

International Council for
the Exploration of the Sea

C.M. 1989/H:21
Pelagic Fish Committee

GROWTH PATTERNS IN THE NORTH SEA AND WESTERN MACKEREL
IN NORWEGIAN CATCHES 1960-85

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ABSTRACT

Length, weight and age in random samples from Norwegian catches of mackerel from 1960 to 1985 have been reviewed. A standard growth curve was constructed by applying a modified von Bertalanffy equation to all data. The deviation from this curve is largely independent of age for adult mackerel, and may be used as a measure of the growth pattern. In the North Sea area, the length at age has increased gradually by 4-5 cm during this period, while it has been nearly stationary in the western spawning area. The condition has remained stable in this period. The mackerel caught in the North Sea is generally larger at age than the typical Western mackerel, even in the years and seasons when Western mackerel dominated in the catches in the North Sea. The mixing of two stock components with different growth patterns also makes the use of length distributions as a measure of age distributions questionable.

1. Introduction

The purpose of this study is to describe changes in growth patterns of the North Sea and Western mackerel as they appeared in Norwegian catches during the period 1960-85. In particular temporal variations in the patterns of length growth and condition, and the dependence of these parameters on catch site and season were considered.

2. Material and methods

Data on body length, weight and age have been collected in samples from Norwegian catches from 1960 onwards. The total number of samples in this period was 763, each consisting of approximately 100 randomly selected specimens. Most samples were from commercial catches, those from the western area were mainly sampled during the Norwegian tagging experiment surveys which have been conducted each year in May since 1970.

In each individual, length and weight were recorded, rounded downward to the nearest centimeter and 10 grammes respectively. Age was determined by counting otolith winter rings. Individuals where the age was undetermined or exceeded 14 years were excluded from the analysis. All samples were taken together and the individuals grouped according to year class, site of catch, season (by quarter of the year) of catch and age. Catch sites were defined as in fig 2.1.

Within each group, the mean and standard deviation were computed. Groups with less than 10 individuals were discarded, and the group means of the remaining groups were used as raw data for the study of growth rate and condition. A number of 885 group means were thus included. The within group standard deviation of the length was between 1.0 and 2.0 cm in the majority of the groups. The condition was computed as weight (in gram) divided by the cube of the length (in cm) and multiplied by 10^5 in each individual, whereafter the group means were computed. The within group standard deviation of the condition was below 10 in most groups, and only exceptionally above 20.

3. Growth curves

Growth curves were constructed for each year class by taking the available length at age means. Growth curves for some selected year classes at the various sites and seasons of catch are shown in figs 3.1 - 3.3. Three features emerge from these curves, which will be discussed further. One is that the length at age differed for different year classes. The second is that the growth curves were different in fish taken in the North Sea and in the western areas. The third is that seasonal variations appeared in the length at age in some sites and seasons.

To compare the length growth between year classes and seasons and sites of catch it would be desirable to replace the growth curve with a single parameter that is largely independent of age. To achieve this a "standard growth curve" was constructed by extending the von Bertalanffy equation to the form:

$$l = (a+bt)(1-\exp(-k(t-t_0))) \quad (2.1)$$

in which the parameters were estimated using all the group means. The equation was preferred to the ordinary von Bertalanffy equation since the growth seemed to approach a linear curve, as judged both from the plots of length at age and Walford plots (not shown). The ensuing equation for the whole material was

$$l_{st} = (32.44+0.68t)(1-\exp(-0.75(t+0.6))) \quad (2.2)$$

This curve is included in figs. 3.1 - 3.3.

Using Friedmans test for column independence (Brownlee, 1965), with some modification (see appendix), the difference $\Delta l = l - l_{st}$ was not significantly dependent on the age, when ages between 3 and 12 years and all groups were included.

This means that within each year class, the Δl in a given season and site of catch is not significantly influenced by the age after 3 years. This also implies that the growth curves for the various year classes after the age of 3 are approximately parallel to the "standard growth curve". Hence, the difference in length at age between the year classes is largely established by the age of 3 years.

Hence, it should be permissible to use the mean of Δl over the ages 3-12 years as a crude indicator of the length at age as compared to the standard growth curve. This parameter is introduced as a measure to compare the growth characteristics of the various year classes, sites and seasons of catch.

Accordingly, to illustrate the change in pattern of length growth over time, the mean of Δl over all ages between 3 and 12 years was plotted for each year class, for the various sites and season (fig 3.4).

In the northeastern North Sea (area B), the mean Δl increased gradually in the year classes 1955 to 1966 from around -3.5 to 0, with little seasonal variation. From the 1966 year class onwards, the mean Δl has been more or less constant for the fish taken in the 3rd quarter in this area. For fish taken in the 2nd quarter, the mean Δl continued to rise up till 1976, giving rise to a drop of up to 2 cm in the mean length at age from the 2nd to the 3rd quarter. The exception to this rule was the 1969 year class. The length at age in this year class, which was the only large one after 1960, was far more homogenous than in the others. Since the 1978 year class, the mean Δl in the 2nd quarter in the area B has declined to the level found in the 3rd quarter.

In the western area, yearly data are available from area F in the 2nd quarter, i.e. from the spawning season and area of the Western mackerel, from 1965 onwards. The mean Δl is consistently lower here than in the Northeastern North Sea, in the 2nd quarter the difference was in the order of 3-4 cm. Also in these data from the western area there is a rising trend of around 0.5 cm/year, terminating with the 1977 year class.

In the other areas, data are more sparse. In areas A and C the trend is similar to that in area B. In the central North sea (area E) the pattern in all seasons resembled that of the 3rd quarter in area B. In the Northwestern areas D,G and H, the pattern was more variable.

To test whether the condition was dependent on year class, year of catch or both, the modified Friedmans test was used. To test for dependence on year class, the data were grouped according to year of catch, site and season, and tested for dependence on year class within

each group. To test for dependence on year of catch, the data were grouped according to year class, site and season, and tested for dependence on year of catch within each group. In both tests significant dependence was found ($\chi^2 = 57.8$ and 132.4 respectively, with 25 degrees of freedom). If the 3 year olds were excluded, the dependence on year class was further reduced ($\chi^2 = 40.3$). Hence, the condition is dependent on both the year of catch and the year class, but the dependence on the year of catch is the stronger of these.

Accordingly, the mean condition was plotted as a function of year of catch (fig. 3.5). Although there are some years where the condition may have been better than in others, the general impression is that the condition has remained fairly constant during the whole period of time. In particular, the change in pattern of length growth during this period is not paralleled in the condition. In the western areas the condition was consistently lower than in the North Sea in the 2nd quarter. These catches contained a large proportion of spawning fish, however. In the other quarters the data from the western area are sparse, but do not seem to differ systematically from those in the North Sea. As might be expected, there was an increase in condition from the first to the second half of the year, but this increase was only marked in some of the years.

4. Growth rate in relation to stock size and exploitation

During the period under consideration, there has been periods of heavy exploitation of both stocks. The North Sea stock was subject to a large purse seine fishery between 1965 and 1970, with a peak of 930000 tons in 1967. Throughout the 1970's the fishery continued at around 200000 tons/year until around 1980. By that time, the North Sea stock was almost extinguished. The fishery in the western area increased gradually during the early 1970's and has remained at around 5 - 600000 tons/year since then. The later years, the fishery in the North Sea has mainly been on the western stock (Iversen and Skagen, 1989).

During this period, the mean length at age increased in the North Sea catches, in the order of 6 cm from the 1955 to the 1975 year classes. It appears, however, that this increase started earlier than the heavy exploitation. Very little is known about changes in the stock size in those early years. The text table below, which shows the mean Δl in

the year classes in area B in the 2nd quarter in the catches before and during the intense purse seine fishery, indicates that the heavy exploitation did not have any substantial influence on the growth pattern of the year classes involved.

Year class	55	56	57	58	59	60	61	62	63
Catches before 1966	-3.5	-1.8		-2.8	-1.9	-.9	-1.3		
Catches in 1966-70	-3.0	-2.5		-2.7	-1.9	-1.2	-.9	-1.2	-.3

In the western area the growth pattern has been fairly stable throughout the whole period, irrespective of exploitation and stock size.

Neither does there seem to be any clear connection between year class strength and growth rate. Admittedly, the two weakest year classes in the Western stock (1972 and 1977) also have the highest values for Δl . The 1969 year class in the North Sea, however, which is the only strong year class there since the early 1960's, is not exceptional with respect to growth rate.

Hence, the present data do not reveal any clear relation between the changes in growth pattern and stock size, exploitation or year class strength.

5. Growth patterns in the North Sea and Western stocks

Our data from the western area are mainly from the spawning season in May. It is known that during the long spawning season, fish of different size spawn at different times, the largest spawn first. Kästner (1977) proposed a fast growing and slow growing component in the Western stock, the Δl of which are approximately 0 and -3 respectively. Our length at age data are slightly below those of Eltink and Gerritsen (1982), which correspond to a Δl of around -1. Hence, our data may not be quite representative for the western spawners, but rather represent a slow-growing fraction.

In the North Sea, data from the first and second quarters probably represent mostly North Sea mackerel. In the third quarter, Western mackerel has dominated the catches at least since the early 1970's, with an exception in 1976-78, according to the Norwegian tagging data (Iversen and Skagen, 1989)

Even though the data from the Western stock may not be quite representative, it is clear that the North Sea mackerel is larger at age than the Western mackerel. Both have increased in length at age during the period under consideration. In earlier studies, this difference in length at age was not visible (Castello and Hamre, 1969), both stocks having length at age comparable to that of our Western stock data from the early 1970's.

In the North Sea, most of our data from the spawning season are from the area B. Some of this fish were actually spawning, the remainder were largely in the pre-spawning stages. Data from egg surveys (Iversen, 1981) point out the central North Sea as the main spawning area, while the south-western coast of Norway and the Skagerak may constitute minor spawning areas. Our data from the spawning season may therefore be more representative for the mackerel spawning in Norwegian coastal areas than for the typical North Sea spawners. The data from the central North Sea in the spawning season are sparse in our material, and very few actually spawning fish are included, but a Δl of around 1.0 may be a reasonable suggestion for the later years. In the year classes from the 1970's, where the Δl tended to be larger than elsewhere in the areas B and C in the 2nd quarter, it is therefore possible that the "coastal spawners" were larger at age than the typical North Sea mackerel. The drop in Δl during the summer in this area may then be due to the feeding migration of the mackerel spawning in the central North Sea, in addition to immigration of Western mackerel.

A complicating factor in this picture is the possibility of gear selectivity. The catches in area B in the 2nd quarter are mostly by drift nets, by which larger fish may be overrepresented. This effect is probably reduced to some extent by the use of the mean Δl as a measure of growth, since this is an average over all ages. A direct comparison between the gears is difficult, since different gears dominate in the fishery in different sites and seasons. The best example is provided by the catches in area B in the 3rd quarter (fig

5.1) Although the Δl may be somewhat larger in the drift net catches, the difference is not impressive. It should also be borne in mind that these catches may have been taken in different parts of the areas and in different years. Therefore, a proper evaluation of the effect of gear selectivity is not possible with our data, but the present approach does not seem to be very sensitive to such effects.

6. Length at age in relation to migration

Neither of the stocks are homogenous with respect to length at age. In the Western stock the slow growing and fast growing component proposed by Kästner (1977) correspond to values of Δl which are approximately -3.0 and 0.0 respectively. It also appears that the length at age decreases throughout the season in this area. In the North Sea, there may at least in some years be a difference in length at age between the different parts of the spawning area. The reason for these diversities is not known. To study how these diversities in growth pattern relate to site and season of catch, the length distributions in single landings were analyzed, using the following strategy.

The year classes from 1967 onwards were considered, since the difference in Δl between the North Sea and western catches was well established by then. Single samples containing at least 50 individuals from these year classes were considered. The Δl in each individual was computed, and the distribution of Δl in each sample constructed. Since landings may consist of several catches, an attempt was then made to split the distribution into two normally distributed components, with parameters μ_1 , μ_2 , σ_1 and σ_2 and relative weights α_1 and $\alpha_2 = 1 - \alpha_1$. An iterative procedure based on the maximum likelihood principle (Mann, Hand and Braslawsky, 1983) was used to estimate optimal values for the means and standard deviations for given values of the α 's. Then, the α 's were optimized by a searching routine, using the least squares principle. This process was repeated until convergence.

The sample was regarded as consisting of two components if the difference between the μ 's exceeded 1.5 cm and both α 's exceeded 0.1. If not, the sample was regarded as one component, and the overall mean used.

In the catches from the western spawners (area F in the 2nd quarter)

the components generally fell into two groups, one with μ from -4.0 to -2.0 and one with μ from -1.5 to -0.5. This grouping corresponds well with the two components described by Kästner (1977). The largest μ recorded in this area was -0.2.

The components were grouped into three categories according to μ : Large ($\mu \geq 0.0$), intermediate ($-2.0 < \mu < 0.0$) and small ($\mu \leq -2.0$). The large component represents fish larger at age than that found in our data from the western area. The small component may be typical for our samples of western spawners.

The results are summarized in table 6.1. In the first half of the year, when the stocks are believed to be well separated, the large type dominated in the areas A,B,C, and E, the small type in areas F and H. From area D the data are too sparse. This pattern is in accordance with the findings discussed above, and confirms the impression that the mackerel of the North Sea stock is larger at age than the Western mackerel.

In the second half of the year, Western mackerel migrates to the North Sea to feed. In the northern North Sea, the Norwegian tagging data indicate that the Western mackerel has dominated the catches in most of the period under consideration. Nevertheless, in areas A,B,C and E most of the catches were of the large type, with only minor contributions from the small type. The same pattern also appears in areas G and H. In area D, the pattern is more diverse, with more of the small type.

This implies that most of the Western mackerel taken in the North Sea is larger at age than that caught in the western areas when the stocks are well separated. Its length at age is also greater than the mean value reported over the whole spawning season in the western area. Hence, the part of the Western mackerel which has a northerly and north-easterly feeding migration seems to be larger at age than the typical Western mackerel.

The fraction of the Western mackerel which migrates into the North Sea for feeding has increased the later years (Iversen and Skagen, 1989). From the present findings, one may suggest that one reason for this is that the living conditions are favourable in the North Sea.

7. Age - length keys.

The fact that the length at age in the catches depends both on season, site of catch and year class, makes the use of length measurements as a tool for determining the age composition difficult. The additional problem encountered by the different growth rates of the two stocks further reduces the confidence of this approach, since the stock composition in the samples may be difficult to predict. Fig. 7.1 illustrates these problems. Here, the length and age distributions in two catches, both from the area B in May 1980 are shown. The length distributions are fairly similar, the one being approximately one centimeter above the other. Even in this presumably standardized situation the age compositions are markedly different, and in fact the large bar at 41 cm includes all ages from 4 to 11 years.

One may therefore raise the question whether it would be more valuable to increase the effort on direct age determination instead of using the resources on large scale length distribution sampling schemes.

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Appendix

A MODIFICATION OF FRIEDMANS TEST FOR COLUMN INDEPENDENCE IN A 2-WAY LAYOUT WITH MISSING DATA.

Consider a 2-way layout with data $x(i,j)$, grouped according to a row factor $i = 1, \dots, p$ and a column factor $j = 1, \dots, q$. Let $R(i,j)$ be the rank of $x(i,j)$ within the its row i . Suppose that we lack some data in the i 'th row, and that the number of valid elements is $q(i) < q$. The appropriate null hypothesis for testing dependence on the column factor is that all $R(i,j)$ in each of the rows have the same probability $1/q(i)$, independent of j . However, if $q(i)$ is different from one row to another, the $R(i,j)$ for different j will have different expectation. We therefore introduce a normalized rank $\alpha(i,j) = R(i,j)/(q(i)+1)$. Then, under H_0

$$E(\alpha(i,j)) = 1/2$$

$$\text{Var}(\alpha(i,j)) = 1/12 \cdot (q(i)-1)/(q(i)+1)$$

which is easily found using the definitions of expectation and variance.

Then, consider the mean of all $\alpha(i,j)$ in the j 'th column

$$\alpha(j) = 1/p(j) \cdot \sum \alpha(i,j)$$

$p(j)$ being the number of rows with values in the j 'th column. Under H_0 we have, noting that the null hypothesis implies that there is no interaction between rows and columns:

$$E(\alpha(j)) = 1/2$$

$$\text{Var}(\alpha(j)) = 1/(12 p(j)^2) \cdot \sum (q(i)-1)/(q(i)+1)$$

If $\alpha(j)$ is normally distributed, one obtains the test statistic:

$$\chi^{2*} = (q-1)/q \cdot \sum (\alpha(j)-1/2)^2 / \text{Var}(\alpha(j))$$

which is approximately χ^2 distributed with $q-1$ degrees of freedom.

1972-75

	1st quarter								2nd quarter								3rd quarter								4th quarter							
	A	B	C	D	E	F	G	H	A	B	C	D	E	F	G	H	A	B	C	D	E	F	G	H	A	B	C	D	E	F	G	H
LARGE	-	-	-	-	-	-	-	-	-	14	-	-	-	-	-	-	-	15	-	-	-	-	-	-	1	10	-	-	-	-	-	3
L+I	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
INTERMED.	-	1	-	2	-	-	-	1	-	4	-	1	-	-	-	-	-	6	1	6	-	-	-	-	-	1	-	-	-	-	-	-
I+S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
SMALL	-	-	-	-	-	-	-	1	-	-	-	-	-	3	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-
L+S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

1976-80

	1st quarter								2nd quarter								3rd quarter								4th quarter							
	A	B	C	D	E	F	G	H	A	B	C	D	E	F	G	H	A	B	C	D	E	F	G	H	A	B	C	D	E	F	G	H
LARGE	-	-	-	3	-	-	-	-	3	6	5	-	4	-	-	-	1	10	2	2	3	-	2	-	-	-	-	1	-	-	-	-
L+I	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	2	1	1	-	-	-	-	-	-	1	1	-	-	-	-
INTERMED.	-	-	-	1	-	-	-	-	-	-	-	-	-	3	-	-	-	-	1	2	1	-	-	-	-	-	-	-	-	-	-	-
I+S	-	-	-	1	-	1	-	-	-	-	-	-	-	1	-	-	-	-	1	5	-	-	-	-	-	-	-	-	-	-	-	-
SMALL	-	-	-	-	-	2	-	-	-	-	-	-	-	1	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-
L+S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-

1981-85

	1st quarter								2nd quarter								3rd quarter								4th quarter							
	A	B	C	D	E	F	G	H	A	B	C	D	E	F	G	H	A	B	C	D	E	F	G	H	A	B	C	D	E	F	G	H
LARGE	-	-	1	-	-	-	-	-	-	17	3	-	3	-	-	1	5	20	2	1	8	-	7	-	-	4	-	3	-	-	-	14
L+I	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	3	6	-	-	-	-	2	1	-	-	-	1	-	-	-	-
INTERMED.	-	-	-	-	-	-	-	2	-	-	-	-	-	3	-	-	-	1	-	-	2	-	6	1	-	-	-	1	-	-	-	1
I+S	-	-	-	-	-	-	-	5	-	-	-	-	-	8	-	-	-	2	-	1	-	-	-	-	-	2	-	1	-	-	-	1
SMALL	-	-	-	-	-	-	-	2	-	-	-	-	-	9	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
L+S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	2

Table 6.1 Classification of landings according to Δl.
Year classes 1967 and later.

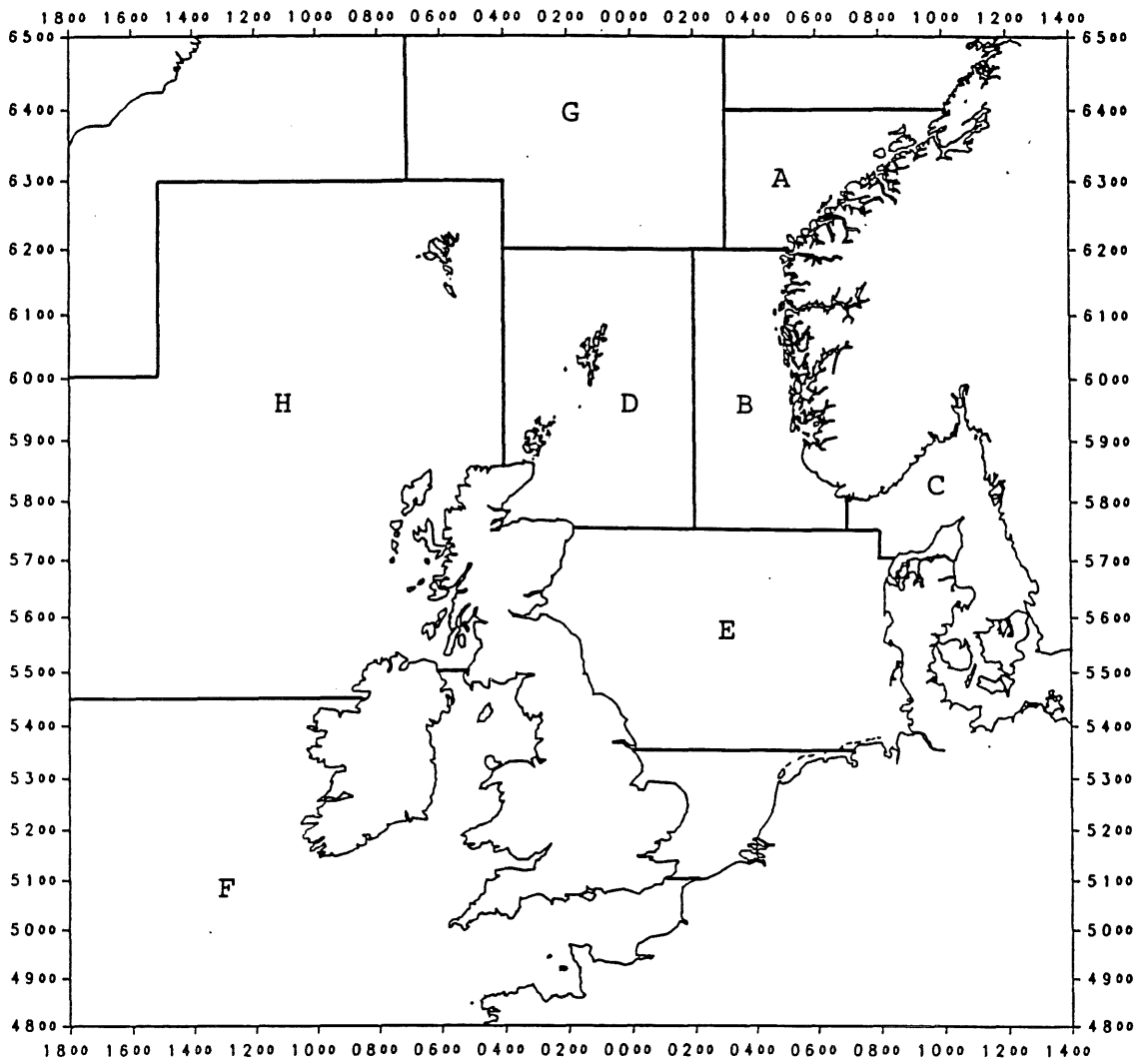


Fig. 2.1. The areas referred to in the text.

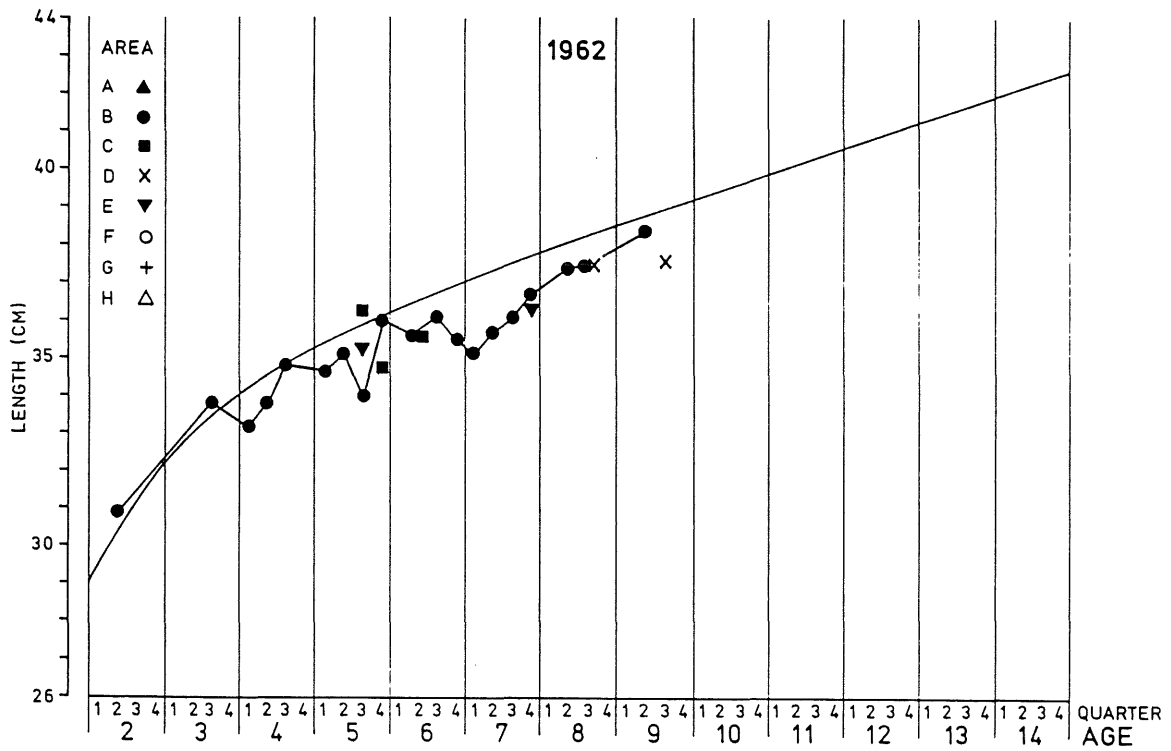
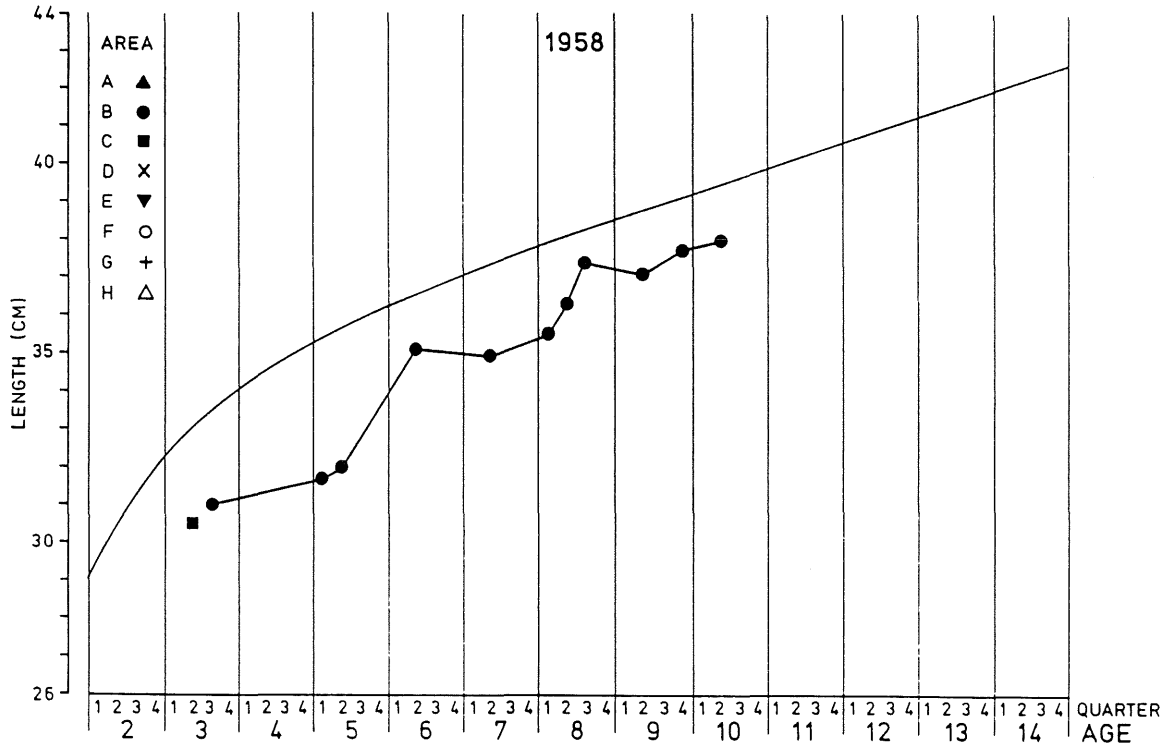


Fig. 3.1. Standard growth curve and length at age for the year classes 1958 and 1962 by area and season.

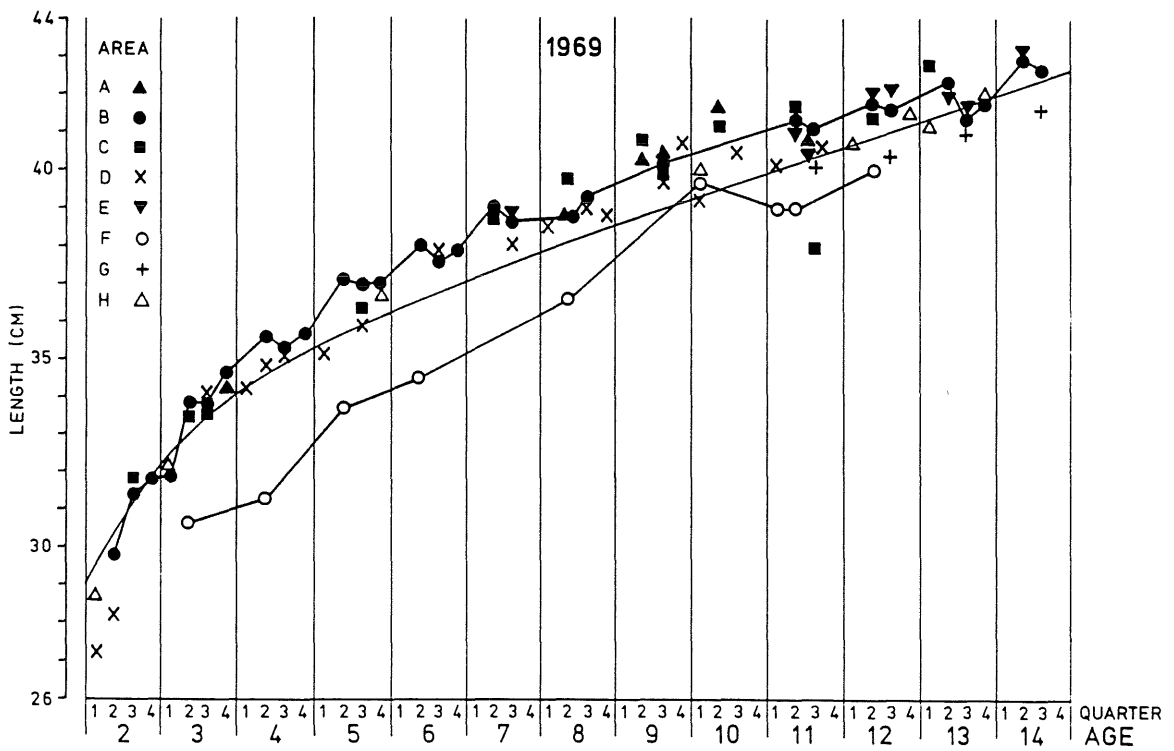
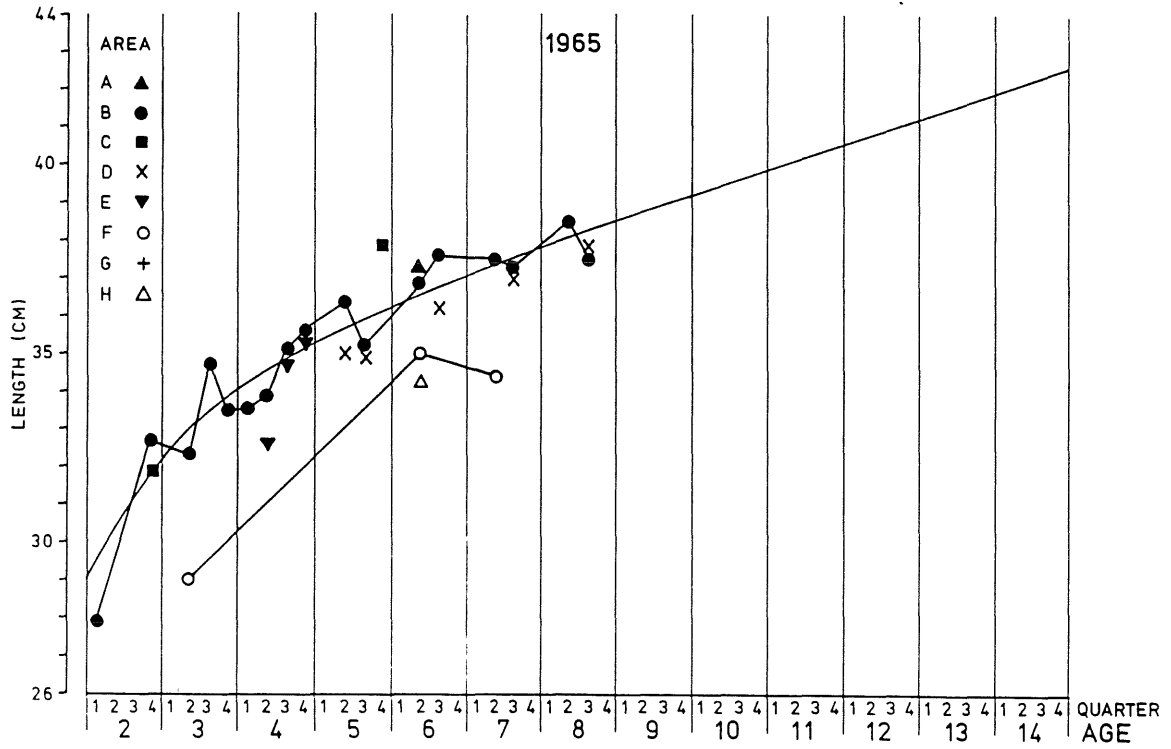


Fig. 3.2. Standard growth curve and length at age for the year classes 1965 and 1969 by area and season.

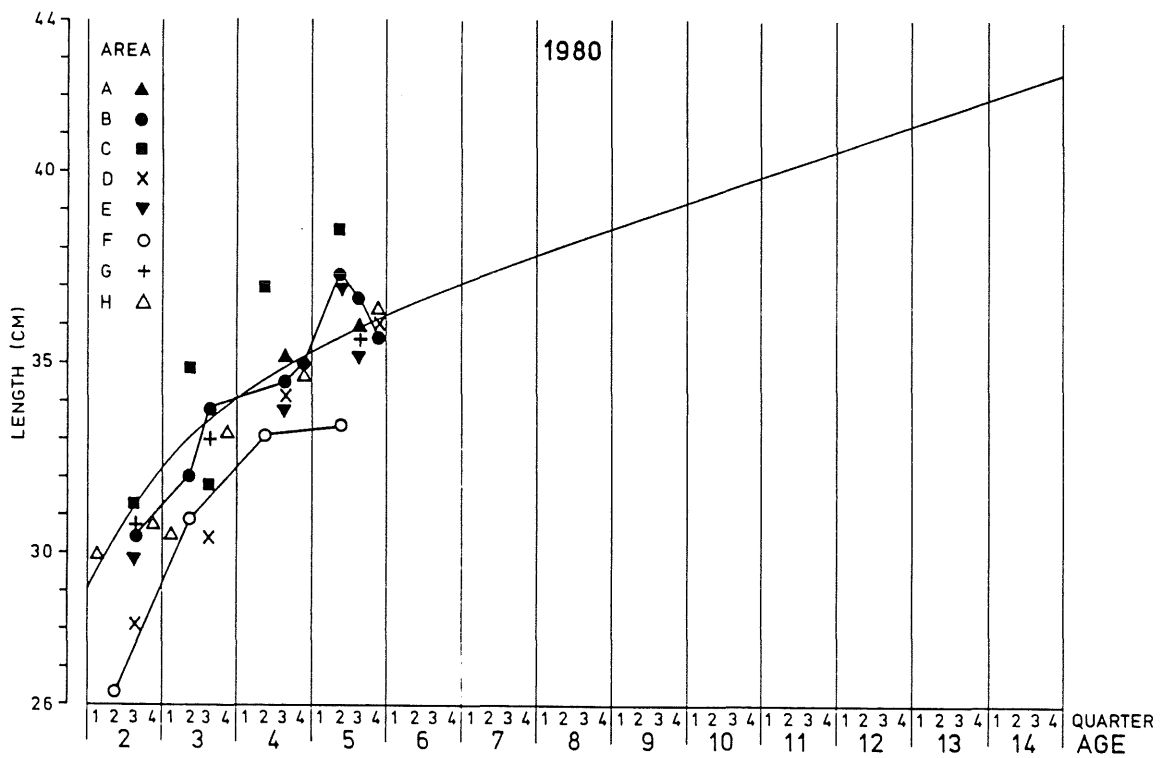
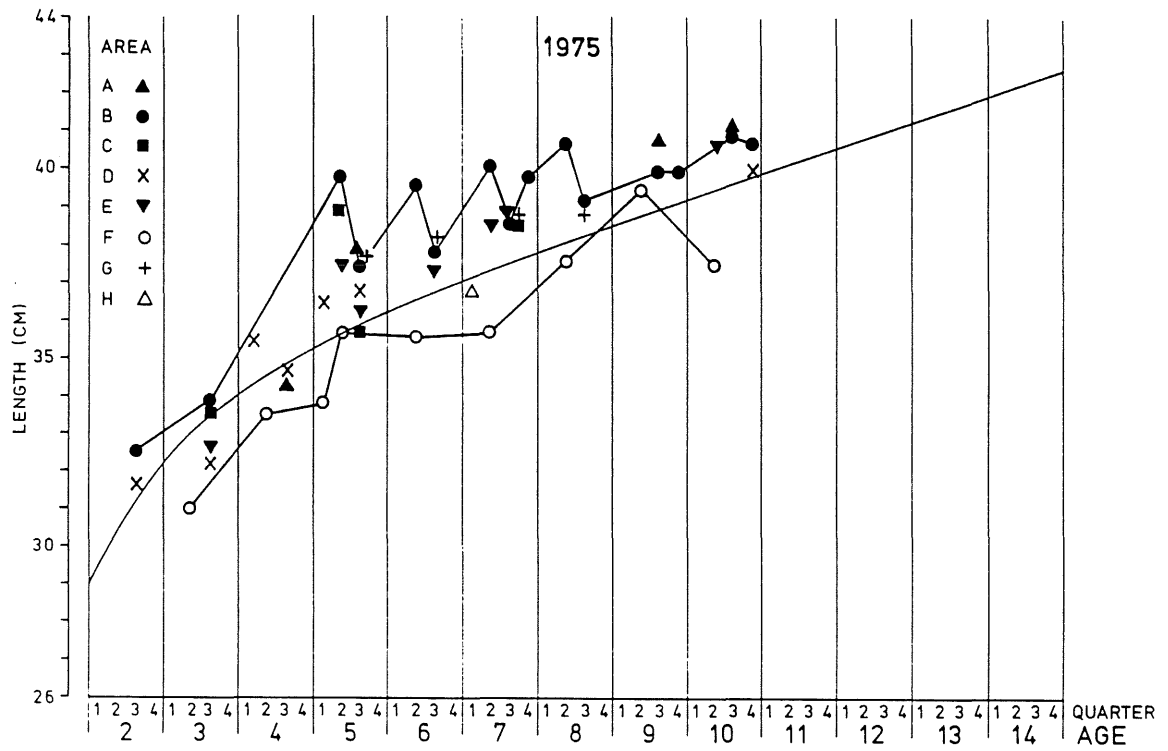


Fig. 3.3. Standard growth curve and length at age for the year classes 1975 and 1980 by area and season.

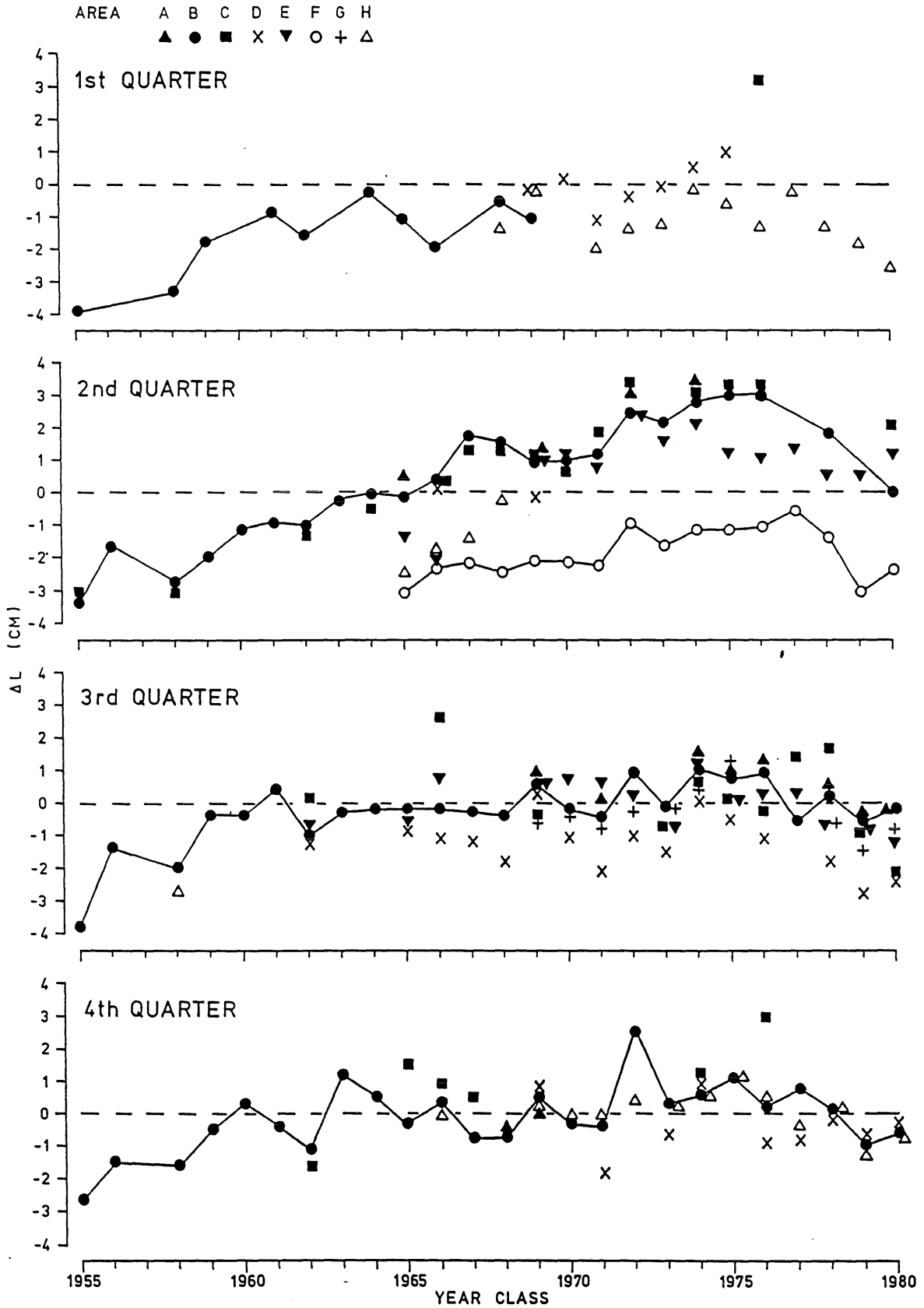


Fig. 3.4. Mean ΔL (deviation from a standardized growth curve) by year class, season and site of catch. The data for areas B and F are connected.

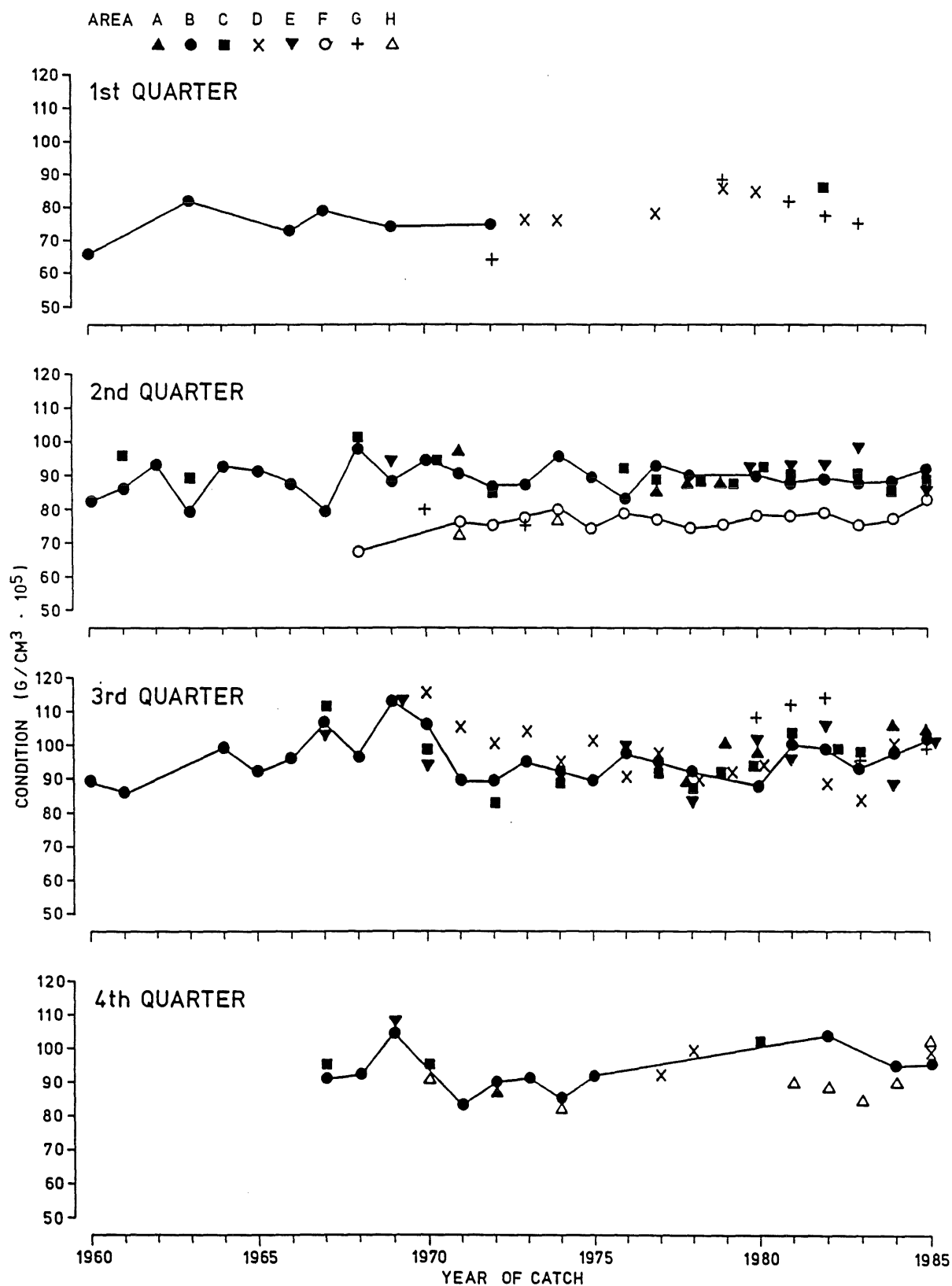


Fig. 3.5. Mean condition by year, season and site of catch. The data for areas B and F are connected.

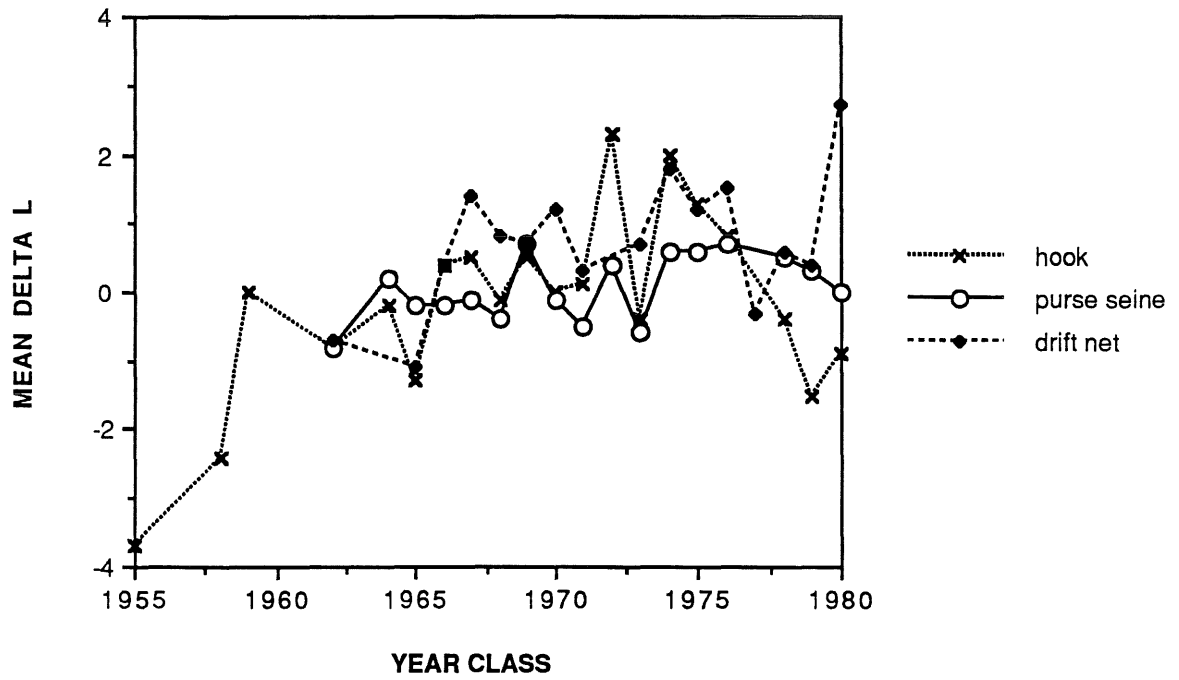


Fig. 5.1. Mean ΔL in catches by various gears in area B in the 3rd quarter.

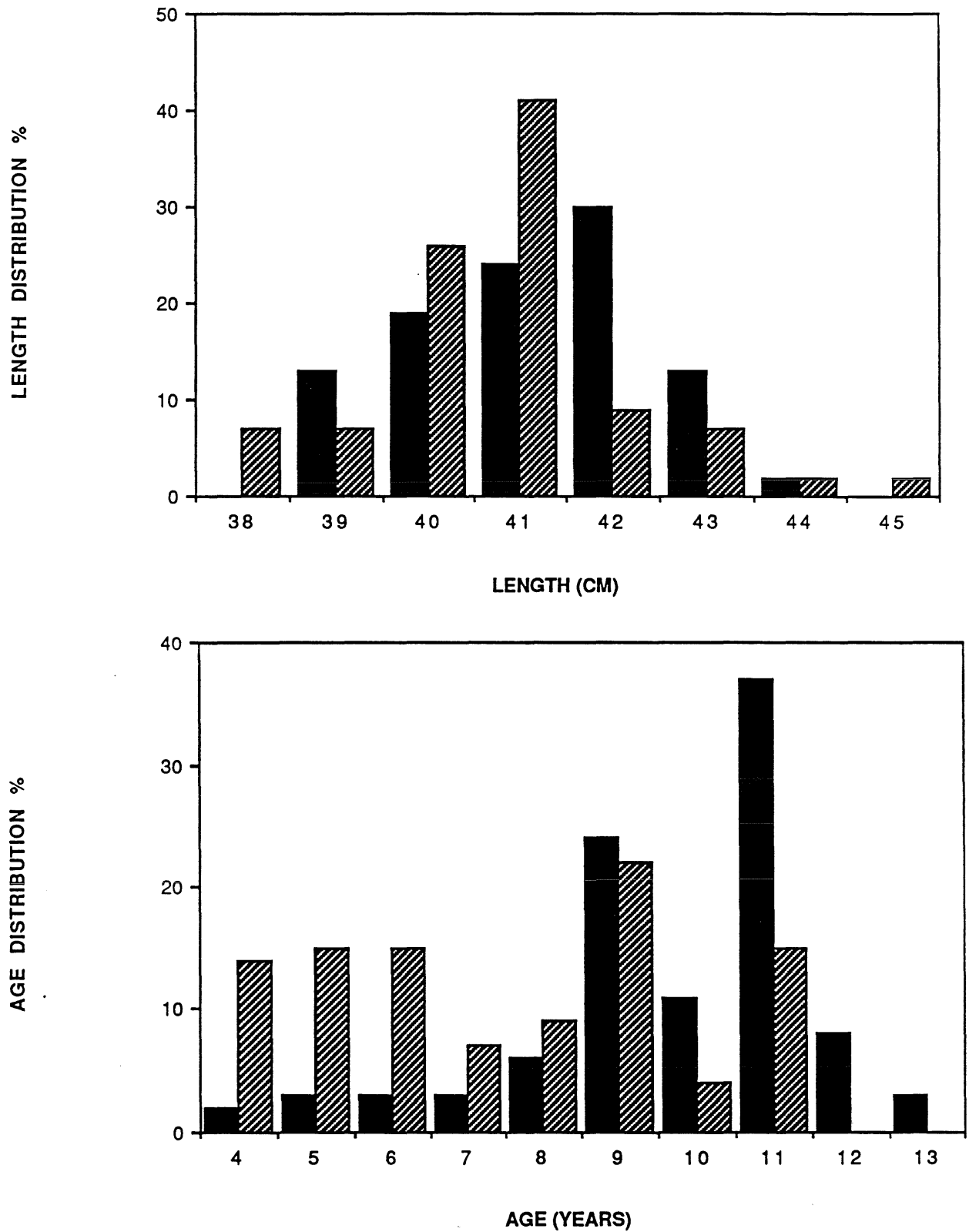


Fig. 7.1. Length and age distributions in two drift net catches, both from area B in May 1980.

