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FISHERY DEPENDANT GROWTH IN THE NORTH SEA SOLE AND ITS CONSEQUENCES FOR FISHERY MANAGEMENT

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Introduction

In the North Sea sole changes in a number of biological parameters, particularly the growth rate, took place over the last twenty years. Over the same period the sole stock, with large fluctuations owing to good or bad year classes, declined and the fishery changed from a state of under-exploitation to strong overfishing. Since 1970 the North Sea Flatfish Working Group has assessed the sole fishery annually and has given advice on fishery management measures.

In an analysis of the observed changes up to and including 1973 a number of possible factors responsible for the changes has been discussed (de Veen, 1976). In conjunction with the decline of the stock and the increase in the growth rate, which suggests a density dependant growth, fishing effort, especially Dutch beam trawler effort, increased considerably.

In the case of sole growth being density dependant, recruitment of good year classes, which may temporarily increase the stock biomass, would be expected to halt the increase in growth rate. However, the data did provide no evidence that this actually happened. The very strong 1963 year class, leading to a considerable rise in sole biomass in the period 1965 - 1967, had no measurable negative effect on the steady increase in growth rate. On the contrary, the growth rate of this year class was faster than that of the previous year classes such as those from 1956 - 1960.

The highest correlation found among the different parameters was the one between fishing effort and growth rate. The curves of the growth rate and of the beam trawl fishing hours, corrected for fishing power, followed each other closely. From additional evidence the author opted for the beam trawl eff•rt as the main responsible factor, through the effect of the tickler chains when chafing the bottom and making food animals available.

For a sole, being a chemical perceptor rather than a visual feeder, the increased smell from injured animals might facilitate location of the prey and less energy would be needed for searching and digging out the prey. Moreover, hitherto unaccessible food resources such as echinoderms might have become available as sole food by the digging effect of the tickler chains on the bottom. It was argued that the energy saving should have led to faster growth. Since this analysis, based on data from the years 1951 - 1973, new growth data have been obtained.

In the period 1975 - present a quota management regime came into force and although in reality hardly any reductions in the amount of fishing per ship was effectualised, the continuous increase in total effort came to an end and through special measures in The Netherlands a reduction of some 15% in effort deployed on the North Sea sole has been achieved.

In the present paper the new growth data will be compared with those from the pre 1974 period and the implications of the conclusions for fishery management will be discussed.

The growth rate in the years 1973 - 1977.

Figure 1 gives the nominal weight at age data for male and female sole in the second quarter, at the beginning of the growth season, for the years 1957 - 1977. Table 1 gives the data for the years 1974 - 1977 which table forms an extension to the table 3 in De Veen (1976).
Growth started to increase in 1962 and reached a level in 1973 of 60% higher, a considerable increase indeed.

Since 1973 growth stopped to increase further and the three, four and five year old soles tend to grow at a slower rate.

The character of the growth curve changed over the years 1957 - 1977. This is shown in figure 2, giving the relationship between annual growth increment and mean nominal weight at age for female sole. The diagrams suggest that the change started off in the youngest age groups (left part of the diagrams) where the annual increments showed the increase first (see graph 1964 - 1970) and gradually also the older age groups became involved, Figure 3, showing individual growth curves for a number of year classes, demonstrates that the more recent year classes from 1969 onward have the same growth curve.

In the analysis of the Flatfish Working Group Von Berthalanffy growth parameters or weight at age data derived from most recent years have been used. In these years growth was more or less constant. Still figure 3 shows that these weight at age arrays were composed of parts of different growth curves. For the older age groups weight at age values from year classes which had grown less fast in their earlier life were used. Thus the weight at age data for the most recent year classes, given another ten years and assuming that the growth rate remains constant should demonstrate higher weight at age values for older age-groups. This, however, is not too serious, because the older age groups represent only a small proportion of the stock and hence the

the catch. Still, strictly speaking, owing to the effect of the increase in growth prior to 1973 the weight at age data generally used in the Working Groups's analysis are biased.

Factor(s) responsible for the observed changes in the growth rate.

Figure 4a shows that the end of the period of increase in growth rate coincides with the end of the steady increase in fishing effort and that the decrease in weight at age shown by the three, four and five year old soles follows the small reduction in fishing effort towards 1977.

This would be expected if the effect of the tickler chains of the beam trawl on the availability of sole food is the main responsible factor. Apparently, the hypothesis put forward in the earlier paper (de Veen, 1976) is confirmed by the recent data and therefore still holds.

However, the possibility of density dependant growth can not be completely ruled out because the steady decline in the sole stock too has come to an end recently as is shown in figure 4b.

A third possibility is that neither fishing effort nor density is responsible but a still unknown factor.

Whatever the responsible factors are, their effects have to be taken into account in future assessments and we should be careful to rely too much on long term predictions based on the assumption of constant growth.

Assessment of the sole fishery.

In order to find out what the effects of fishery dependant or density dependant growth are we start to calculate yield per recruit curves.

Yield per recruit and yield per effort per recruit curves for M = .10 are given in figure 5, based on the exploitation patterns for the various time periods, given by VPA and the weight at age data from these time periods. F at age data derived from VPA show large variations and estimating a maximum value in the exploitation pattern is rather difficult and uncertain. Rather high values may be found,out of proportion to the general shape of the exploitation pattern. For our purpose a smooth line has been drawn through each set of F at age values. From these smoothed curves the maximum was read and taken to be the maximum F at age. These values are generally lower than the actual maximum F at age values observed, but are more consistent from time period to time period. The smoothed maximum F at age figures have been inserted in the Y/R and Y/f/R curves in figure 5 by small circles. The shift observed when going from 1957 to the present indicates the gradual change from under-exploitation through conditional sustainable yield per recruit somewhere between 1963 and 1968 to a stage of increasing over-exploitation in recent years.

Strictly speaking F values derived from VPA are not independant. Each F value in a cohort is influenced by the data on catch and calculated F of older age-groups in the cohort and especially in a short cohort also on the assumptions on terminal F values to be used in the VPA. Thus a F at age array in a given year is not independant from the F at age array in the following years. Estimates of total mortality (Z) derived from catch per unit effort data are independant. The values of c.p.u.e. in consecutive years have no influence on the values of Z per age group in a given year. By subtracting the value of M the F over age array - the exploitation pattern - is obtained.

In the Dutch sole fishery the c.p.u.e. has been calculated for the beam trawl fleet after corrections for the fishing power of the vessels. Table 2 gives the relevant data on c.p.u.e. and the corrections made.

If one does not use VPA and applies the simple Beverton and Holt model with constant F one gets Y/R and Y/f/R curves as shown in figure 6. Per yield curve the average value of F derived from c.p.u.e. is indicated. The advantage of average F is that it is a quantity less variable and subjective than max F at age.

In this constant F model too the general picture is the same: F_{max} of the Y/R curve is on average 0.2, the shapes of the yield curve are similar and the absolute values increase over the years as a consequence of the increased growth rate.

If we plot the observed yield per recruit and the yield per effort per recruit values in the different time periods (the small circles in the curves of figure 5) against max F at age as shown in the upper diagram of figure 7 we find the relationship between Y/R and Y/f/R with fishing mortality which has actually been observed in the last twenty years.

In contrast to the various Y/R curves of figure 5 all based on the assumption of constant growth, the Y/R curve of figure 7 has no optimum. Over the observed range of max F at age the yield per recruit is increasing.

In the lower diagram of figure 7 we have repeated the procedure for the constant F model Y/R curves in figure 6. Here again the same type of relationship: the higest Y/R values occur at present!

Effects of levels of recruitment.

Y/R and Y/f/R curves can only be interpreted in terms of maximum sustainable yield by the population provided recruitment remains constant. In that case the scale of the Y-axis is simply blown up by the figure for average R.

Has recruitment been constant over the period under consideration?

Alternative approaches for considering the trend in average recruitment are possible, but for simplicity a moving average of 10 years has been calculated here over the year classes 1942 - 1975 (derived from various reports of the Flatfish Working Group). The result is shown in figure 8.

During this period three outstanding year classes were born (1947, 1958 and 1963). These are responsible for the variations in the curve. However, we cannot ignore them for they had a large influence on the stock and the fishery. The absence of a strong year class since 1963 explains why the right hand part of the curve is steadily decreasing. The present level - some 80 million recruits - is the lowest level observed in the whole series. Applying values for average recruitment from the curve in figure 8 for the relevant years (1957 - 1959, a.s.o.) to the values in figure 7 gives the observed average total yields and yields per effort in relation to fishing mortality presented in figure 9.

By including the recruitment effect the observed yield curves differ from those in figure 7, having a maximum at low max F at age and at low F values respectively.

However, we should not identify the curves in figure 9 as the sustainable yield and yield per effort curves to be used in any analysis for an advice on fishery management measures, unless recruitment has a causal relationship with fishing effort. It seems unlikely that the lower levels of fishing effort in the past were mainly responsible for the occurrence of good to outstanding year classes. This would require that the effort had brought the stock down to a level at which recruitment is seriously affected. When looking at figure 10, giving the strengths of sole year classes, the recent good year classes 1975 and 1976 show that we have not entered the critical area with reduced recruitment when the stock was at its lowest level recently.

Objectives for fishery management.

From the foregoing sections it is clear that terms as conditional optimum sustainable yield, under-, full and over-exploitation have to be redefined for the North Sea sole.

In its report CM 1976/Gen:3 the Ad Hoc working party on the provision of advice on the biological basis for fisheries management gave a critical review of the MSY concept and offered a new integrated objective: the optimum sustainable yield. Management based on this OSY concept should reduce fluctuations in TACs from year to year, increase the catch rates and reduce the risk of stock depletion.

In the North Sea sole we can no longer be certain that the reduction in fishing effort necessary to prevent overshooting of the TACs, will actually lead to the expected long term effects neither in catch nor in stock levels which resulted from analysis based on constant growth and constant average recruitment.

In the case of a fishery dependant growth as described or even in the case of a density dependant growth, however unlikely, reductions in effort will result in decreases in the growth rate and thus lead to long term losses in yield and smaller increases in the catch rates than expected so far in the assessments carried out by the

Flatfish Working Group.

In the case of a fishery dependant growth the most profitable management action is to increase the effective mesh size, leaving the effect of the tickler chains unaltered and thus keeping the growth rate at the present high level.

In the unlikely case of a density dependant growth the fishery would not benefit from an increase in mesh size. The increased sole stock would then reduce growth.

For the time being a substantial increase in effective mesh size seems to be a fair objective for fishery management next to TACs, since it can be expected to bring the sole stock to the OSY level with the benefits mentioned. One of these benefits is the reduction in variability in TACs which is clearly a nuisance at present. At the moment with the low stock level large variations in TAC are unavoidable.

Figure 11 gives the percentages of the recruiting year classes of the total adult stock. In the late fifties this percentage was on average 15 % (with exceptions owing to the outstanding 1958 and 1963 year classes) but has increased to on average 30 % at present as a result of the low stock size.

An increase in effective mesh size will certainly raise the stock level and reduce the variations in the proportions of the incoming year classes, resulting in less fluctuating TAC advices in the future.

The objective recently used by the Flatfish Working Group by giving TAC advices allowing the stock biomass to be doubled in the long run to prevent recruitment-overfishing still can be used. It should not, however, be achieved by reducing effort but by an increase in effective mesh size.

The changes in growth rate observed so far show a high and causal correlation with beam trawl effort. This does, however, not mean that the tickler chain effect alone determines the growth changes. An unknown factor, working at the same time, in the same direction may have added to the effect of the tickler chains but has been unnoticed so far. Thus the effects of decreases in effort or increases in effective mesh size can only be predicted with certainty when more information becomes available on the tickler chain effects. This autumn research will be started on food consumption of sole in areas with different impacts of tickler chains in order to verify our hypothesis on increased food availability for the sole by the beam trawl.

In view of the uncertainties expressed above it seems wise to set up a management scheme, which allows to reach the objectives step by step and to observed carefully the responses in the biological parameters of the North Sea sole.

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De Veen, 1976 - On changes in some biological parameters i~ the North Sea sole (Solea solea L.). J. Cons. int. Explor. Mer. 37(1): 60-90.

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TABLE 1 - Average nominal weight ($\bar{w}$) in g and number of otoliths (n) used in length-age key for North Sea sole in the second quarter derived from market-sampling per age-group for males and females.

year		age-group 3 $\bar{w}$	n	4 $\bar{w}$	n	5 $\bar{w}$	n	6 $\bar{w}$	n	7 $\bar{w}$	n	8 $\bar{w}$	n	9 $\bar{w}$	n	10 $\bar{w}$	n
1974	♂	176.5	1320	247.3	313	284,7	588	313,7	155	362,9	121	361,0	62	392,5	38	370,0	29
	♀	242,5	1445	368,6	309	480,5	620	535,4	144	611,7	154	687,3	67	695,1	36	785,1	65
1975	♂	175,0	1240	232,4	576	287,5	125	315,6	285	338,9	53	380,0	48	366,0	32	375,9	19
	♀	235,5	1224	376,9	774	490,5	176	550,7	472	623,8	80	680,6	119	749,8	59	731,5	33
1976	♂	165,0	1198	226,0	570	273,8	240	332,7	57	331,6	113	362,7	26	399,3	20	400,2	15
	♀	222,8	1023	374,6	826	484,3	364	580,3	96	641,6	277	678,0	79	758,7	91	803,6	51
1977	♂	179,8	488	224,1	859	263,4	428	297,0	83	346,6	16	359,0	68	382,0	32	343,6	14
	♀	226,0	467	343,5	991	468,1	556	555,1	167	617,0	57	653,6	197	681,3	56	719,0	65

year		age-group 11 $\bar{w}$	n	12 $\bar{w}$	n	13 $\bar{w}$	n	14 $\bar{w}$	n	15 $\bar{w}$	n	16 $\bar{w}$	n	17 $\bar{w}$	n	18 $\bar{w}$	n
1974	♂	403,6	231	463,3	8	502,2	5	436,7	22	452,8	5	424,3	55	445,7	5	486,7	10
	♀	732,7	482	663,1	11	659,3	9	686,8	38	858,1	8	769,6	139	830,0	10	791,2	26
1975	♂	339,0	8	408,3	157	427,4	5	575,9	5	458,3	13	439,7	5	458,9	48	580,2	4
	♀	645,2	23	777,4	355	853,1	3	857,1	13	704,8	26	848,5	16	792,6	126	837,2	15
1976	♂	421,6	17	386,3	10	430,2	97	386,5	5	496,9	5	452,0	6	520,4	3	426,3	19
	♀	759,5	36	828,3	34	822,0	323	809,8	8	787,5	6	738,8	27	867,3	10	906,9	69
1977	♂	413,2	8	475,4	13	491,8	2	440,0	72	415,3	3	536,5	4	440,0	4	429,3	3
	♀	772,8	25	781,0	19	737,2	11	782,2	276	719,1	5	815,1	8	831,9	25	771,5	11

TABLE 2 - Catch per unit effort (100 hours fishing beamtrawl) in kgs. with a correction for fishing power.

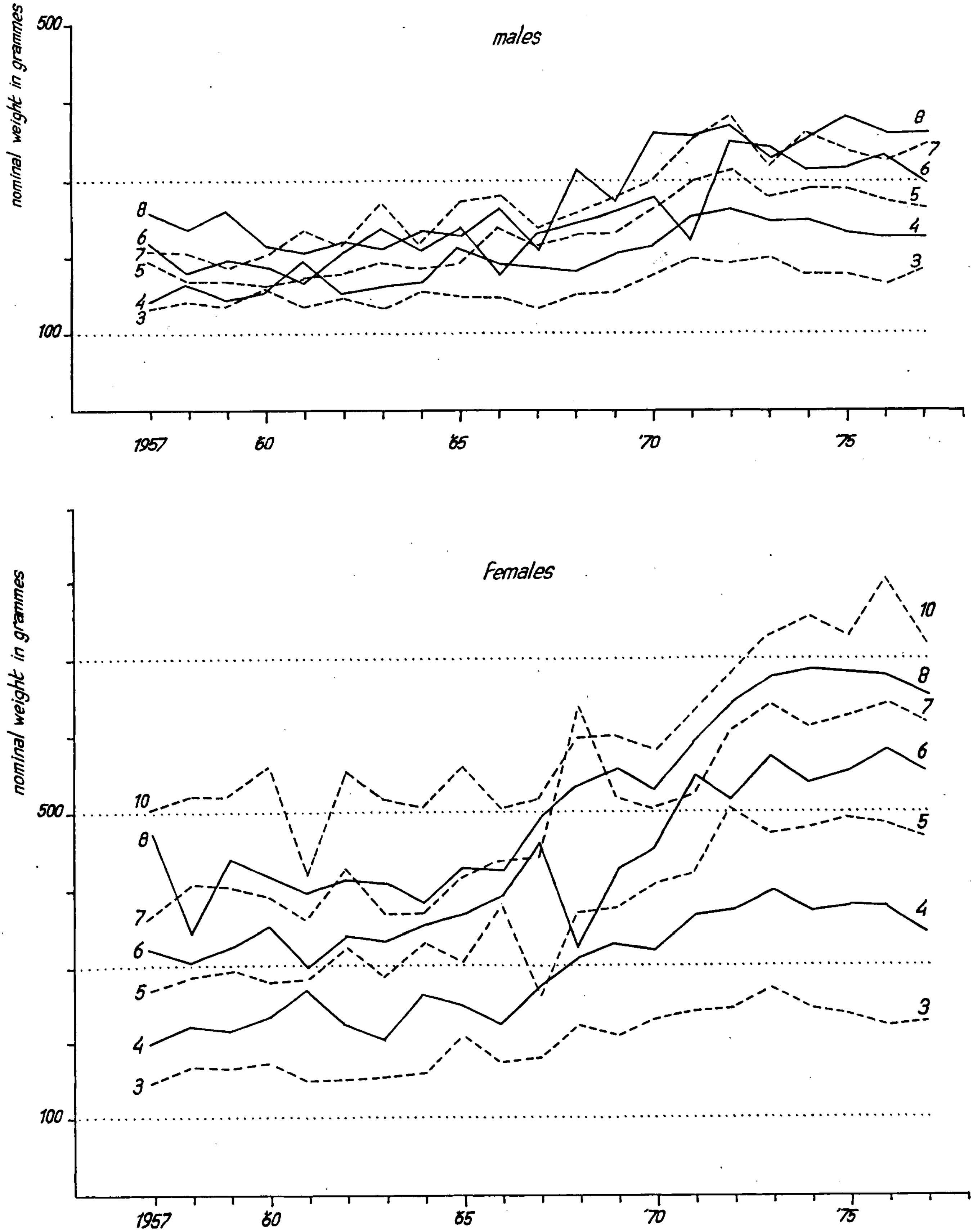
	1962	1963	1964	1965	1966	1967	1968	1969
c.p.u.e.	3647	1958	1468	1850	3957	3158	2701	2592
c.p.u.e. corrected for fishing power	3647	1958	1468	1850	3695	2763	2225	2016

	1970	1971	1972	1973	1974	1975	1976	1977
c.p.u.e.	1657	1727	1597	1180	1076	969	814	868
c.p.u.e. corrected for fishing power	1221	1209	1065	751	685	617	518	553

correction factor for fishing power beamtrawl (1962 = 1)

1962 - 1	1967 - .95	1972 - .76	1977 - .55
63 - 1	68 - .90	73 - .73	
64 - 1	69 - .84	74 - .67	
65 - 1	70 - .80	75 - .62	
66 - .97	71 - .77	76 - .56	

Fig. 1 nominal weight at age in North Sea Sole



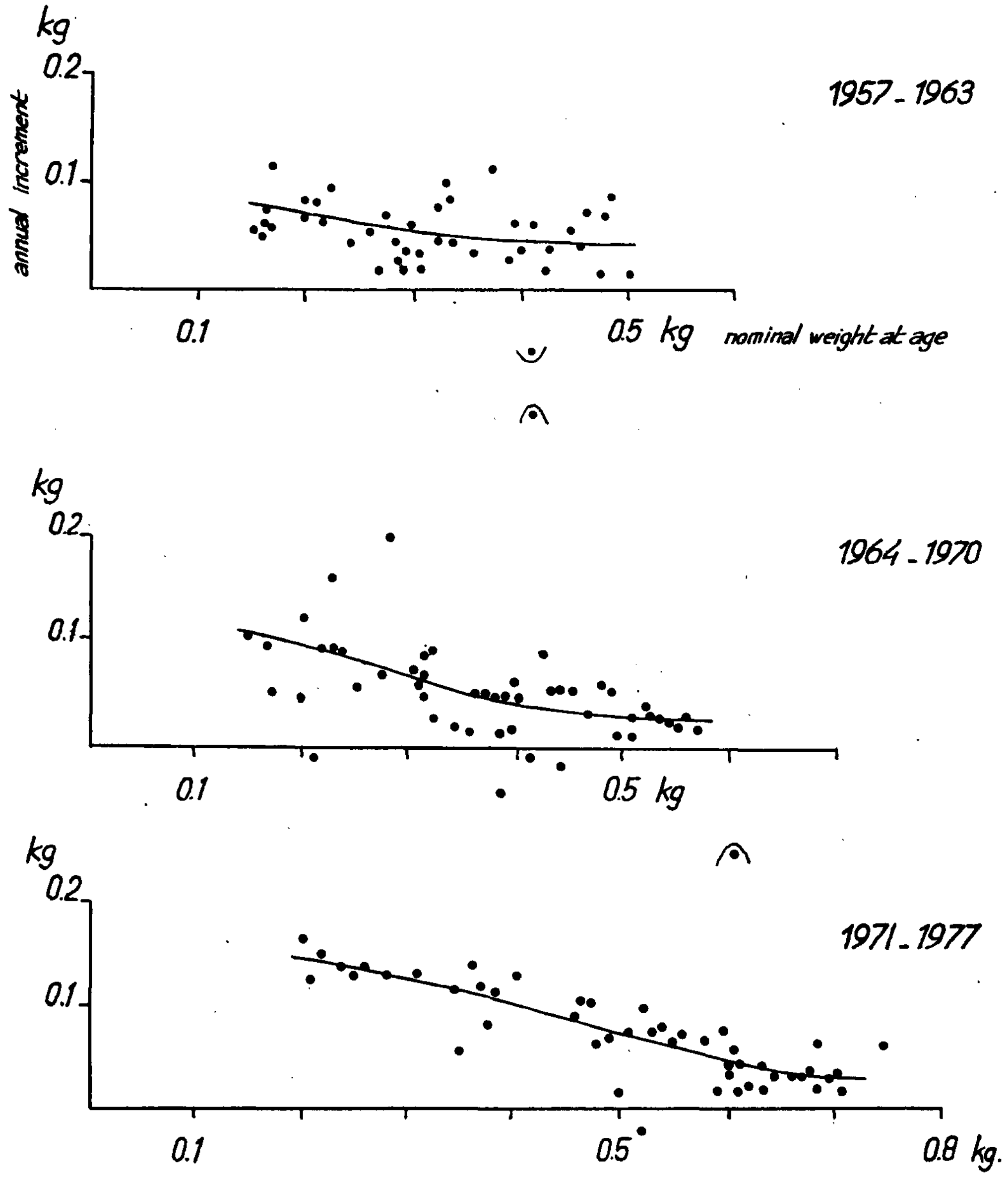


Fig. 2 relationship between annual growth increments and mean nominal weight at age in female North Sea Sole

Fig. 3

Female North Sea Sole

weight at age per yearclass

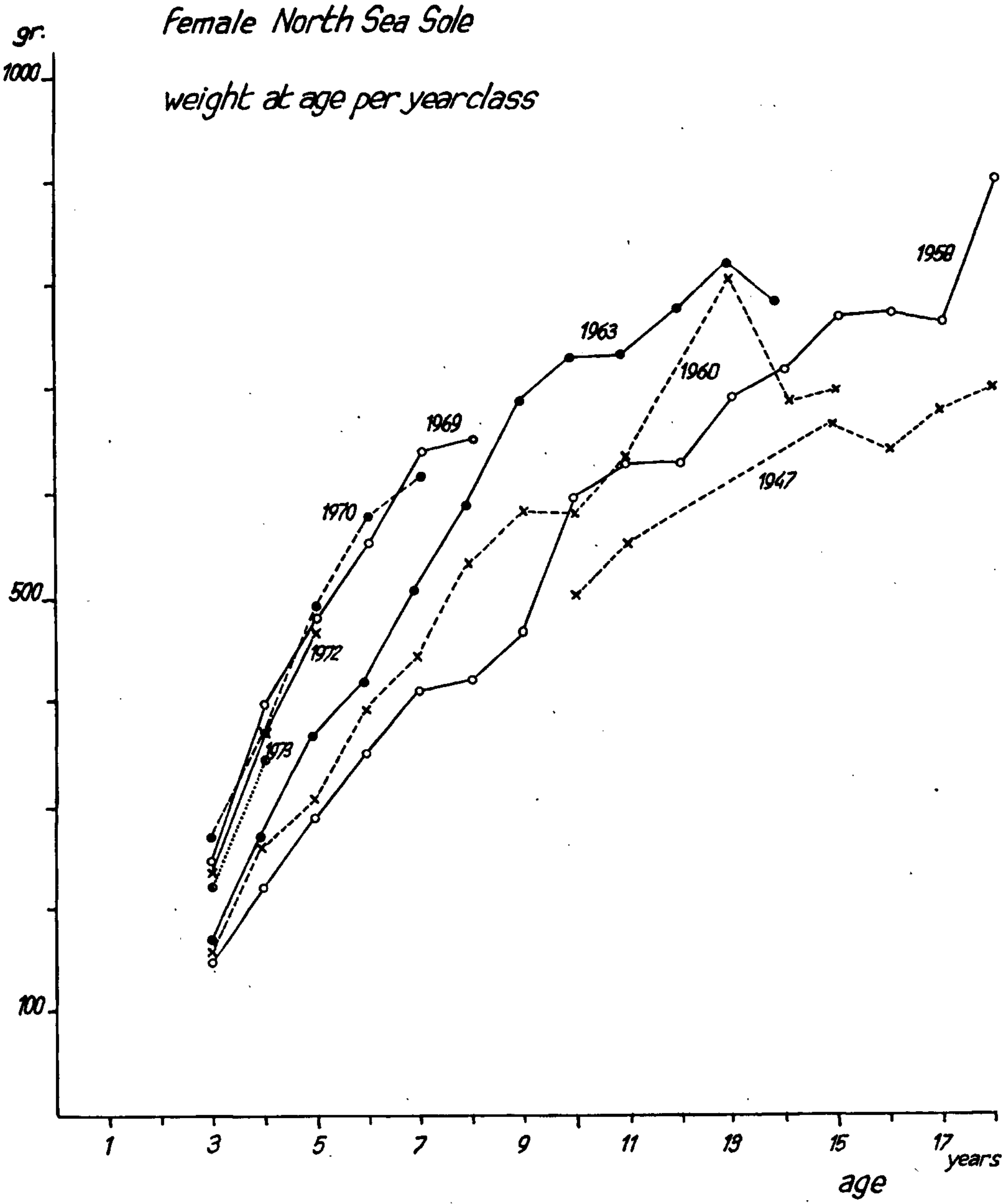


fig. 4a total international effort in equivalent otter trawl fishing hours

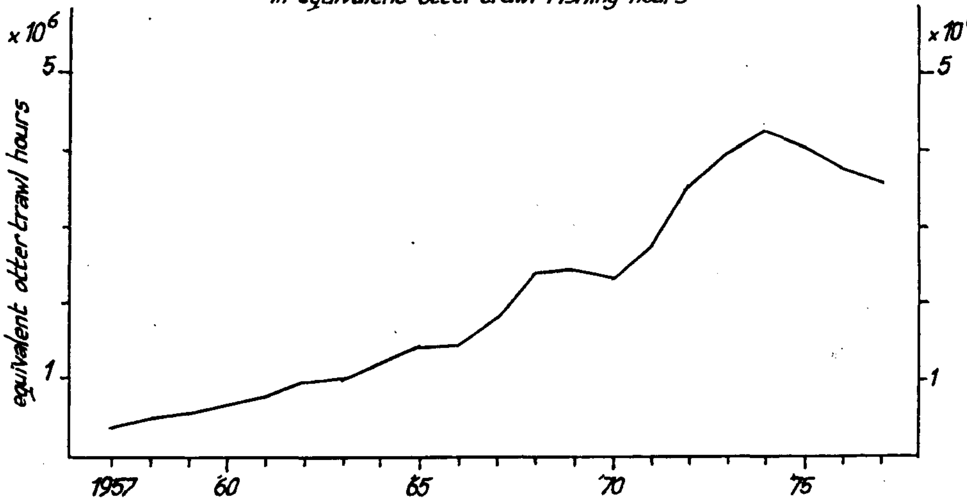
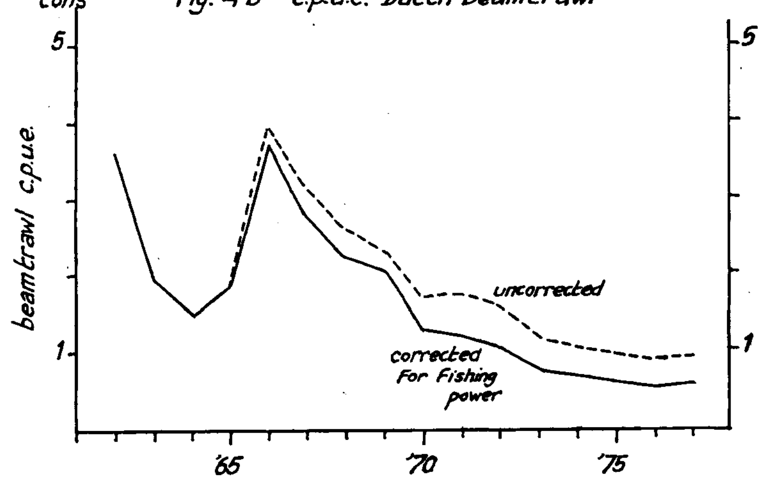


fig. 4b c.p.u.e. Dutch beamtrawl



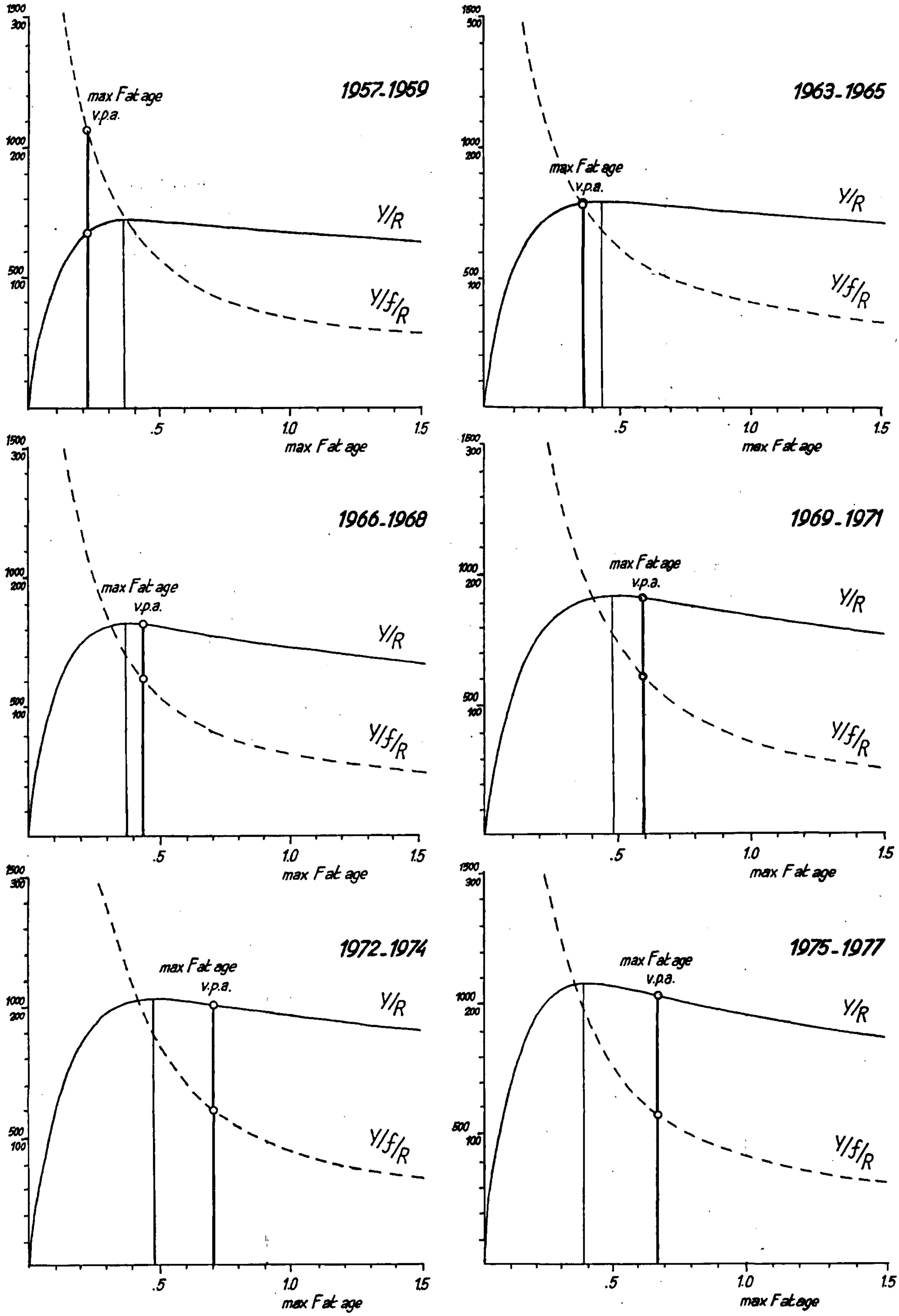


Fig. 5 yield and yield per effort per recruit curves for F varying with age against max. F at age

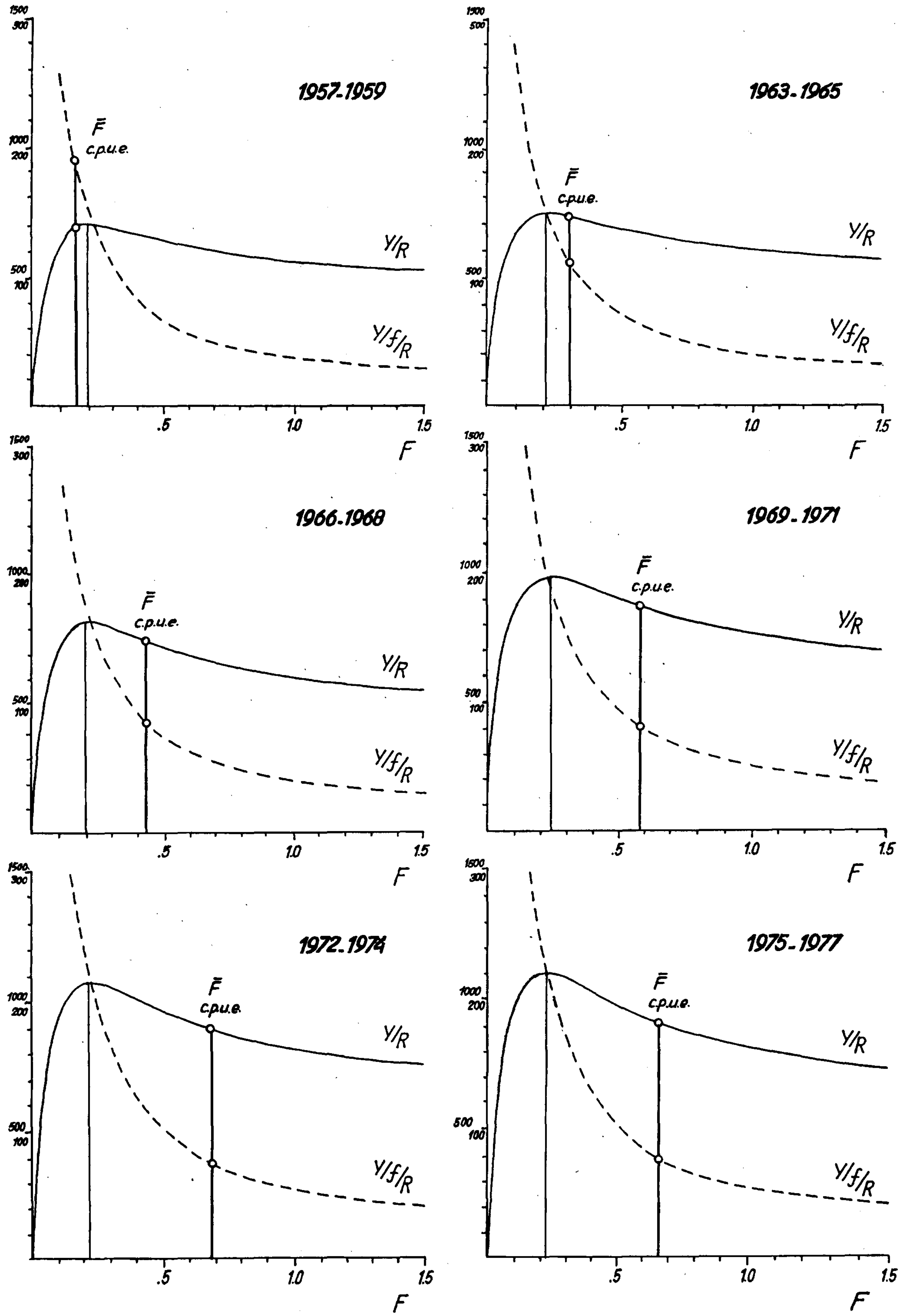
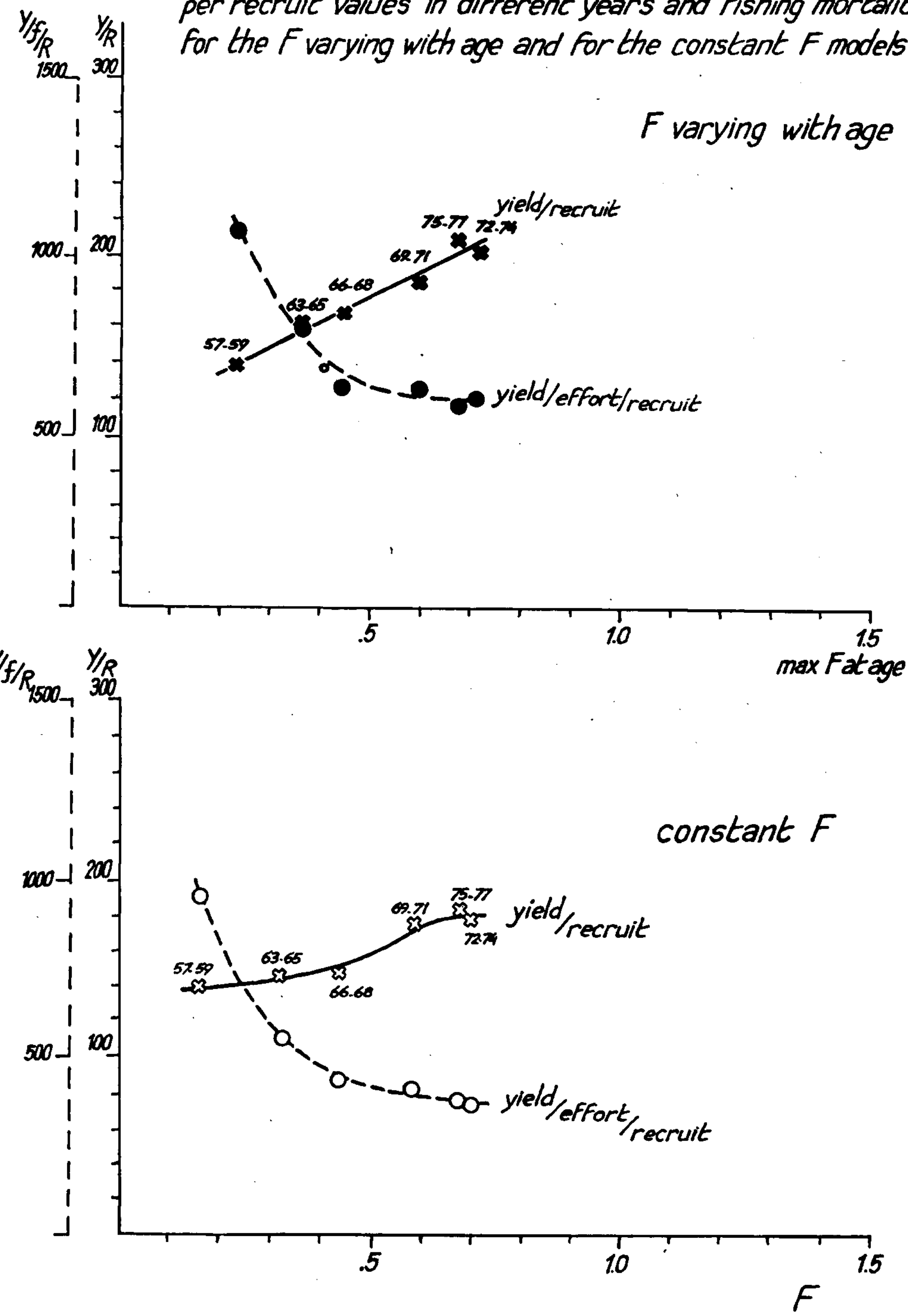
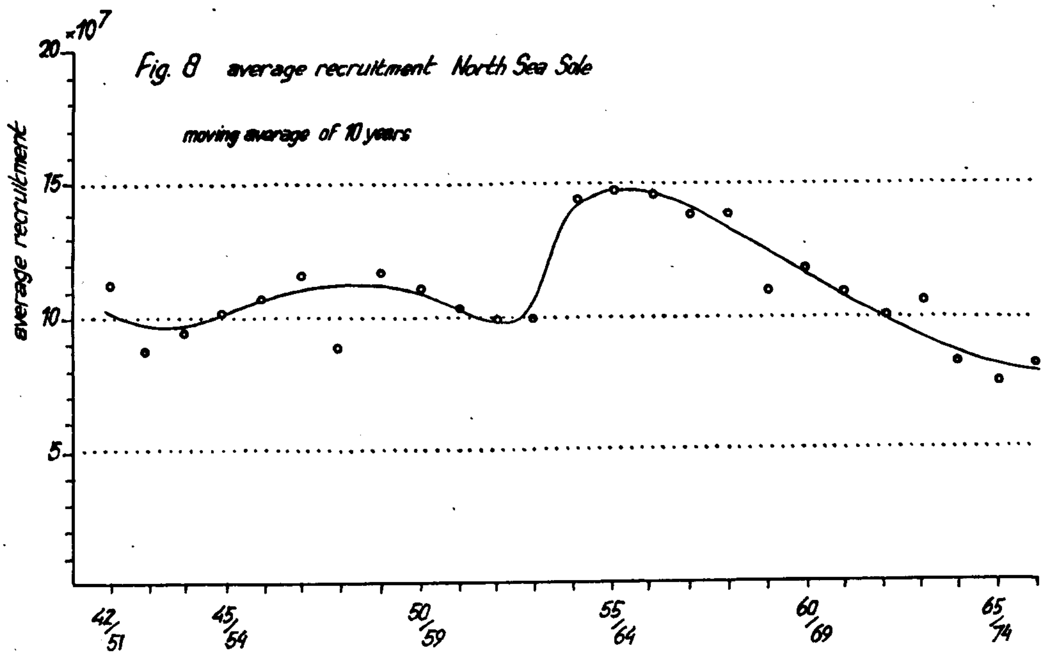


Fig. 6 yield and yield per effort per recruit curves for constant F at age

Fig. 7 relationship between observed yield and yield per effort per recruit values in different years and fishing mortality for the F varying with age and for the constant F models





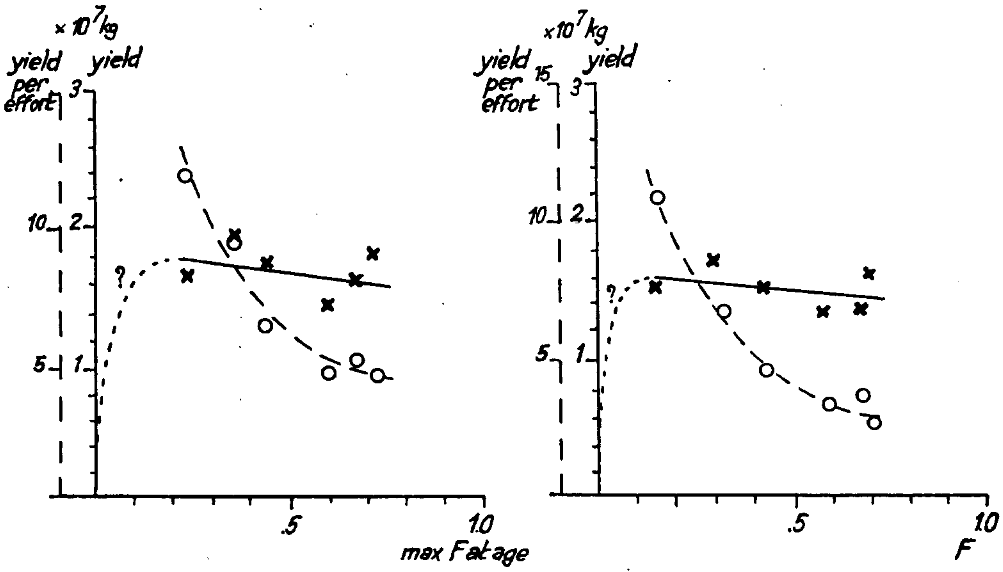
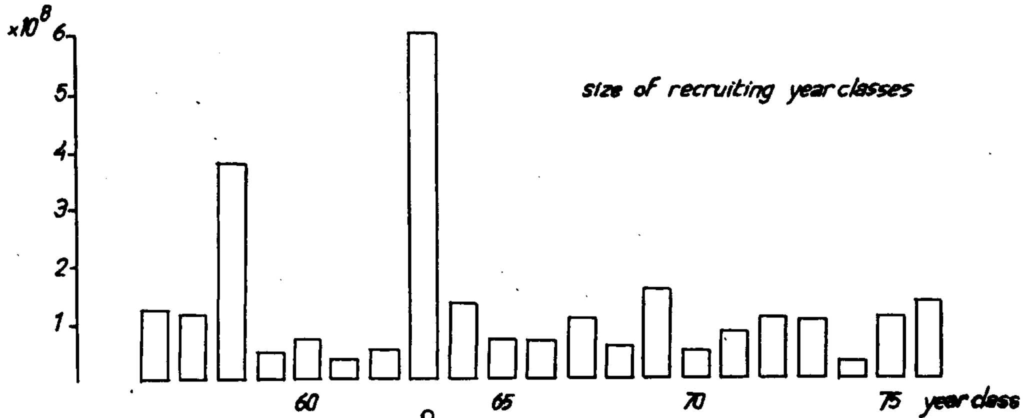


Fig. 9 relationship between observed yield and yield per effort and fishing mortality for F varying with age and constant F models

Fig. 10


×10^8
6
5
4
3
2
1
size of recruiting year classes
60
65
70
75
year class

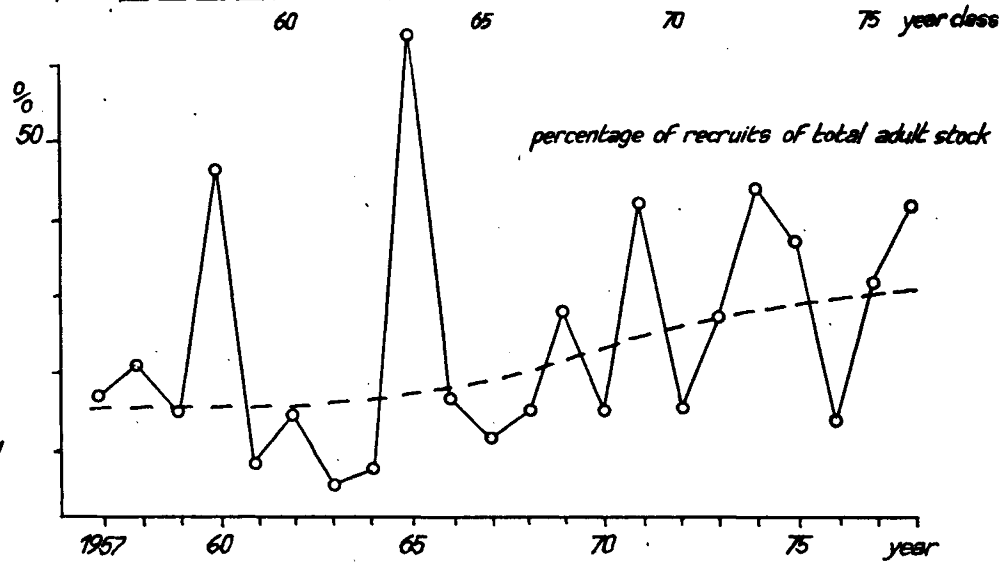

%
50
percentage of recruits of total adult stock
1957
60
65
70
75
year

Fig. 11