30924

Some Aspects of Growth, Canadian Exploitation, and Stock Identification of Atlantic Cod *(Gadus morhua)* on the Scotian Shelf and Georges Bank in the Northwest Atlantic Ocean

Terry D. Beacham

Department of Fisheries and Oceans
Resource Services Branch
Pacific Biological Station
Nanaimo, British Columbia
Canada V9R 5K6

February 1982

Canadian Technical Report of Fisheries and Aquatic Sciences No. 1069

Government of Canada Fisheries and Oceans
Gouvernement du Canada Pêches et Océans

Canadian Technical Report of Fisheries and Aquatic Sciences

These reports contain scientific and technical information that represents an important contribution to existing knowledge but which for some reason may not be appropriate for primary scientific (i.e. *Journal*) publication. Technical Reports are directed primarily towards a worldwide audience and have an international distribution. No restriction is placed on subject matter and the series reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries management, technology and development, ocean sciences, and aquatic environments relevant to Canada.

Technical Reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report will be abstracted in *Aquatic Sciences and Fisheries Abstracts* and will be indexed annually in the Department's index to scientific and technical publications.

Numbers 1-456 in this series were issued as Technical Reports of the Fisheries Research Board of Canada. Numbers 457-714 were issued as Department of the Environment, Fisheries and Marine Service, Research and Development Directorate Technical Reports. Numbers 715-924 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Technical Reports. The current series name was changed with report number 925.

Details on the availability of Technical Reports in hard copy may be obtained from the issuing establishment indicated on the front cover.

Rapport technique canadien des sciences halieutiques et aquatiques

Ces rapports contiennent des renseignements scientifiques et techniques qui constituent une contribution importante aux connaissances actuelles mais qui, pour une raison ou pour une autre, ne semblent pas appropriés pour la publication dans un journal scientifique. Il n'y a aucune restriction quant au sujet, de fait, la série reflète la vaste gamme des intérêts et des politiques du Ministère des Pêches et des Océans, notamment gestion des pêches, techniques et développement, sciences océaniques et environnements aquatiques, au Canada.

Les Rapports techniques peuvent être considérés comme des publications complètes. Le titre exact paraîtra au haut du résumé de chaque rapport, qui sera publié dans la revue *Aquatic Sciences and Fisheries Abstracts* et qui figurera dans l'index annuel des publications scientifiques et techniques du Ministère.

Les numéros 1-456 de cette série ont été publiés à titre de Rapports techniques de l'Office des recherches sur les pêcheries du Canada. Les numéros 457-714, à titre de Rapports techniques de la Direction générale de la recherche et du développement, Service des pêches et de la mer, ministère de l'Environnement. Les numéros 715-924 ont été publiés à titre de Rapports techniques du Service des pêches et de la mer, Ministère des Pêches et de l'Environnement. Le nom de la série a été modifié à partir du numéro 925.

La page couverture porte le nom de l'établissement auteur où l'on peut se procurer les rapports sous couverture cartonnée.

Canadian Technical Report of Fisheries

and Aquatic Sciences 1069

February 1982

SOME ASPECTS OF GROWTH, CANADIAN EXPLOITATION, AND STOCK IDENTIFICATION OF ATLANTIC COD (*Gadus morhua*) ON THE SCOTIAN SHELF AND GEORGES BANK IN THE NORTHWEST ATLANTIC OCEAN

Terry D. Beacham

Department of Fisheries and Oceans

Resource Services Branch

Pacific Biological Station

Nanaimo, British Columbia

Canada V9R 5K6

Cat. No. Fs 97-6/1069 ISSN 0706-6457

ABSTRACT

Beacham, T. D. 1982. Some aspects of growth, Canadian exploitation, and stock identification of Atlantic cod (*Gadus morhua*) on the Scotian Shelf and Georges Bank in the Northwest Atlantic Ocean. Can. Tech. Rep. Fish. Aquat. Sci. 1069: iv + 43 p.

Size and age compositions of otter trawl and long-line landings of cod (*Gadus morhua*) in the Canadian commercial fishery, and variability in growth rates, along with their application to stock identification, were investigated on the Scotian Shelf and Georges Bank in the Northwest Atlantic. Mean length-at-age for cod derived from Canadian groundfish surveys indicated that linear regressions adequately described cod growth and they also indicated that cod in more southerly regions grew faster than those in more northerly ones. Instantaneous growth rates of cod were generally above 0.20 for age 5 and younger cod and this age group comprised from 65% of the landings of Canadian otter trawlers in NAFO Subdiv. 4Vn in the 1970s to over 90% in Subdiv. 5Ze. Growth rates of cod were inversely correlated with stock biomass. The close similarity in growth rates of cod in the summer Subdiv. 4Vn fishery with those of Subdiv. 4Vs suggests a large degree of intermixing of these stocks. Changes in growth rates of cod were correlated in NAFO Subdiv. 4Vs and Div. 4W, and both were unrelated to changes in growth of cod in Div. 4X.

Key words: cod, exploitation, fishery, *Gadus morhua*, growth, population dynamics, Scotian Shelf

RESUME

Beacham, T. D. 1982. Some aspects of growth, Canadian exploitation, and stock identification of Atlantic cod (Gadus morhua) on the Scotian Shelf and Georges Bank in the Northwest Atlantic Ocean. Can. Tech. Rep. Fish. Aquat. Sci. 1069: iv + 43 p.

La répartition des tailles et des âges des débarquements commerciaux canadiens de morue (Gadus morhua) capturée au moyen de chaluts à panneaux et de palangres, et la variabilité des taux de croissance, de même que l'application de ces données à l'identification des stocks, ont été étudiées sur le plateau continental Scotian et sur le banc de Georges dans l'Atlantique nord-ouest. La lonqueur moyenne par âge de la morue obtenue à partir des levés canadiens de poisson de fond a montré que les régressions linéaires caractérisaient convenablement la croissance de la morue et que celle-ci croissait plus rapidement dans les régions situées plus au sud. Les taux instantanés de croissance se sont situés en général au dessus de 0,20 pour le groupe d'âge 5 et pour les morues plus jeunes; ce groupe d'âge a constitué 65 % des débarquements des chaluts à panneaux canadiens dans la sous-division 4Vn de l'OPANO au cours des années 70, dépassant 90 % dans la sous-division 5Ze. On a découvert que les taux de croissance variaient en sens inverse de celui de la biomasse des stocks. La grande similitude entre les taux de croissance observés lors de la pêche estivale dans la sous-division 4Vn et ceux relevés dans la sous-division 4Vx semble indiquer que ces stocks se mélangent beaucoup. On a trouvé que les changements des taux de croissance pour la division 4VS et la division 4W de l'OPANO étaient correlés, mais qu'ils n'étaient pas reliés à ceux observés dans la division 4X.

Mots-clés: Morue, exploitation, pêche, Gadus morhua, croissance, dynamique des populations, plateau continental Scotian.

INTRODUCTION

The Canadian fishery for Atlantic cod (Gadus morhua) on the Scotian Shelf has become of increasing importance in the 1970s, as landings by other countries have declined. Canadian nominal catches of cod were about 80,000 t in 1979 for NAFO areas 4V, 4W, and 4X (Fig. 1). Prior to 1977, Spain had been the major exploiter of the 4VsW cod stock, although the Soviet Union reported substantial landings in the 1960s (Halliday 1976). Otter trawlers are the dominant gear conducting the fishery on 4VsW cod, with long-liners next in importance (Gray MS 1979).

Several stocks of Atlantic cod are thought to be present on the Scotian Shelf and Georges Bank (Subdiv. 5Ze) region of the northwest Atlantic. There are local inshore stocks east of Cape Breton Island (Subdiv. 4Vn) (Templeman 1962), and Halliday (1974) assigned all landings taken by gears other than otter trawlers in Subdiv. 4Vn during May through December to these stocks. There is substantial intermixing among cod on the Banquereau Bank (Subdiv. 4Vs) and Sable Island and Emerald Banks (Div. 4W) (Martin and Jean 1964), and these are managed as a unit stock. There are also stocks on Browns Bank (Div. 4X) and Georges Bank (Subdiv. 5Ze), and also several local inshore stocks along the coast of Nova Scotia (Templeman 1962).

The presence of several stocks of cod on the Scotian Shelf and Georges Bank presented an opportunity for an investigation of variability in growth rates among stocks. Growth rates of Atlantic cod may vary with latitude (Fleming 1960; May et al 1965), and may depend upon stock biomass (Kohler 1964; Paloheimo and Kohler 1968; Lett and Doubleday 1976) and temperature (Wiles and May 1968; Pinhorn 1969). Growth of cod in Subdiv. 4Vs and Div. 4W was investigated by Halliday (1972, 1976), with the finding that cod in Div. 4W were larger than cod of the same age in Subdiv. 4Vs. However, variability in growth rates has not been analyzed in relation to stock identification. Age-specific instantaneous growth rates may be analyzed to determine the age at which a year-class attains maximum biomass in order to optimize yield from a fishery. The present paper presents some aspects of growth and changes in mean size and age compositions of cod in the landings of the Canadian commerical fishery on the Scotian Shelf and Georges Bank in relation to these problems.

MATERIALS AND METHODS

Landing data were organized and analyzed on a calendar year basis. Age and length frequency samples from the landings of Canadian otter trawlers and long-liners in Divs. 4X and 4W were grouped in the November to March period. Samples in Subdiv. 4Vs were grouped from February through May, samples in Subdiv. 4Vn from July through October, and samples in Subdiv. 5Ze from May through August. Intervals were chosen to coincide with periods of seasonal slow growth or failing that, during periods when most samples were collected. There was no standard grouping of samples among areas because there was no unique time interval during which samples were concurrently collected in all areas. In some years in each area, no samples were available in the period under examination. In the case of Subdiv. 4Vn, cod from the southern Gulf of St. Lawrence overwinter in this area in the December through May period (McKenzie 1956; McCracken 1959). The July through October samples should, however, represent local stocks. In the annual research surveys, a #36 Yankee otter trawl was used in the July surveys of the stern trawler A.T. CAMERON, and all surveys have been conducted on a stratified random design since 1970. Otoliths in the commercial and research samples were collected in a sampling design stratified by length, the design based on a method described by Gulland (1955). The age of cod was determined from otoliths as described by Kohler (1964). Fork lengths were measured to the nearest cm in both the groundfish surveys and commercial samples. Cod were weighed to the nearest g at sea during the surveys.

Samples from the landings of the commercial fishery and research surveys were also analyzed on a 5-yr basis. The estimation of age compositions first required increasing the number sampled at each 3-cm length interval to the total catch of the sampled boat. Values from each sample were weighted by the ratio of catch weight of sampled boat to weight of sampled fish. Age-length keys were applied to the length frequencies to give age compositions. For the research survey data, only the July cruises of the A.T. CAMERON on the Scotian Shelf were grouped in 5-yr periods. Grouping of the data increased the number of fish in the youngest and oldest ages, thereby allowing more reliable estimation of mean lengths and weights at these ages. However, grouping of the data in this way will allow only regional and long-term fluctuations in growth to be detected.

The instantaneous growth rates of cod age groups 3 to 15 were calculated as:

$$g_i = \frac{\ln (L_{i+1}/L_i)}{T_{i+1}-T_i}$$

where L_i = length at age i derived from Canadian commercial length-at-age data. This procedure was done separately for each fishing gear. Instantaneous growth rates of ages 3-15 were analyzed by analyses of covariance. Growth rate was the dependent variable, and factors of the analysis were age, sampling year, year-class, and fishing gear, with length as a covariate. Instantaneous growth rate is dependent upon body size (Parker and Larkin 1959), and thus covariance analysis is necessary to correct for length differences among groups.

RESULTS

GROUNDFISH SURVEYS

Age and length frequencies

An analysis of age compositions of cod analyzed on an annual basis in the catch of the research vessel indicated that the 1968 year-class comprised over 70% of the research catch in Subdiv. 4Vs in 1970, 40% in Div. 4W, but under 20% in Subdiv. 4Vn and Div. 4X in 1970. The 1968 year-class comprised over 45% of the research catch in Subdiv. 4Vs until 1973, when it decreased to less than 15%, but it still comprised 50% of the catch in Subdiv. 4Vn in 1973. The 1974 year-class was relatively abundant, and as three-year-olds comprised 35% of the resarch catch in Subdiv. 4Vn, 41% in Subdiv. 4Vs, 40% in Div. 4W, and 36% in Div. 4X in 1977. The 1975 year-class was also relatively abundant, comprising 40% of the research catch in Subdiv. 4Vs and 35% in Div. 4W in 1978. About 80% of the cod caught during the research surveys in the 1970s were generally age 6 or less.

When data from the groundfish surveys were compared in 5-yr intervals, length and age compositions of cod varied among the areas surveyed and among intervals (Fig. 2, 3). The proportion of age 1 and 2 cod generally increased in the catch from Subdiv. 4Vn to Div. 4X. Because all cod were caught with the same type of net, thus ruling out changes in selectivity, this result suggests that younger cod in the southern areas were more available than those in the northern areas.

Changes in length

The data covering the available age range suggests that growth of cod was essentially linear (Fig. 4). Because there was little evidence of asymptotic growth, growth models assuming asymptotic or parabolic relationships were not used, and linear regressions were conducted to describe variability in growth rates. Bowering (1978) followed a similar procedure in describing growth of Greenland halibut (Reinhardtius hippoglossoides). Linear regressions fit the data very well between ages 2 and 10, and accounted for at least 97% of the variability in mean length-at-age (Table 1). Cod in the more southerly areas grew faster than those in the northerly areas, and growth rates were higher from 1975-79 than from 1970-74. Cod grew, on average, about 7 cm/yr after age 2. Age 2 cod caught by the research gear were, on average, about 31 cm in July, suggesting growth of about 12 cm/yr after 2.5 growing seasons.

Regional variability in growth rates was investigated by comparing observed mean length-at-age of same-age cod over all years and all ages and among areas on an annual basis from 1970-79. Sign test analysis (Mendenhall 1971, p. 369) was used to evaluate growth rates. When the mean length of cod in a southerly area was greater than in a northerly area, the comparison was scored "+"; when it was lower, it was scored "-". This sign test analysis indicated that cod of the same age were larger in more southerly areas than in more northerly ones (Table 2). This same trend is evident in Fig. 4, although cod in Subdiv. 4Vs were generally larger than those in Div. 4W from 1975-79, and this accounted for the nonsignificance of the sign test in the comparison of cod in Subdiv. 4Vs and Div. 4W.

The effect of water temperatures on growth rates was investigated by comparing mean lengths-at-age for ages 2 and 10 and mean bottom water temperatures as derived from the July groundfish surveys (Table 3). Mean length-at-age was correlated with bottom water temperature for both age 2 ($r=0.83$, $n=8$, $P<0.02$) and age 10 ($r=0.92$, $n=7$, $P<0.01$). An increasing growth rate of cod from northerly to southerly areas (Table 1), and a similar increasing trend in mean length-at-age, was accompanied by higher mean bottom water temperatures in the more southerly areas as compared with northerly ones (Table 3). During July, the mean weight and age of cod in Subdiv. 4Vs and Div. 4W were generally lower than in other areas (Table 4), which suggests that younger cod were more abundant in these areas than in Subdiv. 4Vn or Div. 4X during the same time.

Changes in weight

Instantaneous growth rates of cod as measured by changes in weight were generally above 0.20 up to age 6, and from 1975-79 were above 0.20 up to age 8 (Table 5). Cod in Div. 4X tended to have higher growth rates at younger ages than did cod in more northerly areas. However, cod in Div. 4X had slower growth rates after age 4 than did more northerly cod (Table 5).

COMMERCIAL SAMPLING

The landings of otter trawlers and long-liners have been the most extensively sampled for all gear types that have conducted the Canadian cod fishery on the Scotian Shelf and Georges Bank. Age compositions and length frequencies for cod are presented in detail for otter trawl landings only but long-line landings indicated similar trends. The number of samples available, along with the number of cod measured and aged in each interval, is indicated in Table 6. Each area will be considered separately.

Subdiv. 4Vn

Cod caught by otter trawlers during May-December in Subdiv. 4Vn are considered to be derived from the migrating 4VsW cod stock, while those caught by long-liners and other inshore gears are assumed to be derived from local stocks (Halliday 1974). The landings of Canadian otter trawlers have not been extensively sampled in the May through December period in Subdiv. 4Vn (Table 6). However, the available data indicate that there has been a decline in the mean age of landed cod by almost 2 yr, but that mean length of landed cod has only marginally declined (Table 6). About 65% of the landings of Canadian otter trawlers between 1970-74 were comprised of cod age 5 or less, and about 80% of the landing from 1975-79 were comprised of this age group (Fig. 5). Cod between 42 and 60 cm comprised over 80% of the landings in the 1970s.

Analyses of covariance indicated that growth rates of cod were variable among years ($F=1.58$, $df=25$ and 186, $P<0.05$) and year-classes ($F=1.78$, $df=34$ and 177, $P<0.01$), and that cod landed by otter trawlers and long-liners had similar growth rates ($F=1.69$, $df=2$ and 177, $P>0.10$).

Mean lengths-at-age for ages 5 to 8 increased in the mid-1950s and mid-1970s and declined in the late 1950s and 1960s (Fig. 6). There has been no unidirectional trend in mean length-at-age with time.

Subdiv. 4Vs

Landings of Canadian otter trawlers have been sampled in Subdiv. 4Vs since 1948. In the intervening period, the mean length and age of landed cod has shown a slight decrease (Table 6), but the modal age of the landings has remained at age 5 and modal lengths in the 48- to 54-cm range (Fig. 7). However, there has been a reduction in the relative proportions of older cod landed. Samples from the Canadian fishery indicated that cod age 5 or younger comprised about 50% of the landings in the 1960s, and increased to about 60% in the late 1970s.

Instantaneous growth rates as determined by changes in length were investigated by analyses of covariance, with the result that growth rates of cod were variable among years (F=3.34, df=20 and 137, P<0.001) and year-classes (F=1.68, df=34 and 123, P<0.05). Mean lengths of ages 5 through 8 have generally been increasing since 1973, and there has been no prolonged decrease with time (Fig. 8). To investigate if growth rates were dependent upon biomass, I examined the relationship from 1966 to 1978 between mean instantaneous growth rate of ages 5 to 8 and age 4+ biomass of area 4VsW cod in total as calculated by Gray (MS 1979), who used the cohort analysis technique of Pope (1972) in order to determine numbers-at-age. Growth rates were inversely related with biomass (r=-0.67, n=10, P<0.05), a result similar to cod in the southern Gulf of St. Lawrence (Lett and Doubleday 1976).

Div. 4W

Landings of Canadian otter trawlers have been sampled in Div. 4W since 1948. Mean age of cod in the otter trawl landings decreased by 2.4 yr from the 1950s to the early 1970s, and mean lengths decreased by 13 cm in the same interval (Table 6). There has been a marked reduction in the proportion of older cod in the landings, with about 75% of the landed cod age 5 or under from 1975-79 (Fig. 9). Cod greater than 72 cm constituted less than 5% of the landings in the 1970s, whereas they constituted about 25% of the landings in the 1950s.

Analyses of covariance indicated that cod landed by otter trawlers and long-liners had similar mean lengths-at-age and growth rates (F=0.77, df=1 and 191, P>0.30), which indicates that the selectivity patterns in these gears have been similar. Growth rates of cod were again variable among years (F=7.06, df=24 and 200, P<0.001) and year-classes (F=1.76, df=33 and 191, P<0.01).

From 1965 through 1978, changes in the annual mean arithmetic instantaneous growth rates of ages 5 through 8 were related with those of Subdiv. 4Vs (r=0.57, n=11, P<0.10). Mean lengths-at-age of cod landed in Div. 4W (Fig. 10) show the same trends as cod landed in Subdiv. 4Vn (Fig. 6) and 4Vs (Fig. 8). In particular, mean lengths-at-age increased in the mid-1950s and mid-1970s and declined in the late 1950s and late 1960s. To determine if growth rates were dependent upon population biomass, I analyzed the relationship from 1966 to 1978 between the arithmetic mean of ages 5 through 8 instantaneous growth rates and age 4+ biomass of the entire area 4VsW cod as determined by Gray (1979). Growth rates were again inversely related with biomass (r=-0.62, n=13, P<0.05), in agreement with the results of Subdiv. 4Vs cod. However, since mean instantaneous growth rates of ages 5 to 8 cod were correlated in Div. 4W and Subdiv. 4Vs, growth rates in both areas will show the same relationship with stock biomass because the same area 4VsW cod stock biomass, as determined by Gray (1979), was used in investigating each relationship.

Div. 4X

Landings of Canadian long-liners have been sampled since 1948, but systematic sampling of otter trawler landings began in the late 1960s. Only 4 samples were available from otter trawl landings before 1965, so firm conclusions cannot be drawn. The available data suggest that there has been a decline in the mean age of cod in the landings since 1965, and if the earlier samples are representative of actual landings, there has also been a marked decline in mean length of cod (Table 6). Cod of ages 3 to 5 have constituted about 70% of the landings since 1965 (Fig. 11). Cod in the 48- to 60-cm range were most abundant in the landings during the late 1970s.

Analyses of covariance indicated that cod landed by otter trawlers and long-liners had similar growth rates ($F=1.90$, $df=1$ and 170, $P>0.15$). Same-age cod landed by the two gears were of similar size. Growth rates of cod were variable among years ($F=3.11$, $df=24$ and 179, $P<0.001$) and year-classes grew at different rates ($F=1.39$, $df=33$ and 170, $P<0.10$).

Trends in mean lengths-at-age for ages 5 through 8 were different than those of Divs. 4V and 4W (Fig. 12). In particular, mean lengths-at-age have not increased in the 1970s. There are no long-term estimates of biomass of Div. 4X cod available. However, there was no correlation of instantaneous growth rates of ages 5 through 8 and cod biomass in area 4VsW ($r=-0.04$, $n=11$, $P>0.20$), which suggests that cod in Div. 4X are of a different stock than the area 4VsW cod stock.

Subdiv. 5Ze

Sampling of cod landed by Canadian otter trawlers from Georges Bank began in 1962. Mean age of cod in the landings has declined from 5.0 y in the 1960s to 3.1 y in the late 1970s (Table 6). Mean length of cod has also undergone a rapid decline during the same interval. In the 1970s over 90% of the landings have been comprised of age 4 or less cod, while cod in the 42- to 54-cm range have been abundant in the landings (Fig. 13).

An analysis of covariance indicated that year-classes grew at different rates ($F=2.14$, $df=19$ and 20, $P<0.05$), and that cod grew faster in some years than in others ($F=2.76$, $df=9$ and 30, $P<0.02$). Sampling of Canadian otter trawl landings in the May through August period has been sporadic, and no visible trends in mean lengths were discernable.

Comparisons among areas

Growth rates of cod as determined from samples of the landings of Canadian otter trawlers were also analyzed in order to investigate variability in growth rates of cod among areas. Although mean lengths-at-age of cod in the commercial landings may be biased by discards of small cod at sea and changes in mesh size and hence selectivity with time, the results from the analysis were in agreement with those of the groundfish surveys, where data has been collected in a standardized fashion. Thus the analysis of growth rates of cod as derived from the commercial landings is presented because these data spanned about a 30-year interval, beginning in many cases in 1948.

The groundfish survey data indicated that cod grew in a linear manner over the range of ages present in the commercial fishery. As a further step in the analysis, linear regressions were fitted to the mean length-at-age data between ages 3 and 10 on data pooled for all years in which samples were available from Subdiv. 5Ze. These results indicated that cod in more southerly areas again grew faster than those in more northerly ones, and that growth rates of cod in Subdivs. 4Vn and 4Vs were similar (Table 7).

DISCUSSION

Growth rates of fish are potentially influenced by many factors. For cod, variability in growth rates has been suggested to be determined by temperature (Hermann and Hansen 1965; Wiles and May 1968; Pinhorn 1969) or population biomass (Paloheimo and Kohler 1968; Lett and Doubleday 1976), with relative food abundance a possible determinant of density-dependent growth (Kohler 1964). This study indicated that for cod in the areas analyzed, there was a positive correlation between the growth rates of cod and temperature and an inverse correlation between growth rates and population biomass. Fleming (1960) found a similar inverse correlation between growth rates and latitude for cod stocks in the Newfoundland area. The present analysis provides evidence that higher rates of growth were observed in stocks in warmer waters, and some of the variability in growth rates between stocks is attributable to varying water temperatures within each area. Water temperature determines average growth rates of cod within a region, and variations about this mean are influenced by fluctuations in stock biomass. Slower growth rates are not necessarily indicative of lower water temperatures. Brett et al. (1969) showed that for sockeye salmon (Oncorhynchus nerka) the optimum temperature for growth was dependent upon the ration available, with fish growing faster at lower temperatures if less than the maximum ration was provided. There may be an interaction between water temperature and food supply for cod, and this question could be studied experimentally.

In addition to environmental influences on growth rates of fish, the genetic composition of the stock has been suggested as influencing growth rates (Favro et al. 1979; Ricker 1980; Ricker et al. 1978). It has been demonstrated that growth rates of rainbow trout (Salmo gairdneri) can be influenced through selection (Kincaid et al. 1977). Selection through fishing by removing fast-growing individuals has been suggested to account for the decrease in size with time of pink salmon (Oncorhynchus gorbuscha) (Ricker et al. 1978) and brown trout (Salmo trutta) (Favro et al. 1979). However, for cod on the Scotian Shelf, there has been no long-term decline in mean length-at-age with time (Fig. 6, 8, 10, 12). This result suggests that environmental influences rather than genetic change through selection have greater influences on growth rates of cod.

The present study indicated that cod age 5 and under comprised about 40% of the landings of Canadian otter trawlers in the 1970s in Subdiv. 4Vn to over 90% in Subdiv. 5Ze. The analysis of age-specific instantaneous growth rates derived from the groundfish surveys indicated that cod age 5 and under had instantaneous growth rates above 0.20. The instantaneous rate of natural mortality for most cod stocks in the Northwest Atlantic is considered to be 0.20 (Halliday 1972, 1976; Pinhorn 1975). If this mortality rate is representative and constant over ages, then yield is being lost from the cod year-classes when the catch is concentrated on the younger fish. However, if there is a link between growth rate and mortality rate (Gerking 1957; Ware 1975), then cod in the more southerly areas should have higher natural mortality rates than those in more northerly areas. The age at which a year-class reaches maximum biomass would then be greater in more northerly areas as compared with southerly areas.

Age compositions and length frequencies of cod caught during the groundfish surveys (Fig. 2, 3) were always considerably shifted to favour younger ages and smaller sizes than in the landings of other trawlers (Fig. 5, 7, 9, 11, 13). This difference may be accounted for by discarding at sea of small cod and by smaller mesh sizes for research gear than those for commercial gear. Both factors were probably responsible for the differences between the commercial and research gears.

Mean lengths-at-age for cod showed an increasing trend during the mid-1950s in both Subdiv. 4Vn (Fig. 6) and Div. 4W (Fig. 10). Unfortunately, data were not available to establish whether this occurred in Subdiv. 4Vs, but the similarities in growth rate trends among all three of these areas suggests that it may well have. Similar increases have been reported for southern Gulf of St. Lawrence cod (Paloheimo and Kohler 1968). However, because an epizootic in herring (Clupea harengus) occurred at the same time (Sindermann 1958), which suggests increased herring availability as food for cod (Kohler 1964), increasing mean lengths-at-age of southern Gulf cod in the mid-1950s were considered as specific to high herring mortality in the southern Gulf (Kohler 1964). The current study suggests that higher mean lengths-at-age were synchronous for southern Gulf of St. Lawrence and northern Scotian Shelf cod in the mid-1950s, although the mechanism producing this change remains unclear.

Cod caught in Subdiv. 4Vn from May to December are considered to be either from a local inshore stock or to be migrants from area 4VsW cod (Halliday 1974). This study indicated that changes in growth rates of cod were correlated in Subdivs. 4Vn and 4Vs and Div. 4W, and all were unrelated to changes in growth of Div. 4X cod. There is known to be considerable mixing between cod in Subdiv. 4Vs and Div. 4W (Martin and Jean 1964), and these are considered as a unit stock for management purposes (Gray MS 1979). There is also some migration of 4Vs cod into Subdiv. 4Vn (Martin and Jean 1964). The analysis of growth rates supports previous results on mixing of stocks in Div. 4W and Subdiv. 4Vs (Martin and Jean 1964), and the conclusion that there is little mixing of these stocks with the Div. 4X stock. Martin and Jean (1964) suggest that the deeper water of the Scotian Gulf provides an effective barrier to mixing of the Div. 4X stock with the more northerly ones. There was a close similarity between growth of cod in Subdivs. 4Vn and 4Vs derived from the commercial landings (Table 7), but more divergence in growth rates when the groundfish survey data were considered (Table 1, 2). However, Beacham et al. (MS 1980) found that there was a strong correlation between catch per unit efforts of Spanish pair trawlers in Subdiv. 4Vs and Canadian long-liners in Subdiv. 4Vn between 1967 and 1976 ($r=0.95$, $n=9$, $P<0.001$), which suggests a close affiliation between cod in these two areas. These circumstantial data suggest that the summer fishery in Subdiv. 4Vn may be more heavily dependent on migrating Subdiv. 4Vs cod than previously thought. If adult cod from the 4VsW stock have a more pronounced migratory habit than do juvenile cod, as is the case with the southern Gulf of St. Lawrence cod stock (Paloheimo and Kohler 1968), then migration of adults during the summer into Subdiv. 4Vn may account for the lower mean weights and age of cod in Subdiv. 4Vs and Div. 4W in the groundfish surveys (Table 3). Future research should investigate ways of incorporating variability in growth rates in models used to assess the status of the stocks in order to provide advice on total allowable catches for the management of these fisheries.

ACKNOWLEDGMENTS

I am indebted to all those people who have sampled the commercial landings and aged the cod. Dr. D. F. Gray and T. MacEachern kindly assisted with some computer programming, and A. Vromans and B. Fowler ably assisted in some of the analysis. Drs. R. G. Halliday and W. T. Stobo made helpful comments on a draft of this manuscript. The final version of the manuscript was prepared with the assistance of the staff at the Pacific Biological Station, Nanaimo, B.C.

REFERENCES

Beacham, T. D., B. A. Fowler, and A. H. Vromans. MS 1980. 1980 analyses of inshore cod stock in Subdivision 4Vn (May-December). Can. Atl. Fish. Sci. Advisory Ctte. Res. Doc. 80/16: 24 p.

Bowering, W. R. 1978. Age and growth of the Greenland halibut, Reinhardtius hippoglossoides (Walbaum) in ICNAF Subareas 2-4. Int. Comm. Northw. Atl. Fish. Res. Bull. 13: 5-10.

Brett, J. R., J. E. Shelbourn, and C. T. Shoop. 1969. Growth rate and body composition of fingerling sockeye salmon, Oncorhynchus nerka, in relation to temperature and ration size. J. Fish. Res. Board Can. 26: 2363-2394.

Favro, L. D., P. K. Kuo, and J. F. McDonald. 1979. Population-genetic study of the effects of selective fishing on the growth rate of trout. J. Fish. Res. Board Can. 36: 552-561.

Fleming, A. M. 1960. Age, growth and sexual maturity of cod (Gadus morhua L.) in the Newfoundland area, 1947-1950. J. Fish. Res. Board Can. 17: 775-809.

Gerking, S. D. 1957. Evidence of ageing in natural populations of fishes. Gerontologia 1: 287-305.

Gray, D. F. MS 1979. 4VsW cod: Background to the 1979 assessment. Can. Atl. Fish. Sci. Advisory Ctte. Res. Doc. 79/30. 35 p.

Gulland, J. A. 1955. Estimation of growth and mortality in a commercial fish popoulation. J. K. Min. Agr. Fish. Invest., Ser. 2, 18(9): 1-46.

Halliday, R. G. 1972. A yield assessment of the eastern Scotian Shelf cod stock complex. Int. Comm. Northw. Atl. Fish. Res. Bull. 9: 117-124.

Halliday, R. G. 1974. The cod stocks of the southern Gulf of St. Lawrence and Sydney Bight (ICNAF Div. 4T-4Vn). Int. Comm. Northw. Atl. Fish. Res. Doc. 74/24, 16 p.

Halliday, R. G. 1976. Eastern Scotian Shelf cod: A reconstruction of possible events in the fishery in 1958 to 1974 and a re-estimation of potential yield. Int. Comm. Northw. Atl. Fish. Sel. Pap. 1: 7-18.

Hermann, F., and P. M. Hansen. 1965. Possible influence of water temperature on the growth of the west Greenland cod. Int. Comm. Northw. Atl. Fish. Spec. Publ. 6: 557-563.

Kincaid, H. L., W. R. Bridges, and B. von Limback. 1977. Three generations of selection for growth rate in fall-spawning rainbow trout. Trans. Am. Fish. Soc. 106: 621-628.

Kohler, A. C. 1964. Variations in the growth of Atlantic cod (Gadus morhua L.). J. Fish. Res. Board Can. 21: 57-100.

Lett, P. F., and W. G. Doubleday. 1976. The influence of fluctuations in recruitment on fisheries management strategy with special reference to the southern Gulf of St. Lawrence cod. Int. Comm. Northw. Atl. Fish. Sel. Pap. 1: 171-193.

Martin, W. R., and Y. Jean. 1964. Winter cod taggings off Cape Breton and on offshore Nova Scotia banks 1959-62. J. Fish. Res. Board Can. 21: 215-238.

May, A. W., A. T. Pinhorn, R. Wells, and A. M. Fleming. 1965. Cod growth and temperature in the Newfoundland area. Int. Comm. Northw. Atl. Fish. Spec. Publ. 6: 545-556.

McCracken, F. D. 1959. Cod tagging off northern New Brunswick in 1955 and 1956. Fish. Res. Board Can. Prog. Rep. Atl. Coast Stat. 72: 8-19.

McKenzie, R. A. 1956. Atlantic cod tagging off the southern Canadian mainland. Bull. Fish. Res. Board Can. 105: 1-93.

Mendenhall, W. 1971. Introduction to probability and statistics. Third edition. Duxbury Press, Belmont, California. 465 p.

Paloheimo, J. E., and A. C. Kohler. 1968. Analysis of the southern Gulf of St. Lawrence cod population. J. Fish. Res. Board Can. 25: 555-578.

Parker, R. R., and P. A. Larkin. 1959. A concept of growth in fishes. J. Fish. Res. Board Can. 16: 721-745.

Pinhorn, A. T. 1969. Fishery and biology of Atlantic cod (Gadus morhua) off the southwest coast of Newfoundland. J. Fish. Res. Board Can. 26: 3133-3164.

Pinhorn, A. T. 1975. Estimates of natural mortality for the cod stock complex in ICNAF Divisions 2J, 3K, and 3L. Int. Comm. Northw. Atl. Fish. Res. Bull. 11: 31-36.

Pope, J. G. 1972. An investigation of the accuracy of virtual analysis. Int. Comm. Northw. Atl. Fish. Res. Bull. 9: 65-74.

Ricker, W. E. 1980. Changes in the age and size of chum salmon (Oncorhynchus keta). Can. Tech. Rep. Fish. Aquat. Sci. 930: 99 p.

Ricker, W. E., H.T. Bilton, and K. V. Aro. 1978. Causes of the decrease in size of pink salmon (Oncorhynchus gorbuscha). Fish. Mar. Serv. Tech. Rep. 820: 93 p.

Sindermann, C. J. 1958. An epizootic on Gulf of St. Lawrence fishes. Transactions of the 23rd North American Wildlife Conference. 23: 349-360.

Templeman, W. 1962. Divisions of cod stocks in the Northwest Atlantic. Int. Comm. Atl. Fish. Redbook, Part III, 1962. 79-123.

Ware, D. M. 1975. Relation between egg size, growth, and natural mortality of larval fish. J. Fish. Res. Board Can. 32: 2503-2512.

Wiles, M., and A. W. May. 1968. Biology and fishery of the west Newfoundland cod stock. Int. Comm. Northw. Atl. Fish. Res. Bull. 5: 5-43.

Table 1. Growth rates (cm/yr) of cod caught in Canadian groundfish surveys on the Scotian Shelf, 1970-79. Linear regressions of mean length-at-age on age were conducted for ages 2 through 10.

	Area			
	4Vn	4Vs	4W	4X
		1970-74		
Rate	5.89	6.45	7.00	7.77
S.E.	0.34	0.38	0.16	0.47
Intercept	17.40	18.22	18.50	27.79
r^2	0.98	0.98	0.99	0.98
		1975-79		
Rate	6.95	7.28	7.34	8.13
S.E.	0.47	0.34	0.34	0.56
Intercept	18.68	18.78	17.58	27.25
r^2	0.97	0.99	0.99	0.97

Table 2. Results of sign test analysis on mean lengths-at-age of cod as derived from Canadian groundfish surveys. When mean length-at-age of cod in a southern area was greater than that of the northern area, the comparison was scored "+"; when it was lower, it was scored "-".

	Area		
	4Vn	4Vs	4W
4X	85+,4-**	81+,6-**	79+,9-**
4W	62+,17-**	51+,35-	
4Vs	69+,17-**		

**P<0.01.

Table 3. Mean lengths-at-age (cm) for cod ages 2 and 10 and mean bottom water temperatures (°C) during July cruises of the A.T. CAMERON on the Scotian Shelf. Number of sets for determination of mean bottom temperature is in parentheses.

Area	Mean length		Mean bottom temperature
	Age 2	Age 10	
		1970-74	
4Vn	24.2	76.0	3.65(61)
4Vs	29.2	86.2	3.51(145)
4W	31.2	88.6	5.63(220)
4X	36.1	102.0	6.90(236)
		1975-79	
4Vn	29.2	82.0	3.80(52)
4Vs	31.3	87.1	3.99(149)
4W	31.3	-	6.48(258)
4X	38.1	106.0	7.19(231)

Table 4. Length, weight, and age parameters for cod caught during groundfish surveys of the A.T. CAMERON on the Scotian Shelf, 1970-79.

		4Vn	4Vs	4W	4X
		1970-74			
Mean length (cm)		46.6	40.3	37.5	55.4
Mean weight (kg)		1.12	0.79	0.69	2.37
Mean age (yr)		4.7	3.4	2.8	3.8
Length (cm)	a	0.0092	0.0063	0.0070	0.0092
Weight (g) relation	b	2.997	3.104	3.081	3.016
$W=aL^b$	n	1,326	1,854	3,333	1,773
	r^2	0.99	0.98	0.98	0.99
		1975-79			
Mean length (cm)		51.2	44.8	42.8	55.4
Mean weight (kg)		1.64	1.17	0.93	2.39
Mean age (yr)		4.7	3.4	3.5	3.6
Length (cm)	a	0.0082	0.0061	0.0065	0.0077
Weight (g) relation	b	3.038	3.13	3.10	3.06
$W=aL^b$	n	769	1,423	3,376	1,983
	r^2	0.99	0.98	0.98	0.99

Table 5. Mean instantaneous growth rate as measured by changes in weight for cod caught during groundfish surveys of the A.T. CAMERON from 1970-1979. Number of otoliths read for younger age group of comparison is in parenthesis

	Area			
Age	4Vn	4Vs	4W	4X
		1970-74		
1-2	0.971(13)	0.959(90)	1.119(285)	1.609(98)
2-3	1.190(171)	0.882(551)	0.693(864)	0.876(365)
3-4	0.475(191)	0.461(435)	0.606(661)	0.693(443)
4-5	0.396(187)	0.420(299)	0.375(402)	0.406(366)
5-6	0.375(269)	0.305(188)	0.363(212)	0.245(245)
6-7	0.172(166)	0.191(120)	0.391(51)	0.197(171)
7-8	0.274(118)	0.160(60)	0.187(28)	0.251(81)
8-9	0.278(70)	0.575(26)	0.364(9)	0.201(47)
9-10	0.332(29)	0.334(8)	0.199(9)	0.196(27)
Mean (5-9)	0.275	0.309	0.326	0.224(16)
		1975-79		
1-2	- (0)	1.238(32)	1.238(221)	1.663(106)
2-3	0.770(51)	0.756(269)	0.710(583)	0.881(404)
3-4	0.554(138)	0.573(498)	0.590(876)	0.539(429)
4-5	0.532(209)	0.435(310)	0.375(834)	0.406(433)
5-6	0.523(125)	0.499(226)	0.406(477)	0.387(286)
6-7	0.260(90)	0.406(86)	0.348(193)	0.306(148)
7-8	0.295(46)	0.270(53)	0.481(52)	0.288(70)
8-9	0.120(34)	0.152(28)	0.180(10)	-0.064(31)
9-10	0.037(22)	0.145(11)	- (5)	0.344(13)
Mean (5-9)	0.300	0.332	0.354	0.229

Table 6. Mean length (cm), mean age (yr), and samples sizes of cod derived from sampling landings of Canadian otter trawlers, 1948-79.

	Area	Period				
		1948-59	1960-64	1965-69	1970-74	1975-79
Mean length (cm)	4Vn	-	53.8	53.8	50.5	51.9
	4Vs	57.2	54.7	52.5	57.4	56.6
	4W	65.8	58.4	57.4	52.6	54.1
	4X	90.1	63.5	59.2	55.0	61.3
	5Ze	-	64.9	64.5	47.8	55.7
Mean age (yr)	4Vn	-	6.8	6.0	5.0	4.9
	4Vs	6.3	5.7	5.7	6.2	5.5
	4W	7.3	5.7	5.4	4.9	5.1
	4X	8.8	5.4	4.7	3.9	4.4
	5Ze	-	5.0	5.0	3.4	3.1
Number of samples	4Vn	0	2	5	4	6
	4Vs	32	4	8	18	41
	4W	60	18	24	23	39
	4X	1	3	46	28	35
	5Ze	0	4	18	2	53
Number measured	4Vn	0	881	1,866	1,305	1,400
	4Vs	9,608	1,400	2,781	5,515	12,424
	4W	18,868	6,054	8,540	7,446	12,549
	4X	33	740	13,673	6,167	9,114
	5Ze	0	1,468	5,394	548	14,829
Number aged	4Vn	0	133	187	162	234
	4Vs	1,927	236	463	890	2,018
	4W	3,642	1,367	1,444	998	1,766
	4X	33	356	2,774	1,239	1,765
	5Ze	0	458	1,155	115	2,543

Table 7. Growth rates (cm/yr) of cod landed in Divisions 4W and 4X and Subdivisions 4Vn, 4Vs, and 5Ze. Linear regressions of length on age were done for ages 3 through 10 for mean lengths-at-age pooled from all years in which data from Subdivision 5Ze was available.

	Area				
	4Vn	4Vs	4W	4X	5Ze
Rate	4.90	4.97	5.79	7.29	8.31
S.E.	0.22	0.33	0.36	0.34	0.48
Intercept	24.30	24.37	24.94	25.80	26.11
r^2	0.93	0.80	0.78	0.92	0.88
Sample size	53	53	48	47	47

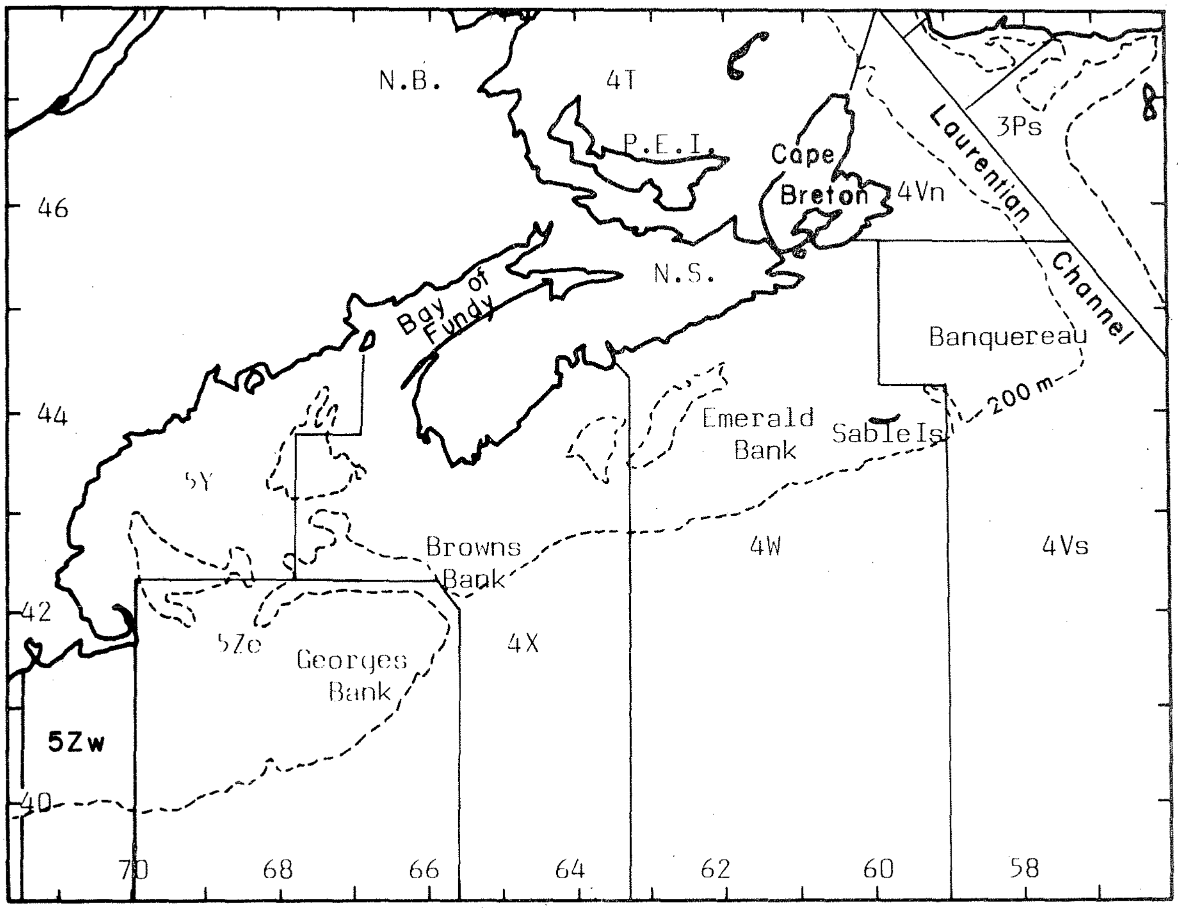

Fig. 1. Northwest Atlantic Fisheries Organization Divisions in Subarea 4.

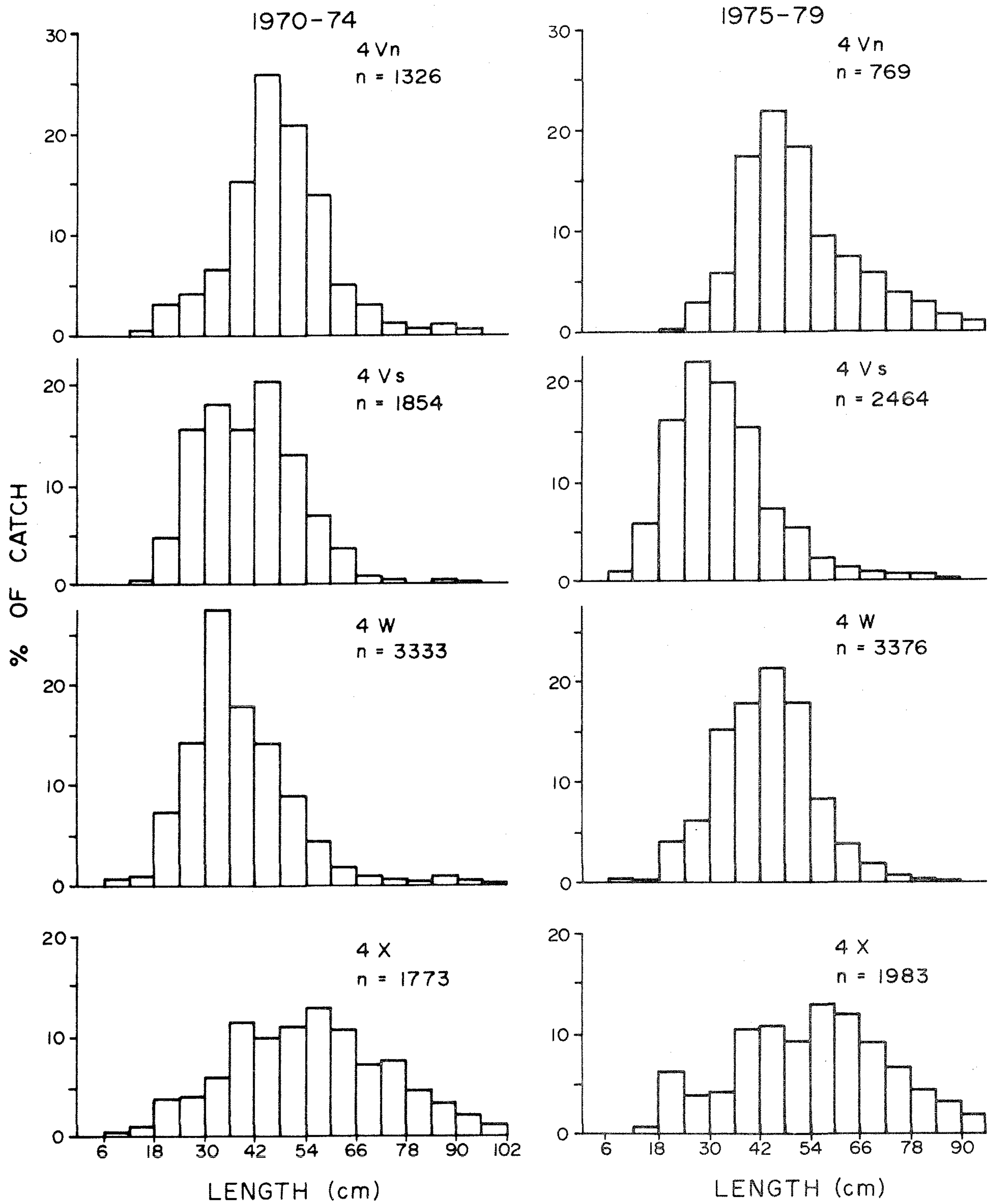

Fig. 2. Length frequencies of cod caught during July groundfish surveys on the Scotian Shelf, 1970-79.

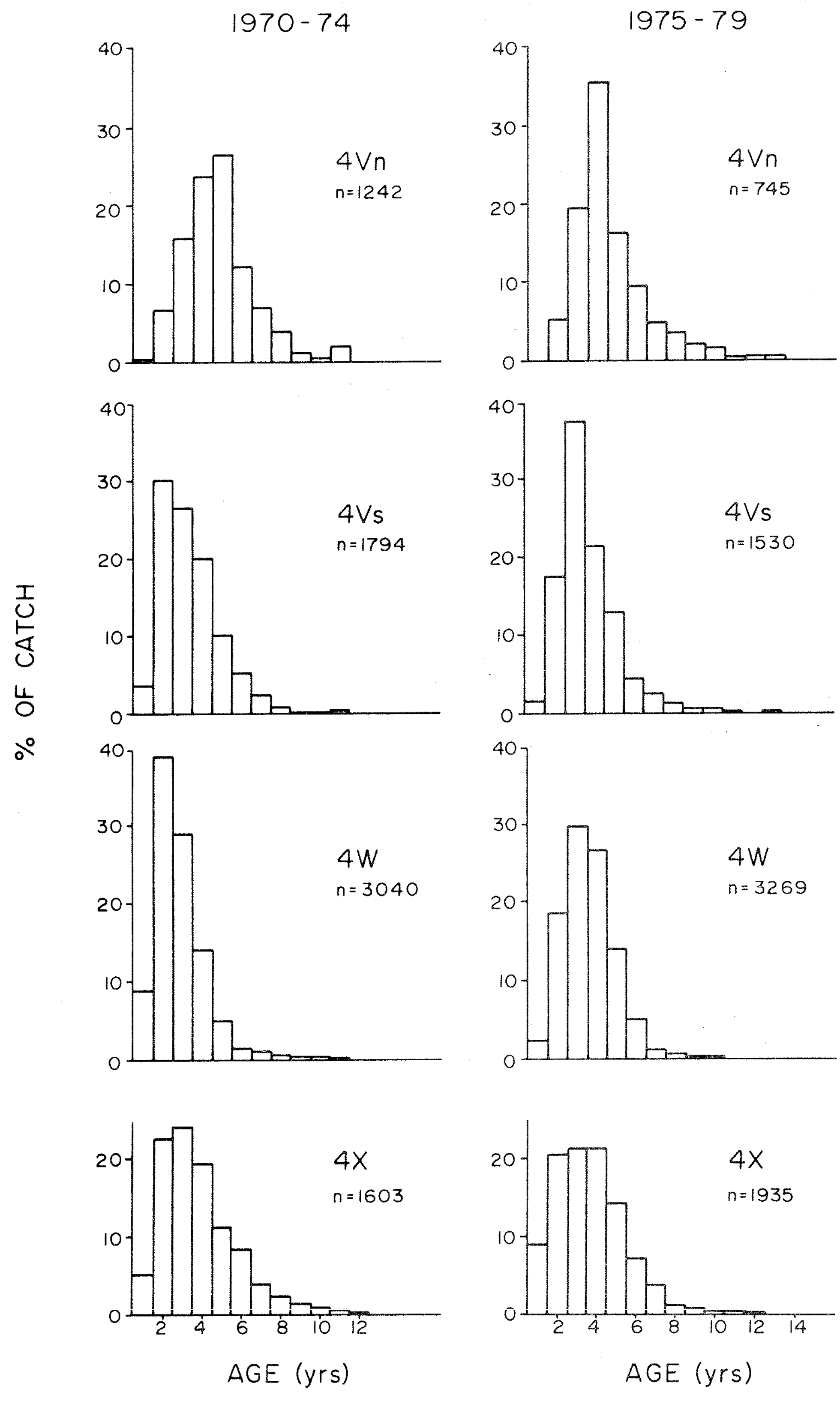

Fig. 3. Age compositions of cod caught during July groundfish surveys on the Scotian Shelf, 1970-79.

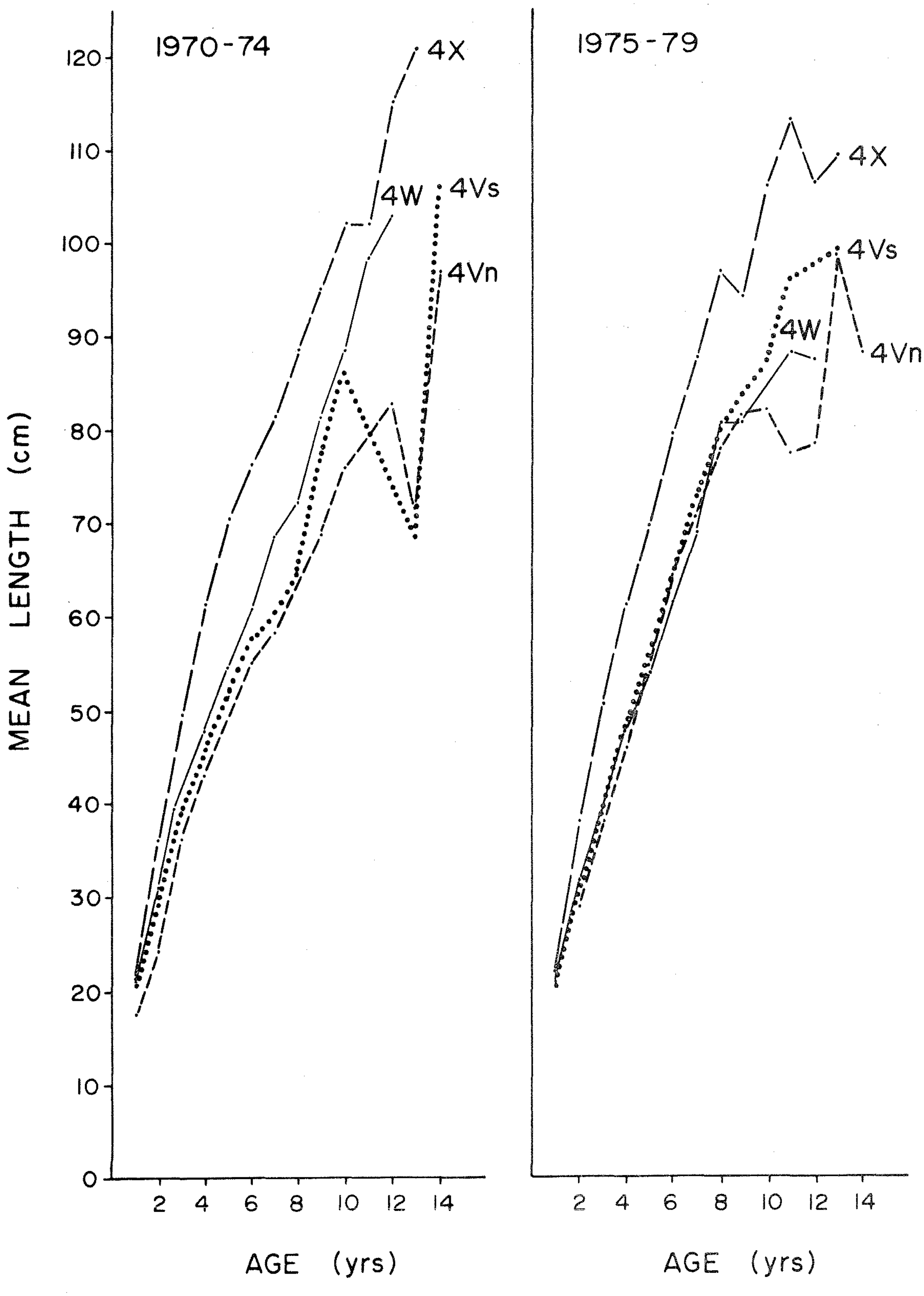

Fig. 4. Observed mean length-at-age for cod caught on July groundfish surveys on the Scotian Shelf, 1970-79.

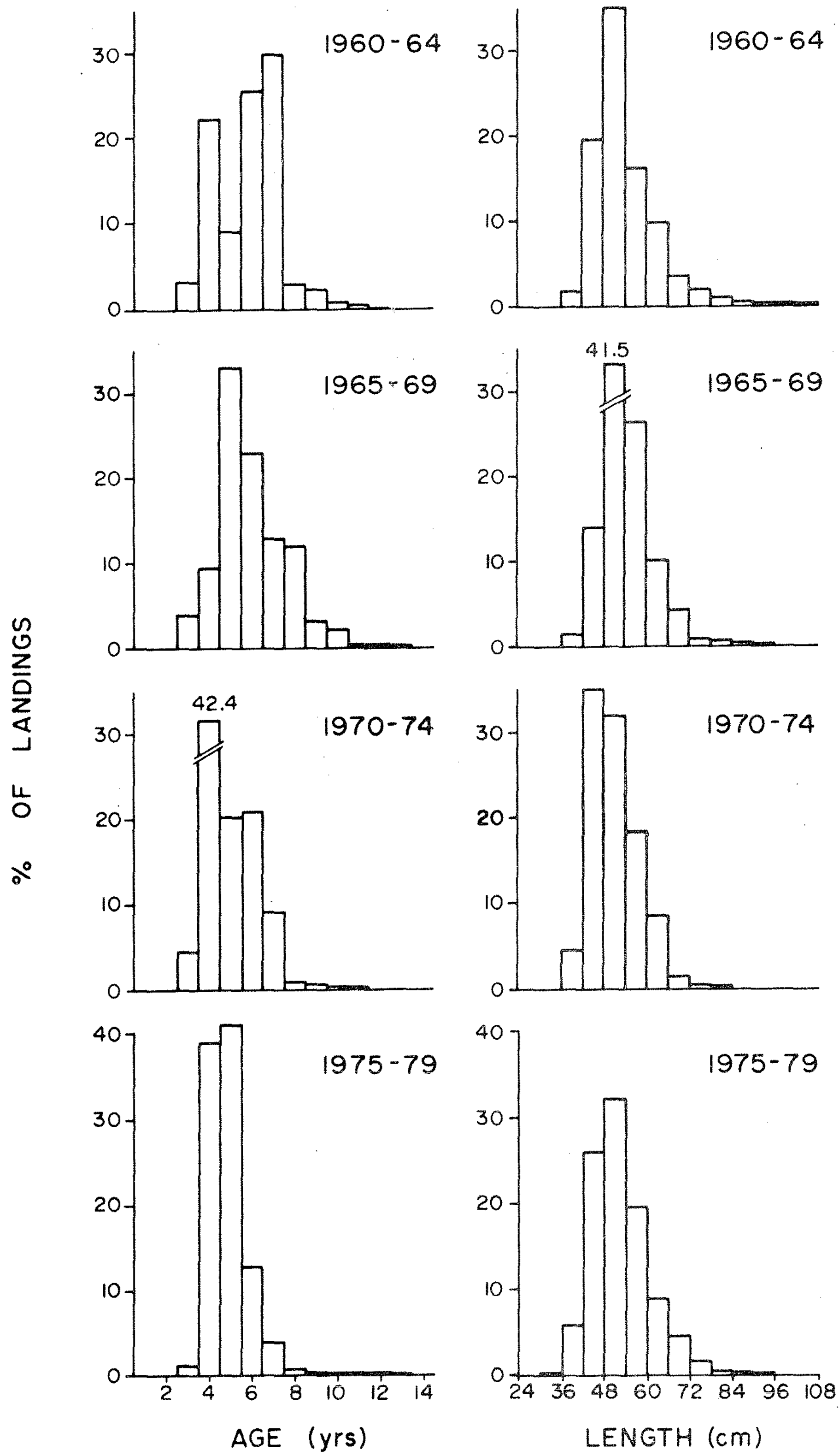

Fig. 5. Age compositions and length frequencies of cod landed by Canadian otter trawlers in Subdivision 4Vn, 1960-79.

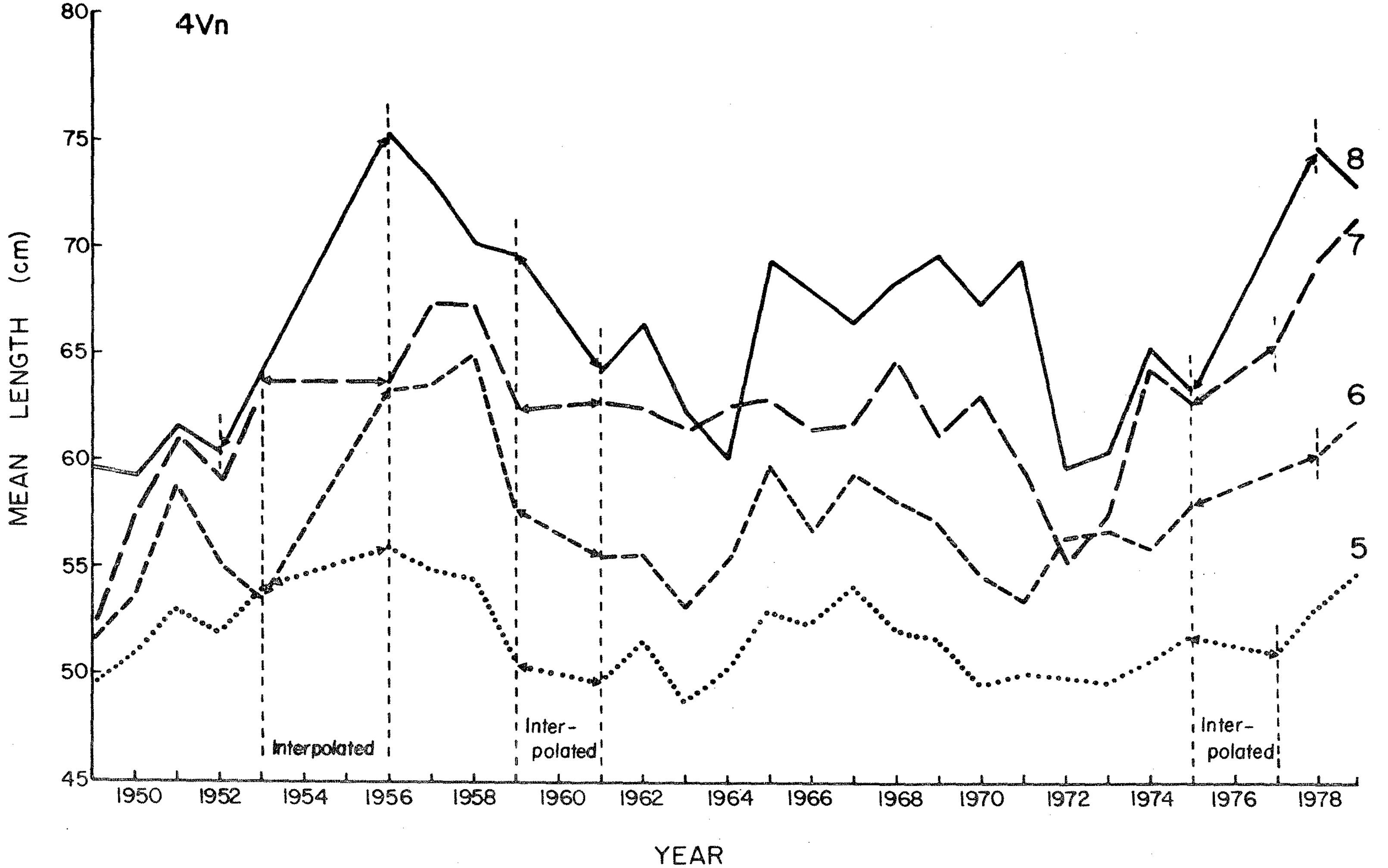

Fig. 6. Mean length-at-age (cm) of ages 5 through 8 cod landed in Subdivision 4Vn in the July through October period of each year.

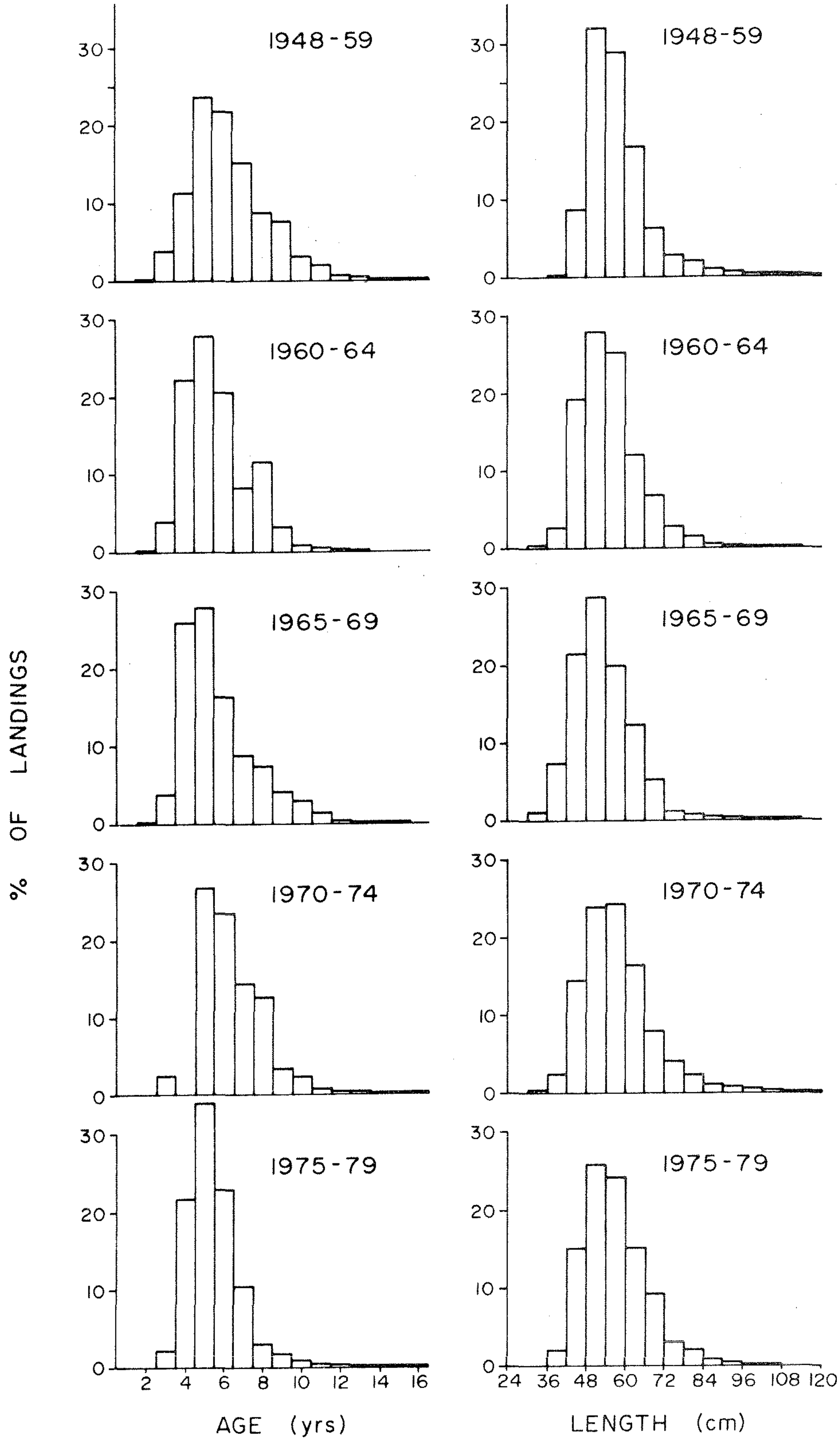

Fig. 7. Age compositions and length frequencies for cod landed by Canadian otter trawlers in Subdivision 4Vs, 1948-79.

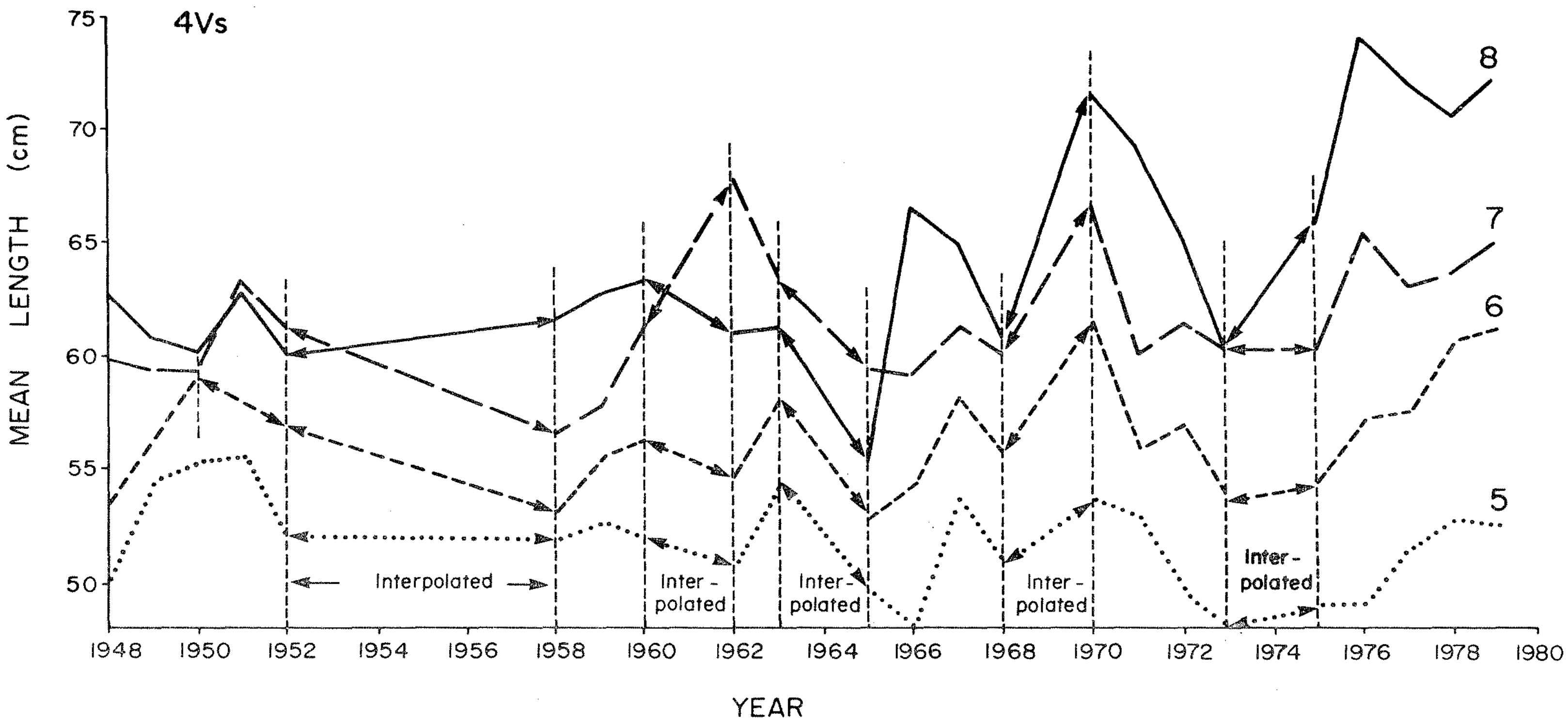

Fig. 8. Mean length-at-age of ages 5 through 8 cod landed in Subdivision 4Vs in the February through May period of each year.

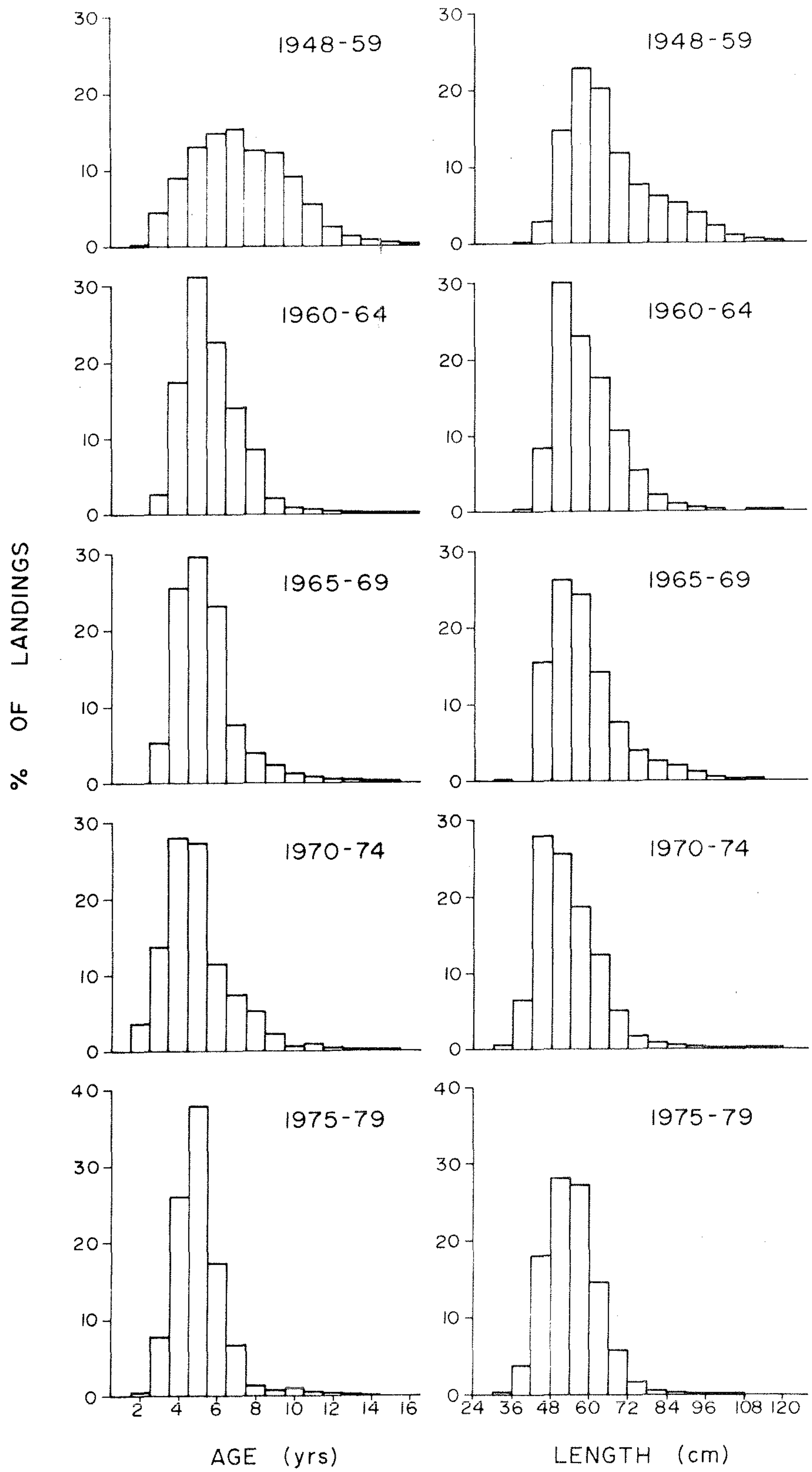

Fig. 9. Age compositions and length frequencies for cod landed by Canadian otter trawlers in Div. 4W, 1948-79.

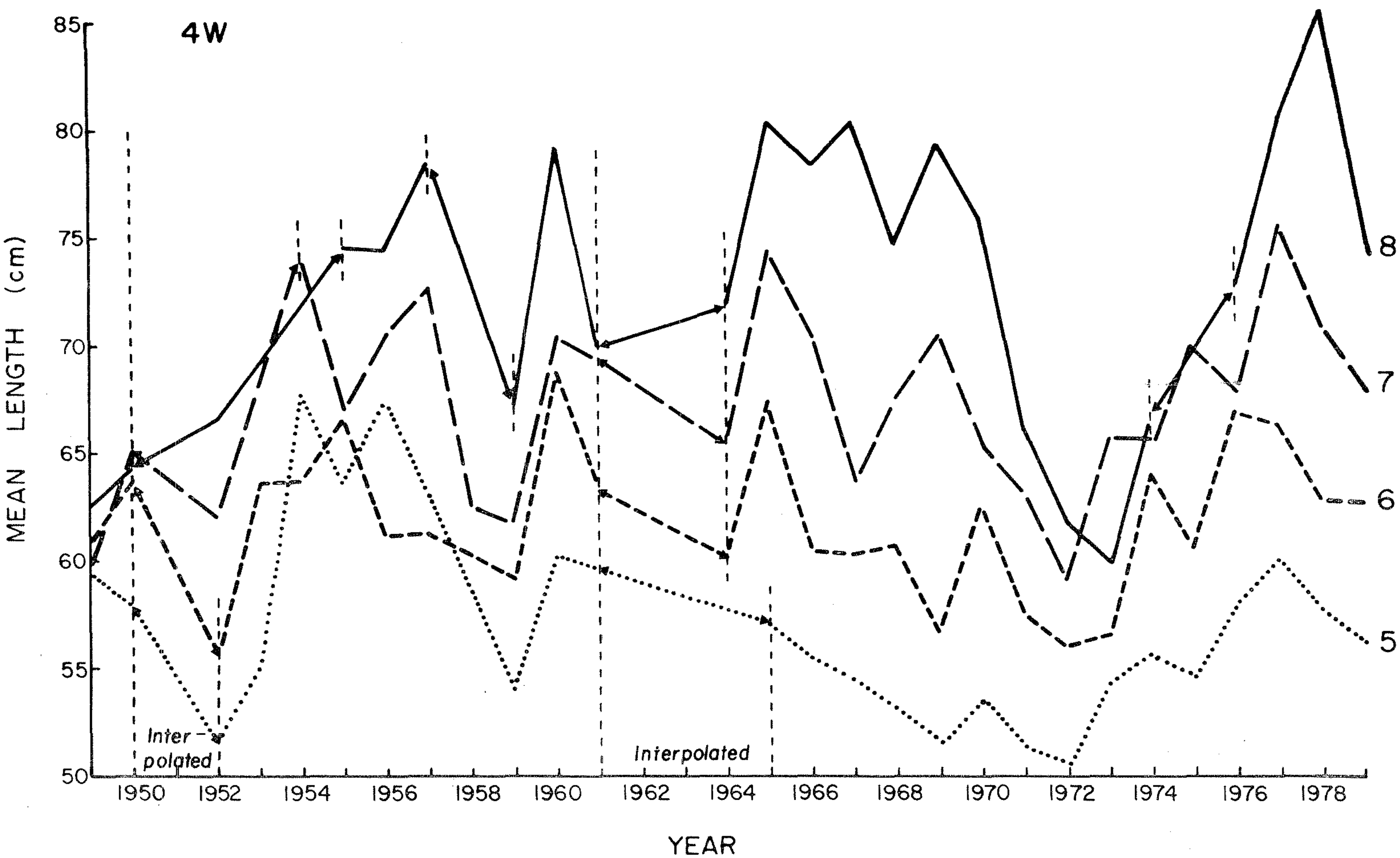

Fig. 10. Mean length-at-age (cm) of ages 5 through 8 cod landed in Division 4W in the November to March period. Mean lengths derived from this grouping are plotted as the year in which the November to December period occurred.

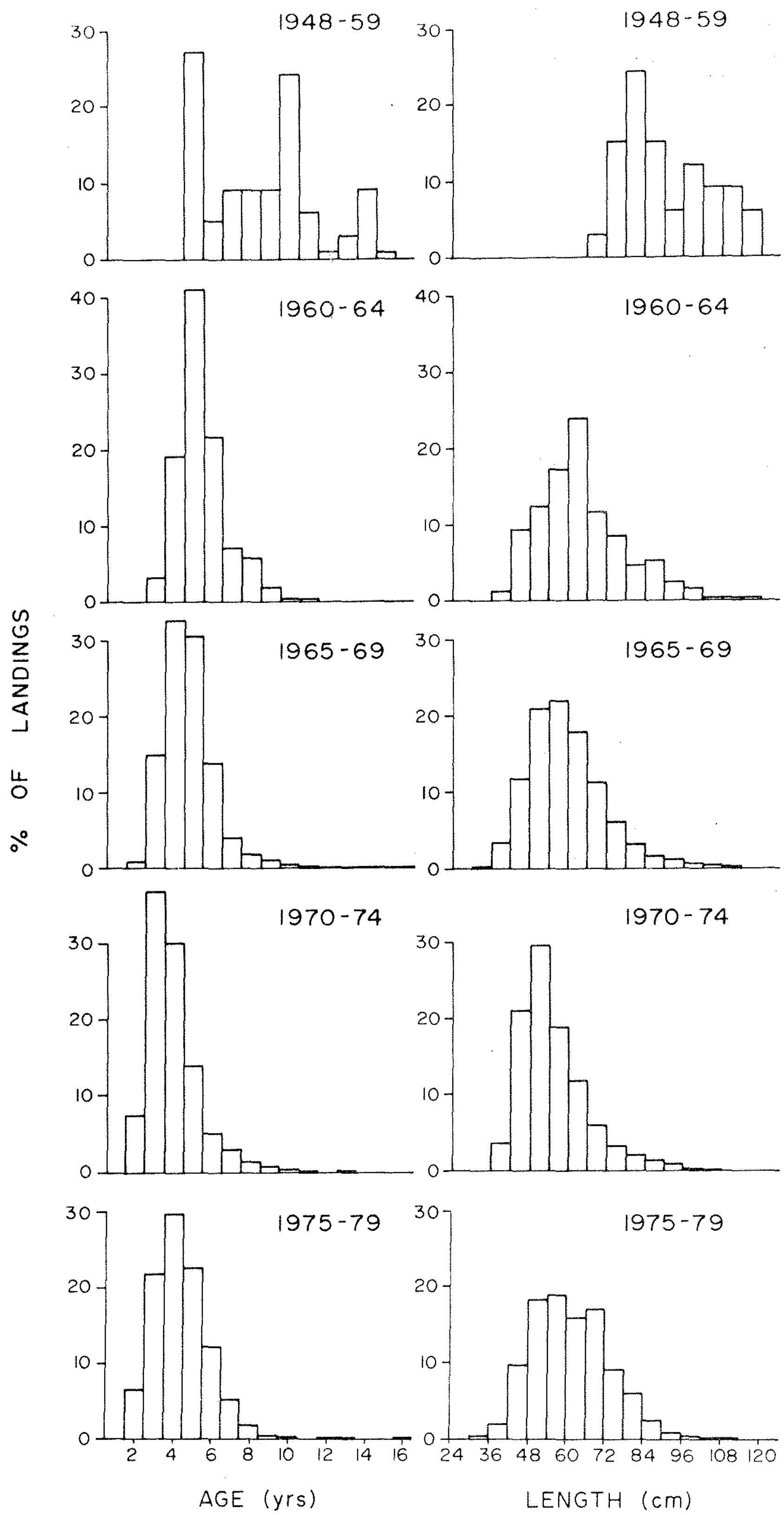

Fig. 11. Age compositions and length frequencies for cod landed by Canadian otter trawlers in Div. 4X, 1948-79.

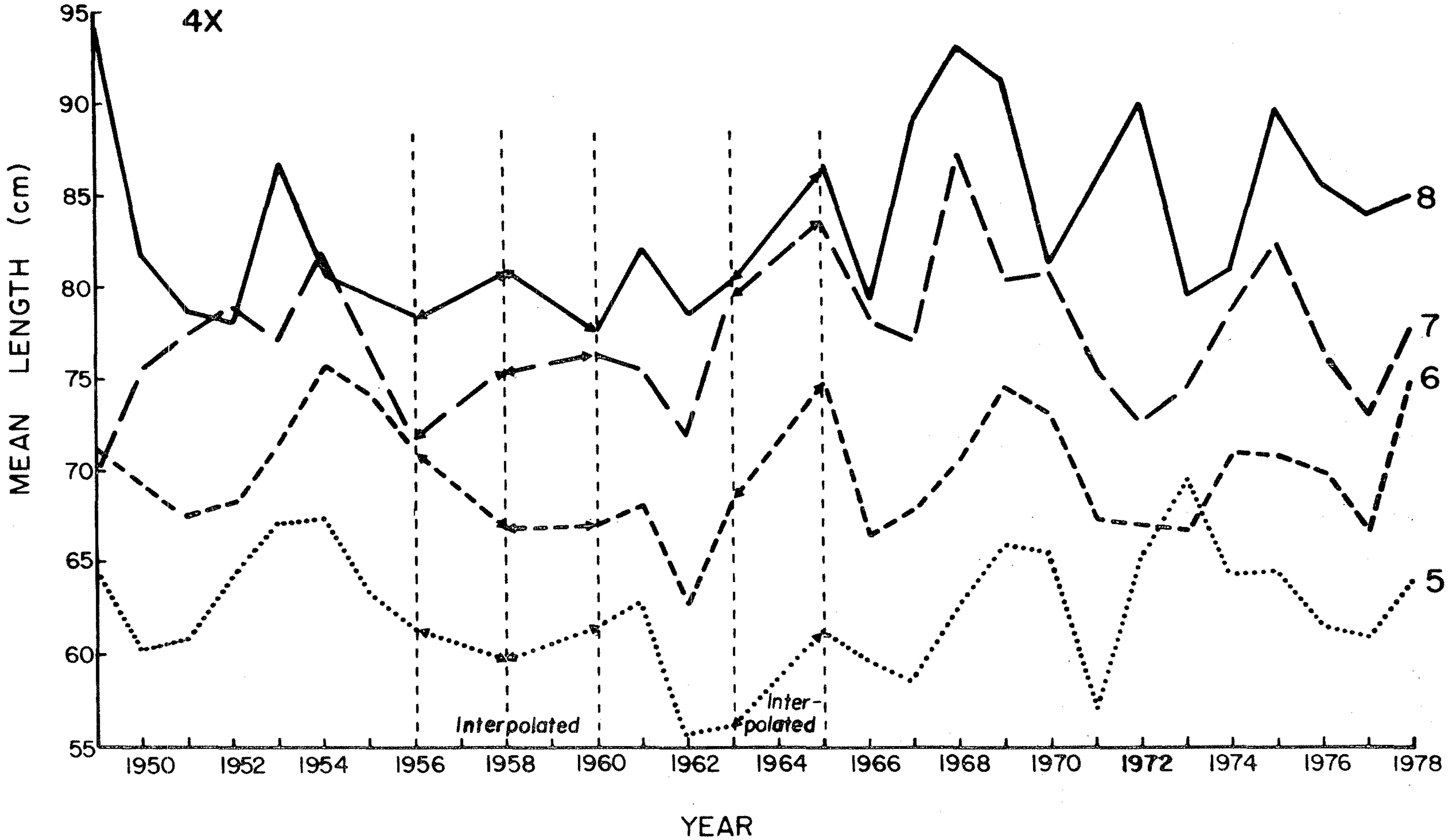

Fig. 12. Mean length-at-age (cm) of cod ages 5 through 8 landed in Division 4X in the November to March period of each year.

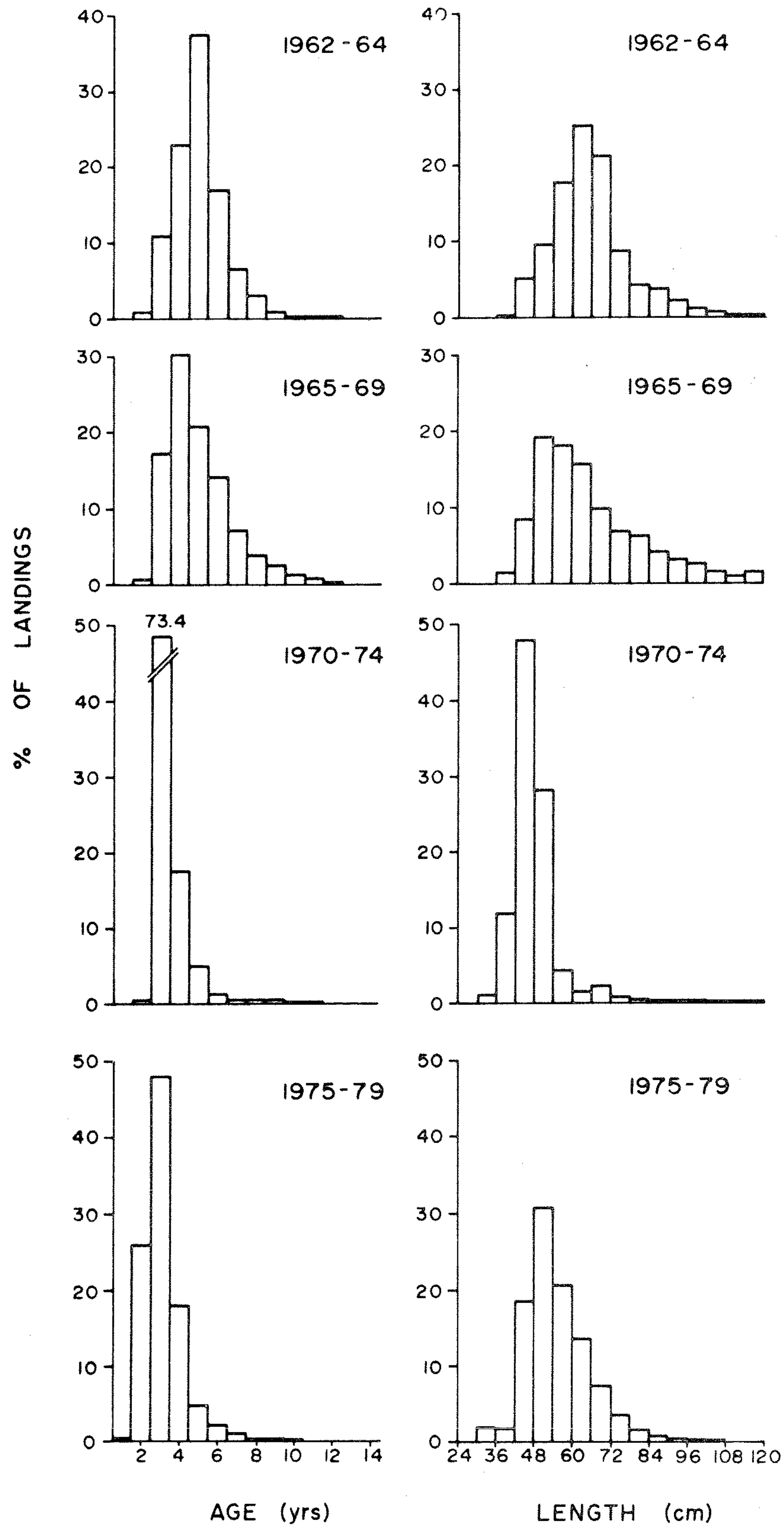

Fig. 13. Age compositions and length frequencies for cod landed by Canadian otter trawlers in Subdivision 5Ze, 1962–79.