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Age and Growth of Mackerel from Skagerak and the Northern North Sea

by

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INTRODUCTION

Previous attempts to age mackerel has been based mainly on otolith reading. Since the scales are so small and so easily rubbed off, the collection of scales for age determination is difficult. Scales have, however, been used by Nilsson (1914) and by Steven (1952). In these cases the fish were caught by hook and line, and kept isolated to prevent scales being transferred from one fish to another. Steven made comparisons between scale and otolith readings and found good agreement between the two methods.

This paper deals with age and growth studies of mackerel based on samples drawn from commercial catches. The study is based on ototlith readings exclusively.

MATERIAL and METHOD

Samples of mackerel are drawn regularly from commercial landings along the coast and sent to the Institute of Marine Research for examination. Most of the samples are from the purse seine fishery off the coast, but those collected during the summer are caught with a variety of gears.

Each sample consists of maximum 100 individuals. The fish are weighed to the unit of 10 grams below, and measured to length to the centimeter below. The fish are measured from the tip of snout to the tip of tail (in natural position). Sex and stage of sexual development is determined. The pairs of otoliths are removed, cleaned and dried, then mounted in Eukit on non-transparent plastic slides.

The otoliths are examined in a binocular microscope with X25 magnification. The age is determined in years by the number of completed winter rings which occur as dark, narrow rings separating the broad opaque zones. (Fig. 1).

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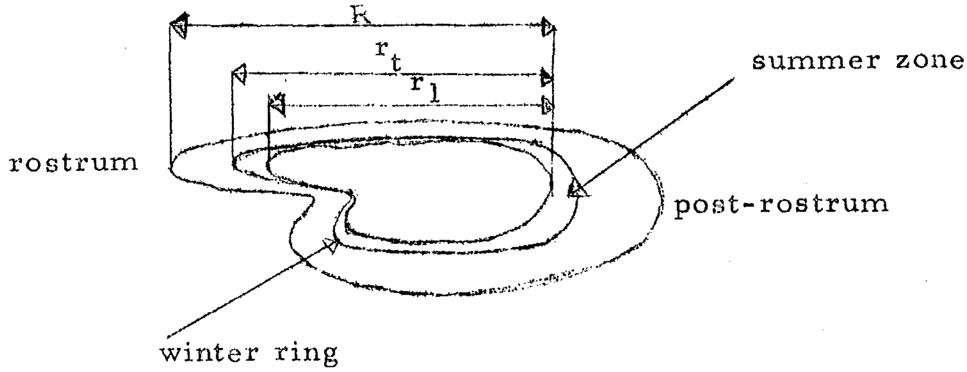

Fig. 1 Diagram of an otolith

Although the winter rings are formed during the period November - April, the last ring is regarded as completed on the 31st of December. This makes the 1st of January the birthday of the fish.

For the purpose of back-calculating body length at prior ages, the otoliths were measured using an eyepiece micrometer of 25 units to 1 mm. The back-calculation of body length is made by assuming a direct proportion of fish length and otolith growth starting from the center of the first ring:

$$l_t = \frac{L}{(R - 0.5\, r_1)} \; (r_t - 0.5 r_1)$$

where L is the length of the fish and R, r_t and r_1 are the otolith measurements as they appear from Fig. 1.

RESULTS

Most otoliths are easily readable up to an age of 6 years. The 7th and 8th winter ring are also fairly well discernible, but older specimens are often doubtful. The rings are found to be most distinct in the rostrum, but Steven's advice to check the number against those in the post-rostrum, in order to detect secondary rings, has been followed. All specimens where the age was doubtful were discarded for growth studies. This applies to 1614 fish out of a total of 4658 examined.

The age composition

In order to reduce any possible influence of gear selectivity, only purse seine caught fish are used for this study. The samples are grouped in two time intervals, one from January to March and the other from April to December. The results are given in Table 1. Most of the unidentified specimens are above 8 years old.

There is a marked difference in the age composition of the two periods. The winter catches contain young fish mainly, whereas fish above 4 years of age dominate the catches during the remainder of the year. This demonstrates that the main part of the adult mackerel stock is not available to the purse seiners during the winter season. Judging from the fishermen's experience, this is due to a deeper distribution of the older ones. This segregation may even exist in the school itself as the nets in winter more frequently catch the top of the school.

It is believed that the purse seine catches landed from April to December represent a fairly true picture of the age composition of the adult stock, (Table 1). The recruitment starts at the second year of age but the peak may be reached in the third year of life. With regard to possible variation in recruitment, the 1962 year class occurs as a dominating year class throughout the period. On the other hand, the 1963 year class appears to be relatively poor, as was also found by Zijlstra and Postuma (1966). The 1965 year class (and 1966) may also be good compared to the other year classes born in the sixties. The group above 8 years of age to which most of the unidentified belong is still substantial.

Growth

The growth is examined by comparing size at various ages and also on the basis of back-calculating body length. In order to analyse seasonal growth, each year's data are grouped according to the time of collection using the four quarters of the year. The age-length and age-weight relationships appears in Tables 2 and 3 respectively. The Tables are illustrated in Fig. 2. The curve at the top of the Figure illustrates the corresponding variation of the condition factor defined as follows:

$$C = \frac{W}{l^3} \cdot 10^2$$

The best growth period of the mackerel is July - September, This includes the end of spawning and the first part of the post-spawning period. It may be noted that in spite of the fact that July-September covers the post-spawning period, the condition factor also reaches its maximum at that time of the year.

The apparent decline in mean length of the age groups from summer to winter may be due to segregation and selection. It is a well known phenomenon, that the recruitment to the adult stage is more dependent on size than age. The first recruits will therefore consist of the most fast growing fish which will result in a decline in average length when the rest of the age group is recruited (Lea's explanation to the Rosa-Lee phenomenon). This leads to an overestimation of the average length of the younger age group.

The drop in average length of the older age groups during winter is most probably due to gear selection combined with a "schooling by size" phenomenon. During winter the gear is found to selectively favour the catch of the small sized fish. Among these may also be found the old but slow-growing specimens.

The seasonal growth in weight follows the same pattern as for the length curve. The variation is, however, somewhat exaggerated due to an actual loss in weight during the winter season. This loss is substantial and may count for some 20% of the summer weight of the fish.

With regard to the annual growth, the mackerel is found to be a very fast growing fish up to an age of $3\frac{1}{2}$ years, i.e. until the fourth growth period is completed. It may be noted that during the third growth period the mackerel may increase its weight with some 150%.

Back-calculated body length

The back-caldulated body length by year class and age are shown in Table 4.

The Table contains the calculated length of the fish when the first (l_1), the second (l_2) and third (l_3) growth periods are completed. These should correspond to the age-length data collected during October - December of the 0-, 1- and 2 age groups respectively.

The over all average of back-calculated l_2 and l_3 appears to be even smaller than the mean length of 2 and 3 year old fish caught in January - March. (Table 2). This supports the assumption made previously that the latter figures are over-estimated compared to the over all average in the stock. The phenomenon is also apparent from the Table 4, especially in the l_2 and l_3 calculations of the younger year classes. This is what can be expected when the fast growing specimens are selected in the time interval 2 to 3 years of age.

Length distributions of the calculated l_1, l_2 and l_3

These are shown in Fig. 3 for the year classes 1961 to 1966. The three years data show individually the same distribution pattern and are therefore grouped together.

The l_1 distribution shows a considerable variation in length, from 12 cm up to 29 cm in 1964. This may be due to late and early spawning. In 1964 there even seems to be a bimodal length distribution, one peak at 16 cm and another at 23 cm. The year classes 1964, 1965 and 1966 have as 1 year old fish been relatively small, whereas the fish of the year classes 1962 and 1963 have been much larger. But a relative slow growth during the first year of life seems to be compensated by a corresponding good one in the second. However, the strong 1962 year class seems to have had a bad growth period in its second year of life and this has not been compensated the year after. The yearly increases during the third year of life are, by the way, very much the same for all the year classes concerned.

DISCUSSION

Postuma (1967) has found the same dominating age-groups (1962 and 1965) in the mackerel catches made by North Sea trawlers during April - May 1967. He also points out that the contribution of older age groups (>9 years) is substantial. This shows that when the purse seine fishery was introduced in the North Sea in the middle of the sixties, the seiners started to fish on an accumulated stock.

Since 1965 some 2.5 million tons have been removed from this stock without changing the age composition essentially. This indicates that the stock has far from been renewed at the same rate as it has been exploited.

Growth studies on mackerel based on otolith reading has been published by several authors and the results coincide fairly well when comparing samples which are collected at the same part of the season. Accurate timing is essential when the data is collected during the growth period, and especially when comparing growth in the younger age-groups:

Age	1		2		3		4		5		6		7	
Season	S	A	S	A	S	A	S	A	S	A	S	A	S	A
Steven	23.8	28.7	30.6	32.1	33.0	33.3	34.1	34.6	35.5	35.9	36.2			
Authors		26.7	28.6	32.0	31.9	34.4	34.0	35.1	35.3	34.6	35.6	36.6	36.1	38.4
Kändler	26.3		30.6		33.8		35.0		35.7		36.2		38.2	

S = summer, A = autumn.

The Table above shows age-length data given by Steven (1952) and by Kändler (1957) compared to the present findings. Steven's data are from mackerel caught in the English Channel and the Celtic Sea. Kändler's data are from the North-Eastern North Sea. Steven found it convenient to group his material into Spring and Autumn samples, using May 1st and September 1st as the approximate mean date of capture. These are compared to our April - June, and July - September samples respectively. (The 1-group is from October - December). According to Kändler, his data are from catches made in June - July.

The minor disagreements which are observed in the mean lengths above 3 years of age may be due to sample variation or/and variation in growth of different year classes. For the younger age-groups Steven's observations indicate a somewhat higher growth rate during the first and second years of life than for the North Sea mackerel, but at the expense of the third year's growth. Another difference in the growth pattern of the mackerel in the North Sea compared to the Celtic one, is the complete stagnation in growth during winter for the former. This is, however, compensated by a much higher summer growth. Steven states that about half the yearly increase is obtained during the months September - April. According to our findings, there is practically no increase in the average length of the year classes from August to May. But some individual length increases may have been lost in our observations if an immigration of slow-growing specimens during autumn and winter have taken place.

The apparent immigration of slow-growing specimens to the catchable stock during autumn and winter complicates the determination of the general growth pattern of the fish. The length distribution of the age groups of the catches are not representative for that of the stock, and this is of fundamental importance for the interpretation of the age-length curve. In the authors' opinion the best approach to the general growth curve of the stock which may be deduced from this study is as follows:

Age	1	2	3	4	5	6	7	8
L cm	18.5	26.4	29.7	34.2	35.8	35.8	36.4	38.1

In this serie we have used the over all average of the back-calculated l_1, l_2 and l_3 as average length obtained during the 1, 2 and 3 years of life, combined with the autumn samples (October - December) of the older ages. Fitting these data into a von Bertalanffy growth function the following growth parameters are obtained:

$$L_\infty = 38.9 \text{ cm}, \quad K = 0.408, \quad t_o = -0.608$$

This corresponds to a W_∞ of 550 grams using 0.93 as an average of the condition factor during summer and autumn. The theoretical length curve is shown in Fig. 4. The apparent low observed values of the 6th and 7th age-groups are due to poor growth of the strong 1962 year class. It is in this connection interesting to note that poor growth in this year class was observed also in the back-calculated age-length values. The stagnation in growth took place during the second growth period, i.e. in the summer of 1963. This may have resulted in an underestimation of the L_∞.

With respect to a growth formula for incorporation into a yield equation, the problems are quite different. In this case the aim is to obtain an analytical formula which most accurately describes the size of the age-groups of the catch as function of age.

If the rate of exploitation were constant throughout the year and the availability of the various age-groups didn't vary, an arithmetic average of the growth parameters of all the seasons could be used for yield studies. This is, however, not the case in the mackerel fishery. The catches during winter have a quite different size and age composition than the rest of the year, and the growth parameters are also different. If we consider the winter catch separately, this will give the following growth parameters:

$L_{\infty} = 36.6$ cm, $K = 0.62$, $t_o = 0.108$

The average condition factor during winter is close to 0.75 which gives $W_{\infty} = 370$ g. The corresponding figures of the summer catch are:

$L_{\infty} = 38.3$ cm, $W_{\infty} = 560$ g, $K = 0.40$, $t_o = -2.027$

It is not within the frame of this paper to discuss the very complex problem of an assessment of the mackerel stock. But it is evident that with this great variation in the growth parameters depending on the season of capture and with the corresponding variation in size and composition of the catch, the various equilibrium stages can hardly be formulated by a simple yield equation with constant parameters.

SUMMARY

1. The present age and growth studies of mackerel are based on otolith readings. With a fairly high degree of accuracy the mackerel can be aged up to 8 years.

2. Seasonal and annual growth appear from Table 1 and 2. The Tables are illustrated in Figure 2.

3. The age-length relationships are compared to back-calculated body length of the first three years of life (Table and Fig. 3).

4. A theoretical growth curve considered to be representative of the stock is given in Fig. 4. Due to broad seasonal variation in the growth parameters, the authors feel, however, that this curve can not be used for yield studies.

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Table 1. Age distribution (in %) for purse seine caught mackerel.
T_1 = January to March, T_2 = April to December, U = unidentified age.

Age	1967		1968		1969	
	T_1	T_2	T_1	T_2	T_1	T_2
1	0	0,8	0,7	6,1	0	0
2	22,0	7,9	83,3	30,2	5,0	0,8
3	12,0	5,0	11,3	12,7	46,9	15,1
4	3,0	2,1	0,7	4,3	13,0	17,4
5	18,0	24,3	0,7	1,4	4,1	5,9
6	6,0	4,4	2,7	12,0	1,3	1,5
7	3,0	3,2	0	1,6	7,9	16,9
8	1,0	3,9	0	1,6	1,3	4,6
>8	10,0	10,0	0,7	9,7	3,3	8,4
U	25,0	38,5	0	20,2	17,1	29,2
N	100	1300	150	490	700	390

Table 2. Age-length of mackerel caught quarterly.
"n" denotes the number of individuals
"l" denotes the mean length in cm.

Age		1		2		3		4		5		6		7		8		> 8	
		n	l	n	l	n	l	n	l	n	l	n	l	n	l	n	l	n	l
Jan.-March	1967			22	27,9	11	33,6	2	33,5	18	34,6	5	36,6	2	35,5	1	36,0	10	37,6
	1968			96	25,0	3	30,4												
	1969			34	28,7	330	31,0	90	33,3	28	34,5	7	36,1	55	35,1	9	37,0	24	37,9
	Sum			152	26,3	344	31,0	92	33,3	46	34,5	12	36,3	57	35,1	10	36,9	34	37,8
Apr.-Jun	1967			10	28,5	18	33,4	4	35,0	43	35,0	12	35,2	12	36,5	14	36,1	74	37,2
	1968			8	28,6	87	32,3	48	34,4	15	35,6	100	35,7	33	37,4	17	37,4	98	38,4
	1969			7	28,7	124	31,5	101	33,8	36	35,5	10	36,2	91	35,6	24	37,6	79	38,1
	Sum			25	28,6	229	31,9	153	34,0	94	35,3	122	35,6	136	36,1	55	37,2	251	38,0
July-Sept.	1967			8	31,8	22	33,8	8	35,3	137	34,5	17	37,1	4	37,5	7	38,0	24	38,2
	1968			7	32,1	39	34,7	21	35,1	13	35,9	55	36,5	14	38,7	11	38,1	27	40,0
	1969																		
	Sum			15	32,0	61	34,4	29	35,1	150	34,6	72	36,6	18	38,4	18	38,1	51	39,2
Oct.-Dec.	1967	97	26,6	91	32,4	46	34,6	15	36,5	188	35,8	39	36,8	33	38,1	33	38,3	72	38,4
	1968	22	27,5	93	30,3	23	33,4	6	34,1	3	34,3	18	35,5			1	36,0	11	37,9
	1969																		
	Sum	119	26,7	184	31,6	69	34,2	21	35,8	191	35,8	57	36,4	33	38,1	34	38,2	83	38,4

Table 3. Age-weight of mackerel caught quarterly .

"n" denotes the number of individuals
"l" denotes the mean weight in grams

Age		1		2		3		4		5		6		7		8		>8	
		n	l	n	l	n	l	n	l	n	l	n	l	n	l	n	l	n	l
Jan.-March	1967			22	159	11	288	2	295	18	350	5	402	2	345	1	380	10	450
	1968			96	116	3	216												
	1969			34	153	330	203	90	279	28	320	7	392	55	362	9	406	24	436
	Sum			152	130	344	206	92	268	46	336	12	396	57	362	10	404	34	440
Apr.-June	1967			10	158	18	302	4	352	43	359	12	356	12	381	14	372	74	421
	1968			8	211	87	340	48	399	15	468	100	451	33	517	17	532	98	566
	1969			7	192	124	275	101	345	36	401	10	435	91	417	24	495	79	515
	Sum			25	184	229	302	153	262	94	390	122	440	136	438	55	475	251	507
July-Sept.	1967			8	318	22	395	8	508	137	456	17	562	4	550	7	601	24	605
	1968			7	300	39	407	21	417	13	461	55	467	14	575	11	548	27	620
	1969																		
	Sum			15	310	61	403	29	442	150	457	72	490	18	569	18	568	51	613
Oct.-Dec.	1967	97	132	91	281	46	364	15	454	188	429	39	471	33	527	33	513	72	530
	1968	22	171	93	242	23	334	6	370	3	360	18	447			1	440	11	493
	1969																		
	Sum	119	139	184	262	69	354	21	430	191	428	57	464	33	527	34	510	83	525

Table 4. Back-calculated body length of mackerel by age and yearclasses.

L_n	Samp.	Yearclasses								
		1967	1966	1965	1964	1963	1962	1961	1960	Average
L_1	1967			18,0	19,3	20,7	19,9	20,2	18,3	19,4
	1968		16,2	17,9	19,1	20,6	19,9	18,9	17,1	18,5
	1969	18,3	15,1	17,9	17,9	20,1	19,3	18,0	16,4	17,8
	$\bar{L}_1$	18,3	15,6	17,9	18,7	20,4	19,7	19,0	17,2	18,5
L_2	1967				27,8	28,2	25,3	26,0	25,7	26,6
	1968			27,6	27,2	26,7	25,6	26,4		26,7
	1969		25,8	26,9	26,5	26,7	24,8	25,8	26,5	26,1
	$\bar{L}_2$		25,8	27,2	27,1	27,2	25,2	26,0	26,1	26,4
L_3	1967					31,6	28,7	29,6	28,6	29,6
	1968				31,4	30,2	28,9	30,1		30,1
	1969			30,6	30,6	30,0	28,0	29,3	29,1	29,6
	$\bar{L}_3$			30,6	31,0	30,6	28,5	29,6	28,8	29,7

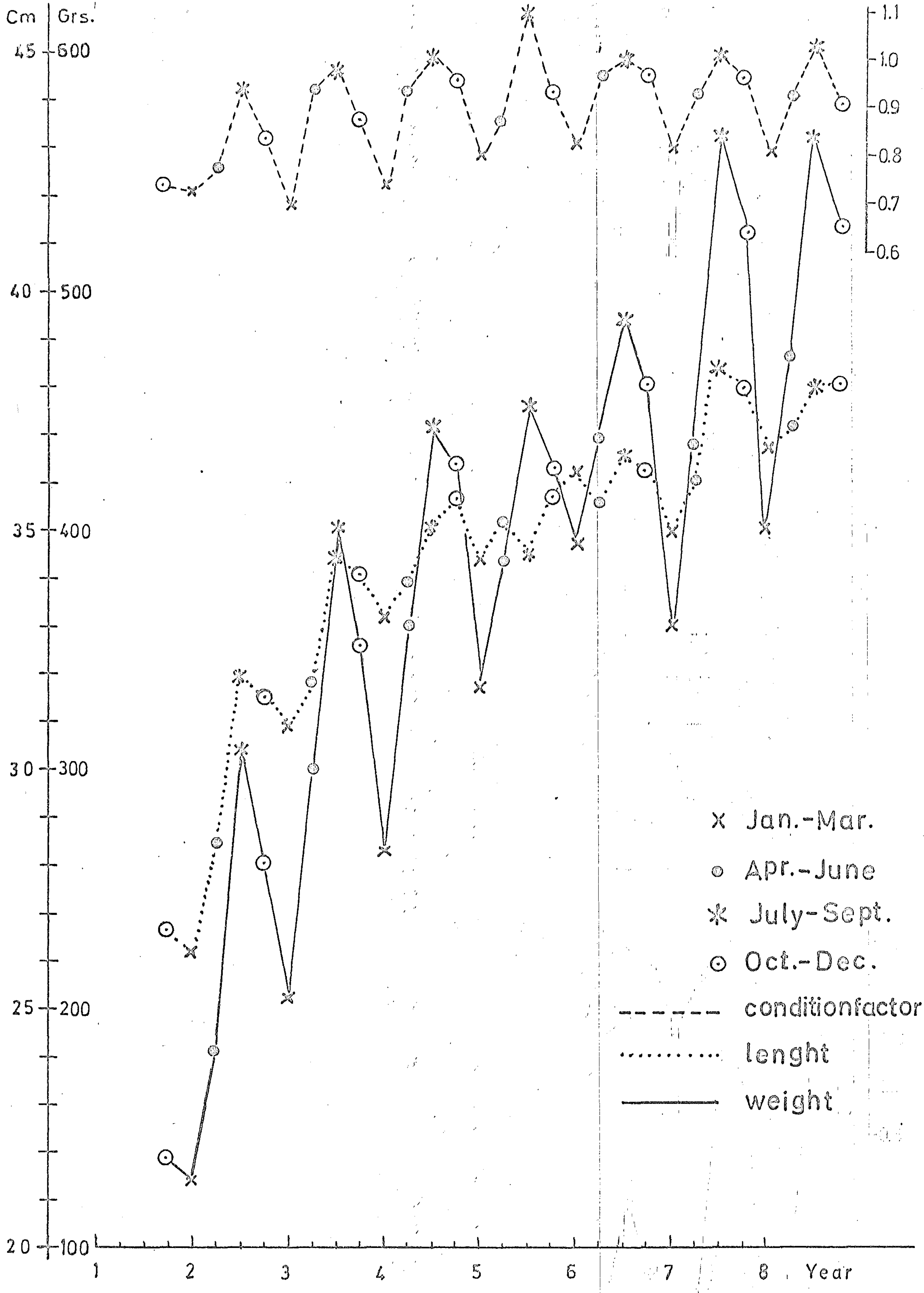

Fig. 2 Growth curves of mackerel in length and weight by season and year. The corresponding condition factor by season and age is shown at the top of the Figure.

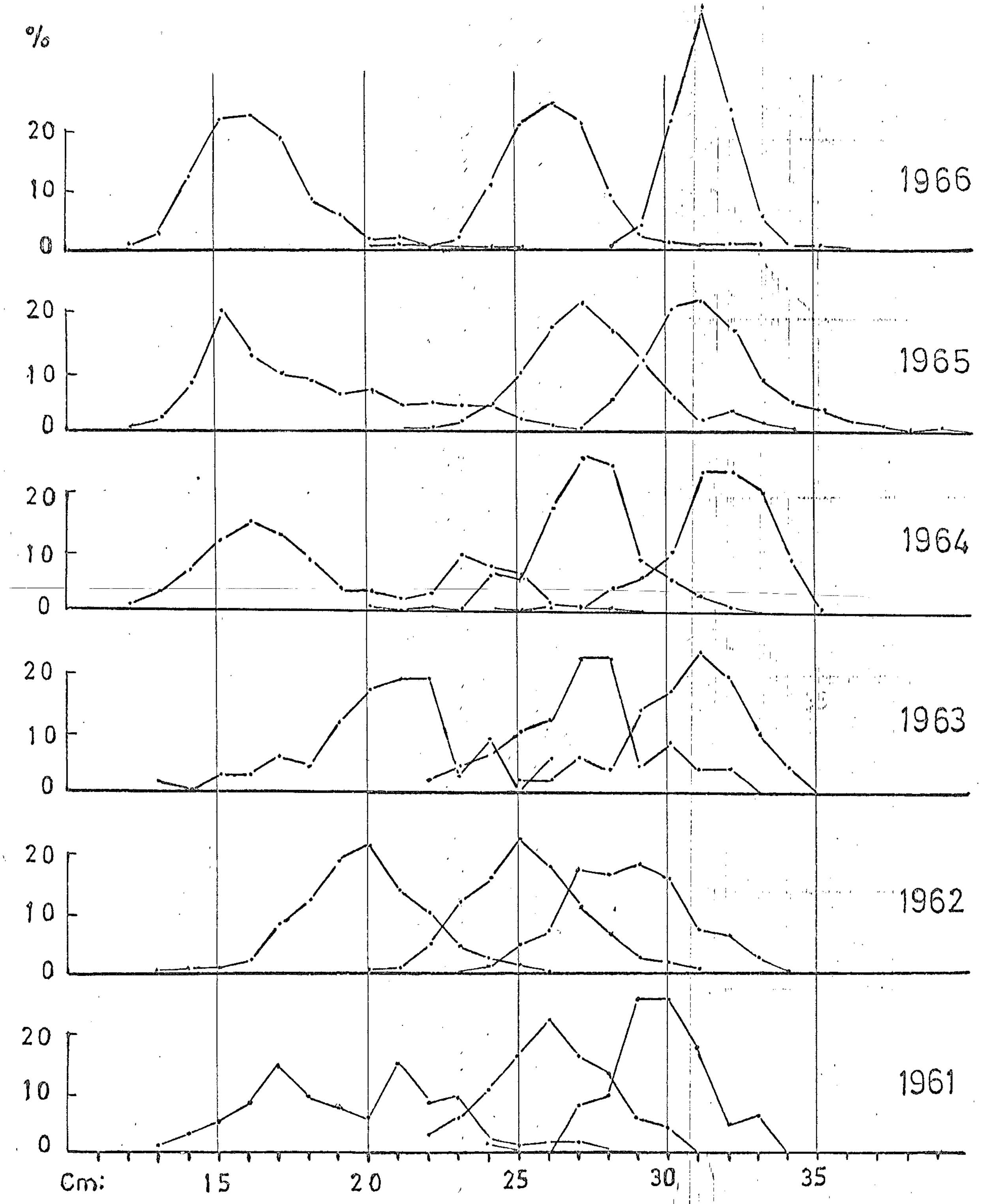

Fig. 3 Back-calculated l_1- l_2- and l_3 distributions by year class.