The Distribution, Age and Growth and Sexual Maturity of Atlantic Halibut *(Hippoglossus Hippoglossus)* in the Newfoundland and Labrador Area of the Northwest Atlantic

W.R. Bowering

Fisheries Research Branch
Department of Fisheries and Oceans
P.O. Box 5667
St. John's, Newfoundland A1C 5X1

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THE DISTRIBUTION, AGE AND GROWTH AND SEXUAL MATURITY OF ATLANTIC HALIBUT (HIPPOGLOSSUS HIPPOGLOSSUS) IN THE NEWFOUNDLAND AND LABRADOR AREA OF THE NORTHWEST ATLANTIC

by

W. R. Bowering

Fisheries Research Branch
Department of Fisheries and Oceans
P.O. Box 5667
St. John's, Newfoundland A1C 5X1

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Atlantic halibut (Hippoglossus hippoglossus) are distributed throughout the Newfoundland-Labrador area generally in small numbers. There are concentrations located in the St. Pierre Bank and southern Grand Bank areas which are large enough to afford a low level of profitable commercial fishing operations. They prefer warm temperatures (>4°C) and can be caught at depths greater than 800 m although the various depths and temperature they inhabit may vary. Atlantic halibut are highly migratory and it is common for specimens to cross the Atlantic ocean between Canada and Iceland as well as migrate over long distances within the region. The age range of Atlantic halibut specimens used in this study was from 4-16 years old and grew approximately 10 cm in length per year. Males mature as early as 4 years old with M_{50} occurring at 8 years old. Females begin to mature at about 6 years-old with M_{50} occurring at approximately 12 years old.

RÉSUMÉ

Bowering, W. R. 1986. The distribution, age and growth and sexual maturity of Atlantic halibut (Hippoglossus hippoglossus) in the Newfoundland and Labrador area of the Northwest Atlantic. Can. Tech. Rep. Fish. Aquat. Sci. 1432: iv + 34 p.

Le flétan de l'Atlantique (Hippoglossus hippoglossus) est généralement réparti en petits bancs dans tout le secteur Labrador - Terre-Neuve. Certaines concentrations qui se trouvent dans les secteurs du banc Saint-Pierre et du sud du Grand Banc sont assez importantes pour permettre des opérations de pêche commerciale rentables à petite échelle. Ce poisson préfère des eaux moins froides (>4°C) et peut être pêché à des profondeurs dépassant 800 m, mais la température et la profondeur des eaux où il séjourne peuvent varier. Le flétan de l'Atlantique migre beaucoup; il est très fréquent que certains individus traversent l'Atlantique, entre le Canada et l'Islande, ou migrent sur des grandes distances dans la région. L'âge des spécimens de flétans de l'Atlantique utilisés pour la présente étude varie de 4 à 16 ans; ils ont grandi de 10 cm par an environ. Les mâles commencement à devenir matures dès 4 ans, avec la valeur M_{50} atteinte à 8 ans. Les femelles, pour leur part, commencement à être matures à l'âge de 6 ans, avec la valeur M_{50} atteinte vers l'âge de 12 ans.

INTRODUCTION

The Atlantic halibut (Hippoglossus hippoglossus) is the largest of the flatfish and highest priced of all groundfish along with the closely related Pacific halibut (Hippoglossus stenolepis). It was first described by Linnaeus in 1758 as Pleuronectes hippoglossus, a name which remained until 1817 when Cuvier made Hippoglossus a genus and named the halibut Hippoglossus hippoglossus. The name was changed to Hippoglossus vulgaris by Fleming in 1828 and this name was used for both the Atlantic and Pacific halibut until 1885 when Jordan reestablished Hippoglossus hippoglossus. Based upon comparisons of the Atlantic and Pacific forms in the early 1900's, the Pacific form was established as a separate species, Hippoglossus stenolepis. However, a detailed taxonomic review of the two forms by Bell (1981) suggests that there is little evidence for separating the Atlantic and Pacific forms into two species.

The Atlantic halibut is prevalent throughout the North Atlantic on both the North American and European coasts. On the European side they have been caught as far south as the Bay of Biscay and are distributed northward as far as the waters of Spitzbergen, Bear Island, and the Barents Sea. In North American waters they have been reported as far south as the coast of Virginia and are distributed northward to the commercial fishing grounds of George's Bank, Scotian Shelf, Newfoundland Grand Banks and the Gulf of St. Lawrence (Fig. 1). They are also common along the west coast of Greenland as far north as Disko Bay although they have not been reported on the Canadian side of the Arctic.

There has been very little published information available on Atlantic halibut in the Canadian Northwest Atlantic, particularly in recent years. McKenzie (1946) discussed the early history of the fishery for the species while McCracken (1958) published the results of a study during the mid 1940's on the biology and fishery of Atlantic halibut with particular reference to the Gulf of St. Lawrence and the Scotian Shelf. Kohler (1964) reported tagging results on Atlantic halibut while Kohler (1967a, b) presented information on changes in the halibut fishery during the 1950's and early 1960's as well as some biological information on maturity, spawning, and feeding of the species, particularly in the area of the Scotian Shelf.

With the exception of some extraneous pieces of information related to the overall fishery for Atlantic halibut in the Canadian Northwest Atlantic, nothing has ever been published on the biology of Atlantic halibut in the Newfoundland and Labrador area.

MATERIALS AND METHODS

DATA COLLECTION

Most of the data used in this study were collected using Canadian, Newfoundland-based research vessels and commercial boats chartered for research purposes. All vessels were conducting research surveys during the period 1972-84 for groundfish or shrimp in NAFO (Northwest Atlantic Fisheries

Organization) Subareas 2 and 3 (NAFO Div. 2G, 2H, 2J, 3K, 3L, 3M, 3N, 3Ø, and 3Ps, 3Pn) (Fig. 4). The vessels used either bottom otter trawl or Sputnik 1600 shrimp trawl fishing gear with nylon liners in the codend having a mesh size of 12.7-28.1 mm to prevent the escapement of small fish. Only catch records of sets in which no damage to the gear occurred were used in this study.

Data on catch rates of Atlantic halibut were also available from the Canadian Foreign Observer Program for 1984. These data were collected at sea by Canadian observers on foreign vessels fishing in Canadian waters. Only catch records of vessels using bottom otter trawl gear where Atlantic halibut occurred as part of the catch were included in the presentation. These catch rates therefore, are only meant to be representative of geographic distributions and are not meant to be indices of stock abundance.

Distribution and Relative Abundance

The geographic distribution and relative abundance of Atlantic halibut in the Newfoundland and Labrador area according to research surveys is shown by indicating within ½° latitude and 1° longitude rectangles, the average weights (kilograms) of fish caught per 30-minute set per rectangle. The number of successful 30 minute sets used in the calculations is presented in Fig. 2. The geographic distribution and relative abundance of Atlantic halibut according to data collected by the Canadian Foreign Observer Program is presented as mean weight (kilograms) per hour fished per statistical unit area. The statistical unit areas are those used by the Canadian Commercial Groundfish Sampling Section of the Northwest Atlantic Fisheries Center.

For the purpose of further analyses, the Newfoundland and Labrador area was divided into two regions, the northern region and southern region which were treated separately. The northern region consists of NAFO Div. 2G, 2H, 2J, 3K, and 3L combined. The southern region consists of NAFO Div. 3M, 3N, 3Ø, 3Ps, and 3Pn (Fig. 4).

Catch rates from research vessel surveys by month were computed for each region in order to determine times in the year when halibut are likely to be more available to otter trawl gear. These are presented as mean number per 30 minute set for each month. Similarly, catch rates were examined by 100 m depth intervals and 1°C bottom temperature intervals in order to examine the distribution of Atlantic halibut by depth and bottom temperature. For these data each region was evaluated by time of year using a January to June period and a July to December period. A further analysis was carried out to examine the mean length of Atlantic halibut caught per 100 m depth interval.

AGE AND GROWTH

Length (using 10 cm length groups) and age compositions were available from the research vessel data and presented by region and sexes separately. Ages were determined from otoliths. Growth (centimeters) was expressed in terms of log-log regressions (Length = $\log_e$ a+b $\log_e$ age (years)) weighted by the number of fish sampled in each age group. Growth curves were computed for

both regions and sexes separately. Growth (kilograms) was expressed in terms of log-log regressions (Weight = $\log_{10}$ a+b $\log_{10}$ length [centimeters]). Growth curves were computed for both whole weight and gutted weight by region with the sexes combined.

SEXUAL MATURITY

Length compositions for mature vs immature fish by region are presented according to 10 cm length groups. Sexual maturity ogives from length frequency data were computed using a probit transformation modification from Bliss (1952) as applied to witch flounder from the Gulf of St. Lawrence by Bowering and Brodie (1984). Due to a lack of mature females an ogive for the northern region females could not be computed.

RESULTS

DISTRIBUTION

a) Geographic distribution and relative abundance

The geographic distribution and relative abundance of Atlantic halibut in the Newfoundland-Labrador area as determined from research vessel surveys is presented in Fig. 3. Atlantic halibut are distributed throughout the range examined from Hudson Strait to the southern Grand Bank. They are most abundant in deepwater channels running between the fishing banks and along the edge of the continental shelf. They are virtually absent from the shallower tops of the fishing banks. This is particularly evident on Saglek Bank and the Grand Bank. They are also absent in areas near the coastline. The areas of highest abundance are the Hudson Strait area, Northeast Newfoundland Shelf, Flemish Pass (the area between Flemish Cap and the Grand Bank), southern edge of the Grand Bank and St. Pierre Bank.

The geographic distribution and relative abundance according to data from the Canadian Foreign Observer Program is presented in Fig. 4 with the exception of most of NAFO Div. 2G. According to these data, the Atlantic halibut are most abundant in the area of Hopedale Channel, Northeast Newfoundland Shelf, northern and southwest slopes of the Grand Bank and St. Pierre Bank. As with the research survey data, the areas of highest abundance are associated with the edges of the continental shelf and the channels running between the fishing banks.

The mean number caught per set by month is shown in Fig. 5 and Table 1. For the northern region there appears to be a clearly increasing trend from about March to August where the August catch rate is considerably higher than that of any other month. There is also a systematic decline from August onward. While the actual mean numbers per set are low, the large numbers of observations (Table 1) would suggest that the trend is meaningful. In the southern region the trend is not as clear as in the north, however, for the period April to October, the pattern trend is very similar. For both regions the catch rate during August month stands out as being much higher than any other time of year.

b) Distribution by depth

Distribution by 100 m depth intervals is shown in Fig. 6 and Table 2. In the northern region during the period January to June the mean number per set reached a maximum at a depth range of 501-600 m where the catch rate was about 6 times higher than any of the shallower depths. The catch rate in the 601-700 m depth range was also high, however, this was based upon only three observations and the standard error was equal to the mean (Table 2). During the July to December period mean numbers per set were very low and the trend is a little more difficult to follow due to scaling. However, the catch per set increased systematically and peaked at 301-400 m followed by a systematic decline. While numbers were low, this information was based upon considerably more observations than the January to June period, particularly for the deeper zones (Table 2).

For the southern region the catch rates are considerably higher and the trends more pronounced than those of the northern region. During the January to June period the mean catch per set was low for depths $\leq$100 m, however, the highest catch rate occurred at the 101-200 m interval. The catch rate declined steadily from there until the 501-600 m interval where a second but much lower peak occurred. This peak is coincident with the best catch rate for the northern region for the same period. During the July to December period the catch rate increased dramatically from depths less than 101 m to reach a peak at the 401-500 m interval, then showed a substantial drop beyond this. Despite this drop, however, the catch rate for the 501-700 m depth range was still relatively high in comparison to other areas and times.

c) Distribution by bottom temperature

Distribution of Atlantic halibut by 1°C bottom temperature intervals is presented in Fig. 7 and Table 3. For the northern region during January to June the relative catch rate was low, up to 4.0°C. Between 4.0-5.0°C the catch rate increased by a factor of 5 and remained fairly steady up to 7.0°C. Bottom temperatures greater than 7.0°C were not encountered during any of the surveys at this time (Table 3). During the July to December period, the relative catch rate was low and steady, up to 4.1 to 5.0°C where it began to increase and maximized at 6.1-7.0°C, the highest temperature range encountered during these surveys. In the southern region during the period January to June, the relative catch rate remained fairly steady, up to 5.0°C. From 5.0° to 6.0° the catch rate tripled and remained at this level, up to 8.0°C. For bottom temperatures beyond 8.0°C, the catch rate further increased, based upon a relatively high number of observations (124) (Table 3). For the period July to December the catch rate up to bottom temperatures of 2.0°C was relatively low. Beyond this, however, the increasing trend was dramatic, up to 5.1-6.0°C where the catch rate was about 25 times that of the 1.1-2.0°C interval. The maximum catch rate occurred at 6.1-7.0°C and remained high beyond that. There was an anomalous drop at the 7.1-8.0°C interval, however, this was based upon a low number of observations with a standard error nearly equal to the mean (Table 3).

d) Distribution by length (cm) and depth

The distribution of Atlantic halibut by mean length (cm) and depth interval is presented in Fig. 8 and Table 4. For the northern region during the period January-June it was difficult to determine if any real trend in mean length over depth occurred (Fig. 8). However, this may be due to the small numbers of observations at some depth intervals (Table 4). For the July to December data there was an increasing trend in mean size with depth. For depths less than 101 m the mean size was about 62 cm whereas the mean size at a depth interval of 401-500 m was about 91 cm.

In the southern region during January to June definite trends are also difficult to establish, as with the northern region despite the fact that sample sizes are much higher (Table 4). In this area at this time of year, the largest mean size occurs at depths $\leq$100 m. The pattern from the 101-200 m interval to the 501-600 m interval is not that different from that of the northern region although the actual mean sizes are not the same. For the July to December period there is a clear increasing trend in mean size with depth, particularly over the depth range of 101-500 m where sample sizes are reasonably high and standard errors of the means are relatively low (Table 4).

AGE AND GROWTH

a) Length composition

The length composition of male and female Atlantic halibut by region is presented in Fig. 9 using 10 cm length groups. For the northern region there were no Atlantic halibut caught of either sex less than 50 cm in length. The males ranged from 50-169 cm in length, however, there were very few males caught beyond 109 cm with the mode occurring at about 50-70 cm. The females ranged from 50 to 229 cm in length, however, as with the males, few were caught beyond 109 cm. The mode for females was somewhat larger than for males at 80-89 cm although there were substantial numbers at the 50-79 cm range.

For the southern region, no fish were caught less than 40 cm in length for either sex. The males ranged from 40 to 189 cm in length, however, few were caught beyond 119 cm with the mode occurring at 70-79 cm. The females ranged from 40 to 199 cm in length. Few were caught beyond 119 cm, however, there were more females caught in the larger length groups for both regions.

b) Age composition

The age composition of Atlantic halibut by region is shown in Fig. 10. For both regions there were no fish in the catches younger than age 4 or older than age 16. Males generally predominated the younger age groups whereas the females generally predominated the older age groups. In the northern region about half the catch was made up of 6 and 7 year olds whereas in the southern region more than half the catch is made up of 7 and 8 year olds. In the southern region there were also higher percentages of fish of 11+ years old than in the north. However, this could be an artifact of sample size.

GROWTH CURVES

It would appear from the growth curves in Fig. 11 and Table 5 that the growth rate for females is greater than males in both regions (growth rate is defined as the rate of change of length with age). The divergence of the growth curves begins at about age 6 in both regions, however, for practical purposes, it is better defined at about age 7 in the north and age 8 in the south. In nearly all cases the mean length at age for the older ages is above the fitted lines (Fig. 11) as a result of the weighting procedure in the regression analyses. It would suggest that had more observations been available in the older ages, the computed growth rates would probably be higher than those presented.

A comparison of growth curves by region is presented in Fig. 12. For both males and females the mean size at age is greater for the southern region. Although statistical analyses were not performed, it would appear that the slopes (growth rates) of the fitted lines are about the same. It is likely that given the variation in size at each age the growth patterns of both regions are probably the same statistically. It should be noted, however, that most sampling in the northern region is late in the year as opposed to early in the year for the southern region. Therefore, the real difference in mean size at age is probably somewhat greater than that shown here.

Length-weight relationships for length versus whole weight and length versus gutted weight are presented in Fig. 13 and 14 respectively and Table 6. All relationships were highly significant ($P < 0.001$) with all correlation coefficients (r) equal to 0.98 (Table 6). For practical purposes there was no difference between the length-weight relationships of the northern region, compared to the southern region.

SEXUAL MATURITY

The length distributions of mature and immature fish are shown in Fig. 15. In the northern region mature males first appeared in the catches at the 50-59 cm length interval (Fig. 15) and although the overall catch was low, males were all mature at the 110-119 cm interval. There were very few mature females caught from the northern region. Mature females first appeared at the 50-59 cm interval and were all mature at the 130-139 cm interval. In the southern region there were considerably more mature males than in the northern region, particular y in the smaller sizes (Fig. 15). Mature males first occurred in the catches at the 40-49 cm intervals and as in the north all were mature at the 110-119 cm interval. Although more plentiful than in the northern region the number of mature females was still low in comparison to the numbers of immatures in the catches. Mature females first occurred in the catches at the 70-79 cm interval and all were mature when they reached a length of 140-149 cm.

Sexual maturity ogives for northern region males and southern region males and females is presented in Fig. 16. Chi-square tests indicated acceptance of the fitted lines to the observed data at the 5% significance level for all

three probit anlayses. For the northern region males the computed length at 50% maturity (M_{50}) was 87.5 cm, corresponding to an age of 9.1 years using the age-length relationship in Table 5. The M_{50} for southern region males occurred at a length of 75.7 cm or 7.6 years old. The females for the southern region had a M_{50} length of 119.5 cm or an age of 13.5 years.

DISCUSSION

DISTRIBUTION

Atlantic halibut in the Newfoundland-Labrador area are distributed from Hudson Strait southward to the southern Grand Bank and St. Pierre Bank, particularly at the continental slope and the channels running between the fishing banks. The only areas of commercial concentration, however, appear to be along the southern edges of the Grand Bank (particularly the southwest slope), the southwest slope of St. Pierre Bank and the channels running between St. Pierre Bank and the Grand Bank. These are now the only areas in the Newfoundland-Labrador area where directed commercial fishing operations using longlines for Atlantic halibut occur. In the early part of this century some directed fishing for Atlantic halibut by Canadian and American vessels (using longlines) occurred in some of the deep channels off Labrador and the Northeast Newfoundland Shelf (McKenzie 1946), however, these operations did not continue into the second half of the century due to lack of sufficient raw material. In the late 1800's American vessels carried out a lucrative Atlantic halibut fishery in the Davis Strait-West Greenland area until the 1890's when it became unprofitable (Devold 1938). This area was not fished for Atlantic halibut again until 1924 when actual halibut expeditions using mother ships and motorized dories began. In the early 1930's as much as 30% of all halibut consumed in Europe came from this fishery (Devold 1938). While catches in this area were relatively low in recent years they are still higher than the total landings in the Newfoundland-Labrador area (from NAFO Statistical Bulletins).

Based upon distribution and relative abundance estimates presented here, experimental fishing for Atlantic halibut was conducted in the Labrador-eastern Newfoundland area during 1985 with two Newfoundland longliners. The experiment was conducted under the auspices of the Fisheries Development Branch of the Canadian Department of Fisheries and Oceans using conventional halibut trawls with circle hooks. It was determined from the experiment that for the Labrador-eastern Newfoundland area, Atlantic halibut was not present in sufficient quantity to afford a profitable directed fishing operation (L. Yetman, Project Officer, Fisheries Development Branch, Department of Fisheries and Oceans, pers comm.).

Little is known about the delineation of halibut stocks in the Northwest Atlantic although McCracken (1958) and Kohler (1967) suggested that spawning stocks occur in the Gulf of St. Lawrence, the Scotian Shelf and the southern Newfoundland Banks (referring to the Newfoundland Grand Bank, St. Pierre Bank and Green Bank). There is insufficient information for the Labrador-eastern Newfoundland area to determine if there are localized stocks. It's possible that the low numbers of fish throughout the area are migrants from southern stocks or from more northerly areas since post larval stages of Atlantic

halibut have been caught in the West Greenland area and presumably spawning takes place there.

It has been confirmed through many tagging studies that the Atlantic halibut is a highly migratory species and there is likely to be considerable mixing of stocks as adults. Martin and McCracken (1950), based upon tagging studies, suggested there was little mixing of Atlantic halibut within the Gulf of St. Lawrence and those of the Scotian Shelf with little movement across deepwater channels to other banks. Subsequent to this, however, McCracken and Martin (1955) reported that an Atlantic halibut (measuring 120 cm in length) tagged near Anticosti Island on June 24, 1946 was captured on December 1, 1953 near west Iceland, a straight line distance 1600 nautical miles. This was the first authentic record of a tagged Atlantic halibut to have crossed the Atlantic Ocean. More recently, however, seven Atlantic halibut (all measuring $\leq$57 cm in length) tagged at southwest Iceland were recaptured in Newfoundland waters (4 fish) and West Greenland waters (3 fish) (Dr. Gunnar Jonsson, Marine Research Institute, Reykjavik, Iceland, personal communication). These records indicate that both large and small Atlantic halibut will cross the Atlantic Ocean in both directions.

McCracken and Martin (1955) also reported that a halibut tagged at southwest Nova Scotia was recaptured on the southwest edge of the Grand Bank contrary to their previous suggestion that halibut will not cross the Laurentian Channel between the Scotian Shelf and the Grand Bank. Tagging studies at southwest Nova Scotia by Jensen and Wise (1961) further confirmed this migration with nearly all returns coming from more easterly areas of the Scotian Shelf and more than one third of the recaptures (4 out of 11) coming from the Grand Bank. The most intensive tagging study in Canadian waters was conducted by Kohler (1964) who tagged more than 700 halibut in the Sable Island area of the Scotian Shelf during March of 1962. During the remainder of 1962 most tag returns came from the proximity of where the fish were tagged with one coming from the southwest Grand Bank. In the following year, however, seventeen of thirty-two tags returned were recaptured on the southwest Grand Bank or the channels running between St. Pierre Bank and the Grand Bank. Of 85 Atlantic halibut tagged on the Southwest Grand Bank in 1963, 6 were recaptured in the proximity of the tagging area (Kohler 1964) with 3 recaptures coming from the Scotian Shelf area (Dr. J. D. Neilson, St. Andrews Biological Station, St. Andrews, New Brunswick, Canada, personal communication). While localized spawning may occur on both the Scotian Shelf and the St. Pierre Bank-Grand Bank areas, this high degree of mixing as adults would probably warrant the consideration of both areas together for stock assessment purposes.

For the Atlantic halibut in the Northeast Atlantic, long distance migrations have also been noted. Taning (1938) reported that small halibut tagged in Faroese water would frequently migrate to the North Sea area as well as the north Norwegian Sea. The results of many tagging studies on the Pacific halibut (Bell 1981) suggest that this species also intermingles among stocks with many records of long distance migrations of several hundred miles from the Bering Sea to the British Columbia coast.

The catch rates for halibut tend to increase from late spring to mid summer, peaking around the month of August, according to survey data, somewhat

similar to results presented by McCracken (1958) for the Scotian Shelf area. McCracken (1958) suggested that halibut at the southwest Nova Scotia area moved from deeper water by June to the more intermediate layers where good catches occurred in June-July, then began to decline later in the season. It is possible that the decline is mainly due to maturing fish moving to deeper water where temperatures are likely to be more conducive to spawning. It is also shown here that catch rates generally increase with depth from earlier in the year to later in the year although halibut tend to prefer warm temperatures (>4.0°C) throughout the year. Jespersen (1936) and Taning (1938) reported that halibut in Norwegian waters spawn in temperatures of about 5-7°C in depths of 700-1000 m or greater which are generally beyond commercial fishing depths. Devold (1938) also found that catches of halibut in Norwegian waters increased in both shallow and relatively deep water in summer and attributed this to an increased number of larger halibut on the fishing grounds, probably comprised of post spawning fish moving up from very deep water to feed. This could also be interpreted here by comparison of mean length over depth range. For the winter-spring months there doesn't appear to be any obvious trend in mean size over depth and could be a result of most large mature fish living out of the survey depth range at this time of year. On the other hand, the increasing mean length with depth later in the year could be interpreted as the larger maturing fish gradually migrating to deep water for spawning.

AGE AND GROWTH

Age and length compositions for the whole Newfoundland-Labrador area were relatively similar with ages ranging from 4 to 16 years. Due to the fact that none were caught younger than 4 years old, it is likely that the younger halibut are located in areas outside the bounds of the survey areas. Whether such localities are towards the coastline or in waters deeper than that which the surveys covered is not known. It should be pointed out, however, that from the distribution charts presented here, the abundance of halibut varies from very low to zero as the surveys approach the coastline.

Less than 5% of the total catch of halibut in the survey data was older than 11 years old for the Newfoundland-Labrador area. Data from exploratory fishing using longlines in the Gulf of St. Lawrence during 1946 and 1947, however, indicated that halibut up to 29 years old were frequent in the catches (McCracken 1958). In fact, more than half the catches were older than 17 years old with very few less than 9 years old. None were reported less than 5 years old. For western Nova Scotia, on the other hand, few fish were caught older than 18 years, however, more than half the catches were older than 10 years (McCracken 1958). In Icelandic waters during the early 1900's it was not unusual to catch halibut up to 20 years old nor was it difficult to capture large numbers of fish less than 4 years old, particularly in some fijords (Jespersen 1917). According to Devold (1938) the commercial fishery in Norwegian waters concentrated on halibut from about 12-42 years old with few fish taken less than 110 cm in length.

Given the variation in age range for halibut throughout the North Atlantic the question arises whether the low numbers of fish greater than 11 years old presented here is a result of catchability or availability. It is quite likely

that the catchability of otter trawls for the large halibut is quite low, however, it is difficult to ascertain whether this is a complete explanation for not catching fish beyond 16 years old. It is also possible that there has been a reduction in the number of older age groups due to exploitation. It is unlikely that Atlantic halibut would not reach ages beyond 16 years old for this area, considering the migration rate from the southern Scotian Shelf (Kohler 1964) where ages have already been recorded up to 24 years old. Unfortunately, data from the commercial fishery using longlines which might help somewhat in resolving the problem, are unavailable for the areas in question. On the other hand, the fishery is primarily directed towards young halibut less than 20 kg which brings the highest price in the market place. Therefore, even with such data the full age structure of the population may be difficult to determine.

The growth rates for both regions presented suggest that for practical purposes the growth rates are the same by sex for the whole Newfoundland-Labrador area. There is a divergence of growth rate between sexes at about age 6 with the divergence slightly larger in the southern region. McCracken (1958) compared growth curves of Atlantic halibut from various regions of the North Atlantic and found some growth patterns to be vastly different. Growth of halibut from the northern Faroes indicated a considerably higher mean length at age than any other area compared (from Joensen 1954) while NAFO Subarea 4 (Gulf of St. Lawrence and Scotian Shelf combined) had the lowest mean length at age for ages at least up to 15 years old. This growth pattern is similar to that of the West Greenland area according to data from Jespersen (1917). An approximate comparison of the mean lengths at age presented here and those of McCracken (1958) suggest that the growth patterns over the age range available are similar. It would appear then that the growth patterns of halibut throughout the Northwest Atlantic are similar. Although a statistical comparison is not possible, it would appear from Fig. 14 and 15 in McCracken (1958) that while mean lengths at age vary from one region to another, the growth rates (slopes of the lines) are probably not different at least from ages 5 to 15 years. If this can be accepted as true, then the growth rates of halibut throughout the North Atlantic are similar with the exception of some early stage in the life history of the halibut which varies among some populations.

SEXUAL MATURITY

Male halibut can mature as early as about 4 years old in Newfoundland-Labrador waters, however, the level at which 50% were mature (M_{50}) was about 80 cm in length which corresponds to approximately 8 years old. The length at M_{50} for male halibut in the northern region was somewhat larger than that of the southern region, however, it is difficult to determine if this is a real difference in the rate of maturity or simply a difference in the relative abundance of mature fish in one area versus another. Since the proportion of mature versus immature fish overall is greater in the southern region and the fact that the southern area has been previously postulated as a spawning area, then the maturity rate for the southern region is probably a more meaningful representation of the total population. The youngest females mature at about 6 years old with the M_{50} for females about 125 cm or approximately 12 years old

from the southern region, however, there were insufficient data to determine maturity rates for females in the northern region due to a lack of mature females in the catches. As with the males the overall proportion of mature females was higher in the southern region, therefore, similar conclusions may be drawn regarding the maturity rate. It should be noted, however, that if maturing fish have a tendency to migrate into deep water as indicated in Jespersen (1936), Taning (1938), and Devold (1938), then it is possible that the proportions of mature fish shown here could be under-represented if trawling did not cover an adequate depth range. If this is the case, then the levels of M_{50} indicated here may be higher than those of the population as a whole. On the other hand, the results here are very similar to those of McCracken (1958) for the Scotian Shelf where the data were collected by longlines considered more capable of catching the larger halibut. It should be kept in mind when assessing these maturity data that these data were collected throughout the year. As a result there may be mature gonads that are fully absorbed and difficult to distinguish from immature fish.

In the Northeast Atlantic Rae (1959) found male halibut in the immature condition up to a length of 102 cm and females up to 137 cm. He also found that M_{50} for males was approximately 85 cm in length while for females it was about 122 cm, values not too different than that reported here.

Jespersen (1917) concluded that halibut in Icelandic waters do not mature before 9 or 10 years of age at the earliest. Devold (1943) reported that mature male fish were found as young as 7 years old although immature males were caught as old as 17 years old. The first mature females were aged at 8 years old with some immature at 18 years old, suggesting that the maturity rates for Atlantic halibut in the Icelandic waters are more delayed by age than those of the Northwest Atlantic. Rae (1959), using his maturity data on length and Joensen's (1954) data on age and growth, concluded that some male halibut mature in Faroese waters as early as 5 years old and females at 7 years old, results a little more closely related to that reported here. Given the similarities among lengths at which maturity is reached throughout the Atlantic, and the variation in ages, then it is possible that for Atlantic halibut, maturity may be more a function of size than age.

CONCLUSIONS

1) Atlantic halibut were caught throughout the area examined from Hudson Strait to the southern Grand Bank and St. Pierre Bank.

2) The only areas of commercial abundance appear to be along the southern slopes of the Grand Bank and to a lesser extent St. Pierre Bank. They are more numerous on the fishing grounds during the summer months.

3) They generally prefer water temperatures >4°C and depths 100-700 m with larger fish usually more abundant in the deeper water.

4) The fish caught ranged in age from 5-16 yrs old with females growing faster than males after age 6. Fish in the southern area were slightly larger at age than those in the north.

5) Males were mature as early as 4 yrs old with 50% of the males mature at 8 yrs old. Females were mature as early as 6 yrs old with 50% of the females mature at 12 yrs old.

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Table 1. Mean number of Atlantic halibut caught per month from research vessels surveys in the Newfoundland area, 1975-84.

Region	Month	No.of sets Fished	Mean No. per set	Std. err. of mean
Northern	Jan.	96	0.05	0.03
	Feb.	113	0.06	0.03
	March	10	0.00	-
	April	105	0.02	0.01
	May	848	0.03	0.01
	June	113	0.06	0.02
	July	992	0.05	0.01
	Aug.	479	0.12	0.04
	Sept.	336	0.07	0.02
	Oct.	595	0.07	0.01
	Nov.	1841	0.06	0.01
	Dec.	482	0.04	0.01
Southern	Jan.	351	0.12	0.06
	Feb.	701	0.05	0.01
	March	246	0.60	0.15
	April	669	0.23	0.03
	May	739	0.31	0.04
	June	723	0.50	0.06
	July	49	0.08	0.05
	Aug.	44	1.84	0.47
	Sept.	137	0.89	0.17
	Oct.	66	0.32	0.16
	Nov.	74	0.69	0.17

Table 2. Distribution of Atlantic halibut according to depth (m) in the Newfoundland area, 1972-84.

Region	Time of year	No. of sets	Depth range (m)	Mean no. per set	Std. err. of Mean
Northern	Jan.-June	308	≤100	0.01	0.01
		590	101-200	0.01	0.01
		279	201-300	0.06	0.02
		172	301-400	0.08	0.02
		18	401-500	0.06	0.06
		16	501-600	0.50	0.22
		3	601-700	0.33	0.33
		1	700	0.00	-
	July-Dec.	155	≤100	0.01	0.01
		755	101-200	0.03	0.01
		1195	201-300	0.07	0.01
		1014	301-400	0.10	0.02
		603	401-500	0.09	0.02
		350	501-600	0.06	0.02
		87	601-700	0.01	0.01
		105	700	0.00	-
Southern	Jan.-June	1217	≤100	0.08	0.01
		864	101-200	0.57	0.06
		990	201-300	0.39	0.05
		481	301-400	0.14	0.03
		213	401-500	0.02	0.01
		88	501-600	0.21	0.10
		57	601-700	0.00	-
		2	700	0.00	-
	July-Dec.	131	≤100	0.08	0.04
		60	101-200	0.30	0.20
		106	201-300	0.94	0.20
		82	301-400	1.26	0.24
		22	401-500	1.66	0.67
		17	501-600	0.44	0.26
		12	601-700	0.42	0.19

Table 3. Distribution of Atlantic halibut according to bottom temperature (°C) in the Newfoundland-Labrador area, 1972-84.

Region	Time of year	No. of sets	Temperature range (m)	Mean no. per set	Std. err. of mean
Northern	Jan.-June	525	≤0.0	0.00	-
		212	0.1-1.0	0.03	0.01
		188	1.1-2.0	0.03	0.01
		179	2.1-3.0	0.07	0.02
		92	3.1-4.0	0.12	0.05
		5	4.1-5.0	0.60	0.24
		2	5.1-6.0	0.50	0.50
		2	6.1-7.0	0.50	0.50
	July-Dec.	945	≤0.0	0.02	0.00
		437	0.1-1.0	0.04	0.01
		522	1.1-2.0	0.07	0.01
		980	2.1-3.0	0.06	0.01
		1212	3.1-4.0	0.12	0.02
		98	4.1-5.0	0.09	0.04
		11	5.1-6.0	0.18	0.18
		2	6.1-7.0	0.50	0.50
Southern	Jan.-June	487	≤0.0	0.09	0.04
		374	0.1-1.0	0.08	0.02
		394	1.1-2.0	0.11	0.02
		230	2.1-3.0	0.28	0.06
		774	3.1-4.0	0.12	0.02
		408	4.1-5.0	0.23	0.04
		326	5.1-6.0	0.75	0.12
		198	6.1-7.0	0.79	0.18
		114	7.1-8.0	0.65	0.11
		124	8.0	0.97	0.15
	July-Dec.	58	≤0.0	0.02	0.02
		63	0.1-1.0	0.02	0.02
		40	1.1-2.0	0.07	0.04
		53	2.1-3.0	0.60	0.14
		63	3.1-4.0	0.94	0.22
		27	4.1-5.0	0.95	0.31
		26	5.1-6.0	2.59	0.71
		25	6.1-7.0	2.70	0.75
		8	7.1-8.0	0.88	0.74
		7	8.0	2.29	0.94

Table 4. Mean length (cm) of Atlantic halibut by depth and time of year in the Newfoundland area as determined from research vessel surveys 1972-84.

Region	Time of year	No. of fish caught	Depth range (m)	Mean length (cm)	Std. err. of mean
Northern	Jan.-June	2	≤100	72.50	13.50
		4	101-200	73.25	11.99
		10	201-300	74.80	4.33
		9	301-400	85.89	9.41
		1	401-500	64.00	-
		7	501-600	74.14	4.95
		1	601-700	78.00	-
	July-Dec.	19	101-200	62.32	2.31
		56	201-300	74.86	2.84
		73	301-400	73.44	1.89
		30	401-500	74.23	2.60
		15	501-600	90.73	10.77
Southern	Jan.-June	62	≤100	91.35	3.40
		200	101-200	76.13	1.26
		240	201-300	84.22	1.27
		54	301-400	88.61	2.90
		2	401-500	80.50	22.50
		16	501-600	82.31	4.61
	July-Dec.	6	≤100	80.50	11.87
		15	101-200	76.27	2.92
		51	201-300	82.49	1.44
		88	301-400	88.08	1.72
		33	401-500	92.33	4.45
		6	501-600	88.67	4.85
		3	601-700	86.67	17.32

Table 5. Regression parameters and retransformed equations for age length relationships of Atlantic halibut in the Newfoundland area. (All regressions were highly significant, $P<0.0001$).

Region	Sex	No. of fish	Slope	Intercept	Corr. coeff. (r)	Retransformed equation (cm)
Northern	Male	110	0.7872	2.7245	0.87	$L = 15.25A^{0.79}$
	Female	114	0.9215	2.5129	0.90	$L = 12.34A^{0.92}$
Southern	Male	460	0.7393	2.8737	0.83	$L = 17.70A^{0.74}$
	Female	317	0.9171	2.5564	0.90	$L = 12.88A^{0.92}$

Table 6. Regression parameters and retransformed equations for length weight relationships of Atlantic halibut in the Newfoundland area. (All regressions were highly significant, $P<0.001$).

Condition of fish	Region	No. of fish	Slope	Intercept	Corr. coeff. (r)	Retransformed equation (kg)
Round	Northern	61	3.2395	-5.3829	0.98	$W = 0.0000041L^{3.2395}$
	Southern	186	3.0755	-5.0642	0.98	$W = 0.0000086L^{3.0755}$
Gutted	Northern	56	3.2015	-5.3648	0.98	$W = 0.0000043L^{3.2015}$
	Southern	171	3.1133	-5.1913	0.98	$W = 0.0000064L^{3.1133}$

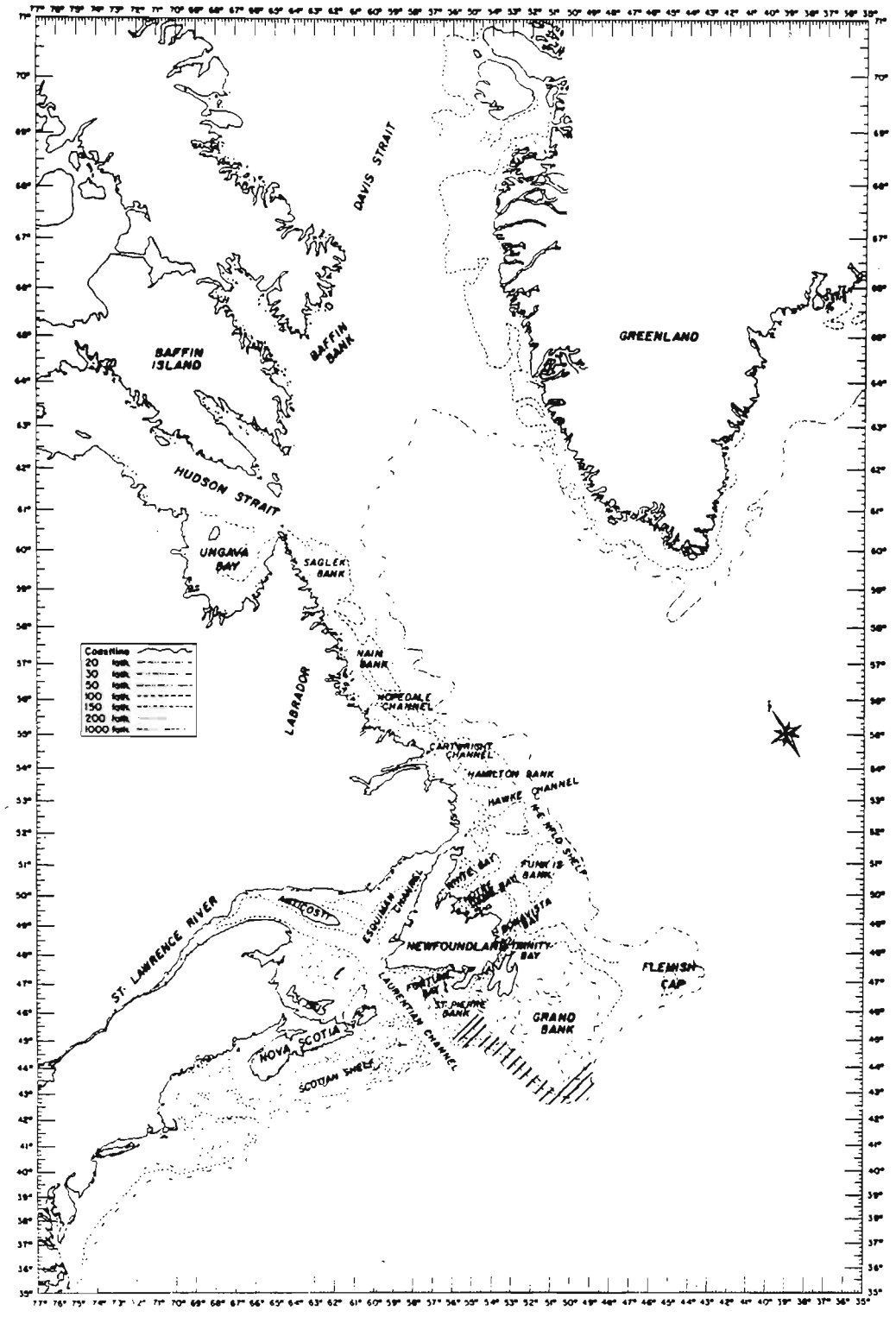

Fig. 1. Map of major place names mentioned in the text. Hatched portion indicates the major fishing area for Atlantic halibut in the Newfoundland Region.

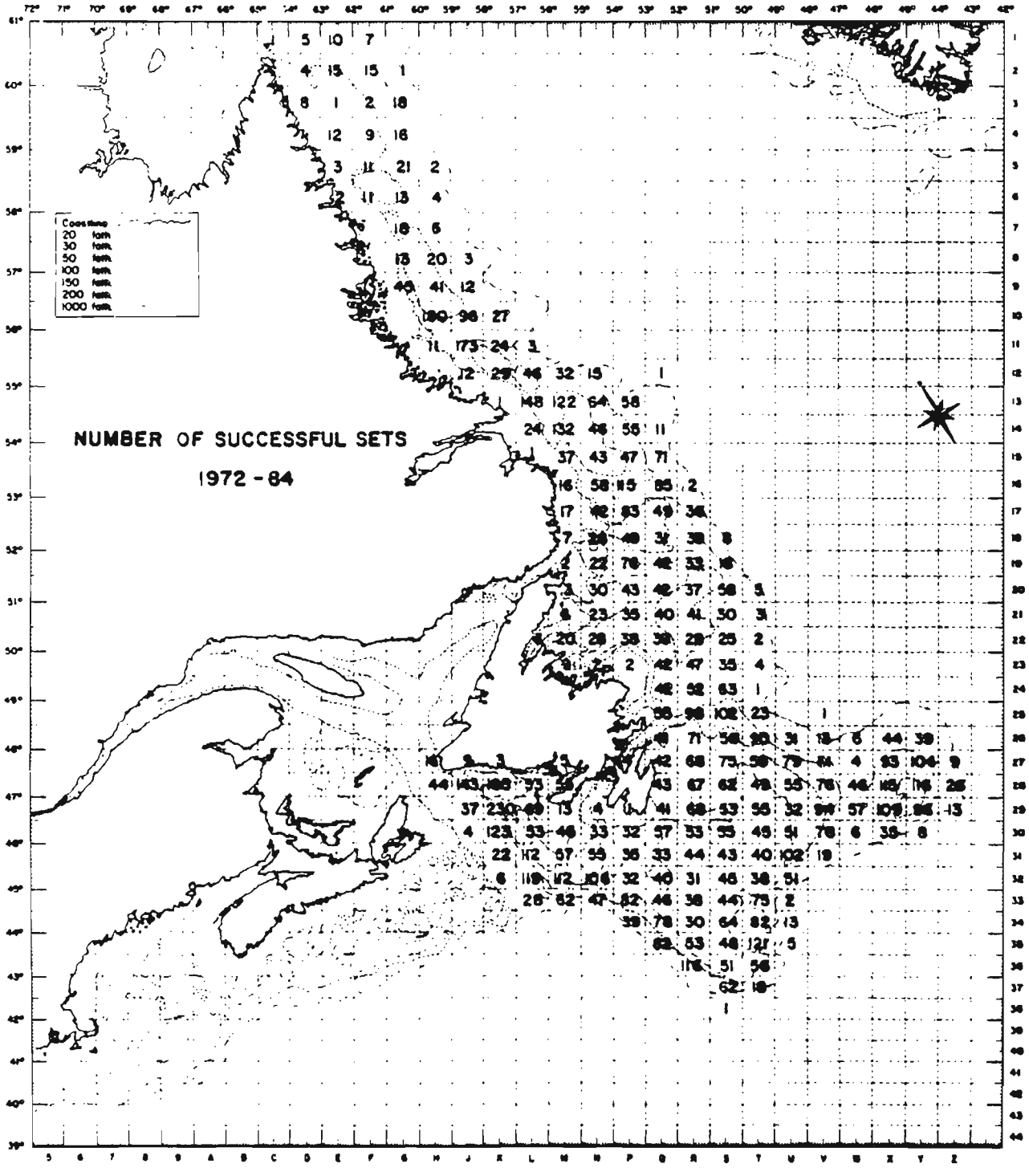

Fig. 2. Number of successful 30 minute sets per unit area from research vessel surveys in the Newfoundland-Labrador area during 1972-84.

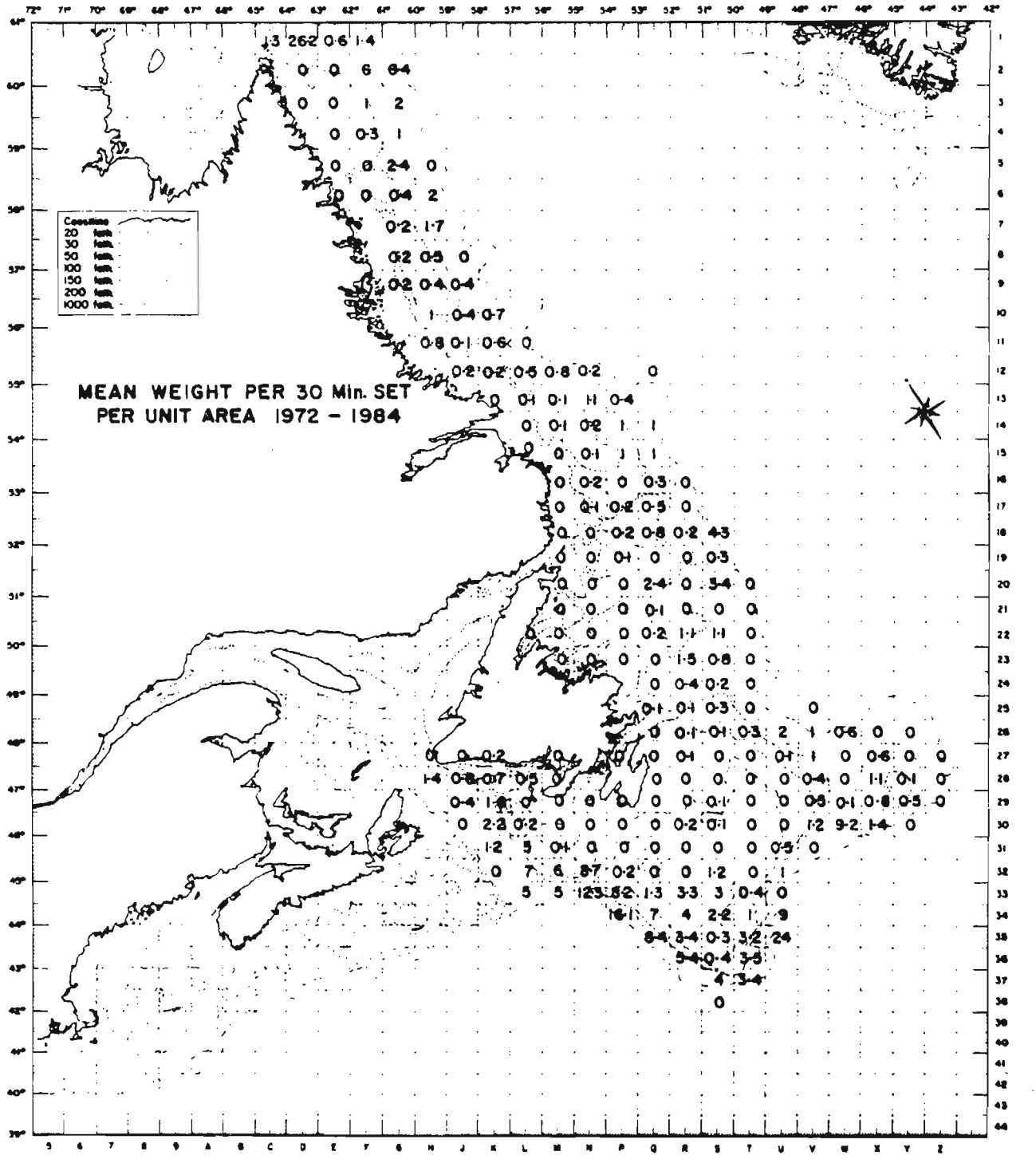

Fig. 3. Mean weight (kg) of Atlantic halibut per 30 minute set per unit area from research vessel surveys in the Newfoundland-Labrador area during 1972-84.

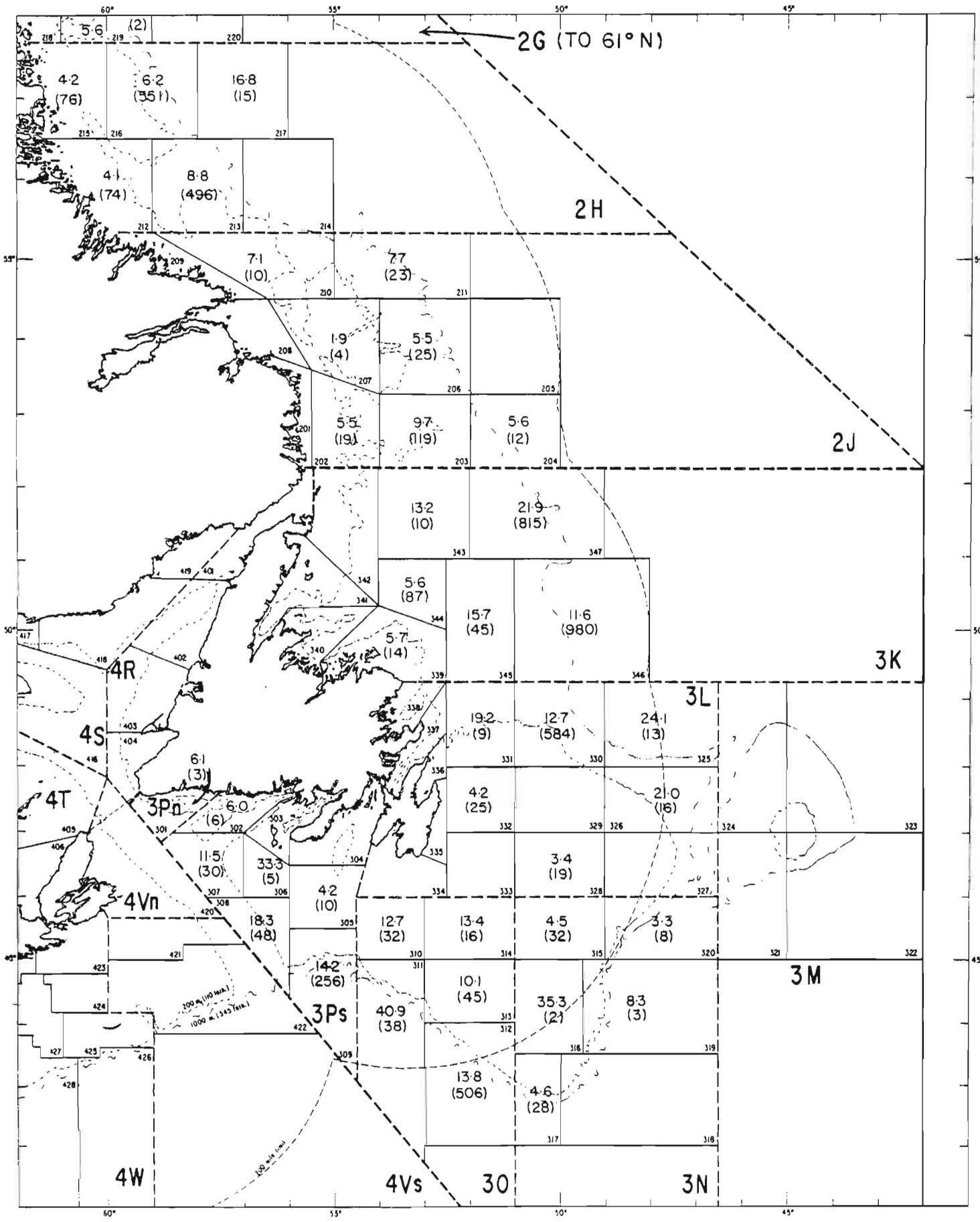

Fig. 4. Catch rates (kg/hr) of Atlantic halibut per statistical area from foreign commercial vessels fishing in the Newfoundland-Labrador area during 1984. (Bracketted numbers are hrs. fished in which Atlantic halibut were caught.)

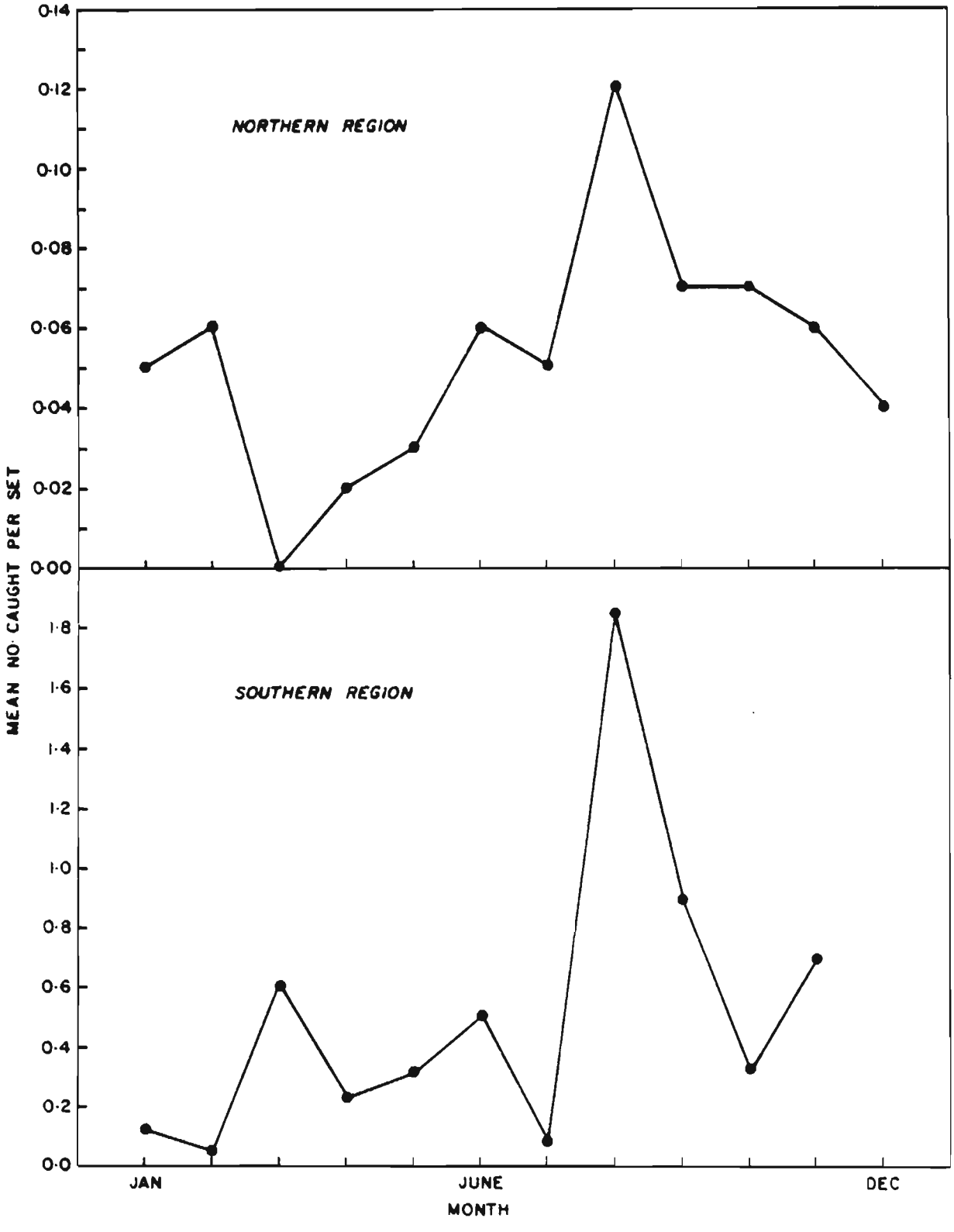

Fig. 5. Mean number of Atlantic halibut caught per 30 minute set by region and month from research vessel surveys in the Newfoundland-Labrador area during 1972-84.

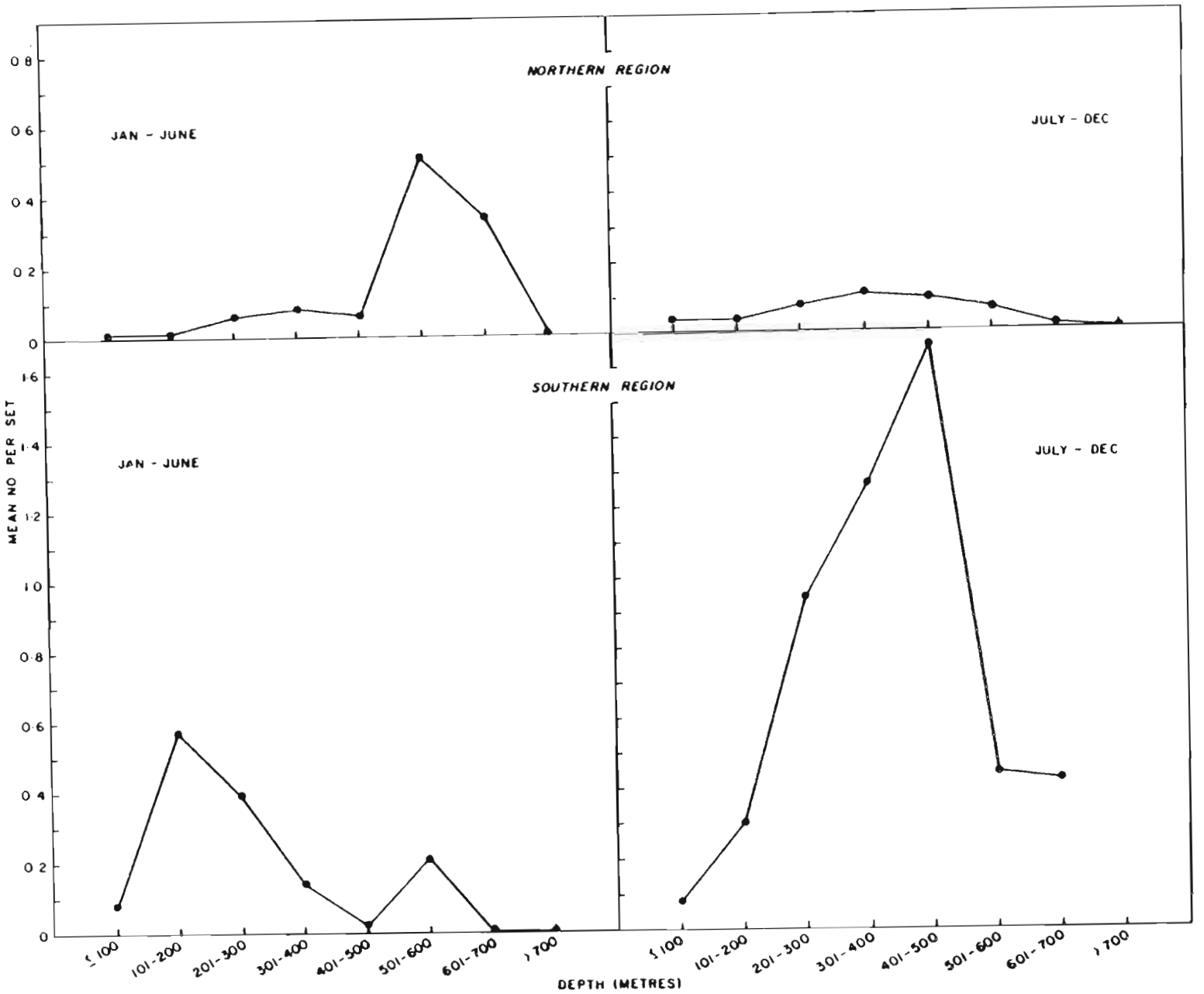

Fig. 6. Mean number of Atlantic halibut per 30 minute set by region and time of year according to depth range (m). Data from research vessel surveys conducted in the Newfoundland-Labrador area during 1972-84.

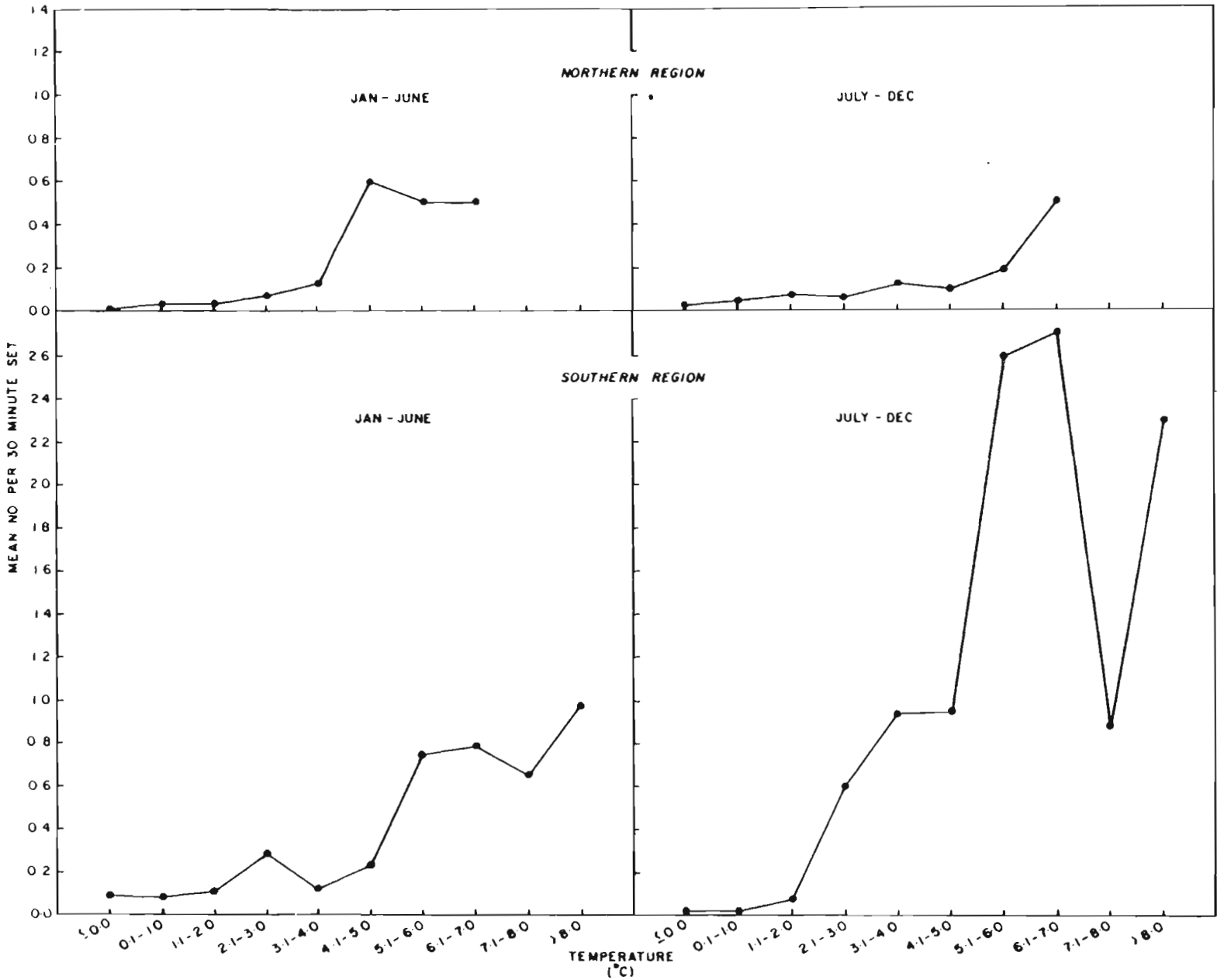

Fig. 7. Mean number of Atlantic halibut per 30 minute set by region and time of year according to bottom temperature range (°C). Data from research vessel surveys conducted in the Newfoundland-Labrador area during 1972-84.

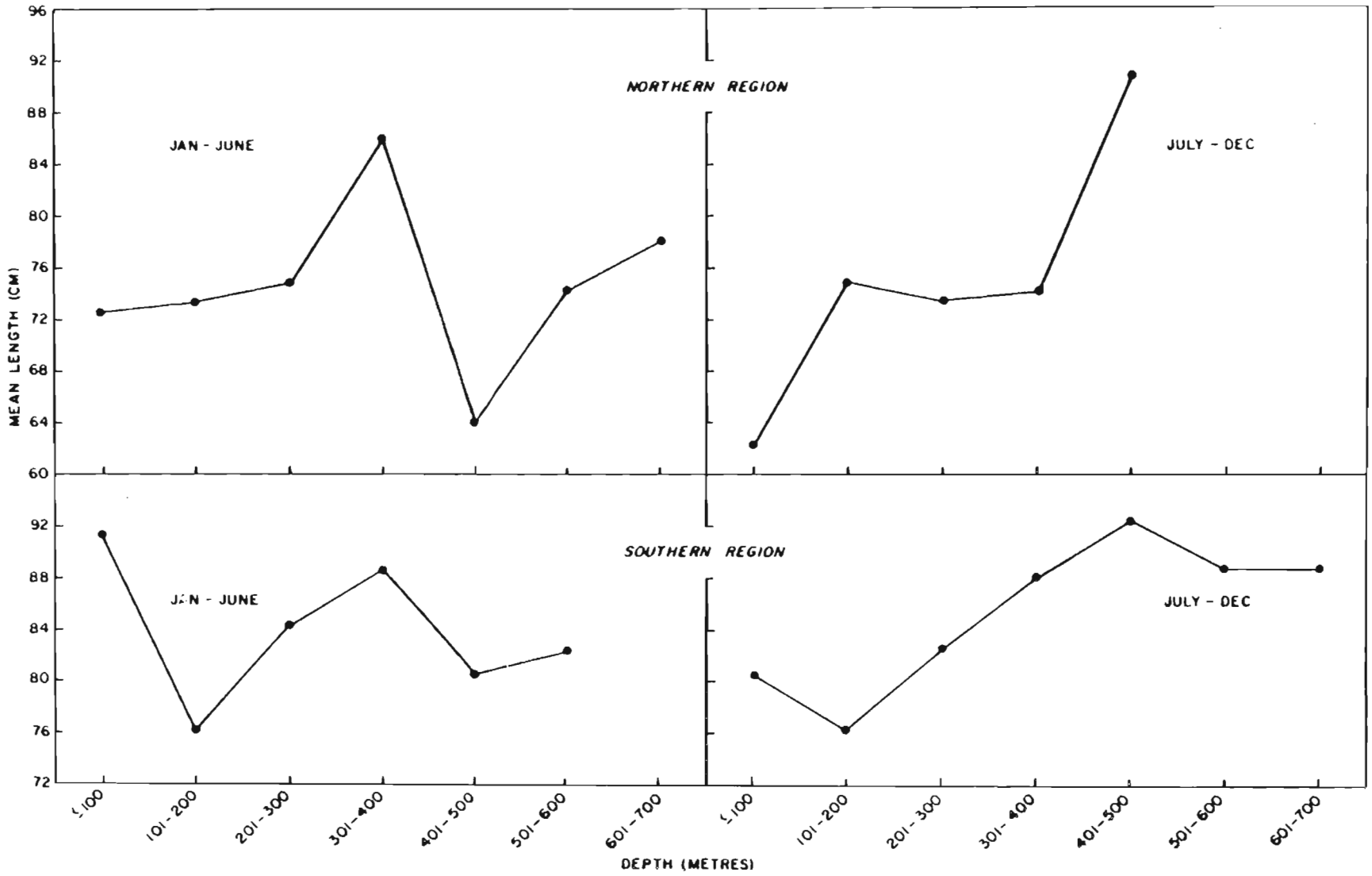

Fig. 8. Mean length (cm) of Atlantic halibut per 30 minute set by region and time of year according to depth (m) range. Data from research vessel surveys conducted in the Newfoundland-Labrador area during 1972-84.

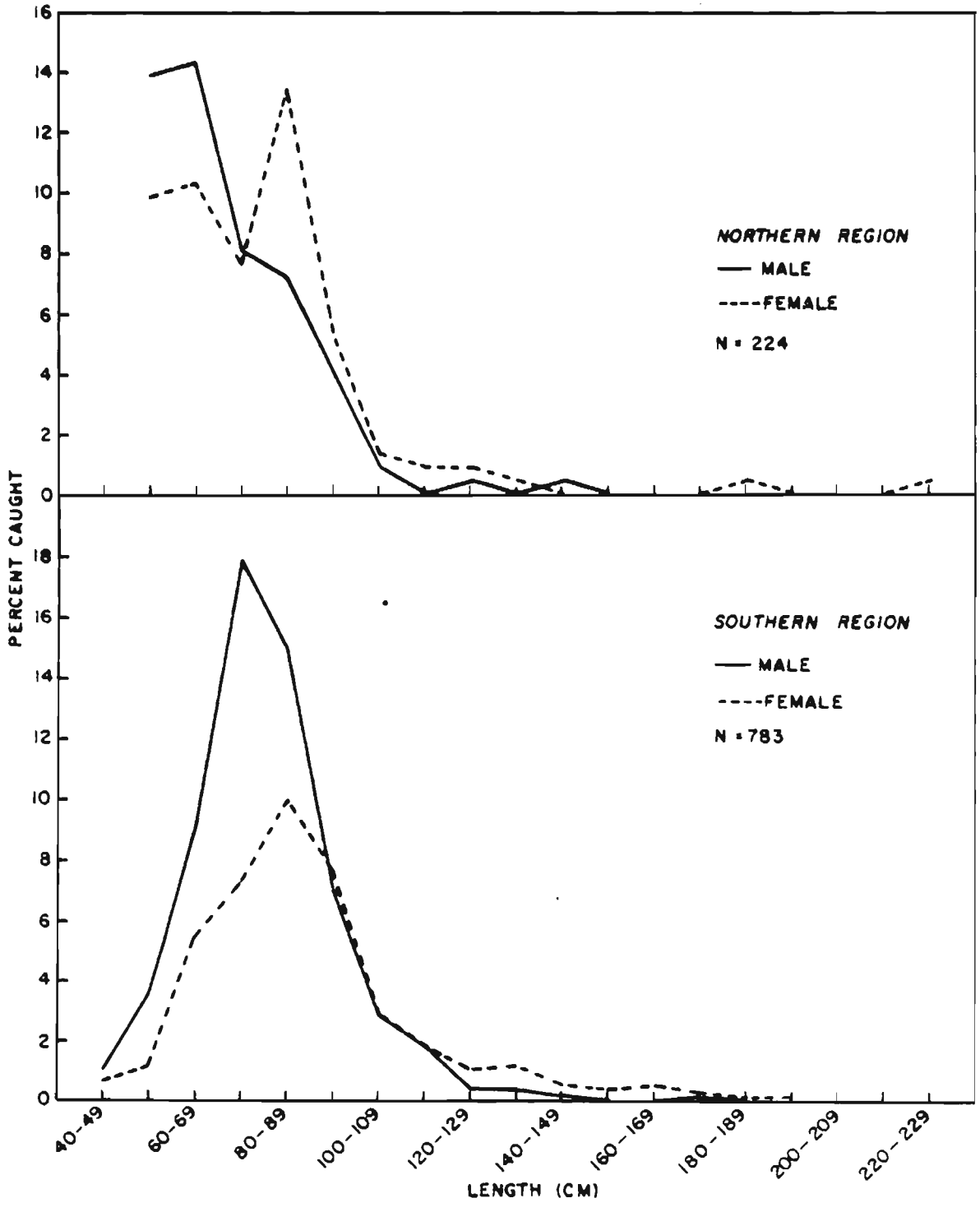

Fig. 9. Length frequency distribution for male and female Atlantic halibut by region from research vessel surveys conducted in the Newfoundland-Labrador area during 1972-84.

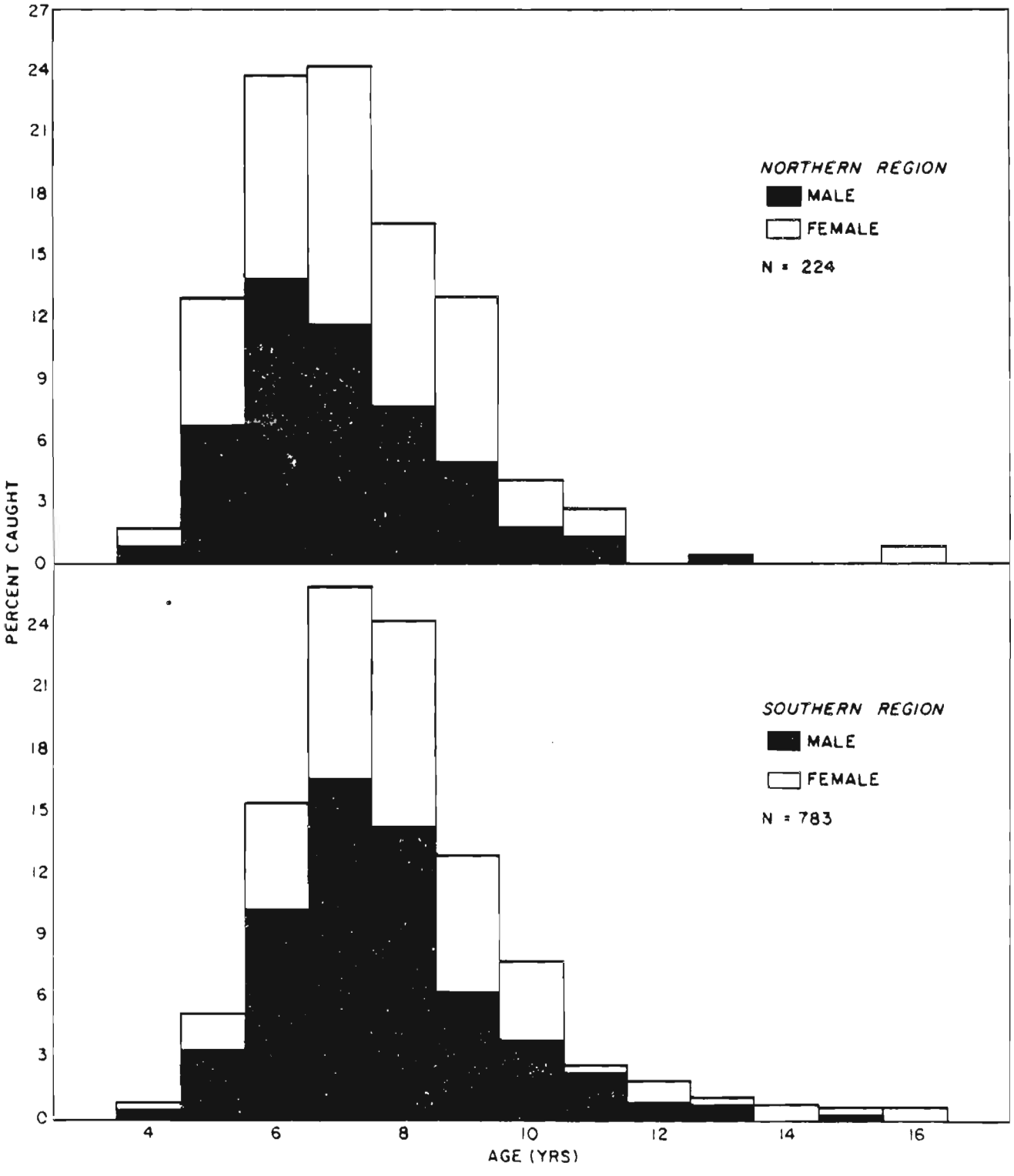

Fig. 10. Age composition of male and female Atlantic halibut by region from research vessel surveys in the Newfoundland-Labrador area during 1972-84.

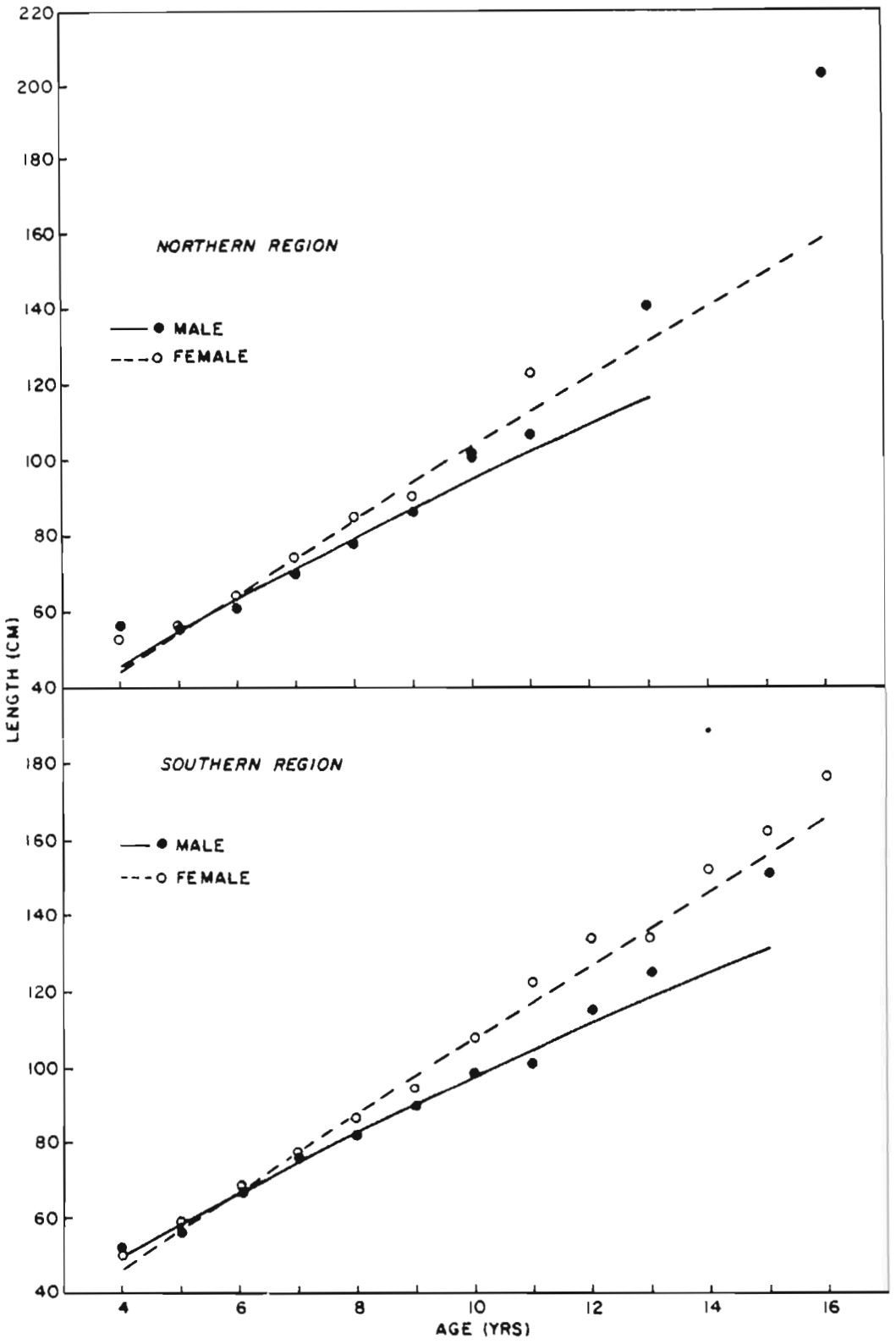

Fig. 11. Growth curves of male and female Atlantic halibut by region from research vessel surveys in the Newfoundland-Labrador area during 1972-84.

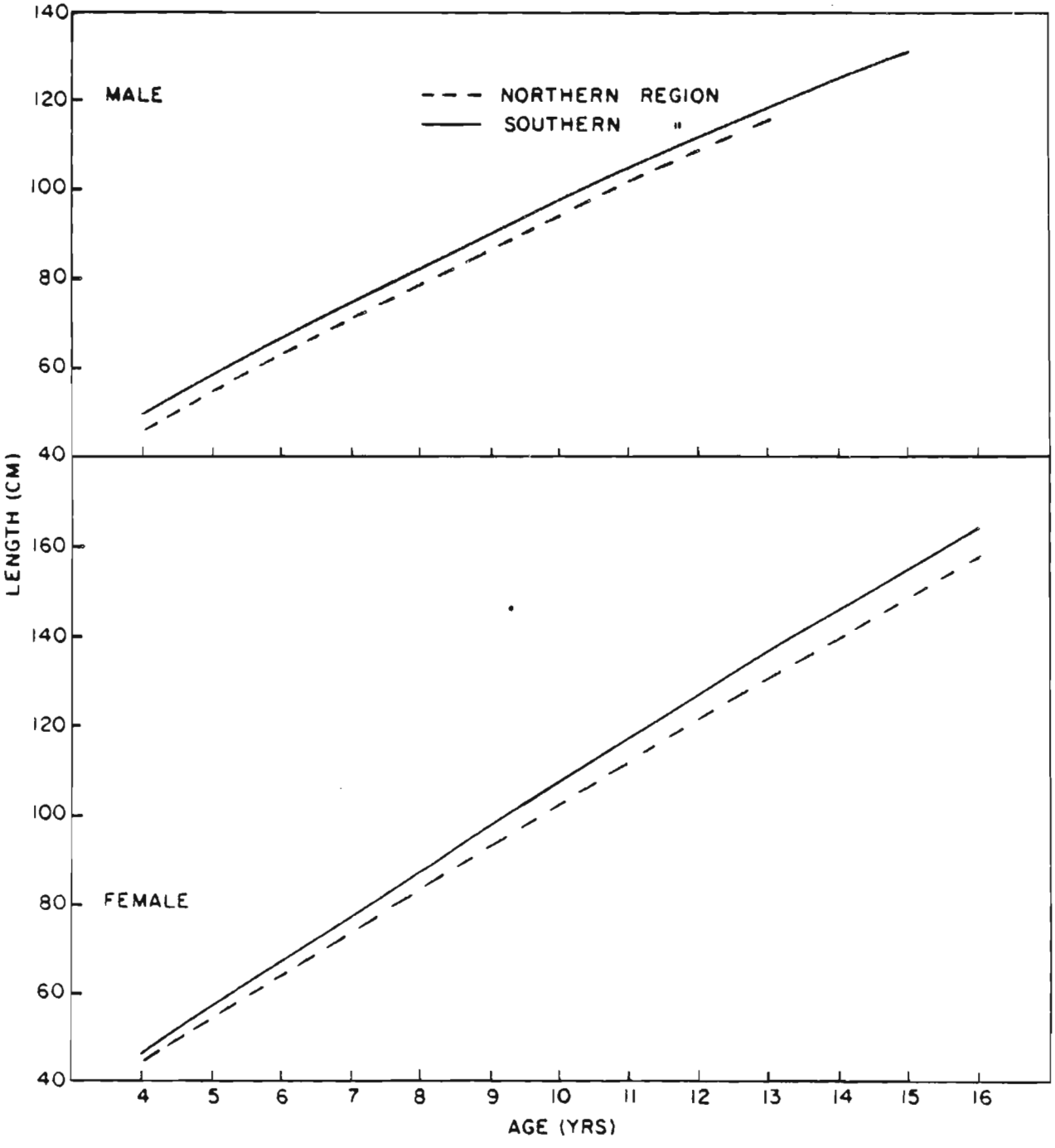

Fig. 12. A comparison of growth curves by region of male and female Atlantic halibut from research vessel surveys in the Newfoundland-Labrador area during 1972-84.

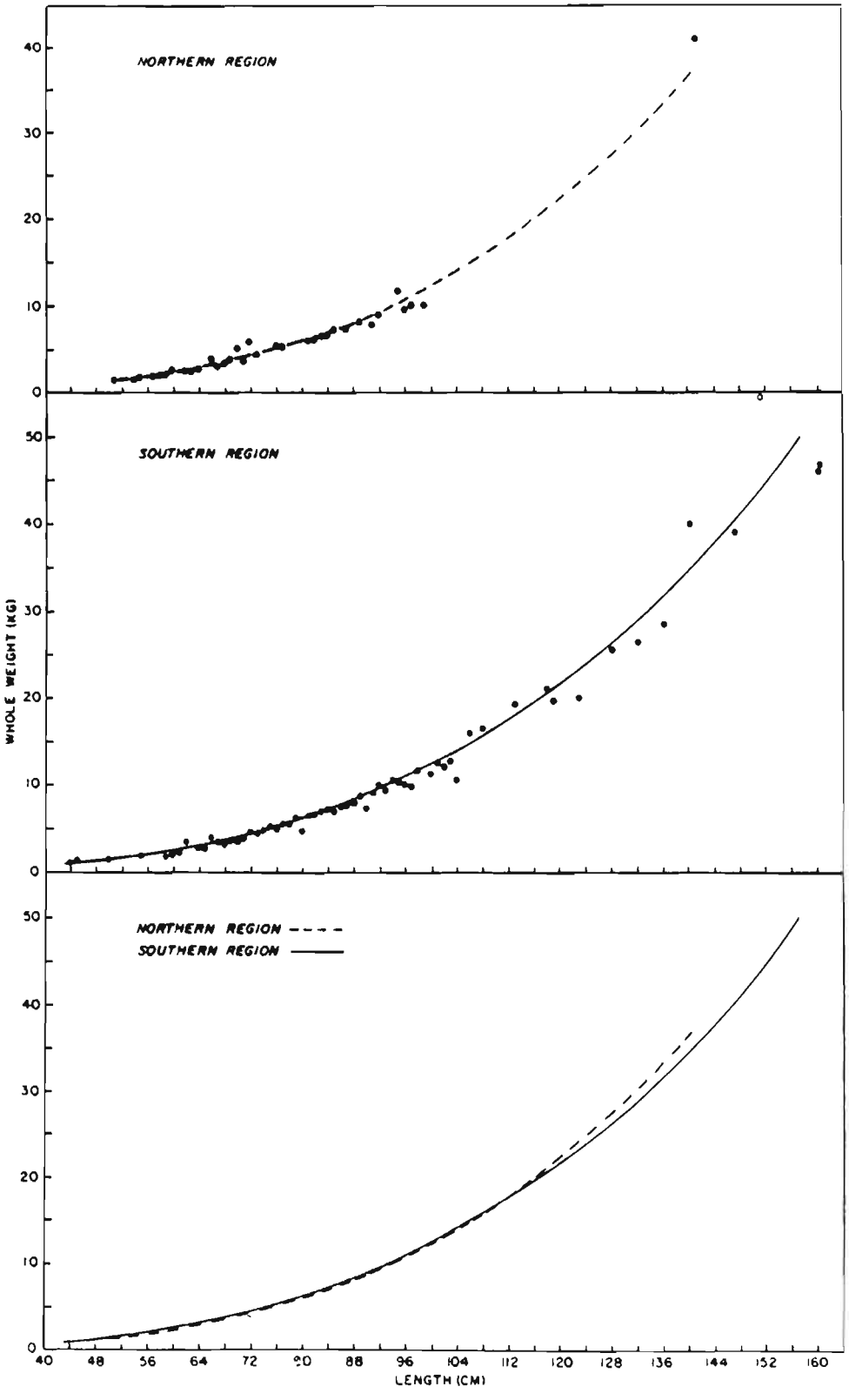

Fig. 13. Length (cm) - whole weight (kg) relationships of Atlantic halibut by region from research vessel surveys in the Newfoundland-Labrador area during 1972-84.

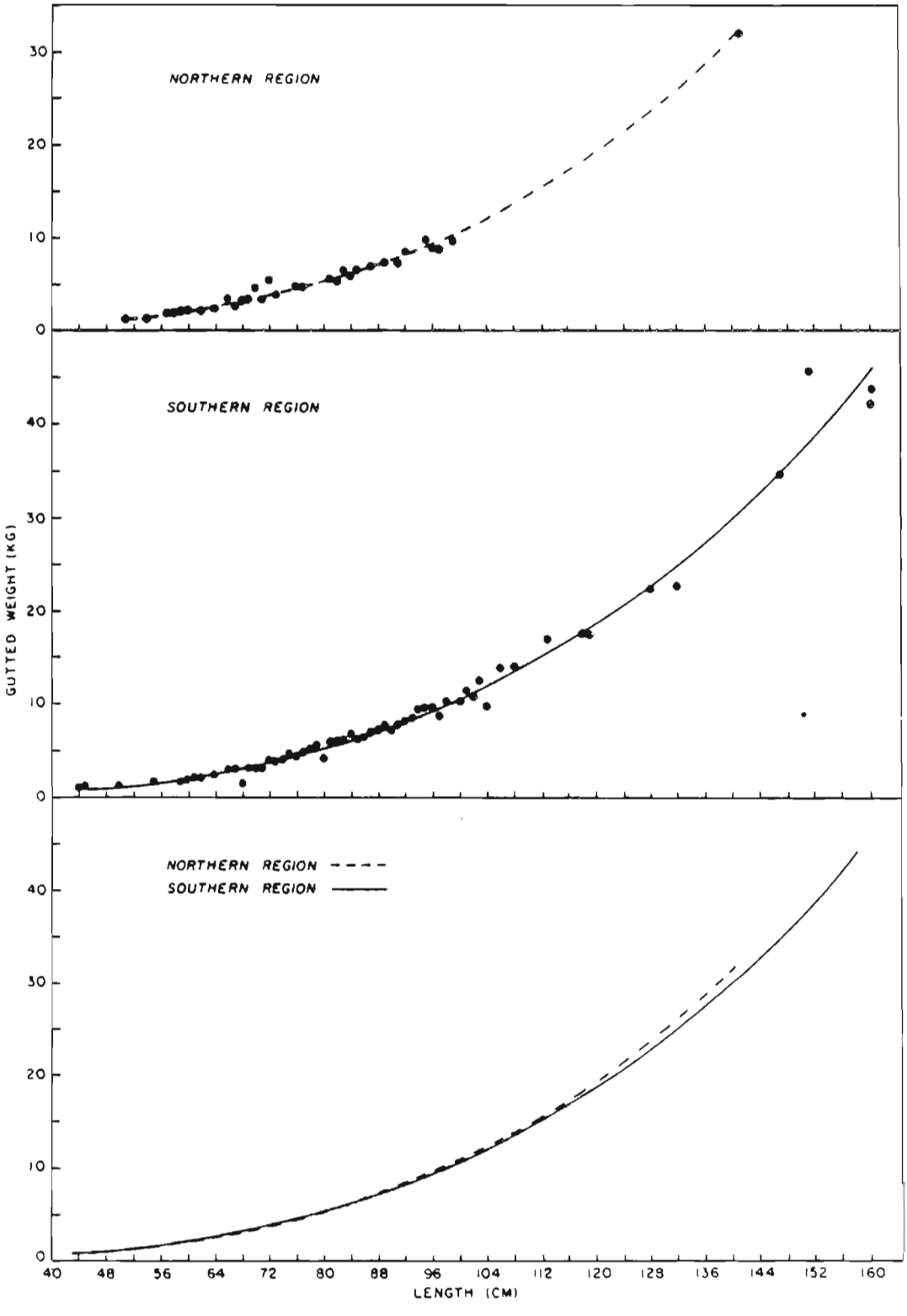

Fig. 14. Length (cm) - gutted weight (kg) relationships of Atlantic halibut by region from research vessel surveys in the Newfoundland-Labrador area during 1972-84.

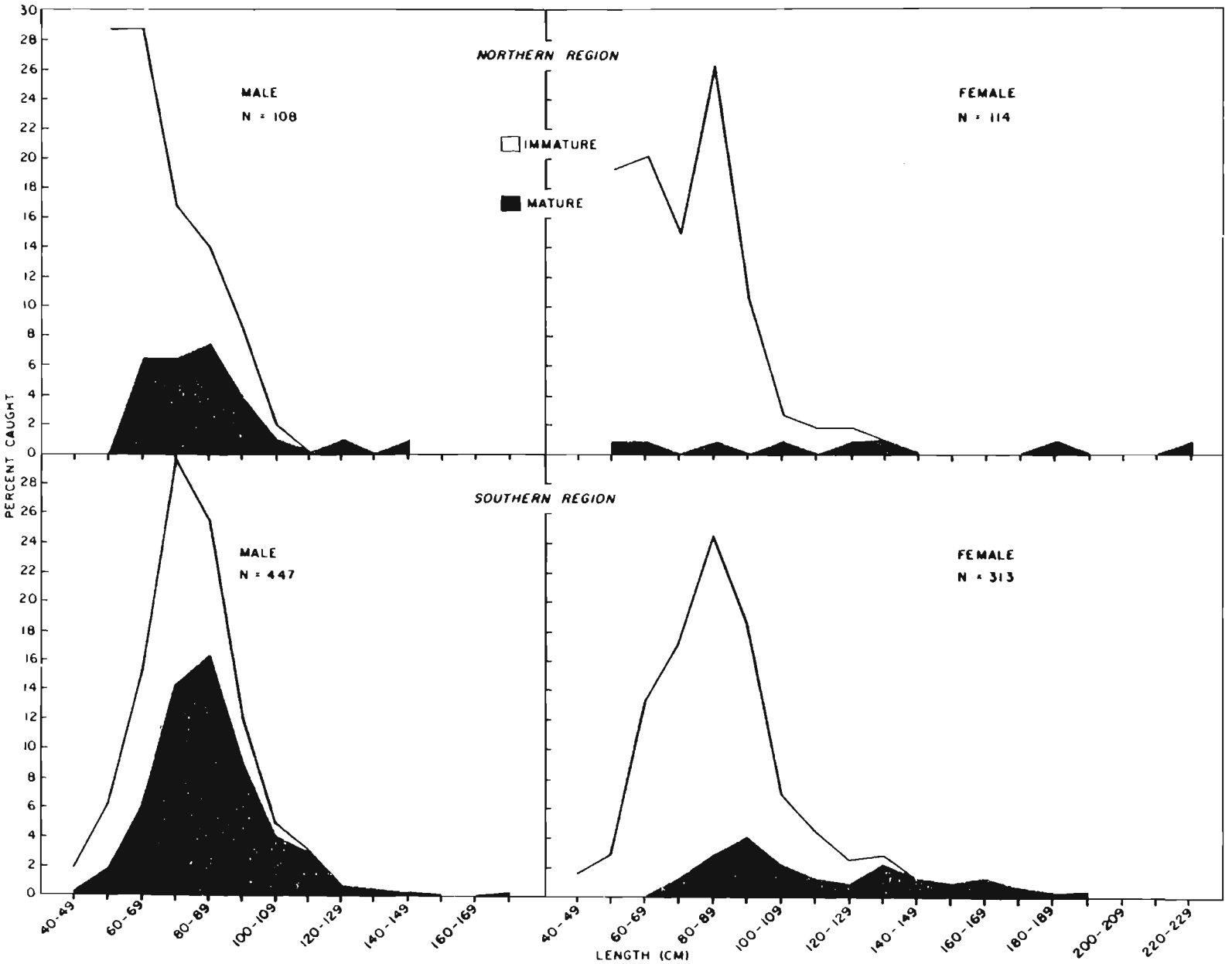

Fig. 15. Length frequency distribution by region and sex of mature and immature Atlantic halibut from research vessel surveys in the Newfoundland-Labrador area during 1972-84.

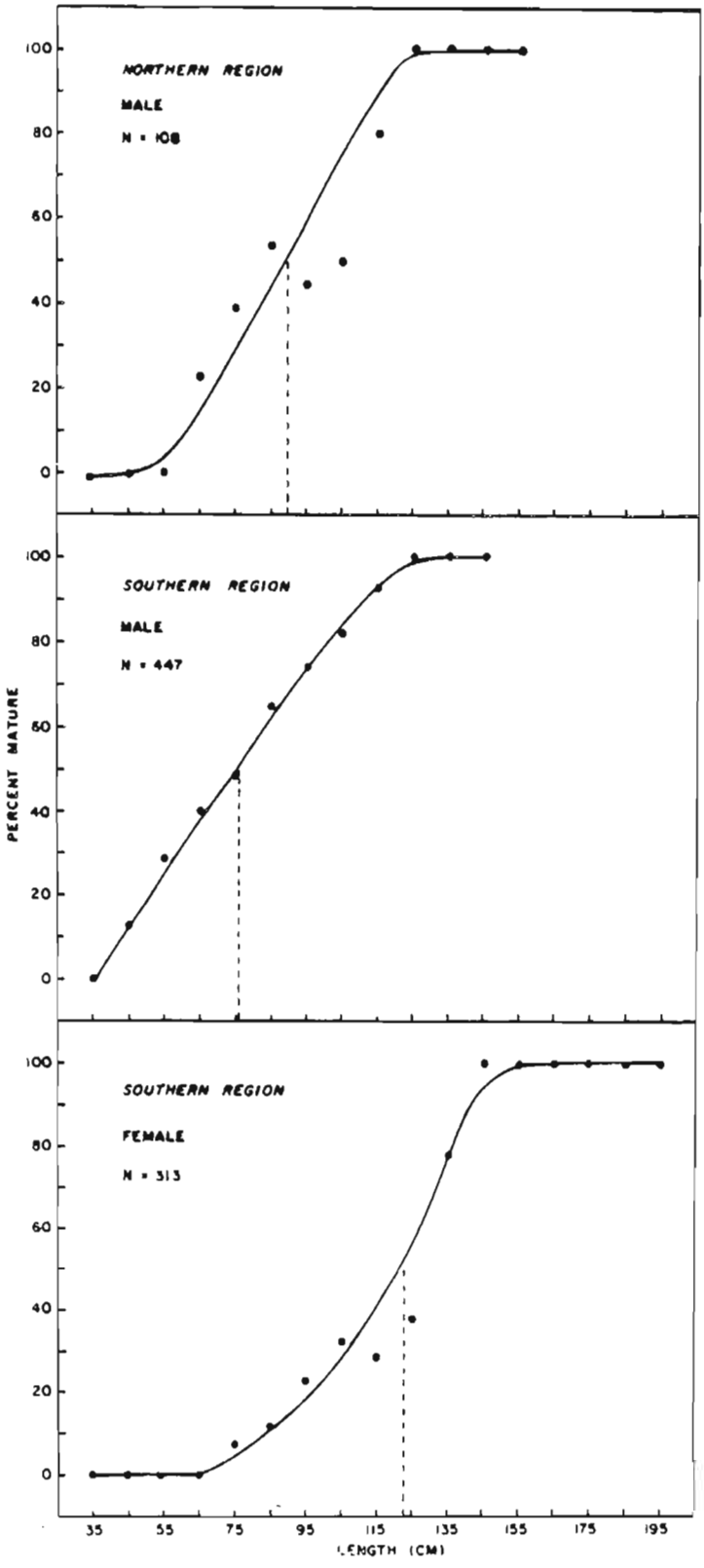

Fig. 16. Sexual maturity ogives of male and female Atlantic halibut by region from research vessel surveys in the Newfoundland-Labrador area during 1972-84.