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INTERNATIONAL COUNCIL FOR THE EXPLORATION OF THE SEA

C.M. 1984/H : 33
Pelagic Fish Committee

MEAN LENGTH AND WEIGHT CHANGES DURING SPAWNING OF WESTERN MACKEREL IN 1981 - 1983.

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Abstract

In this paper, mean length and weight data of mackerel by month by sex or sexes combined, by age and by maturity stage in the main spawning area (Division VIIj) are summarized for 1981, 1982 and 1983. The migration of the mackerel to and fro the spawning grounds is explained on the basis of changes in mean length and weight of the fish present in this area. The monthly mean length of female mackerel in maturity stage 6 (hyaline eggs present in the ovary) being higher than the mean length of males in this stage, was used by the ad hoc Working Group on Mackerel Egg Surveys (ANON., 1984a) for calculating the mean fecundity at the mid-point of each plankton cruise. With this mean fecundity the total egg production curve could be converted into a curve of the spawning stock in number. The monthly mean weight data of both males and females in maturity stage 6 were used for calculation of the biomass spawning at the mid-point of each plankton cruise, to get the curve of the spawning stock biomass of the Western Stock. A method for estimating the mean weights at age in the stock, which can be used for converting the spawning stock in number into spawning stock biomass in the Virtual Popualtion Analysis is also described.

Résumé

Dans ce papier sont présentés les tailles et poids moyens mensuels et par sexe ou pour l'ensemble des deux sexes par stade de maturité et par âge pour le maquereau sur la principale frayère (Division VIIj) en 1981, 1982 et 1983. La migration du maquereau vers et à partir de la zone de frai est expliquée sur la base de changements dans les tailles et poids moyens des poissons présents dans cette zone. La taille moyenne mensuelle des femelles au stade 6 de maturité (oeufs hyalins dans l'ovaire) étant supérieure à celle des mâles au même stade, elle a été utilisée par le groupe de travail ad hoc sur les évaluations de la ponte du maquereau (Anon., 1984a) pour calculer la fécondité moyenne du milieu de chaque campagne de récolte de plancton. A partir de cette fécondité moyenne on a pu transformer la courbe de production totale d'oeufs en une courbe de stock en nombre. Les poids moyens mensuels des mâles et femelles au stade 6 ont été utilisés pour calculer la biomasse qui se reproduisait à la date du milieu de chaque campagne de récolte de plancton pour établir la courbe de la biomasse féconde de stock dit de l'Ouest. Une méthode d'estimation des poids moyens dans le stock permettant de convertir l'effectif du stock fécond en biomasse féconde dans l'analyse de population virtuelle est également décrite.

Introduction

Two mackerel (Scomber scombrus L.) stocks occur around the British Isles: a) the North Sea Mackerel Stock in the central and northern North Sea and b) the Western Mackerel Stock in the Bay of Biscay, Celtic Sea and the northern North Sea and on the Irish Shelf, Malin Shelf, Hebrides Shelf and West Shetland Shelf. This paper deals only with the Western Mackerel stock. These mackerel migrate from the overwintering areas west and northwest off Ireland to the spawning grounds of which the main areas are: Great Sole Bank, Little Sole Bank and La Chapelle Bank. The spawning season is March - July.

For conversion of the egg production curve of the Western Mackerel stock (ANON., 1984a) into a curve of spawning mackerel in number, a mean fecundity has to be defined. The mean length, used for calculating the mean fecundity is not constant due to changes in the length distribution of mackerel on the spawning grounds. These changes in the length distributions have already been described by LOCKWOOD et al. (1981a) and ELTINK & GERRITSEN (1982). In the spawning population an age-length succession can be observed. Older and/or larger fish spawn earlier than younger and/or smaller fish, causing a downward shift in the length composition during the spawning season. For this reason, spawning stock in number and spawning stock biomass must be estimated on a monthly basis, when an egg survey is carried out. In this paper changes are described in mean length and mean weight by month, by age, by maturity stage and by sex of mackerel caught during the spawning seasons 1981, 1982 and 1983 in Division VIIj.

These changes in mean length and weight of fish on the spawning grounds are explained in terms of migrations during spawning time.

Material and Methods

The data in this paper are derived from commercial mackerel catches, taken by the Dutch freezing trawlers employing pelagic trawls, fishing in Division VIIj in 1981, 1982 and 1983 during spawning time (March - July). Samples of a fishery in 1982 in ICES Division VIIj were used in addition for the calculation of the percentage of fish in a certain maturity stage by sex and month for the period: January - June 1982.
Monthly mean length and mean weight were calculated during the spawning season by year and years combined, for males, females and sexes combined, by maturity stage and maturity stages combined, by age and ages combined.
The number of otoliths sampled per statistical ractangle in ICES Division VIIj in these years in March - July shown in figure 1 reflect the fishery pattern in this area.
The number of otolith readings and weight measurements by year and by month in ICES Division VIIj, which form the basis of this paper, are listed in the text table below:

	1981	1982	1983	total
January		69		69
February		225		225
March	150	150	25	325
April	175	325	250	750
May	250	250	200	700
June	75	100	-	175
July	100	-	-	100

The maturity stages in mackerel used in this paper are scaled from 1 to 8 as in MACER (1976), except that stage 7(1) (= partly spent) is combined with stage 6 (= spawning). These maturity stages are briefly described in the text table below:

	OVARY	TESTIS
1. Virgins	Small Slender torpedo shaped Wine red colour	Small Thinner more blade shaped Paler colour
2. Maturing virgins	Slightly larger than in stage 1	Also enlarging Paler colour than ovaries
3. Early developing Both virgins and Recovering Spents	Half length of body cavity	Half length of body cavity Darkgrey
4. Late developing	1/2 to 3/4 of body cavity Pronounced orange-yellow Conspicuous opaque eggs	1/2 to 3/4 of body cavity Clear creamy, milky white

5. Ripe	Most of body cavity In the ovary: Large and conspicuous superficial blood-vessels No hyaline eggs	Most of body cavity A uniform milky whiteness
6. Spawning	Ripe hyaline eggs in the ovary	Large, clean milky white Ripe milt can be expelled on slight pressure
7. Spent fish	Slack, very bloodshot A few residual oocytes may be present	Small, flabby and blood-shot
8. Recovering spent	Quite small Firmer than stage 7 Somewhat bloodshot	Quite small Flabbier than in virgins Somewhat bloodshot Dark yellow

The data from the spawning season in ICES Division VIIj in table I till III are by year and years combined, by sex and sexes combined, by month, by maturity stage and all maturity stages combined: the number of mackerel in table I, the mean length in table II and the mean weight of mackerel in table III. Number and percentage of mackerel by sex, by month and by maturity stage caught in Division VIIj in January - June in 1982 are listed in table IV. The data from the spawning season in ICES Division VIIj in table V till VII are by month, by age and by maturity stage and all maturity stages combined: the number of mackerel in table V, the mean length in table VI and the mean weight of mackerel in table VII.
In all figures, only those mean length and weight data are given, which are based on the mean of more than five fish.
Table VIII, showing the percentages of mackerel in maturity stage 6 and in maturity stage 3 - 5 by age and by month in 1981-1983, is derived from table V.

Results and Discussion

The samples discussed in this paper, originate from that part of the spawning area, where the highest egg production occurs (ANON., 1984a) and will therefore represent the major part of the Western Mackerel spawning stock (figure 1).
The total egg production curves, estimated from the mackerel eggsurveys in 1977, 1980 and 1983, were highly similar and did not indicate a shift in the spawning period or the peak of spawning (ANON., 1984a). Mean length and weight data for maturity stage 5 and 6 during the spawning period for the three successive years 1981 - 1983 were also very similar (figure 2 and 3). This similarity justified a combination of these three years to get better and more reliable data and to minimize the effects of fluctuations in year class strength. The data by year show a substantial decrease in mean length and weight of spawning fish during the spawning season (figures 2 and 3). For this reason mean length and weight throughout the spawning period must be estimated at least on a monthly basis.

Changes in mean length and weight during spawning

The mean length and weight of spawning mackerel (maturity stage 6) is constantly decreasing during the whole spawning period (table II, III and figure 3). Older and/or larger fish spawn first, because there is an age-length succession in spawning as earlier described by LOCKWOOD et al.(1981a) and ELTINK &GERRITSEN (1982). Mean length and weight increase with maturity stage during every month of the spawning season (table II, III and figure 4 and 5), consequently older and/or larger fish spawn first. The highest mean lengths and mean weights were observed for maturity stage 6 in all months. Each month of the spawning season the mean length and weight decrease for each maturity stage and a sharp decrease in the monthly mean length and weight data of fish in maturity stage 3 - 6 is shown from May to June and June to July (figure 4 and 5).
In addition a difference exists in mean length and weight by month between males and females, which decreases at the end of the spawning season (figure 6). Males are maturing earlier, as demonstrated by the higher maturity stage from January onwards (figure 7 and table IV). Therefore, males are smaller than the females spawning at the same time in a particular time period as a result of the age-length succession, which decreases the mean length and weight of the males for that time period. The discrepancy in mean length and weight between spawning males and females is not caused by a different growth rate between male and female mackerel, for the mean length at age and the mean weight at age of males and females do not show a significant difference (figure 8). But this lower mean length and weight of the males by month corresponds with a lower mean age by month (figure 6). The mean age in figure 6 is a slight underestimate, because the 11 plus age group is used as 11 in the calculations, but can still be used as an age index. The much higher percentages of males in maturity stage 6 in the onset of the spawning season, demonstrate that differences in mean length and weight of male and female mackerel are caused by the earlier maturing of the males (figure 9).
The mean fecundity, used to estimate stock size from results of egg surveys, must be estimated by month due to changes in mean length and weight. The mean length, used for calculation of the mean fecundity per month, should be based only on female mackerel in maturity stage 6 from the spawning area. The mean fecundity can be used then to convert the egg production curve into a spawning stock in number curve.
To estimate the mean weight by month, only female and male mackerel in maturity stage 6 from the spawning area have to be used, to enable the conversion of the spawing stock in number curve into a spawning stock biomass curve. A monthly estimate of mean length and weight of spawning mackerel will be an underestimate if the mean is taken of all maturity stages instead of only maturity stage 6 (see also table II and III). This underestimation of the mean length is especially relevant during the first months of the spawning season, when the percentage of mackerel in maturity stage 6 is still very low (see also table VIII).

Sex ratio, maturity ogive and duration of stay

LOCKWOOD et al. (1981a) found that males were more abundant than females in a relatively small number of samples taken on the spawning grounds. The sex ratio is difficult to estimate on the spawning grounds due to this earlier maturing of the males, because the time of sampling will influence the sex ratio. In 1981 - 1983 944 females and 1012 males in maturity stage 3,4,5 and 6 occurred in the samples, which is 48.3% females and 51.7% males. Most of the sampling was in the beginning of the spawning season, which possibly causes a higher percentage of males. In 1981 - 1983 464 females (44.3%) and 583 males (55.7%) were found to be in maturity stage 6.

The best results, when estimating a sex ratio, will probably be obtained when nearly all fish are gathered in the spawing area in April and May (this assumption will be enunciated later). Samples taken in these months yielded 676 females and 754 males in maturity stage 3,4,5 or 6, which is 47.3 % females and 52.7 % males. However a different maturity ogive can result in a different sex ratio, because the length at which males and females reach maturity differs. Especially at the end of the spawning season (June - July), when almost only young mackerel are spawning, one would expect such a changed sex ratio caused by a different maturity ogive (figure 9).

One would expect a high percentage of females at the end of the spawning season, because the males are maturing earlier and were abundant at the onset of spawning. But there seem to be more males than expected in July, possibly caused by a different maturity ogive of males and females. The mean length at age 2 is nearly 2 centimetres less for males than for females (figure 8). SETTE (1943) demonstrated also a different maturity ogive for males and females for the Northwest Atlantic Mackerel. The length at which 70% of 2 year old male Atlantic mackerel matures was nearly 2 centimetres less in comparison with females, while there was nearly no difference in the maturity ogive for 3 year old males and females. If this different maturity ogive is not an artefact, it certainly will cause a small shift in the sex ratio, resulting in a clear increase of males especially in July and a small increase of the males over the whole spawning season. However, age-length succession and male-female succession during spawning could result in a different maturity ogive for males and females, if the samples are taken in a wrong period and/or area. Results of routine monthly sampling of the Cornish commercial mackerel fishery during the period February to July 1972 - 1977, show that females were more abundant than males in the ratio 1 : 0.64 (LOCKWOOD et al., 1981a). This high percentage of females will probably be caused by the males, having a lower length at which they become mature in comparison to females, while the mature fish have left the Cornish area to spawn on the spawning grounds. A large proportion of these mackerel will probably have been 2 year olds. To a much lesser extend this high percentage of females is probably contributed to earlier maturing of the males, since the sampling period is from February - July.

A further influence on the sex ratio of mackerel on the spawning grounds can be expected from the duration of the stay on the spawning grounds by individual males and females. An investigation in the sex ratio of mackerel west and northwest of Ireland during winter (November, December, January and February) in 1981 till 1983 inclusive resulted in 674 females and 707 males, which is 48.8 % females and 51.2 % males. These mackerel occurring here during winter are all mature overwintering mackerel, returned from the feeding grounds in the norhtern North Sea and of which the sex ratio is assumed to reflect the Western spawning stock (ELTINK & GERRITSEN, 1982). The sex ratio on the overwintering grounds is approximately the same as was estimated on the spawning grounds (April and May), which indicates about the same duration of the stay of individual males and females on the spawning grounds.

A further influence on the sex ratio of mackerel can be expected from the duration of maturity stage 6 of individual males compared with females. A longer duration of maturity stage 6 of individual males is indicated by relatively more males than females in maturity stage 6 than in maturity stage 3 - 6, but this can be caused by staging females in maturity stage 6 as maturity stage 5 just after spawning, because they do not have hyaline eggs in the ovary.

The sex ratio on the spawning grounds is probably influenced by the maturity ogive and the duration of stay of males and females on the spawning grounds. However, the sex ratio in the spawning stock is probably only influenced by the maturity ogive. At peak spawning time, which is the end of May and the beginning of June (figure 9), the sex ratio is 1:1, as was used for the stock size estimates from the 1980 egg survey (LOCKWOOD et al., 1981b) and from the 1983 egg survey (ANON., 1984a). This sex ratio of 1 : 1 is probably only omitting the possible difference in the maturity ogive between males and females.

Explanation of the changes in mean length and weight

The following hypothesis concerning the migration of the Western Mackerel is giving an explanation for the observed changes in mean length and weight at spawning time in ICES Division VIIj. Overwintering of mackerel occurs in recent years west and northwest off Ireland. In February the mackerel starts migrating southward in the direction of the main spawning area (Great Sole Bank), taking place already before most of the mackerel are able to spawn. In March only 8% of the mackerel in ICES Division VIIj is in maturity stage 6, while the rest of these mackerel still have developing ovaria and testes (figure 10 and 11). The older mackerel, which start spawning earlier (figure 10), are leading this migration to the spawning grounds, while schools of younger mackerel are following. This is demonstrated by data of R.V. "Anton Dohrn" from the 1983 mackerel egg survey (figure 12). The trawl stations from this survey (figure 12), carried out from north to south, lie in the direction of the migration of the mackerel, but if the survey would have been from south to north, the differences in mean weight would probably even have been greater. The increase in mean weight from north to south is caused by migration of older mackerel, maturing earlier and migrating southward earlier than the younger and/or smaller mackerel. The highest concentration of mackerel however was found west off Ireland and these fish will be near or on the Great Sole Bank later, probably by the end of April or the beginning of May (figure 12). The downward shift in the length distribution of mackerel in ICES Division VIIj from March to April (figure 11) is caused by a migration of younger and smaller mackerel in that period from the overwintering grounds into the spawning area, which is in agreement with the catches of R.V. "Anton Dohrn" (figure 12).

In the northern contingent of the Northwest Atlantic Mackerel an age-length succession occurs, when the overwintering schools are migrating to the spawning area along the coast of Nova Scotia, although SETTE (1950) did not recognize it as such. The explanation of Sette was: "This, I believe, indicates (1) that in 1926 there was a mass movement of mackerel northeasterly alongshore causing the fishery to shift in that direction, and (2) that schools from offshore (or from places not previously fished by the fleet from which our samples were taken) joined those already alongshore in sufficient numbers to change the size composition of the alongshore population." Figure 14 shows clearly that along the coast of Nova Scotia the whole downward shift in the length distribution occurs within not more than two weeks, which makes detection of the age-length succession in the migration very difficult.

By the end of April and the beginning of May the whole spawning stock will be gathered on the spawning grounds, probably including many mackerel, spawning for the first time and migrating to the spawning ground from the areas where the juveniles concentrate. Indications that first time spawners are already present at that time in the spawning area can be seen in table V, where they appear mainly as two and three year old mackerel in maturity stages 3, 4 and 5 in April and in maturity stages 4, 5 and 6 in May. Maturing of the gonads continues on the spawning grounds in an age-length succession (table V and VI and figure 10)and a male-female succession (table I and figure 9).

The assumption of the presence of the whole spawning stock by the end of April and the beginning of May is affirmed by figure 4 and 5, which show not only the mean length and weight by month and by maturity stage, but also the monthly mean length and weight in maturity stage 3 - 6. These monthly mean length and weight changes in maturity stage 3 - 6 show a very slow decrease during March, April and May, caused by an immigration of younger mackerel in the beginning of the spawning season and in in the end of May an emigration of older fish, which started spawning in March. This slow decrease of mean length and weight is followed by a very sharp decrease from May to June, caused most probably by a mass emigration of the April-May spawners. The less sharp decrease from June to July is caused by the May-June spawners leaving the spawning area.

The distribution of 3 combinations of age groups: 2-3 year olds, 4-10 year olds and over 10 year olds given in percentages of mackerel in maturity stage 6 together with mackerel in maturity stage 3-6 indicates that many 2-3 year old mackerel are already present in March and April, but that nearly no spawning takes place during this time period (figure 13). The increase in 2-3 year olds from March to April must be caused by the later migration of younger fish to the spawning area, which results in a downward shift in the length distribution (figure 11). The increase in 2-3 year olds from May to July must be caused by an emigration of mainly older and/or larger mackerel, which finished spawning relatively earlier than the younger and/or smaller fish. This results in a decrease of over 10 year olds and a downward shift of the length distribution (figure 11). By the end of May older and larger mackerel leave the spawning area, which causes a decrease in the monthly mean length and weight (figure 4 and 5). The decrease in mean length and weight is thus caused by a migration of younger fish to the spawning area by the end of April or the beginning of May and further by a migration of older fish out of the spawning area from the end of May up till July inclusive, assuming a spawning period of about two month of individual mackerel.

Within an age group the largest fish spawn first and the smallest later, which causes a continuous decrease in mean length at age of mackerel present on the spawning grounds during the spawning season; see for example age group 6 in figure 15. Only the smallest fish of each age group are still present on the spawning grounds at the end of the spawning season. The fast and slow growing components, as shown by KAESTNER (1977), CORTEN & VAN DE KAMP (1978) and ANON. (1981) are the results of these selective migrations, but are certainly not based on two subpopulations or populations.

An affirmation of the migrations to and fro the spawning grounds described above can be found in a comparison between an age composition of the spawning population as estimated by the Virtual Population Analysis (ANON., 1984b) and the age composition from Division VIIj from April and May combined (figure 16). Samples from this time period will underestimate to some degree the old fish, which started spawning in March and already left the spawning area at the end of May and will underestimate also to some degree a small amount of young fish, which have not yet entered the spawning grounds in the beginning of April. There seems to be a good agreement between both age compositions of figure 16, except for an overestimate of the younger age groups in the age composition of the spawning stock according to the estimate of the VPA. The maturity ogive (ANON., 1981) seems to overestimate the fraction of 1 year old spawners (0.18), for no 1 year old mackerel were found in maturity stage 3 - 6 during 1981 - 1983. One year old mackerel, which were found during the spawning season in VIIj, were not in maturity stage 3 - 6, but were assumed to swim together with the maturing fish going to spawn. More probable the fraction mature of 2 year olds (0.38) will be an overestimate too. Figure 13 indicates only a small immigration of 2 and 3 year olds in maturity stage 3 - 5 in June, but does not explain the high number of 1 - 3 year olds in the spawning stock derived from the Virtual Population Analysis compared with the low number on the spawning grounds in April and May. However the data are poor for June and July compared with the data from March, April and May. Comparison of the age composition of overwintering mackerel (samples from November, December, January and February after the spawning season from Division VIIb and southwest VIa are assumed to reflect the Western Mackerel population) and the age composition of the spawning stock as derived from the Virtual Population Analysis showed a good similarity (especially 1981 and 1983). This indicates that the right maturity ogive has been applied to the stock in numbers from the Virtual Population Analysis to get the spawning stock in numbers (figure 17). However, these 1 - 3 year olds could have joined the overwintering stock without spawning before. Further investigations are needed on this matter. Sampling mackerel in some periods or areas will reflect above mentioned changes and sampling should therefore be done with full knowledge of the migrations of the mackerel.

The length of the spawning season

In the beginning of the spawning season, nearly the whole spawning stock of the Western Mackerel is concentrated near the bottom at a depth of about 150 till 200 metres at temperatures of about 10 - 11.5 degrees celcius (LOCKWOOD et al., 1981b), while a very high percentage of these mackerel still have developing gonads (table I). Oceanic water, moving on the continental shelf, has a rather constant temperature during the whole spawning season and this temperature is increasing only very slowly. It is likely that of this slow increasing temperature the gonads will develop slowly, which is probably the reason for such a long spawning period: March - July, which is different from other mackerel stocks. However the changes in mean length and weight during the spawning period are therefore more clear.
Other mackerel stocks like the North Sea Stock and Northwest Atlantic Mackerel have much shorter spawning seasons of approximately three months (Iversen, 1977 and Sette, 1943), because they spawn in shallower waters, where the water is warming up much faster and where a thermocline is established much faster in time after the minimum temperature for spawning is reached. The water temperature has probably a very great influence on the development of the ovaries and testes in mackerel. The bottom temperature of the spawning area of the Western Mackerel has a very slow increase in temperature in the onset of spawning and onwards, however this rather constant temperature over a long period will develop the gonads slowly and will therefore increase the period of spawning till 5 months on account of the existing age-length succession.

Selective migration

The age-length succession in migration from overwintering grounds to spawning grounds, to feeding grounds and back to overwintering grounds (ELTINK & GERRITSEN, 1982) is biologically relevant, because it results in schools of different size ranges. Larger fish can swim faster than smaller specimens of the same species (BLAXTER & DICKSON, 1959). This is probably the reason, why selective migration in an age-length succession is so important for a species like mackerel, not having a swim bladder. The age-length succession in migration from the overwintering area to the spawning area seems to be regulated by a difference in maturity per age group and within each age group per length and by a difference in maturity by sex. Migration from the spawning area to the feeding grounds starts directly after the spawning of individual mackerel and will therefore result again in an age-length succession and probably also a male-female succession. After the feeding season there is again an age-length succession in migration to the overwintering grounds, starting with the old and large fish (ELTINK & GERRITSEN, 1982). On the overwintering grounds mackerel schools are often still in different size distributions.

Mean weight at age in the spawning stock

The whole spawning stock is probably gathered on the spawning grounds by the end of April and the beginning of May, and therefore this is the right time to estimate mean weight at age in the spawning stock, which is used to convert spawning stock in numbers from the Virtual Population Analysis into spawning stock biomass.

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TABLE I. Number of mackerel by sex or sexes combined, by month and by maturity stage in Division VIIj in 1981, 1982 and 1983.

Year Sex	Month	Maturity stage 2	3	4	5	6	7	8	Total
1981 Males	March		8	13	39	15	1	1	77
	April		1	6	25	42	3	1	78
	May		1	2	12	121			136
	June	1	2	4	11	23	1		42
	July					26	23	3	52
1981 Females	March		4	26	37	6			73
	April	3	3	14	25	49	3		97
	May			1	6	105	2		114
	June	7				19	7		33
	July	2	1			29	13	3	48
1981 Both sexes	March		12	39	76	21	1	1	150
	April	3	4	20	50	91	6	1	175
	May		1	3	18	226	2		250
	June	8	2	4	11	42	8		75
	July	2	1			55	36	6	100
1982 Males	March	3	16	22	21	5			67
	April		2	2	68	114			186
	May				42	94			136
	June	2			5	37	1		45
	July								
1982 Females	March	5	31	27	20				83
	April	2	2	11	83	41			139
	May	2	3	2	57	50			114
	June	1			2	52			55
	July								
1982 Both sexes	March	8	47	49	41	5			150
	April	2	4	13	151	155			325
	May	2	3	2	99	144			250
	June	3			7	89	1		100
	July								
1983 Males	March		1	5	5				11
	April	2	5	26	60	26			119
	May			6	19	80	1		106
	June								
	July								
1983 Females	March		11	2	1				14
	April	1	16	25	63	26			131
	May				7	87			94
	June								
	July								
1983 Both sexes	March		12	7	6				25
	April	3	21	51	123	52			250
	May			6	26	167	1		200
	June								
	July								
81-83 Males	March	3	25	40	65	20	1	1	155
	April	2	8	34	153	182	3	1	383
	May		1	8	73	295	1		378
	June	3	2	4	16	60	2		87
	July					26	23	3	52
81-83 Females	March	5	46	55	58	6			170
	April	6	21	50	171	116	3		367
	May	2	3	3	70	242	2		322
	June	8			2	71	7		88
	July	2	1			29	13	3	48
81-83 Both sexes	March	8	71	95	123	26	1	1	325
	April	8	29	84	324	298	6	1	750
	May	2	4	11	143	537	3		700
	June	11	2	4	18	131	9		175
	July	2	1			55	36	6	100

TABLE II. Mean length of mackerel by sex or sexes combined, by month and by maturity stage in Division VIIj in 1981, 1982 and 1983.

Year Sex	Month	Maturity stage 2	3	4	5	6	7	8	All Stages
1981 Males	March		33.2	36.4	38.6	39.5	33.7	34.8	37.7
	April		30.7	38.0	36.9	37.3	33.1	34.3	36.9
	May		40.1	27.8	36.1	36.9			36.7
	June	26.2	27.3	27.2	30.5	35.2	39.1		32.7
	July					33.5	30.5	32.7	32.1
1981 Females	March		33.6	37.3	38.6	40.7			38.0
	April	26.2	32.0	34.5	36.2	38.3	34.4		36.5
	May			43.2	34.1	37.7	34.6		37.5
	June	27.2				34.9	38.7		34.1
	July	27.4	29.5			33.5	29.3	31.6	31.9
1981 Both sexes	March		33.4	37.0	38.6	39.9	33.8	34.9	37.9
	April	26.2	31.7	35.6	36.5	37.8	33.7	34.3	36.7
	May		40.1	32.9	35.4	37.3	34.6		37.1
	June	27.1	27.3	27.2	30.5	35.1	38.7		33.3
	July	27.4	29.5			33.5	30.1	32.1	32.0
1982 Males	March	31.2	34.3	36.0	36.8	39.0			35.9
	April		25.9	34.4	37.1	38.2			37.6
	May				31.9	35.6			34.5
	June	25.5			26.8	32.6	27.3		31.5
	July								
1982 Females	March	29.7	34.7	36.7	37.9				35.8
	April	33.0	30.4	34.7	37.9	39.9			38.0
	May	25.5	26.6	28.5	37.3	37.1			36.6
	June	24.6			31.9	34.2			34.0
	July								
1982 Both sexes	March	30.2	34.6	36.4	37.3	39.0			35.8
	April	33.0	28.1	34.7	37.5	38.7			37.8
	May	25.5	26.6	28.5	35.0	36.1			35.4
	June	25.2			28.3	33.5	27.3		32.9
	July								
1983 Males	March		33.0	33.1	36.0				34.4
	April	26.8	31.3	31.0	35.2	37.8			34.5
	May			28.8	33.1	36.1	39.7		35.1
	June								
	July								
1983 Females	March		34.8	34.1	39.8				35.1
	April	29.2	31.0	32.5	36.8	39.3			35.7
	May				37.1	35.8			35.9
	June								
	July								
1983 Both sexes	March		34.7	33.4	36.6				34.8
	April	27.6	31.1	31.7	36.0	38.5			35.1
	May			28.8	34.2	35.9	39.7		35.5
	June								
	July								
81-83 Males	March	31.2	33.9	35.8	37.8	39.4	33.8	34.9	36.7
	April	26.8	29.8	32.4	36.3	37.9	33.1	34.3	36.5
	May		40.1	28.6	32.9	36.3	39.7		35.5
	June	25.7	27.3	27.2	29.4	33.6	33.2		32.1
	July					33.5	30.5	32.7	32.1
81-83 Females	March	29.7	34.6	36.9	38.3	40.7			36.7
	April	28.9	31.1	33.6	37.2	39.1	34.4		36.8
	May	25.5	26.6	33.4	37.0	36.9	34.6		36.7
	June	26.9			31.9	34.4	38.7		34.0
	July	27.4	29.5			33.5	29.3	31.6	31.9
81-83 Both sexes	March	30.2	34.4	36.4	38.1	39.7	33.8	34.9	36.7
	April	28.4	30.8	33.1	36.8	38.4	33.7	34.3	36.7
	May	25.5	30.0	29.9	34.9	36.5	36.3		36.0
	June	26.6	27.3	27.2	29.7	34.0	37.4		33.0
	July	27.4	29.5			33.5	30.1	32.1	32.0

TABLE III. Mean weight of mackerel by sex or sexes combined, by month and by maturity stage in Division VIIj in 1981, 1982 and 1983.

Year Sex	Month	Maturity stage 2	3	4	5	6	7	8	All Stages
1981 Males	March		239	346	457	470	251	236	413
	April		196	399	382	375	213	241	369
	May		437	131	350	379			374
	June	151	156	155	228	340	432		282
	July					304	224	286	268
1981 Females	March		246	400	449	534			427
	April	102	204	277	349	424	253		362
	May			572	290	413	299		406
	June	167				341	407		318
	July	154	201			286	201	263	255
1981 Both sexes	March		241	382	453	488	251	326	420
	April	102	202	314	365	402	233	241	365
	May		437	278	330	395	299		388
	June	165	156	155	228	340	410		298
	July	154	201			295	216	275	261
1982 Males	March	183	269	321	375	475			331
	April		108	279	373	402			387
	May				244	354			320
	June	118			143	269	146		246
	July								
1982 Females	March	169	277	359	420				332
	April	211	188	288	398	464			403
	May	123	130	171	408	400			388
	June	115			269	315			309
	July								
1982 Both sexes	March	174	274	342	397	475			331
	April	211	148	286	387	419			394
	May	123	130	171	338	370			351
	June	117			179	296	146		281
	July								
1983 Males	March		256	252	342				294
	April	113	192	195	318	414			303
	May			157	272	347	433		324
	June								
	July								
1983 Females	March		289	294	512				305
	April	151	190	240	375	486			347
	May				396	358			361
	June								
	July								
1983 Both sexes	March		286	264	371				300
	April	125	190	217	347	450			326
	May			157	305	353	433		341
	June								
	July								
81-83 Males	March	183	259	321	422	471	251	236	369
	April	113	171	236	353	398	213	241	358
	May		437	150	268	363	433		340
	June	129	156	155	201	296	289		263
	July					304	224	286	268
81-83 Females	March	169	277	376	440	534			371
	April	147	192	261	382	452	253		372
	May	123	130	304	397	390	299		386
	June	160			269	322	407		313
	July	154	201			286	201	263	255
81-83 Both sexes	March	174	271	353	431	485	251	236	370
	April	138	186	251	369	419	233	241	365
	May	123	207	192	331	375	343		362
	June	152	156	155	209	310	381		288
	July	154	201			295	216	275	261

TABLE IV. Number and percentage of mackerel by sex, by month and by maturity stage in Division VIIj in 1982 (January till July).

IN NUMBER

Sex	Month	Maturity stage 2	3	4	5	6	7	8	Total
1982 Males	January	10	13	4				3	30
	February	7	41	55	8				111
	March	3	16	22	21	5			67
	April		2	2	68	114			186
	May				42	94			136
	June	2			5	37	1		45
	July								
1982 Females	January	15	21	1				2	39
	February	3	70	41					114
	March	5	31	27	20				83
	April	2	2	11	83	41			139
	May	2	3	2	57	50			114
	June	1			2	52			55
	July								

PERCENTAGE

Sex	Month	Maturity stage 2	3	4	5	6	7	8	Total
Males	January	33.3	43.3	13.3				10.0	100%
	February	6.3	36.9	49.5	7.2				100%
	March	4.5	23.9	32.8	31.3	7.5			100%
	April		1.1	1.1	36.6	61.3			100%
	May				30.9	69.1			100%
	June	4.4			11.1	82.2	2.2		100%
	July								
Females	January	38.5	53.8	2.6				5.1	100%
	February	2.6	61.4	36.0					100%
	March	6.0	37.3	32.5	24.1				100%
	April	1.4	1.4	7.9	59.7	29.5			100%
	May	1.8	2.6	1.4	50.0	43.9			100%
	June	1.8			3.6	94.5			100%
	July								

TABLE V. Number of mackerel by month, by age and by maturity stage in Division VIIj in 1981, 1982 and 1983.

Year	Month	Age	Maturity stage 2	3	4	5	6	7	8	All Stages
81-83	March	1								
		2	3		1					4
		3	4	21	12	6				43
		4	1	15	8	7	2			33
		5		5	7	8	1			21
		6		13	22	21		1	1	58
		7		5	16	9	1			31
		8		3	7	21	1			32
		9		3	7	2	2			14
		10		1	4	9	3			17
		11+		5	11	40	16			72
81-83	April	1								
		2	5	11	13	5	2			36
		3	2	9	25	46	25			107
		4	1	3	16	49	21			90
		5		2	10	23	17	3		55
		6			8	32	28	2	1	71
		7		2	2	42	41	1		88
		8		2	1	24	25			52
		9			2	16	18			36
		10			1	17	21			39
		11+			6	70	100			176
81-83	May	1	1							1
		2		3	5	17	20			45
		3	1		5	34	89	1		130
		4				13	49	1		63
		5				7	49			56
		6				6	47	1		54
		7				16	56			72
		8		1		11	44			56
		9				9	22			31
		10				4	36			40
		11+			1	26	125			152
81-83	June	1	3							3
		2	8	2	4	7	3	2		26
		3				5	34			39
		4				2	13			15
		5				3	10			13
		6				1	25	1		27
		7					16	1		17
		8					5	2		7
		9					7			7
		10					5	2		7
		11+					13	1		14
81-83	July	1						1		1
		2	2	1		5	20	3		31
		3					13	5		18
		4							2	2
		5					12	8		20
		6					10			10
		7					3			3
		8					5	1		6
		9					1			1
		10					3			3
		11+					3	1	1	5

TABLE VI. Mean length of mackerel by month, by age and by maturity stage in Division VIIj in 1981, 1982 and 1983.

Year	Month	Age	Maturity stage 2	3	4	5	6	7	8	All Stages
81-83	March	1								
		2	28.3		30.1					28.7
		3	30.7	32.8	33.7	32.9				32.8
		4	34.3	33.4	34.4	34.9	35.7			34.1
		5		33.5	35.5	35.6	36.6			35.1
		6		35.5	36.2	36.5		33.8	34.9	36.1
		7		35.8	37.3	37.1	37.3			37.0
		8		36.5	36.8	38.5	34.7			37.8
		9		37.3	38.0	36.9	39.9			37.9
		10		34.5	37.3	39.2	37.3			38.1
		11+		37.3	39.7	40.6	41.3			40.4
81-83	April	1								
		2	26.4	28.6	28.5	29.7	28.4			28.4
		3	30.6	30.7	32.0	31.7	33.0			32.0
		4	33.8	31.8	32.3	34.2	35.1			34.0
		5		33.0	34.3	35.4	35.8	33.1		35.1
		6			35.2	36.7	37.0	34.4	34.3	36.5
		7		34.4	37.2	37.7	37.8	34.3		37.6
		8		35.4	37.1	38.8	38.7			38.6
		9			37.4	39.4	38.5			38.8
		10			34.6	39.1	38.8			38.8
		11+			41.4	40.6	41.5			41.1
81-83	May	1	21.0							21.0
		2		26.6	27.6	28.4	29.3			28.6
		3	30.0		29.5	29.9	31.5	31.3		31.0
		4				33.8	33.7	39.7		33.8
		5				34.9	35.3			35.3
		6				35.4	36.2	38.0		36.2
		7				37.8	37.9			37.9
		8		40.1		38.8	37.8			38.0
		9				39.3	39.2			39.2
		10				37.6	38.4			38.3
		11+			43.2	40.8	40.9			40.9
81-83	June	1	25.2							25.2
		2	27.1	27.3	27.2	27.2	29.0	29.4		27.6
		3				28.5	30.2			30.0
		4				31.9	33.3			33.1
		5				34.6	34.2			34.3
		6				33.2	34.7	41.0		34.9
		7					35.4	39.8		35.7
		8					36.2	38.0		36.7
		9					35.7			35.7
		10					37.1	39.7		37.9
		11+					39.7	42.2		39.9
81-83	July	1						27.1		27.1
		2	27.4	29.5		28.5	27.6	28.4		27.9
		3					31.7	30.8		31.4
		4							33.2	33.2
		5					33.5	34.3		33.8
		6					34.7			34.7
		7					34.4			34.4
		8					34.2	35.2		34.4
		9					37.2			37.2
		10					36.5			36.5
		11+					38.8	39.4	41.4	39.4

TABLE VII. Mean weight of mackerel by month, by age and by maturity stage in Division VIIj in 1981, 1982 and 1983.

Year	Month	Age	Maturity stage 2	3	4	5	6	7	8	All Stages
81-83	March	1								
		2	132		156					138
		3	180	228	261	239				234
		4	276	251	291	302	362			279
		5		251	328	328	361			311
		6		297	347	370		251	236	341
		7		308	374	402	397			372
		8		319	361	446	316			411
		9		357	386	384	502			396
		10		271	373	464	395			419
		11+		340	479	527	540			509
81-83	April	1								
		2	110	144	148	167	136			144
		3	164	179	216	215	238			217
		4	226	204	225	278	294			269
		5		214	269	312	330	211		300
		6			306	359	358	259	241	348
		7		271	359	395	393	246		388
		8		309	361	434	439			430
		9			341	445	413			424
		10			261	442	445			439
		11+			494	497	530			516
81-83	May	1	70							70
		2		130	138	160	175			162
		3	176		171	188	224	226		212
		4				279	276	433		279
		5				319	329			327
		6				330	357	371		354
		7				408	405			406
		8		437		417	410			412
		9				468	453			457
		10				391	434			430
		11+			572	520	523			522
81-83	June	1	117							117
		2	165	156	155	157	184	186		164
		3				173	207			203
		4				269	283			281
		5				325	313			316
		6				281	323	472		327
		7					355	427		359
		8					353	392		364
		9					357			357
		10					391	412		397
		11+					480	547		485
81-83	July	1						156		156
		2	154	201		179	165	191		170
		3					246	217		238
		4							299	299
		5					291	306		297
		6					323			323
		7					319			319
		8					309	336		314
		9					382			382
		10					389			389
		11+					447	442	477	452

TABLE VIII. Percentage of mackerel in maturity stage 6 compared with mackerel in maturity stage 3 till 6 inclusive (calculated from table V).

Age	March	April	May	June	July
2	0.0	6.5	44.4	18.8	76.9
3	0.0	23.8	69.5	87.2	100.0
4	6.3	23.6	79.0	86.7	100.0
5	4.8	32.7	87.5	76.9	100.0
6	0.0	41.2	88.7	96.2	100.0
7	3.2	47.1	77.8	100.0	100.0
8	3.1	48.1	78.6	100.0	100.0
9	14.3	50.0	71.0	100.0	100.0
10	17.6	53.8	90.0	100.0	100.0
11+	22.2	56.8	82.21	100.0	100.0
Mean	8.3	40.5	77.3	84.5	92.1

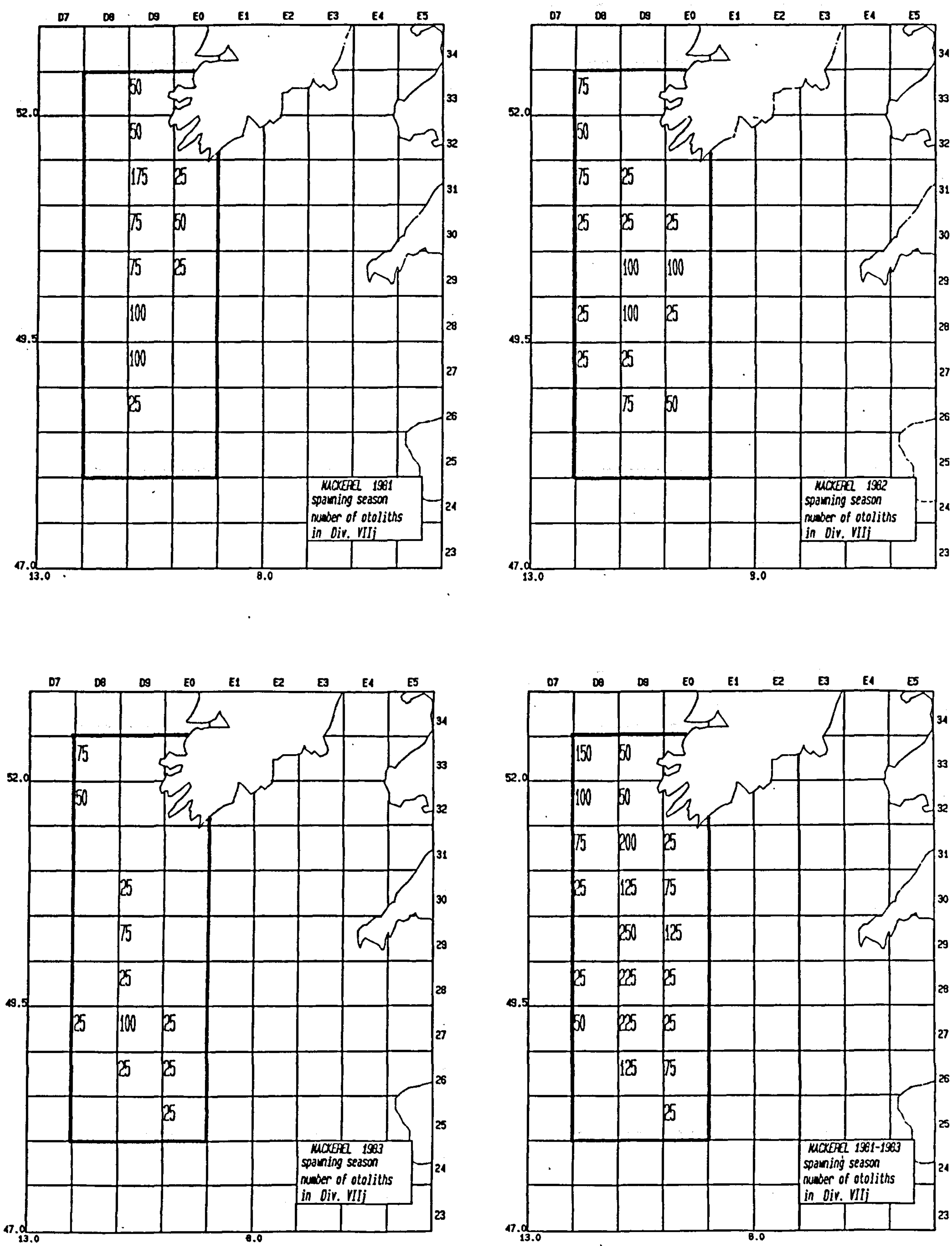


FIGURE 1. The sampling of mackerel otoliths during the spawning season March - July in 1981 - 1983.

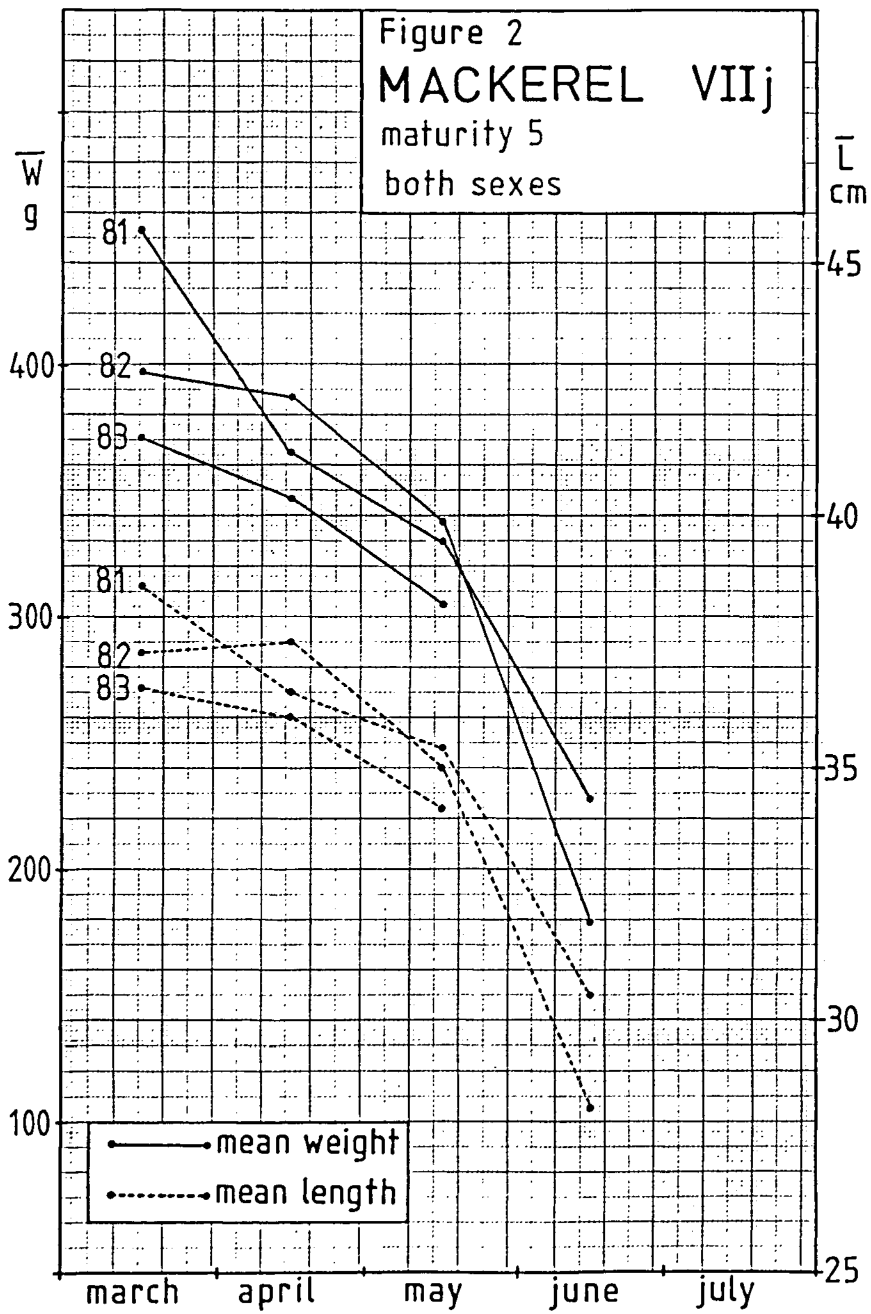


Figure 2
MACKEREL VIIj
maturity 5
both sexes
W̄ g
L̄ cm
400
300
200
100
45
40
35
30
25
81
82
83
81
82
83
mean weight
mean length
march
april
may
june
july

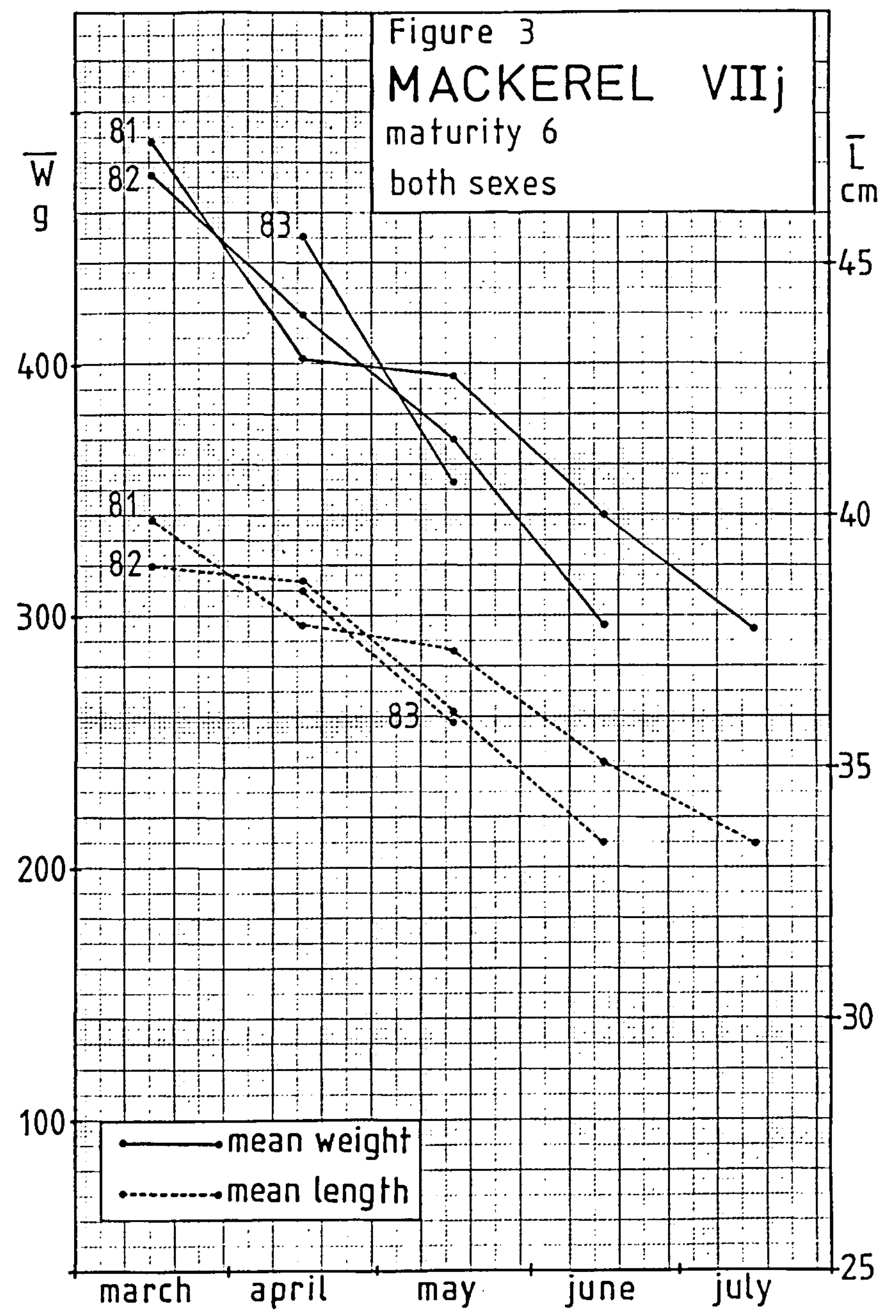


Figure 3
MACKEREL VIIj
maturity 6
both sexes
W̄ g
L̄ cm
400
300
200
100
45
40
35
30
25
81
82
83
81
82
83
mean weight
mean length
march
april
may
june
july

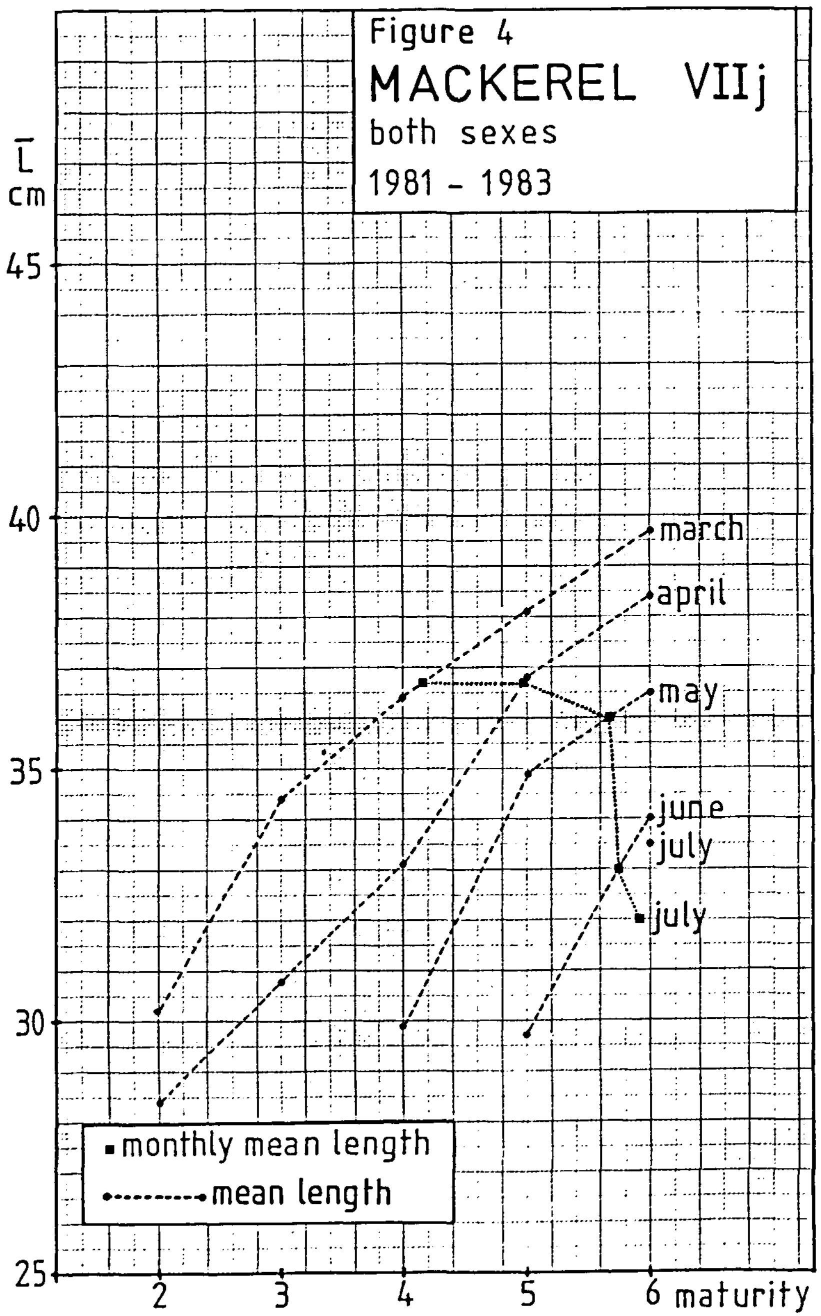


Figure 4
MACKEREL VIIj
both sexes
1981 - 1983
L̄ cm
45
40
35
30
25
2
3
4
5
6 maturity
march
april
may
june
july
july
monthly mean length
mean length

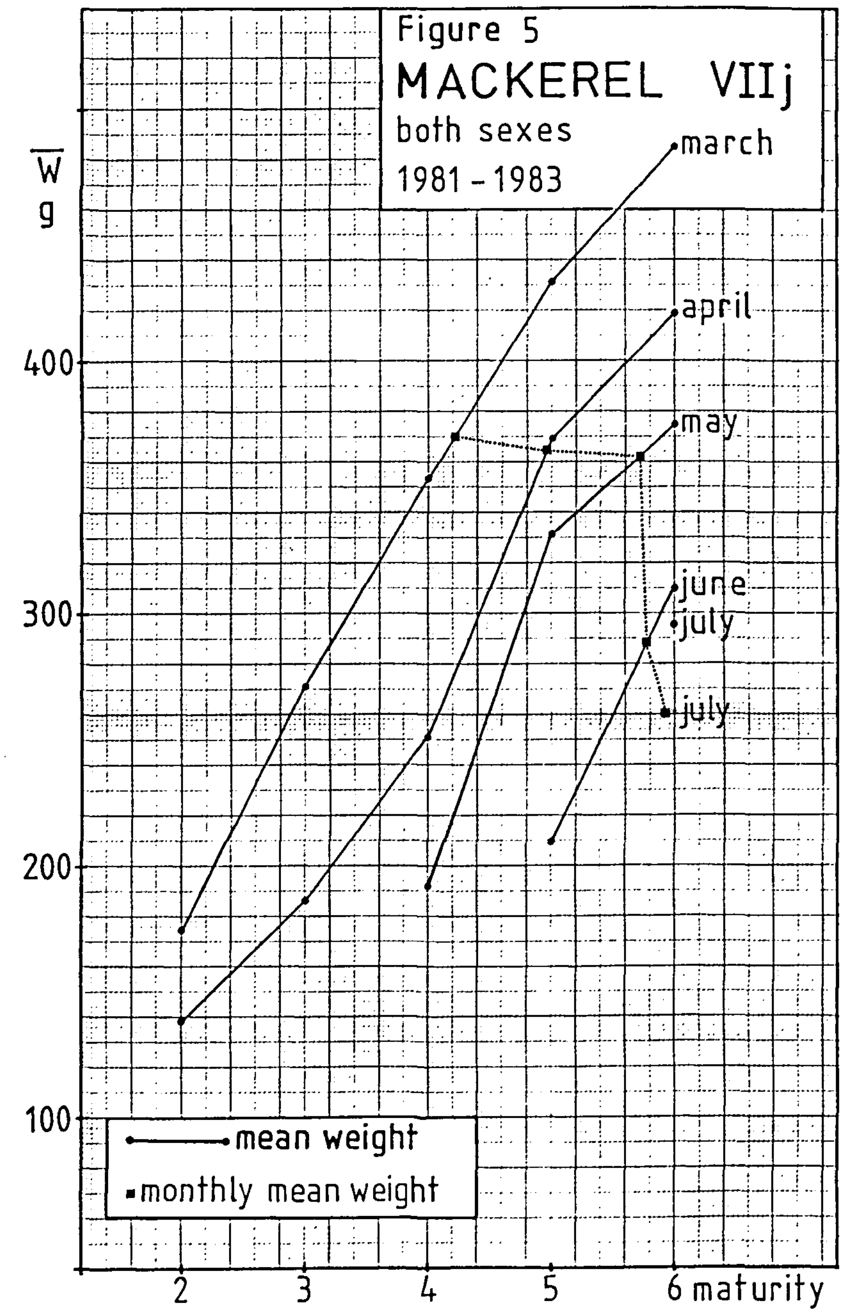
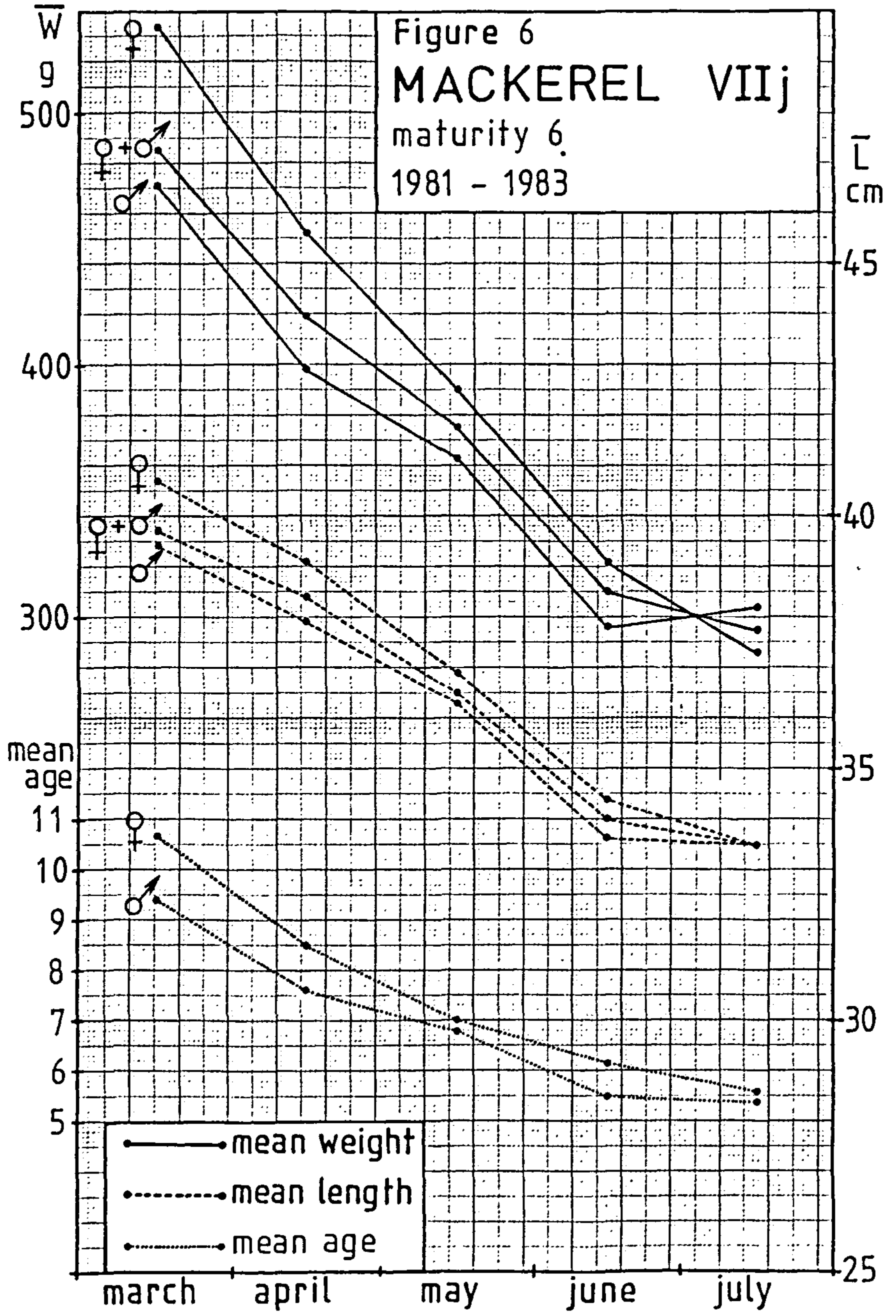


Figure 5
MACKEREL VIIj
both sexes
1981 - 1983
W̄ g
400
300
200
100
2
3
4
5
6 maturity
march
april
may
june
july
july
mean weight
monthly mean weight



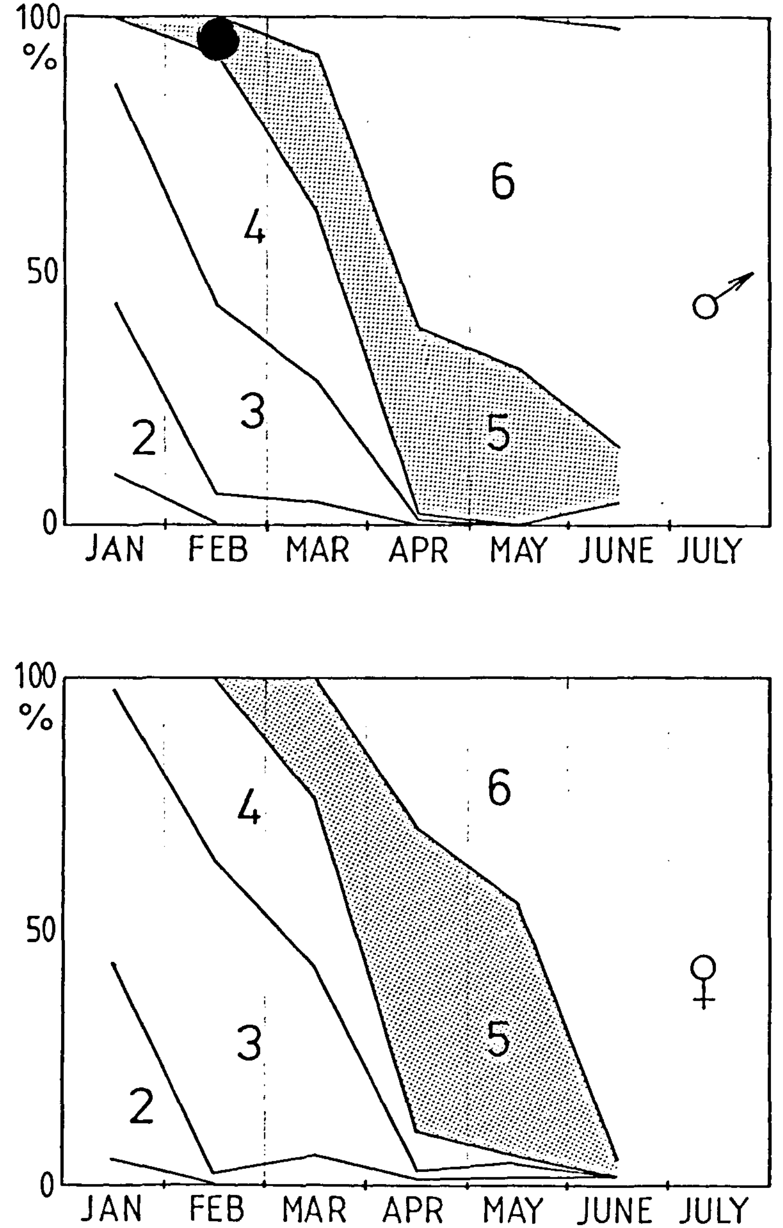
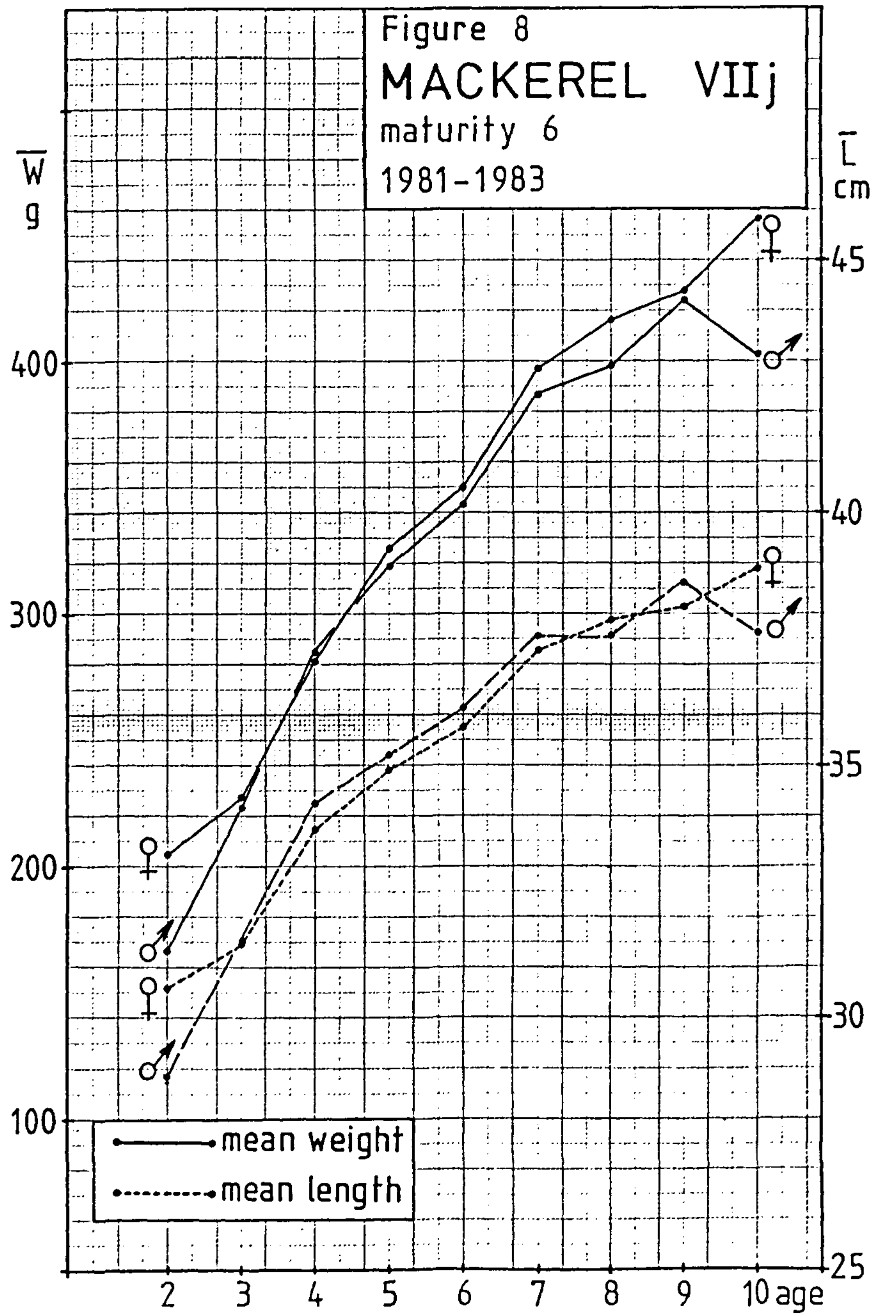


FIGURE 7. Percentage of maturity stages of mackerel by month for males (above) and females (below) in ICES Division VIIj in 1982.



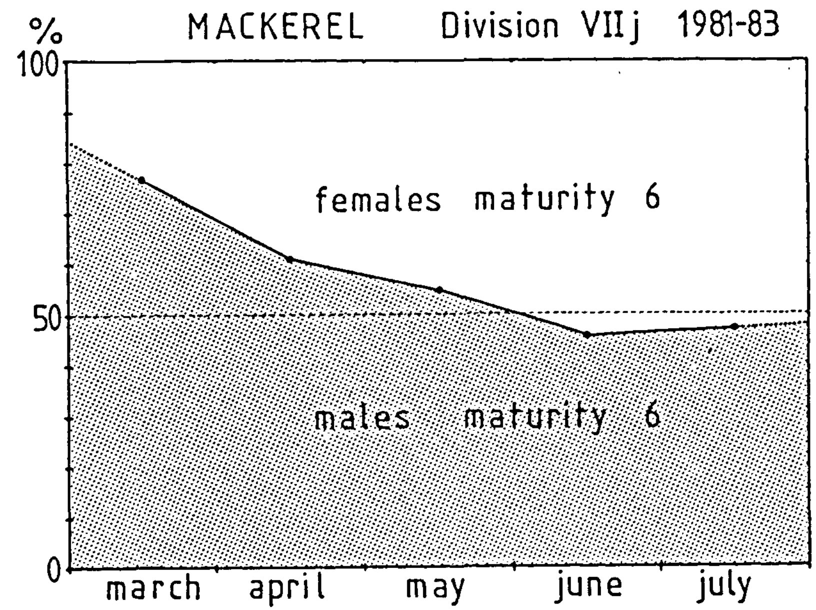


FIGURE 9. The percentage male and female mackerel in maturity stage 6 by month in Division VIIj in 1981 - 1983.

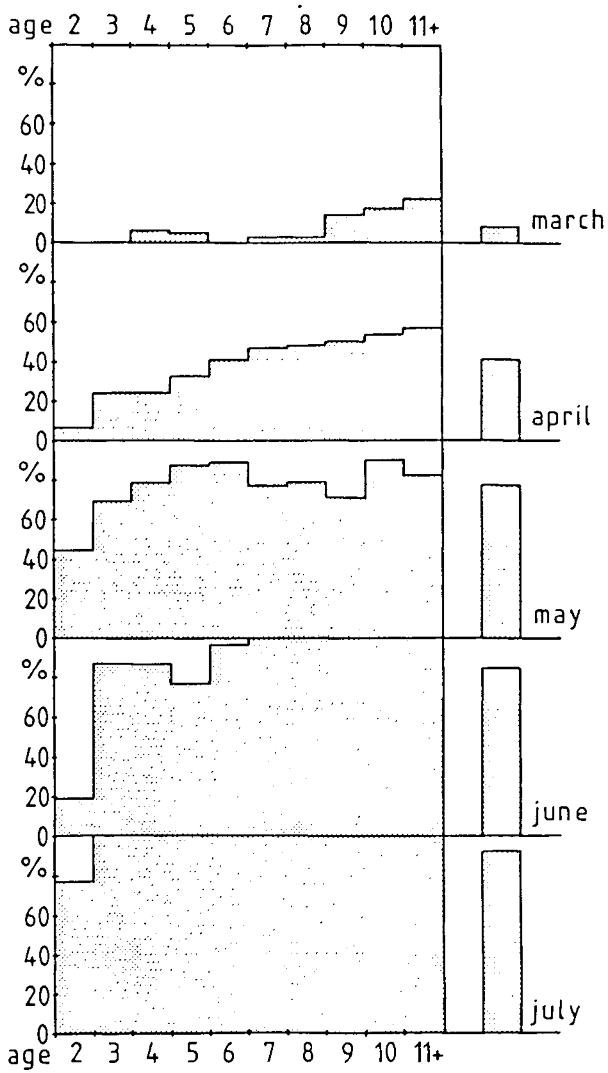


FIGURE 10. The monthly percentage spawning mackerel (dotted = maturity stage 6) in comparison with mackerel, wich is going to spawn (not dotted = maturity stages 3 - 5) by age group and by ages combined in Division VIIj in 1981 - 1983.

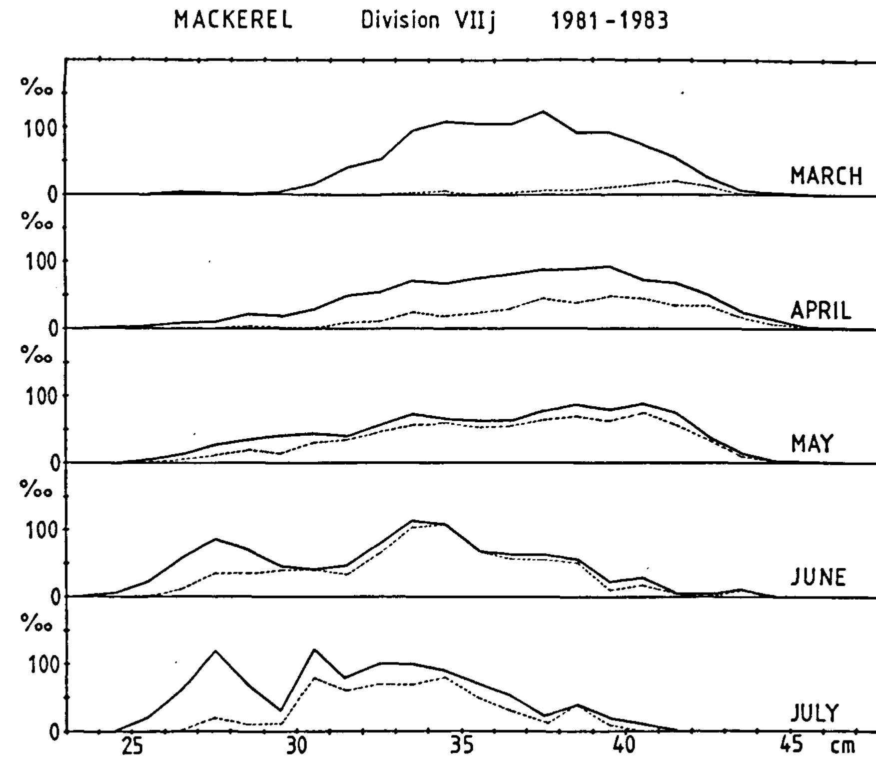
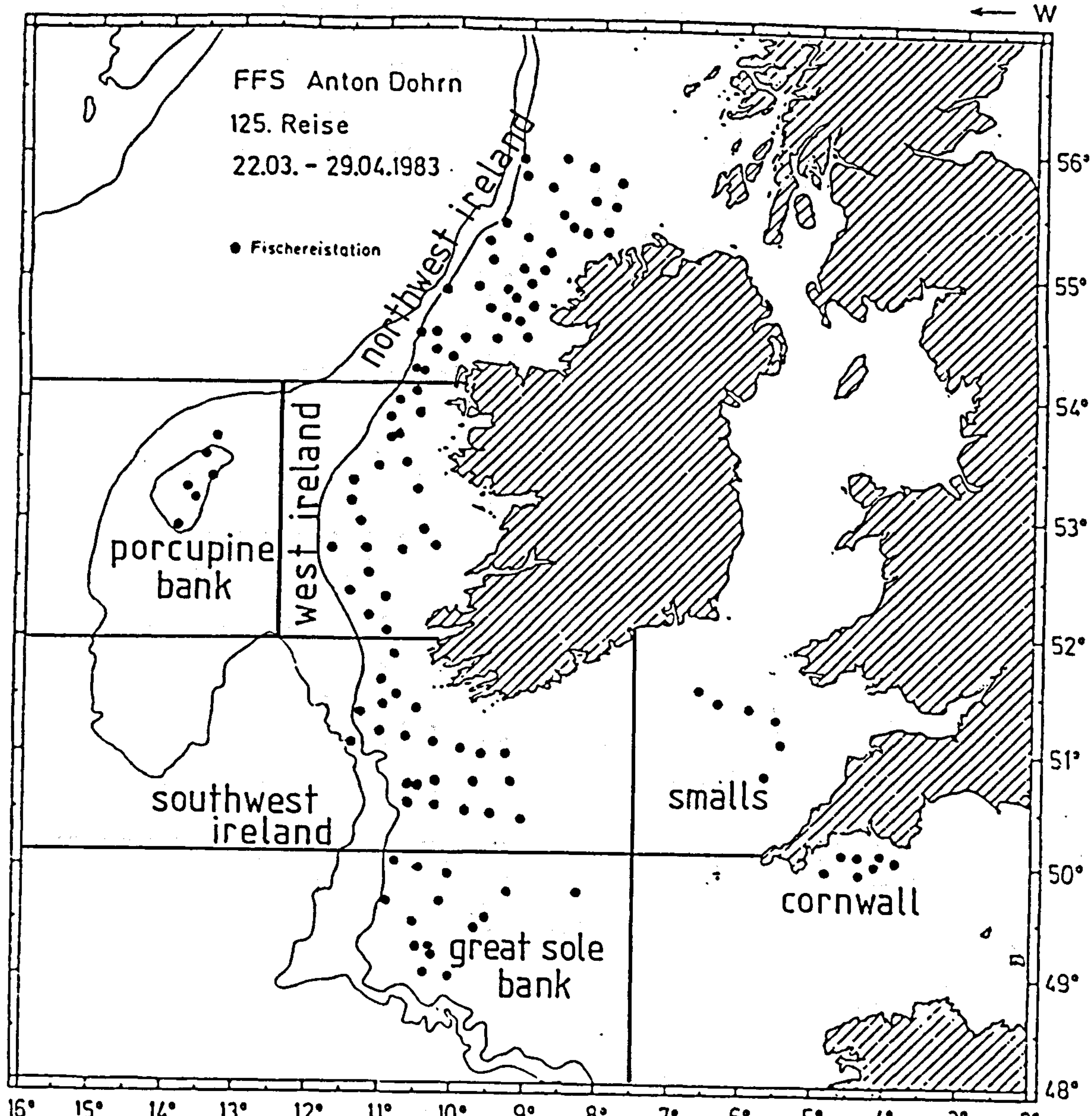


FIGURE 11. Monthly length distributions of mackerel in all maturity stages (unbroken line) and of spawning mackerel in maturity stage 6 (broken line) in ICES Division VIIj in 1981 - 1983.



	mean weight	kg/hour
northwest ireland	238	344
west ireland	246	1530
southwest ireland	292	1070
great sole bank	378	840

FIGURE 12. Trawl stations of R.V. "Anton Dohrn" around Ireland and the southwest of England with information on mean weights and kg/hour fishing in the different areas.

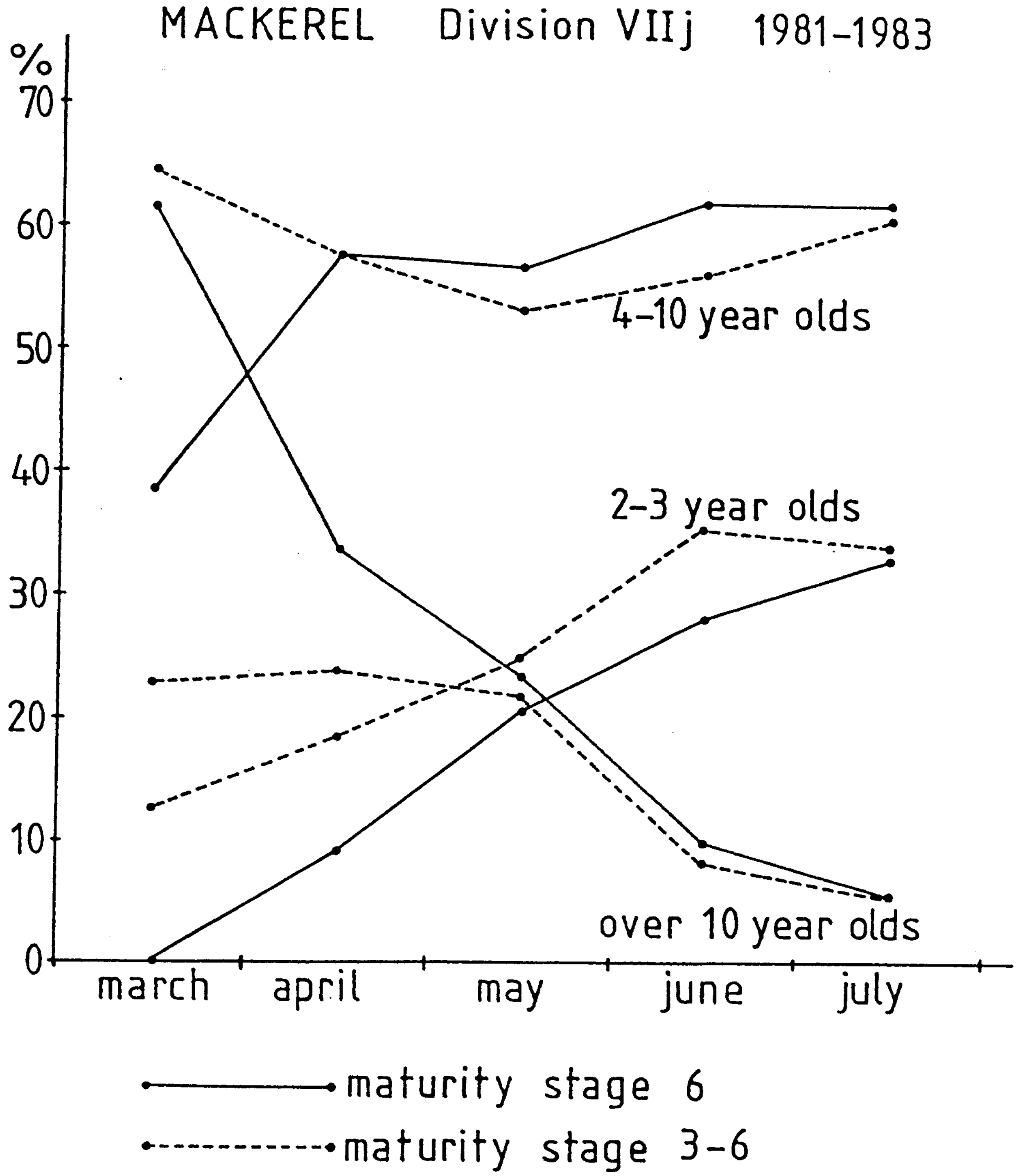


FIGURE 13. The distribution of 3 combinations of age groups: 2 – 3 year olds, 4 – 10 year olds and over 10 year olds in percentages of mackerel in maturity stage 6 together with mackerel in maturity stages 3 – 6.

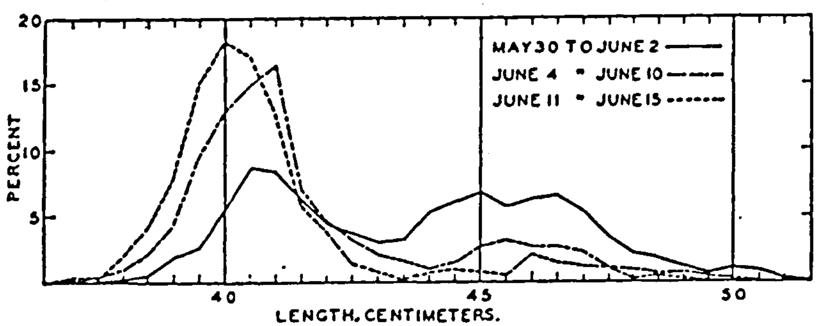
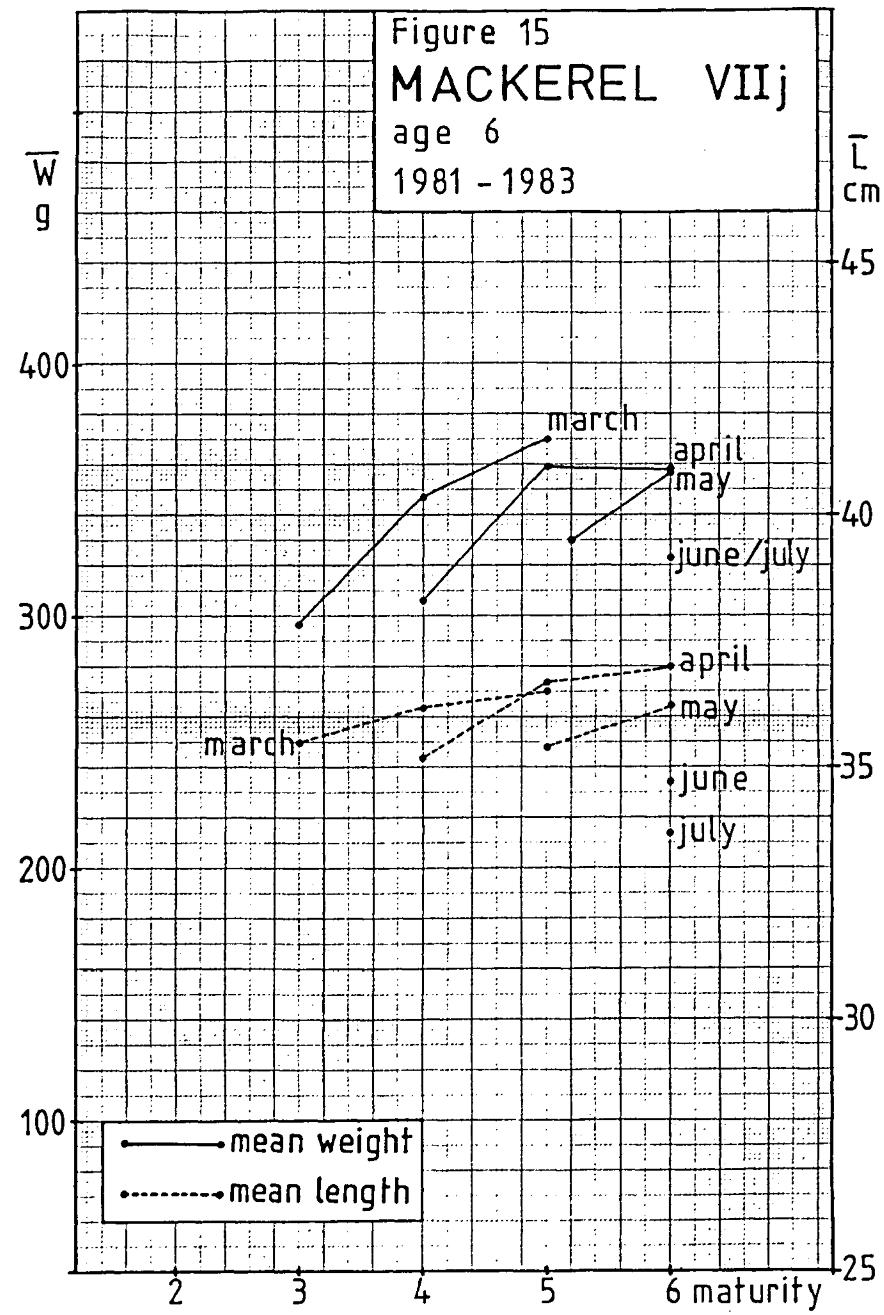


FIGURE 14. Changes in the mackerel population along the coast of Nova Scotia in the spring of 1926, as indicated by length frequency distributions (SETTE, 1950).



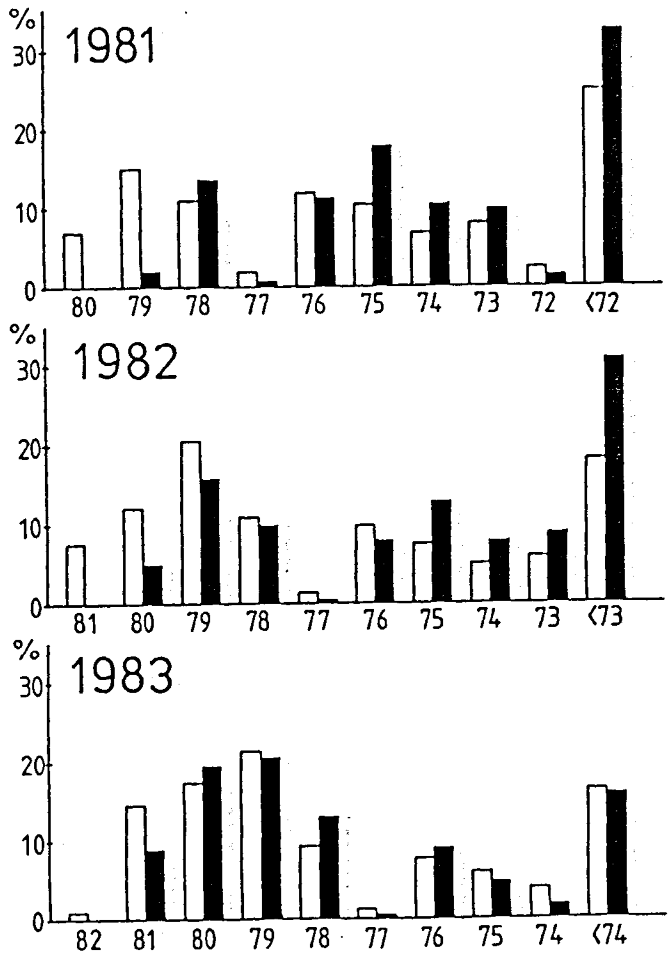


FIGURE 16. Age compositions of the spawning population as estimated by the Virtual Population Analysis (white) and from ICES Division VIIj from April and May combined (black).

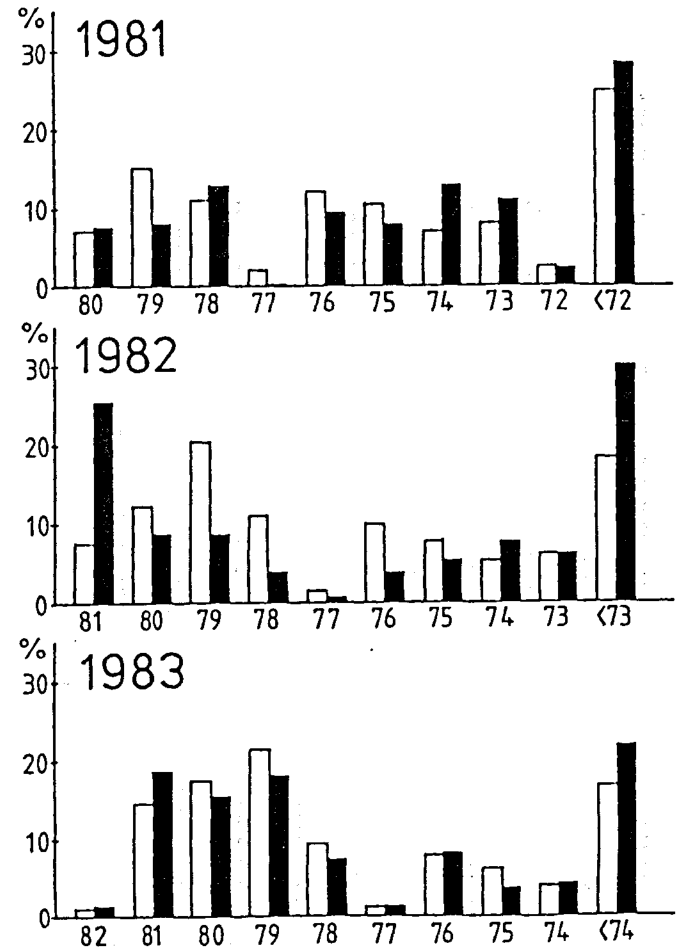


FIGURE 17. Age compositions of the spawning population as estimated by the Virtual Population Analysis (white) and of the overwintering population west and norhtwest of Ireland during November till February (black).