J. mar. biol. Ass. U.K. (1957) 36, 377–382
Printed in Great Britain

ANNUAL VARIATIONS IN FISH FECUNDITY

By T. B. Bagenal
The Marine Station, Millport

The variation in the fecundity of a fish species from year to year has not received much attention, although the changes in the numbers of young fish in the plankton are well documented for the Plymouth area (Russell 1930–47; Corbin, 1948–51). The most important work considering fecundity fluctuations is that of Simpson (1951) who, working on Plaice, *Pleuronectes platessa* L., concluded that during 1947, 1948 and 1949 there was a steady decrease in the number of eggs laid, this being due to a decrease in the mean size of the spawning fish which he showed to be correlated with the egg numbers. Simpson's interest in the fecundity was to provide a more accurate estimate for determining the number of plaice in the total population from planktonic egg surveys similar to the work of Buchanan-Wollaston (1923). He did not consider in detail whether the fecundity for a given length might change from year to year. It is this problem which will be considered here. Estimates of fecundity of Long Rough Dabs, *Hippoglossoides platessoides* (Fabr.), will be analysed, and Simpson's Plaice data will also be considered.

MATERIAL AND METHODS

The fecundity of the fish is defined, for the purposes of this paper, as the number of eggs in the ovary before spawning.

The data for Plaice are taken from the admirably complete appendix I given by Simpson (1951), where full details are presented for Plaice caught in the North Sea Southern Bight during 1947/48 and 1948/49.

The data for Long Rough Dabs for 1954 are given in table 30, appendix 4, of Bagenal (1957) and for 1955 and 1956 in the Appendix of this paper (p. 382). The details of sampling methods and subsequent laboratory treatment of the fish, together with particulars of the storage, subsampling, counting of the eggs and statistical analysis are all given in the earlier paper (Bagenal, 1957).

I would like to thank Miss Sheila Morris who counted the eggs and did much of the computation, my wife for statistical advice and the master and crew of M.V. *Calanus* who caught the fish.

LONG ROUGH DAB FECUNDITY IN 1954, 1955 AND 1956

The mean length, weight, age and fecundity are given in Table 1 for fish caught in 1954, 1955 and 1956, together with the expected weight ($\hat{W}$) of a fish 22 cm long. $\hat{W}$ has been calculated from the log length–log weight relation and may be taken as a measure of the condition of the fish (Le Cren, 1951; Bagenal, 1957).

The expected fecundity ($\hat{F}$) of a 22 cm Long Rough Dab is also given for each year and has been calculated from the log length–log fecundity relation (Bagenal, 1957). The results of the statistical analysis are given in Table 2 and show that the fecundities, even after allowance has been made for the length differences, differ significantly at the 1 % level from year to year. The condition, as shown by expected weights, for fish of 22 cm is also significantly different over the three years, and it is of interest that the ranked order is the same for condition and fecundity.

TABLE 1. SUMMARY OF DATA GIVEN IN TABLE 5

Year	1954	1955	1956
Number of fish	116	12	23
Mean length (cm)	21·85	21·04	22·70
Mean weight (g)	72·06	55·54	79·53
Mean age (years)	3·2	4·2	3·7
Mean fecundity	90,341	68,292	98,339
$\hat{W}$ for 22 cm	73·65	64·32	71·74
$\hat{F}$ for 22 cm	92,238	78,468	89,193

TABLE 2. ANALYSIS OF COVARIANCE OF LENGTH AND FECUNDITY DATA FOR LONG ROUGH DABS IN 1954, 1955 AND 1956

Source	Sum of squares	D.F.	Mean square	F	Significance
Due to total regression	19·043581	1	19·043581	1466·1	**
Difference between 'means regression' and 'average within years regression'	0·034180	1	0·034180	2·67	N.S.
Deviations of means about 'means regression'	0·099176	1	0·099176	7·75	**
Between adjusted fecundity means	0·133356	2	0·066678	5·22	**
Between years regression coefficients	0·043802	2	0·021901	1·71	N.S.
Total deviations about years regressions	7·642091	598	0·012779	—	
Average within years regression	7·685893	600	0·012801	—	
Deviations about total regression	7·819249	602	0·012989	—	
Total	26·862830	603	—		

** indicates significance at 1 % probability level.
* indicates significance at 5 % probability level.
N.S. indicates not significant.
The degrees of freedom are based on four counts for each fecundity estimate.

The large mean square for the deviations of the means about their regression, when contrasted with the very large mean square due to total regression and the smaller mean square after adjustment to a common length, emphasizes the utility of an analysis of covariance based on all the data.

PLAICE FECUNDITY IN 1947/48 AND 1948/49

The fecundity data given by Simpson (1951) for Southern Bight North Sea Plaice caught in 1947/48 and 1948/49 are summarized in Table 3.

The mean weights are based on the gutted weight minus ovary weight, as with the Long Rough Dabs, and the 'condition' ($\hat{W}$) also applies to somatic tissue only. The mean age is calculated assuming the queried ages Simpson gives were correctly assessed; to ignore the doubtful otolith readings would introduce bias since older fish are the most difficult to age.

TABLE 3. SUMMARY OF SIMPSON'S DATA ON PLAICE FECUNDITY IN THE SOUTHERN BIGHT IN 1947/48 AND 1948/49

Year	1947/48	1948/49
Number of fish	169	54
Mean length (cm)	37·14	37·08
Mean weight (g)	515·21	528·37
Mean age (years)	7·28	7·17
Mean fecundity	84,030	87,740
$\hat{W}$ for 37 cm	509·34	525·20
$\hat{F}$ for 37 cm	82,996	87,152

TABLE 4. ANALYSIS OF COVARIANCE OF REGRESSION OF LOG FECUNDITY ON LOG LENGTH

Source	Sum of squares	D.F.	Mean square	F	Significance
Due to total regression	16·348027	1	16·348027	641·80	**
Difference between 'means regression' and 'average within years regression'	0·037850	1	0·037850	1·49	N.S.
Deviations of means about 'means regression'	—	—	—		
Between adjusted fecundity means	0·037850	1	0·037850	1·48	N.S.
Between years regression coefficients	0·007882	1	0·007882	—	—
Total deviations about years regressions	5·583633	219	0·025496	—	
Average within years regression	5·591515	220	0·025416	—	—
Deviations about total regression	5·629365	221	0·025472	—	
Total	21·977392	222	—	—	

The relation of log fecundity to log length has been re-examined by an analysis of covariance, and the results are given in Table 4. A note arising out of this analysis is given in Appendix 2.

The degrees of freedom are based on one fecundity estimate for each fish.

An examination of Tables 3 and 4 show that the decrease in length in the catches over the two years is barely reflected in the data given by Simpson. The general level of fecundity increased, but this is not statistically significant, and Simpson was justified when he pooled the results for the two years. The weights adjusted to a common length are also not significantly different.

DISCUSSION

Simpson was correct in his conclusion that the drop in the mean number of eggs laid per female Plaice in the Southern Bight in 1947, 1948 and 1949 was only due to a decrease in the mean size of the spawning fish. The fecundity adjusted to a given length actually increased, though this was not significant over the two years for which data are given. In Long Rough Dabs from the Clyde area, however, significant changes have been found in the fecundity even after allowance has been made for length differences. If population estimates based on fish egg estimates are made over several seasons one cannot necessarily assume that the fecundity–length relation remains constant. An examination of Tables 1 and 3 shows that fecundity differences cannot be explained by the different age structure of the population.

It may, however, be significant that for the Long Rough Dabs and the Plaice the ranked order of fecundity and condition for the years considered are the same. Within a year (1954) no correlation was found between the condition and fecundity of individual Long Rough Dabs (Bagenal, 1957). Comparisons between years and different localities may help to explain some of the enormous variability in fecundity of otherwise apparently similar fish, and a programme of fecundity estimates of a number of species over several years is being initiated at Millport.

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APPENDIX 1

TABLE 5. THE LENGTH, WEIGHT, AGE AND EGG COUNTS OF FEMALE LONG ROUGH DABS

Fish no.	Total length (cm)	Weight (g)	Age (years)	Egg count 1	2	3	4	Fecundity estimates
				16 March 1955				
2017	25·5	98·0	4	583	646	704	603	126,800
2019	20·0	52·5	4	356	330	358	384	71,400
2020	20·5	51·5	4	313	301	271	305	59,500
2021	20·5	55·0	4	396	395	405	321	75,850
2022	21·0	46·5	4	207	225	191	234	42,850
2039	24·5	86·5	5	273	288	283	277	56,050
2040	17·0	26·5	3	142	186	171	177	33,800
2075	22·0	63·5	4	604	574	605	514	114,850
2076	19·5	36·5	5	243	189	271	235	46,900
2077	19·5	36·0	4	343	326	346	332	67,350
2082	23·0	72·5	5	448	469	367	384	83,400
2083	19·5	41·5	4	190	223	199	203	40,750
				22 February 1956				
1	17·0	25·5	3	158	204	157	158	33,850
2	18·0	33·5	3	231	275	234	186	46,300
3	19·0	38·5	2	241	250	239	234	48,200
4	19·5	44·5	3	289	316	296	279	59,000
5	20·5	58·5	3	376	315	372	340	70,150
6	22·0	76·0	3	429	449	440	396	85,700
7	22·0	70·5	4	392	349	368	408	75,850
8	23·5	87·0	3	589	601	565	577	116,600
9	23·5	96·0	3	716	709	704	759	144,400
10	25·5	103·0	4	629	676	721	636	133,100
11	26·0	110·0	4	760	790	694	835	153,950
12	27·5	151·0	5	958	906	850	842	177,800
13	23·0	77·0	4	362	438	482	368	82,500
14	22·5	68·5	5	518	421	516	478	96,650
15	22·5	67·5	4	328	308	346	252	61,700
16	20·5	48·0	4	349	383	383	470	79,250
17	20·5	45·0	4	270	304	270	315	57,950
18	24·0	81·0	5	396	350	329	428	75,150
19	24·5	92·0	4	424	394	524	452	89,700
20	24·0	94·0	3	586	657	594	539	118,800
21	25·0	117·0	4	927	939	1089	922	193,850
22	25·5	113·5	3	411	427	437	545	91,000
23	26·0	131·0	4	896	762	806	943	170,350

APPENDIX 2

In the analysis of the data the values of fecundity and length were transformed to their logarithms in order to produce a linear relation and to use the standard methods of regression analysis. An interesting point which emerges from the transformation of Simpson's North Sea Southern Bight data is that the geometric mean fecundity is larger for 1947/48, whereas the arithmetic mean fecundity is greater for the 1948/49 winter. The figures are summarized in Table 6. Had the differences between the means for the two seasons been significant, it might have appeared from the analysis that this was a decrease and not an increase. The reason for this anomaly can be seen from the relation between the arithmetic and geometric means for a normal distribution which has been given by Bagenal (1955) and may be written

$$\text{G.M.} = \text{A.M.}/(1+\sigma^2/\text{A.M.}^2)^{\frac{1}{2}},$$

where A.M. and G.M. are the arithmetic and geometric means and σ^2 is the variance. This gives for 1947/48 calculated G.M. = 72,458; for 1948/49 calculated G.M. = 67,126. The discrepancy between the actual and calculated geometric means is probably due to the data not being normally distributed, which is shown by the difference between the range and 6σ (Table 6).

TABLE 6. SUMMARY OF FECUNDITY STATISTICS FOR SOUTHERN BIGHT PLAICE

	1947/48	1948/49
Arithmetic mean fecundity	84,030	87,740
Variance (σ^2)	2,439,500,000	6,764,600,000
Range	332,000	280,000
6σ	296,316	493,500
Mean log fecundity	4·8317	4·7916
Geometric mean	67,874	61,888

It is clear that the difference between the ranked order of the arithmetic and geometric means of the two sets of plaice fecundity data is due to the large difference between the variances.