions to which the fish are subjected, it gives some indication of the environment. Most of the fish from Subarea 2 were caught in the range 0° to 2°C. while most of those from Trinity Bay were caught in temperatures from 1° to 3°C. Most of the fish caught in the Gulf of St. Lawrence (Subarea 4) came from water with temperatures from 3° to 5°C. The Greenland halibut from Subarea 2 were taken in shallower depths than those from Division 3K and 3L generally, and in these shallower depths the temperatures would be lower than in the deeper waters of Trinity and Notre Dame bays.

The growth rate of the fish from Division 3L during 1966-68 is higher than that for the same area during 1953 and is much higher than that for the other more northern areas. Possible reasons for this are the higher temperatures in Trinity Bay than in these northern areas and also the increased availability of food because of the decrease in numbers in Trinity Bay as a result of the high fishing intensity.

The growth rate of males in Subarea 4 is slightly greater than that for Division 3K for the older fish (ages 6-11 years) while the growth rate of the older females (ages 12-14 years) decreases for Subarea 4 and is less than that for Division 3K (Fig. 31). The similarity of the growth rates for these two areas is possibly due to similar hydrographic conditions during July-August at least on the basis of a comparison of temperature profiles between Divisions 3K (Templeman, 1964) and 4R (Lauzier and Bailey, 1957). There is a cold layer of water less than 0°C. present in the Gulf of St. Lawrence during most of the year, having a maximum volume in spring and a minimum in autumn (Lauzier and Bailey, 1957). Fig. 22 shows the temperature profiles for Subarea 4 in the Esquiman Channel (between Bay of Islands and Cape Whittle Bank) during January 9 - February 1, 1968 and May 16-19, 1967. Most of the otolith samples were taken in the area previously mentioned as well as in the area between Cape Ray and Anticosti Island. This latter region is also influenced by the Labrador Current from the east (Bailey et al. MS, 1954).

The fish from Division 3P (Placentia Bay and Hermitage Bay) have a fast growth rate especially for the ages 1 to 4 years for both sexes while the older fish (ages 6 to 10 years) have a very slow growth rate. The faster growth rate of the smaller fish from Division 3P is possibly because of higher temperatures than in the other more northern areas although the Labrador Current passes into and around Placentia Bay. The slower growth rate of the older fish may be because of factors affecting the availability of food or by migration of the older or faster growing fish to other areas. Since there are very few fish in this area over 60 cm there must be migration of these larger fish to other areas. There might be some migration to Fortune Bay but this is probably small since gillnet surveys in Fortune Bay during September-October, 1969 failed to find any large concentrations of Greenland halibut. There were relatively very few fish longer than 70 cm caught in the 6", 7" or 8" mesh nets.

(d) Length-Weight Relationships. Comparison of the length-round weight curves of female Greenland halibut from various areas (Fig. 35) shows that the fish from Division 3L have the greatest average weight at length especially for the larger fish (50-100 cm). The difference is even greater when it is considered that the Subarea 2 length-weight curve is based on fish caught during September-October when they are in prime condition after the summer's feeding. Paschen (1968) reports that the average weights of both male and female Greenland halibut from Icelandic waters were much greater during September than they were during May of the same year.

The fish from Division 3L were caught throughout the year and as such the curve is an average of the yearly length-weight relationship. Lear (1969) found that for Greenland halibut from the commercial fishery (both sexes combined) in Trinity Bay (ICNAF Division 3L) the equation of the whole weight versus length was $8.702 \times 10^{-6} L^{3.2114}$. These fish were also sampled throughout the year with most being sampled during May-September. These values are below those calculated from the research data. The average weight at length for Division 3K is less than for Subarea 2 on the basis of fish measured during September-October. The low average weights at length of fish from Division 3P and Subarea 4 are probably because all the fish from the former division were caught during April-May and those from the latter subarea were caught mainly during May with about 1/3 of them being taken during October-November. The length-weight curves may be biased by the amount of food in the stomach at the time the fish were caught.

The length-gutted-weight curves, which are a better indication of the condition of the fish than the round-weight curves because the source of bias caused by varying amounts of food in the stomach at time of sampling is removed, show a different length-weight relationship for the females of the various areas. In this case the length-weight curves for Division 3K and 3L are very similar with the average weights at length being slightly higher for 3K than for 3L. The average weights at length for the larger females of Subarea 2 are again lower than those for 3L and in this case lower than those for 3K. The smaller fish (50 cm and less) are all approximately the same weight at any given length for all areas under consideration. The length-gutted weight curve for Division 3P lies between that of 3L and Subarea 2. The length-weight curves for both gutted and whole weights of females from Subarea 4 are lower than those from the other areas possibly because of the seasonal differences in the condition of the fish and other reasons to be discussed later.

The differences in the length-weight relationships from the various areas, apart from the seasonal differences, may be because of the same factors influencing the average length at age, namely the availability of food in the area and the environmental conditions such as temperature influencing the rate of utilization of the available food supply (Dawes, 1930: Molnár and Tolg, 1962). Smidt (1969) found that the Greenland halibut of Godthaab Fjord in West Greenland were in very poor condition while those of Umanak and Julianehab Districts were in good condition. He suggested that rich prawn stocks occurred in those areas where Greenland halibut in good condition occurred, with very poor prawn stocks being found in Godthaab Fjord, where the Greenland halibut were in poor condition.

Another contributing factor to the lower average weight at length of Subarea 4 females is that these fish mature faster than those in the east coast bays and off Labrador. The Subarea 4 samples were collected during May when some of the female Greenland halibut, ranging in length from 51 to 81 cm (average 64.7 cm) were found to be in a post-spawning condition. These fish had from 20 to several hundred old eggs remaining in the central part of the ovary and new developing eggs present. Relatively fewer fish in this stage of maturity have been seen in the east coast bays but some have been found with new developing eggs during September-November. The maturing fish from Trinity Bay were 83-106 cm (average 90.8 cm), from Notre Dame Bay 73-94 cm (average 85.9 cm) and from Hamilton Inlet Bank 83-105 cm (average 90.9 cm).

The fish from the Gulf of St. Lawrence were caught mainly in the spring when their condition was low because of decreased growth during the winter and the utilization of food material for production of eggs. This, plus their maturing at an earlier age and shorter length than those on the east coast of Newfoundland and off Labrador serves to explain why there is a lower average weight at length for fish from the Gulf than from these other areas, especially so for the older females.

Mortality Rates

It should be re-emphasized that the mortality rates for some of the areas may be in error in view of the small numbers of fish and also the possibility of error in reading the ages of the older fish.

The annual mortality rates (a) of both males and females for Subarea 2 are low (31.6% and 24.4% respectively). This is probably because there is no commercial fishery for Greenland halibut in this area. There would be some fishing mortality as a result of incidental catches which amounted to approximately 2 million pounds in 1964 (Templeman, 1966). The mortality rates for Subarea 2 could be interpreted as being a little greater than the upper limit of the natural mortality rates for the age groups under consideration.

The annual mortality rates (a) for Division 3K (40.6% for males and 30.9% for females) are a little higher than those for Subarea 2 possibly because of sampling error considering the small numbers of fish involved in the calculations of the rates for 3K or because of errors in age reading of the older fish, a factor which enters into all calculations of mortality rates.

The annual mortality rate (a) for Trinity Bay males during 1953 is exactly the same (31.6%) as that for the males in Subarea 2 during 1966-67 while the rate for the females (32.3%) is slightly higher for Trinity Bay than for Subarea 2. The high rate for the females may again be because of the sampling error of small numbers of fish from Trinity Bay during 1953 or because relatively very few fish were caught in 1953 by the Investigator II because of her slower towing speed compared with that of the A.T. Cameron which caught the fish in the other areas and in Trinity Bay during 1966-68.

The annual mortality rates (a) for 1966-68 (47.3% for males and 37.5% for females) do not show any great increase over those for 1953 in Trinity Bay. During 1953 in Trinity Bay there was only a very limited fishery for Greenland halibut. The total Newfoundland landings during 1945-53 ranged from ½ to 1 million pounds (round fresh) per year, most of which came from the north-western part of Notre Dame Bay so the fishery in Trinity Bay during this time was very low.

Fishing intensity increased in Trinity Bay during 1965 when approximately 18 million pounds of Greenland halibut were caught in the Newfoundland area, most of the catch coming from Trinity Bay. This increased fishing intensity which was relatively stable during 1966-68 is not reflected in the mortality rates. The first important age in the gillnet catches is 6 years with a modal age of 8-10 years and a mean modal age of 9 years. Thus according to Ricker (1958) it would take at least 6 years for this increased fishing intensity during 1966-68 to be reflected in the catch curves. This would then only be reflected in 3 year-classes beyond the modal age since the mortality of the 6-year-olds has to pass through the fishery to be reflected in the catch curve. The mortality of the fish older than the modal age would not be affected by the increased fishing intensity since only those fish being recruited to the fishery respond to the fishing intensity with a change in mortality.

The apparently high annual mortality rates (a) for Division 3P males (65.0%) and females (42.9%) are probably caused by migration of the larger fish from the area since relatively few fish larger than 60 cm were caught in this area.

The annual mortality rates for Subarea 4 males (45.7%) and females (37.5%) are lower than those for Division 3P and approximately the same as those for Division 3L (Trinity Bay).

SUMMARY

1. The Newfoundland landings of Greenland halibut increased from the usual 1 to 2 million pounds to 36.6 million pounds in 1967 with a landed value of 1 million dollars.

2. The average catch per 50-fathom gillnet decreased from 348 pounds (round weight) in 1966 to 150 pounds in 1967 and to 51 pounds in 1969.

3. The largest concentrations of Greenland halibut in the Newfoundland area occurred in depths ranging from 150 to 325 fathoms and temperatures from 1° to 3°C.

4. In Trinity Bay capelin are the major food of Greenland halibut in the length range 21-80 cm. Below 20 cm the major food consists of euphausiids and above 80 cm it consists of Greenland halibut, cod, shrimp and other fish.

5. Capelin are the major food of Greenland halibut larger than 20 cm in all depths except the 201-225 and 251-275 fathom intervals where Greenland halibut formed the major item in terms of volume.

6. Capelin are the major food of Greenland halibut larger than 20 cm in all months of the year although there is some seasonal fluctuation because the capelin are not always readily available.

7. The otolith age method was validated for Greenland halibut of Subarea 2 by using the Petersen method of polymodal length distribution.

8. The growth rate of Greenland halibut decreases from south to north possible because of the increasing influence of the cold Labrador Current in the northern areas. There is also a decrease in average weight at length from south to north.

9. The growth rate of Greenland halibut in Trinity Bay has increased since 1953 possibly because of an increase in temperature in this area and also because of a decrease in numbers resulting from the high fishing intensity in Trinity Bay during 1964-66.

10. Sufficient time had not elapsed since the increase in effort in Trinity Bay for the expected increase in total mortality to be reflected in the catch curves at the time of sampling.

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Table 1. Newfoundland Landings and Values of Greenland Halibut (1857-1968).

Year	Lbs. (Round Fresh) Landed	Value $	Year	Lbs. (Round Fresh) Landed	Value $
1857	1,800	18.	1881	1,500	50.
58	750	7.	82	1,200	40.
59	-	-	83	3,000	100.
60	-	-	84	-	-
61	-	-	85	900	30.
62	-	-	86	-	-
63	-	-	87	-	-
64	-	-	88	-	-
65	2,520	45.	89	-	-
66	40,800	1,088.	1890	1,200	20.
67	2,400	48.	91	4,200	42.
68	10,080	180.	92	-	-
69	3,900	78.	93	39,000	130.
1870	1,512	36.	94	48,000	160.
71	6,888	184.	95	57,900	193.
72	3,696	176.	96	45,600	152.
73	-	-	97	3,000	20.
74	1,512	21.	98	1,350	83.
75	3,864	196.	99	3,150	42.
76	-	-	1900	2,700	36.
77	-	-	01	3,800	68.
78	900	3.	02	13,500	252.
79	2,100	42.	03	52,500	874.
1880	600	20.	04	103,500	1,487.

Table 1. (Cont'd.)

Year	Lbs. (Round Fresh) Landed	Value $	Year	Lbs. (Round Fresh) Landed	Value $
1905	51,000	850.	1931	1,041,640	25,175.
06	27,600	490.	32	1,399,200	26,489.
07	85,800	1,520.	33	627,260	10,425.
08	105,000	2,068.	34	1,169,140	17,041.
09	172,800	3,317.	35	1,279,173	13,451.
1910	174,240	3,420.	36	1,411,858	26,670.
11	75,060	1,556.	37	1,562,326	28,123.
12	65,560	1,182.	38	915,600	18,163.
13	45,645	953.	39	655,500	14,421.
14	107,900	2,369.	1940	1,084,500	32,535.
15	362,100	9,762.	41	1,263,320	41,624.
16	1,268,700	31,424.	42	879,900	30,153.
17	721,200	17,838.	43	833,700	32,268.
18	2,123,100	70,917.	44	1,108,200	53,631.
19	1,016,500	41,045.	45	793,963	39,568.
1920	533,960	23,481.	46	619,118	38,239.
21	1,539,672	54,600.	47	514,480	38,626.
22	615,816	16,914.	48	758,376	58,061.
23	750,127	20,765.	49	909,700	79,084.
24	329,725	11,152.	1950	734,000	44,040.
25	589,940	18,666.	51	743,000	44,580.
26	1,407,970	44,275.	52	968,000	48,200.
27	862,366	25,713.	53	1,090,000	74,200.
28	1,283,640	35,146.	54	1,191,000	95,400.
29	1,145,950	32,369.	55	1,446,000	144,100.
1930	1,965,718	52,672.	56	1,727,000	172,000.

Table 1. (Cont'd.)

Year	Lbs. (Round Fresh) Landed	Value $	Year	Lbs. (Round Fresh) Landed	Value $
1957	1,308,000	122,900.	1963	1,735,000	196,600.
58	2,101,000	202,000.	64	3,909,000	465,000.
59	1,762,000	156,600.	65	17,964,000	451,000.
1960	1,621,000	125,400.	66	36,012,000	955,000.
61	1,667,000	135,200.	67	36,589,770	1,014,000.
62	1,312,000	140,200.	68	29,902,000	819,000.

1857-1949 Landings and Values from Customs Returns.
1950-1954 Landings and Values from Canadian Fisheries Statistics.
1955-1967 Landings from ICNAF Statistical Bulletin.
1968 from Department of Fisheries Statistics. (preliminary tables)
1955-1968 Values from Canadian Fisheries Statistics.
(Values from 1857 to 1949 inclusive are export values from Customs Returns.
Values from 1950 to 1968 inclusive are landed values.)

Table 2. Greenland Halibut Landings from ICNAF Subareas 1, 2, 3, 4.

(Thousands of pounds round fresh)

Country	1961	1962	1963	1964	1965	1966	1967	1968	Total	%
Can (N)	1,667	1,312	1,735	3,909	17,964	36,012	36,590	29,523	128,712	53.35
Can (M)						642	939	1,631	3,212	1.33
Den (G)	3,091		5,890	5,927	6,714	5,673	4,044	3,457	34,796	14.42
U.K.		4							4	0.00
Germany			578	450		977	662	302	2,969	1.23
Norway				29	2	4			35	0.01
Poland				4,044	1,303	2,465	7,323	12,802	27,937	11.58
Den (F)					40	4		4	48	0.02
U.S.S.R.				1,557	2,417	891	15,909	22,694*	43,468	18.02
Non-M						68		**	68	0.03
Total	4,758	1,316	8,203	15,916	28,440	46,736	65,467	70,413	241,249	99.99

1961-67 figures were obtained from ICNAF Statistical Bulletins.

1968 figures were obtained from ICNAF Preliminary Tables.

* Includes 3,181,815 pounds from "Baffin Island" which is outside the ICNAF Area.

** Non-member countries and Romania have not reported their landings for 1968.

Table 3. List of all items found in the stomachs of Greenland halibut from Trinity Bay.

Fishes

Raja radiata

Clupea harengus harengus

Mallotus villosus

Gadus morhua

Macrourus berglax

Lycodes lavalaei

Lycodes vahlii

Sebastes mentella

Cottidae (spec. unid.)

Glyptocephalus cynoglossus

Hippoglossoides platessoides

Reinhardtius hippoglossoides

Unidentified fish

Fish eggs

Invertebrates

Polychaete worms (spec. unid.)

Amphipods (spec. unid.)

Euphausiids (*Thysanoessa* sp.)

Chionoecetes opilio

Pandalus borealis

Pandalus montagui

Eualus macilentus

Sabinea septemcarinata

Argis dentata

Gonatus fabricii

Rossia palpebrosa

Unidentified invertebrates