"Fecundity in the North Sea herring"

by

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Differences in fecundity between herrings have been noted by several workers. These differences are at least partly related to length or weight of the fishes, as was pointed out by Jenkins (1902) and as could be confirmed by several other investigators.

Apart of this variation in fecundity related to length, marked differences in egg-production were found between herrings, spawning in different regions and seasons. As to the causation of these differences nothing definite is known. Kändler and Dutt (1958) suggested a difference in environmental factors as a possibility, whereas Baxter (1958) mentioned a possible genetical causation.

The fecundity studies, discussed below, were started with the intention to gain information on the egg-producing capacity of some spawning populations of North Sea herring, this in connection with numbers of larvae produced. It was hoped, however, that these data might also give some further insight in the relationship between the different spawning groups.

The material used in these studies was collected in the years 1954-1957, and originate from the following regions and months:

Area	Months	Years	Number investigated
Dogger area	September-October	1954-1957	160
East-Anglian area	October-November	1954 & 1956	99
Sandottié area and eastern English Channel	November-December	1955-1957	73

Although ovaries in stage VI would have been the most suitable for our purposes, we considered that we could not be absolutely sure, that ovaries in this stage had not lost already some eggs. We therefore decided to use only material in stage V, although this introduces an uncertainty about the grounds, where the collected specimens intented to spawn.

Two different techniques we used for counting the egg-number in the ovaries. For both techniques the ovaries were preserved in formaldehyd of approx. 3%. For working up the 1955-1957 material use was made of the counting technique described by Simson (1950). For the 1954 material, a different technique was applied in which one first weighed the whole wet ovary and next 5 small samples. The 5 samples were then counted and the egg-numbers thus found raised by the ratio total weight/weight of samples in order to get the total number of eggs.

From all herrings collected length and age were determined; in many cases the weight too has been recorded.

Results:

The main relationship studied was that of length and fecundity. This relationship was calculated as an exponential equation ($y = a\ x^{b}$). As these equations did not seem to describe the relationship satisfactorily as will be pointed out below, we also calculated the average fecundity per cm-group (cm-below).

The length-fecundity relation was studied:

a. for each spawning ground, comparing fecundities in different areas of the North Sea;
b. for separate age-groups;
c. for separate sampling years.

Finally, for each spawning ground the fecundity-weight relation was calculated as a linear equation. No statistical tests were applied to judge whether the differences found were significant.

a. Length-fecundity relation in different spawning areas:

Calculated as exponential equations the relationship between length and fecundity is described by the following formulae:

Doggerbank area	: $F = 0.00060\ L^{5.5211}$	$(n = 160)$
Southern Bight	: $F = 0.00985\ L^{4.5922}$	$(n = 172)$
East-Anglian area	: $F = 0.01247\ L^{4.5314}$	$(n = 99)$
Sandettié and eastern English Channel	: $F = 0.00431\ L^{4.8276}$	$(n = 73)$

The average fecundity, calculated per cm-group (cm-below), is shown in table I:

	Length in cm									
	22	23	24	25	26	27	28	29	30	31
Buchan spawners x)		34 (3)	39 (4)	53 (6)	55 (8)	76 (6)	85 (13)	96 (11)	98 (5)	77 (2)
Doggerbank	22 (3)	21 (6)	25 (8)	35 (14)	49 (18)	45 (19)	74 (35)	84 (28)	89 (21)	102 (6)
Southern Bight	14 (5)	21 (17)	23 (26)	30 (19)	39 (29)	46 (18)	47 (31)	53 (18)	55 (8)	
East Anglian		22 (11)	24 (20)	29 (12)	39 (21)	44 (10)	49 (12)	56 (7)	52 (4)	
Sandettié E. Channel	14 (4)	19 (6)	17 (6)	33 (7)	39 (8)	49 (8)	46 (18)	51 (11)	57 (4)	

Table I. Average fecundity per cm-group, for different spawning areas of North Sea herring.

x) Data on Buchan spawners after Baxter (1958). Number of observation between brackets.

A priori one could expect the material from the East-Anglian area and that of Sandettié + eastern English Channel to be similar; the data in table I confirm this assumption. In order to increase the number of observations the data on both areas have been combined and recorded under the heading "Southern Bight".

In figure I the relationships between length and fecundity are shown according to the equations, combined with the average fecundity per cm-group. The actual observations are not shown for the sake of clearness.

It may be noticed:

1. that both the equations and the actual observations, expressed as averages per cm-group, point to differences in fecundity between the three groups.

2. that the differences are greatest between Southern Bight and Buchan spawners and that the Dogger data are intermediate, in such a way, that fecundity in the smaller length-groups tends to correspond to that of the Southern Bight, herring, fecundity in the larger length-groups to that of the Buchan spawners.

3. that the calculated equation for the Dogger data is very similar to the one calculated by Kändler and Dutt (1958) for this area and that the regression lines, found by Baxter (1958) and by us for the Southern Bight are in good accordance, as a trial showed us, although the exponential equations

b. Length fecundity relations, for different age-groups.

1. Doggerbank.

The exponential equations have been calculated for the age-groups 3, 4, 5, 6 - 8, over 8, and over 4 years.

3 years	$F = 0.01600$	$L^{4.4866}$	(n= 30)
4 years	$F = 0.1172$	$L^{3.9160}$	(n= 34)
5 years	$F = 0.000,000,000,2132$	$L^{9.985}$	(n= 35)
6 - 8 years	$F = 0.000,00413$	$L^{6.9832}$	(n= 36)
over 8 years	$F = 0.000,6181$	$L^{5.4759}$	(n= 20)
over 4 years	$F = 0.001,514$	$L^{5.2479}$	(n= 91)

The average fecundity, calculated per cm-group, is given in table II.

Table II. Average fecundity, per cm-group, for different age-groups (Doggerbank data). ( ) = number of observations.

	Length in cm									
	22	23	24	25	26	27	28	29	30	31
3 years	22 (3)	21 (6)	25 (8)	32 (9)	44 (3)	46 (1)				
4 years			17 (1)	41 (4)	49 (14)	49 (10)	62 (5)			
5 years					68 (1)	37 (6)	87 (15)	89 (12)	124 (1)	
6 - 8 years						43 (2)	64 (13)	81 (11)	93 (7)	121 (1)
over 8 years								74 (4)	81 (11)	96 (6)

The regression lines with the averaged fecundity-observations per cm-group are shown in fig.2, for age-groups 3, 4 and over 4 years.

2. Southern Bight.

The exponential equations for the length-fecundity relationship, calculated for the age-groups 3-, 4-, 6-8-, and over 4 years, were for this area:

3 years	$F = 0.1914$	$L^{3.6405}$	(n= 55)
4 years	$F = 39.66$	$L^{2.0788}$	(n= 42)
6 - 8 years	$F = 0.01587$	$L^{4.4161}$	(n= 40)
over 4 years	$F = 0.3277$	$L^{3.5495}$	(n= 64)

Calculated per cm-group, the average fecundity for the different year-classes is shown in table III.

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Table III. Average fecundity per cm-group, in different age-groups for the Southern Bight. ( ) = number of observations.

Length in cm

	22	23	24	25	26	27	28	29	30	31
3 years	14 (4)	20 (14)	22 (27)	27 (7)	34 (2)					
4 years				32 (11)	38 (21)	41 (6)	38 (3)			
5 years					43 (6)	44 (3)	53 (4)	42 (2)		
6 - 8 years						52 (7)	47 (18)	53 (11)	51 (4)	
8 years							54 (2)	55 (4)	61 (3)	

The regression lines with the averaged observations for fecundity per cm-group are shown in fig.3.

From the data on the length-fecundity relationship for different age-groups it may be noticed, that

1. the exponential equations, describing the length-fecundity relationships, are different for different age-groups. This is probably partly connected with the length-range of the age-groups, which means that the exponential equations are changing when calculated for different length-ranges. The same is true for the linear regressions, as trials showed us, and which could be expected.
2. the length-fecundity relationship is different for different age-groups. Both the Doggerbank data and Southern Bight data show that fecundity increases with age, at least between 3-5 years. The Doggerbank data suggest, that in herrings over 5-years of age fecundity may fall off again.
3. the length-fecundity relationship for an age-group is different in different areas.

c. Length-fecundity relations in different years.

In order to find out whether the length-fecundity relation was constant, irrespective of the year of sampling, observations of some sampling years have been compared.

Due to the restricted number of observations, it was only possible to compare two years of the Southern Bight material and four years of Doggerbank material.

The calculated equations for Doggerbank were:

Year		
1954	$F = 0.000{,}6767\ L^{5.471}$	n= 27
1955	$F = 0.006{,}273\ L^{4.779}$	n= 44
1956	$F = 0.000{,}8572\ L^{5.361}$	n= 28
1957	$F = 0.006{,}054\ L^{4.888}$	n= 59

The average egg-number per cm-group is shown in table IV.

Table IV. Average fecundity per cm-group, for different observation years (Doggerbank).

Length in cm

Year	22	23	24	25	26	27	28	29	30	31
1954		22 (2)	29 (3)	33 (5)	33 (2)	44 (3)	71 (6)	74 (3)	90 (3)	
1955	19 (1)	26 (1)	25 (2)	36 (3)	35 (4)	43 (7)	62 (6)	73 (8)	77 (10)	88 (2)
1956	23 (2)	16 (2)	22 (3)	32 (3)	32 (1)	46 (7)	45 (6)	90 (3)	120 (1)	
1957		28 (1)		40 (3)	59 (10)	51 (3)	90 (17)	92 (14)	101 (7)	109 (4)

In fig. 4 the calculated regression lines are shown.

For the Southern Bight the equations were:

1954 $F = 0.1182\ L^{3.8385}$ (n= 51)

1956 $F = 0.0016\ L^{5.1661}$ (n= 48)

In table V the averaged number of eggs per cm-group (cm-below) are given.

Table V

Length in cm

Year	22	23	24	25	26	27	28	29	30	31
1954		20 (5)	24 (9)	32 (7)	36 (12)	40 (5)	45 (8)	56 (2)	47 (3)	
1956	14 (1)	22 (6)	24 (11)	24 (5)	42 (9)	48 (5)	57 (5)	57 (5)	70 (1)	

The calculated regression-lines are shown in fig. 5.

A comparison of the observations on fecundity in different years reveals, that the data correspond very closely indeed, so that there is virtually no reason for assuming yearly differences of some importance. The only exception could be the material from the year 1957 in the Dogger-area, which shows rather high fecundities for the whole length-range compared with the observations in 1954-1956. This could perhaps be due to an age-question, as follows from the data presented above. Therefore the fecundity-length relation has been analysed for those age-groups where the available material permitted it, comparing the years 1954-1956 with the year 1957 (see table VI).

Table VI. ( ) = number of observations.

Age	Length-group	period 1954-1956	1957
4 years	26 cm	34 (5)	57 (9)
5 "	28 cm	62 (4)	96 (11)
5 "	29 cm	73 (3)	95 (9)
6-8 "	28 cm	62 (3)	73 (3)
6-8 "	29 cm	74 (6)	90 (5)
6-8 "	30 cm	86 (3)	99 (4)

From the data in the table it follows that even after eliminating the factor age the year 1957 still shows higher fecundity figures.

d. Fecundity-weight relation.

The fecundity-weight relations have been investigated for the material from the Doggerbank region and for the Southern Bight material. The weight-fecundity relation appears to be linear, the computed regressions equations are:

Doggerbank area $F = 490\ W - 30400$

Southern Bight $F = 325\ W - 14500$

In fig. 6 the regression lines are given, together with the regression lines for the Buchan spawners, calculated by Baxter (1958).

As to the length-fecundity relation, the Doggerbank material appears to be intermediate between the Southern Bight with a lower, and the Buchan area with a higher fecundity.

The equation, found here for the Dogger area, differs somewhat from the one given by Kändler and Dutt (1958) for the same area, showing a slightly higher fecundity. The equation for the Southern Bight, too, gives a somewhat higher fecundity as the one calculated by Baxter (1958).

Discussion:

The fecundity of North Sea herring, spawning off the Scottish coast in August down to the Eastern part of the English Channel in December, seems to decrease gradually during the spawning season. An irregularity in this gradual decrease, however, is found in the fecundity of the herring from the Dogger area, where the fecundity in the lower length-range is similar to that of the Southern Bight herring, but in the higher length-range to the Buchan spawners. This gives the impression, that the Dogger herring with regards to fecundity forms a mixture between young Southern Bight stock and older Buchan stock. When indeed the Dogger-stock forms a mixture with regards to fecundity, this peculiar point in the length-fecundity relation of the Dogger herring would be explained, when young Dogger herring were living with Southern Bight herring in the same environment, whereas the older and larger fish of the Dogger group stays with the Buchan spawners, provided the environment is responsible for the differences in fecundity.

When genetic factors were the cause of the differences, the aberrant length-fecundity relation of the Dogger herring would point to a gradual southwards migration during the life-time of the North Sea herring. There are, I think, no other indications of such a migration. Besides, it is hard to see how genetic differences could be maintained in this case.

The possibility remains, however, that the peculiar length-fecundity relation of the Dogger herring is inhaerent to this stock.

We must mention furthermore the possibility, that especially the young specimens of the herring, collected in the Dogger region in stage V, do not spawn on the Dogger at all but belong to the Southern Bight groups, the members of which migrate through the Dogger area in September-October, i.e. in the months of sampling. Although this does not seem very probably, of herring females of the same length increases. For the Dogger herring there is an indication of a reduction of the fecundity later, at an age of 5 or 6 years, pointing possibly to senescens. In the length-fecundity relations of both the Buchan stock (Baxter) and the Southern Bight herring a decrease of fecundity at the end of the length-range may be noted, pointing to the same phenomon. Farran (1938) mentions for the Irish Sea herring too a reduction of the fecundity in large herrings.

The dependance of fecundity on both age and length makes the description of the relationship length - fecundity by a rather simple formula less valuable. The obtained equation is influenced by the age-composition of the analysed sample and different equations may be obtained from samples of varying age-compositions of the same herring groups.

In the material analysed in this investigations one indication was found of a possible influence on fecundity of conditions prevailing in the year of sampling. Although technical inaccuraties are very slight at most, we have no means to check this exceptional observations, b y lack of material. We therefore would like to see this one case confirmed in the future before giving any definite comment.

Summary:

Fecundity in the North Sea herring, spawning in the northern North Sea in summer, down to the southern part of the North Sea in winter, is decreasing with the advancement of the spawning season. An irregularity was noted in the length-fecundity relation of the Dogger herring, compared with those of the Buchan grounds and the Southern Bight spawners.

Apart of length and area, age seems to have an influence on fecundity. With increasing age fecundity goes up. There are indications of a decrease in fecundity at still higher ages and, at the end of the length-range of the herring investigated.

One instance is given where conditions in the year of sampling seems to have influenced fecundity.

References:

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Simpson, A.C. (1951): "The fecundity of the plaice". Fish. Invest., Lond., 17 (5), pp.27.

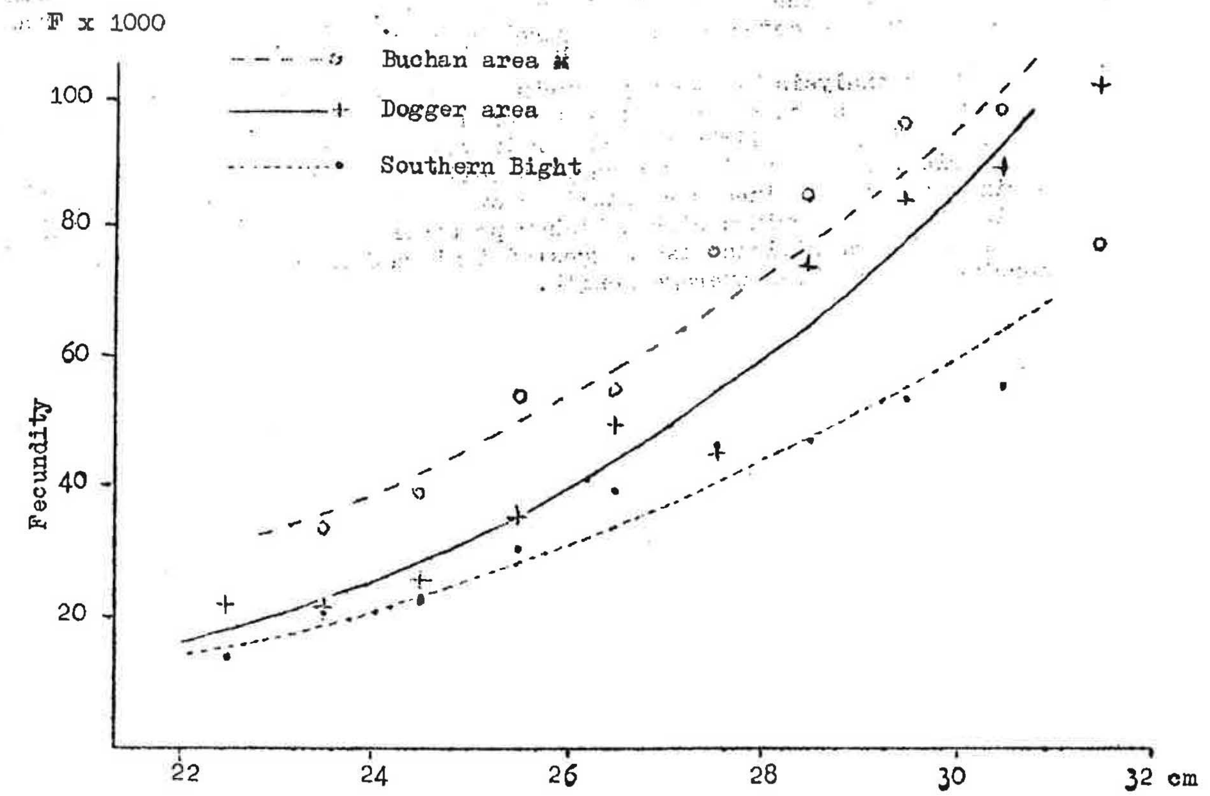
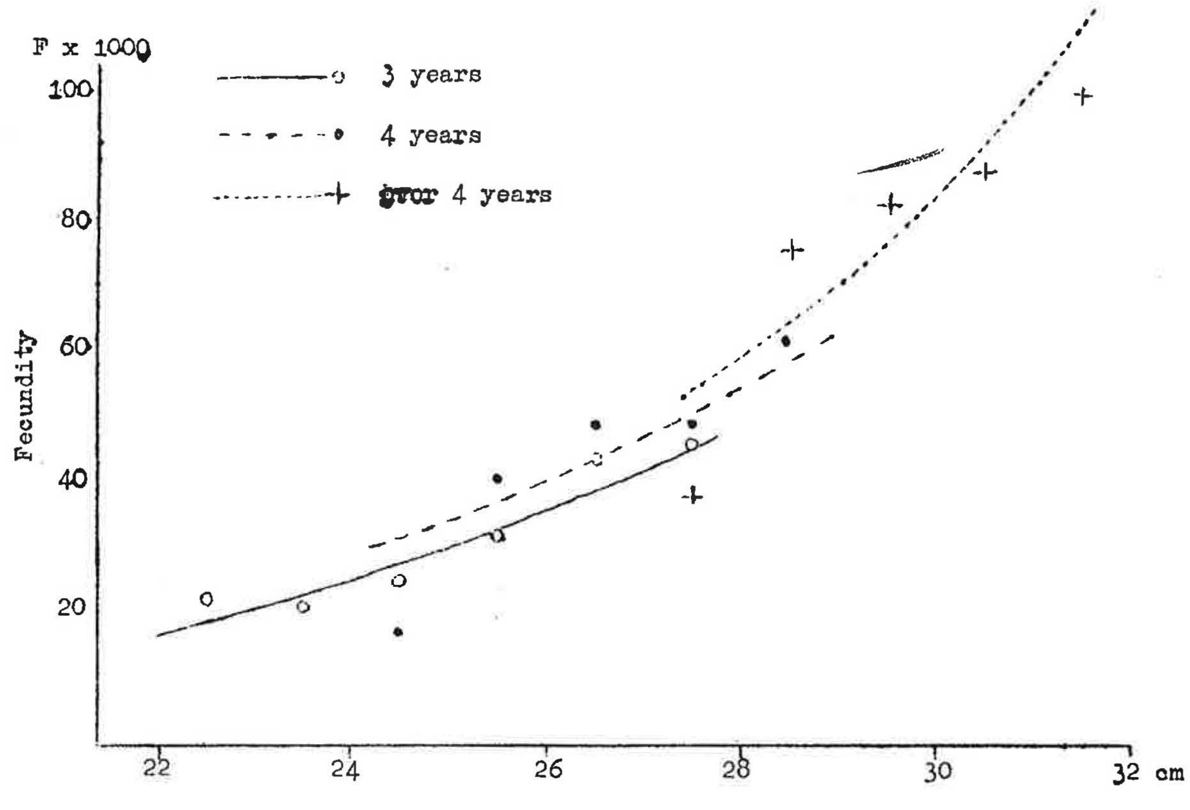


Fig. 1. Length-fecundity relations for three spawning areas of North Sea herring. Actual observations averaged per cm-group. (* Data for Buchan area after Baxter (1958)).



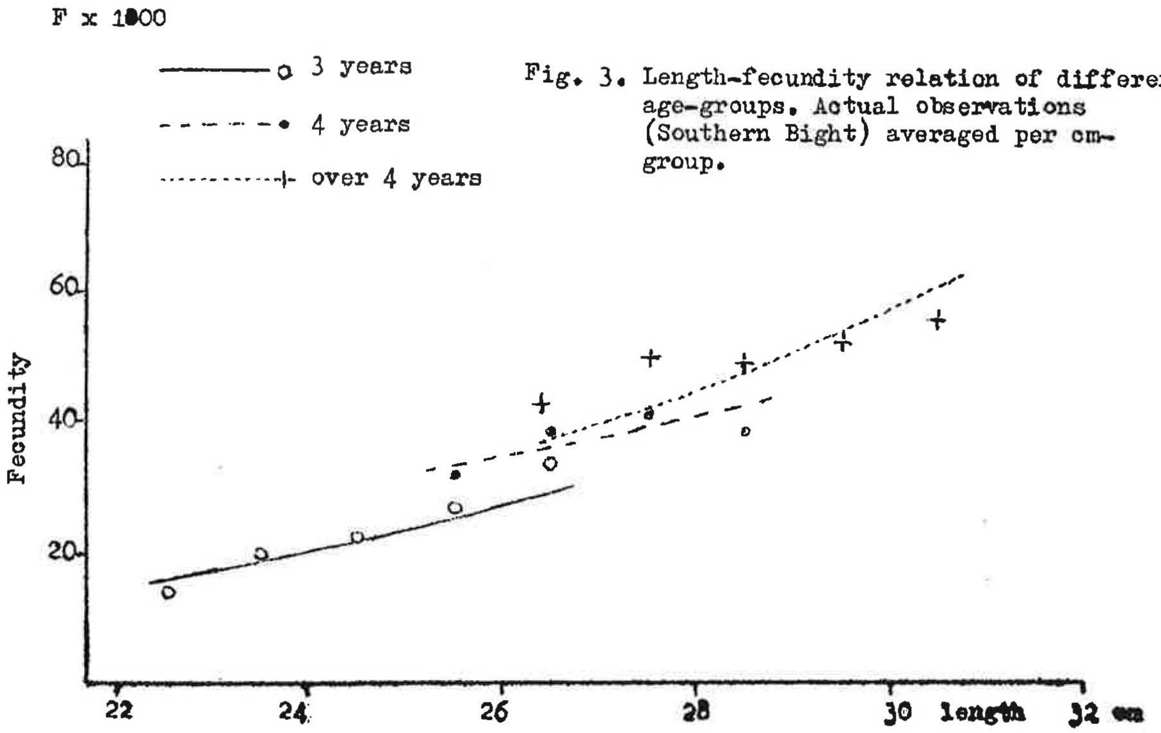


Fig. 3. Length-fecundity relation of different age-groups. Actual observations (Southern Bight) averaged per cm-group.

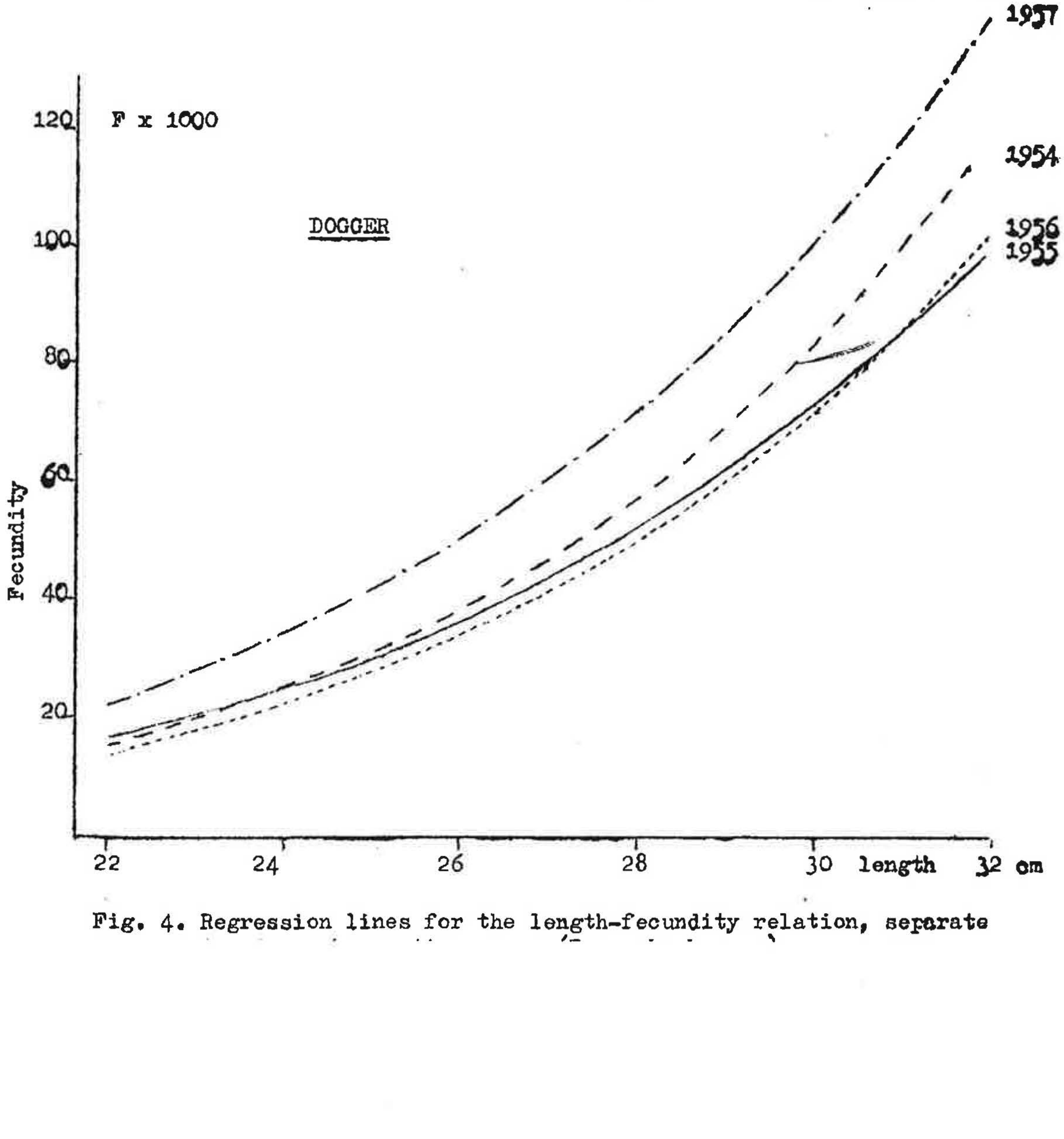


Fig. 4. Regression lines for the length-fecundity relation, separate

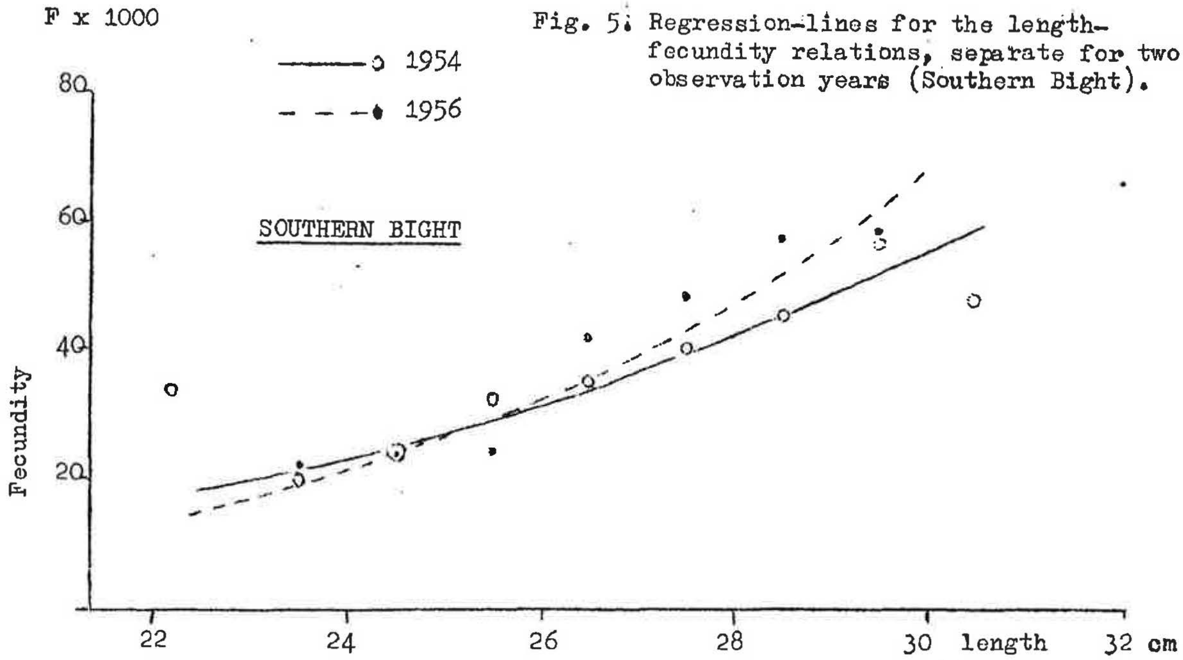


Fig. 5. Regression-lines for the length-fecundity relations, separate for two observation years (Southern Bight).

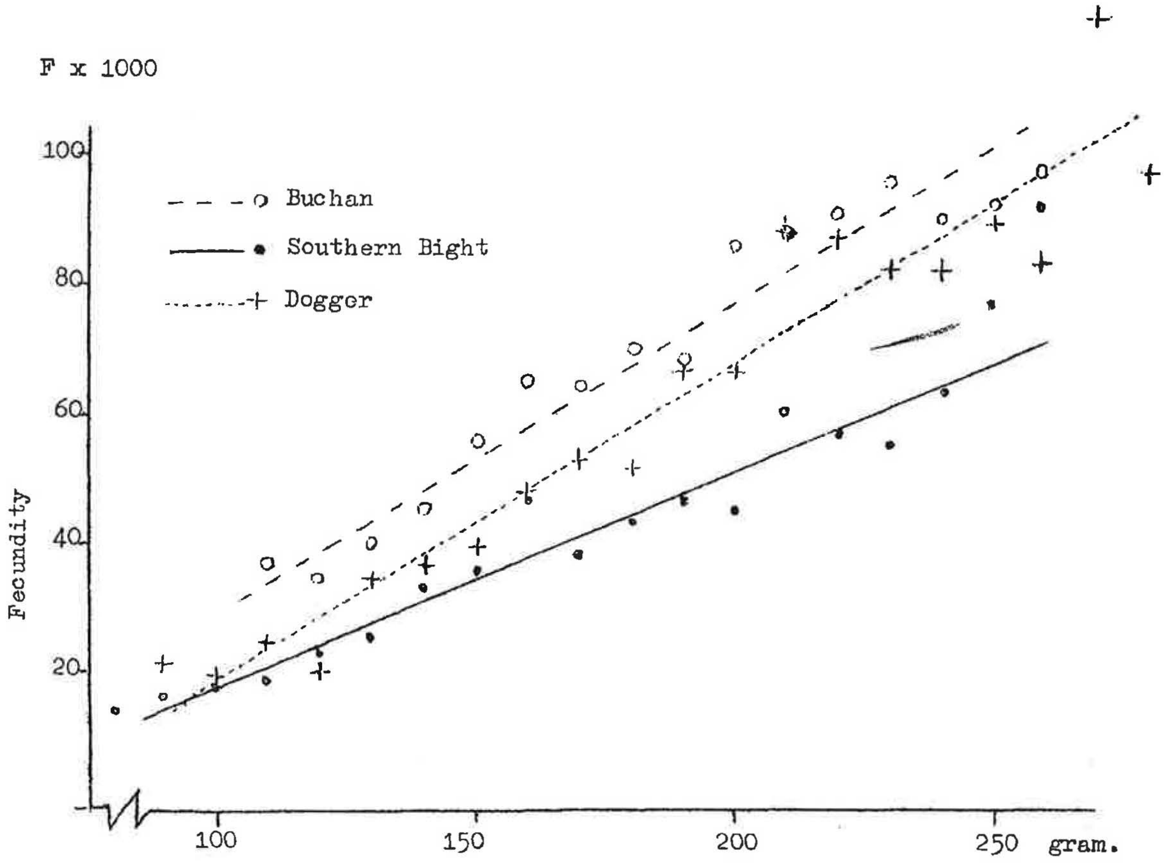


Fig. 6. Weight-fecundity relation for three North Sea areas (Buchan-data after Baxter 1958). Observation given as averaged fecundity per 10 gr-groups.