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FECUNDITY STUDIES ON SPRAT, *SPRATTUS SPRATTUS* L., FROM A FJORD ON THE NORWEGIAN SKAGERRAK COAST.

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ABSTRACT

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Data were collected monthly from sprat caught with trawl in Frierfjord, during January-May in 1985 and 1986. Sprat used ranged from 7 to 15 cm and from 2.1 to 27.9 g. Ichthyoplankton was sampled to follow the spawning progress. Interannual variations in fecundity are indicated, which might depend on differences in spawning stock compositions. Absolute fecundity varied from 3825 to 78955 (mean: 21134) in 1985 and between 2939 and 42822 in 1986 (mean: 12260). Fecundity estimates are based on number of developing oocytes, i.e. equal or larger than 150 µm, assumed to be shed during the spawning season (determinated spawning). The results indicate, however, that the spawning of sprat is indetermined and thus the fecundity estimates are underestimated. Atresia is not considered.

INTRODUCTION

A preliminary estimate of spawning stock biomass of sprat (*Sprattus sprattus*) from egg production in two west Norwegian fjords, Ryfylke and Nordfjord, was made by Torstensen (1984). To estimate spawning stock size from total egg production we need to know the annual fecundity of the species. In the absence of fecundity data on sprat in Norwegian areas, published data from the western North Sea were used (Bailey and Pipe 1977). As considerable differences in fecundity between and within species have been reported (Blaxter 1969), and racial differences in fecundity have been described for several species, it was of interest to collect information on sprat fecundity in Norwegian waters. Studies were therefore, conducted in a fjord area on the Norwegian Skagerrak coast, Frierfjord, where earlier studies have indicated annual sprat spawning (Dannevig 1930, Ellingsen 1979). The aim of the present report is thus

to present estimates of sprat fecundity in a Norwegian fjord area, and from two years surveys, to evaluate changes in fecundity between years.

MATERIALS AND METHODS

The location of Frierfjord is shown in Fig. 1. Sprat were collected from January to May in 1985 and 1986 (Table 1), by pelagic trawl (Engel, 8 x 8 fathoms). Ichthyoplankton was sampled to trace the initiation of the spawning process.

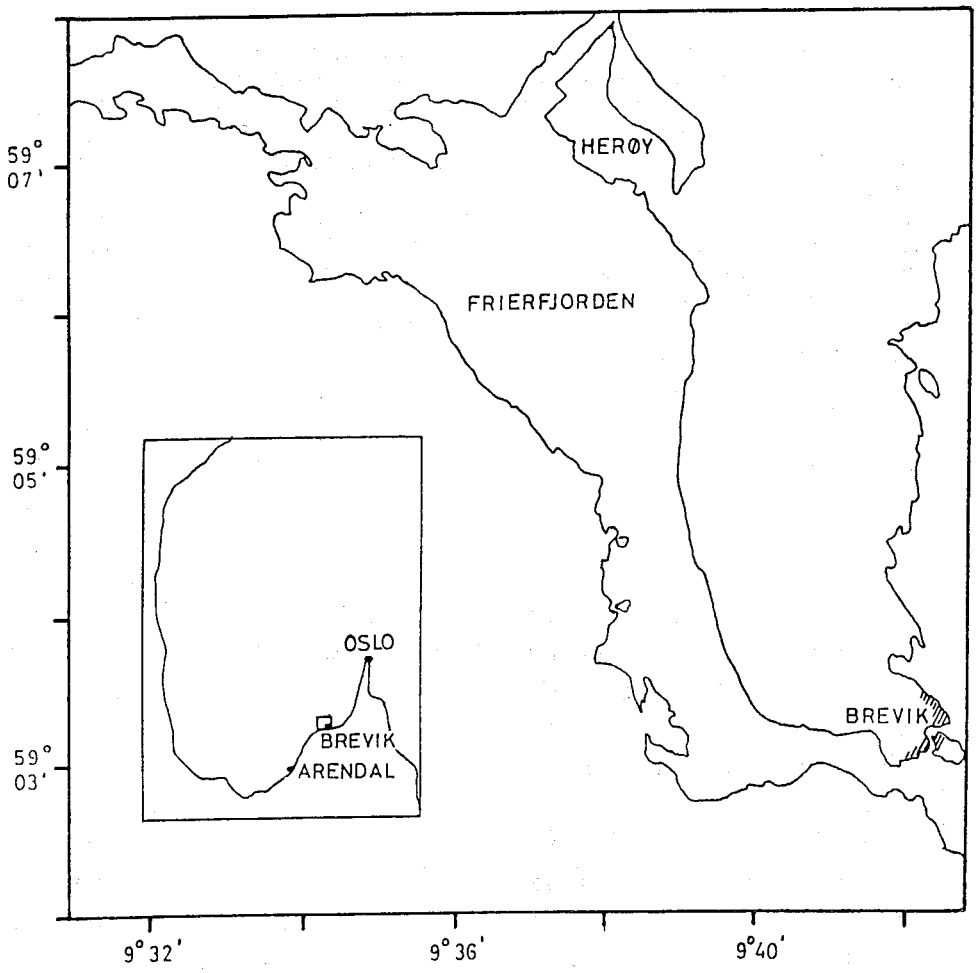

Fig. 1. Location of Frierfjorden on the Norwegian Skagerrak coast

Table 1

Sampling of sprat for fecundity studies, 1985 and 1986.

Coverage	1985	No. of fish	1986	No. of fish
1.	29 January	21	23 - 24 January	12
2.	28 February- 1 March	42	5 - 6 March	31
3.	28 - 29 March	28	19 - 20 March	25
4.	16 - 17 April	17	19 April	11
5.	6 - 7 May	17	5 - 6 May	26

Random samples of fish were measured for length (TL) to the nearest 0.5 cm below and weighed. Age was determined by reading otoliths, and the maturity stage was assessed based on the macroscopic appearance of the gonad (Table 2).

Table 2

Macroscopic characteristics of maturity stages in the ovaries of sprat.

Stage	Macroscopic characteristics
I. Immature	Gonads very small, thread-like.
II. Immature	Gonads thicker, but not possible to distinguish the sexes
III. Immature/ recovering	Ovaries round in section
IV. Ripening	Ovaries beginning to fill the body cavity. Opaque and translucent oocytes visible.
V. Ripe/running	Ovaries soft, translucent oocytes.
VI. Spent	Ovaries empty and flaccid, may contain a few residual eggs. Succeded by stage 3 with which there is over-lapping

A total of 125 (1985) and 105 (1986) ovaries were collected from sprat over a wide size range, from 7 to 15 cm in total length and from 2.1 to 27.9 g in weight. Ovaries in late stage III to V were examined. Few

ripe-running ovaries were caught. As these were losing ripe-mature oocytes during the capture and handling process afterwards, they are not included in the analysis. Methods used for preservation are described in Iversen and Adoff (1983).

Fecundity in the present work is defined as the number of ripening eggs produced by a female in one spawning season (absolute fecundity) or as the number of eggs per unit body weight (relative fecundity). The stock of developing oocytes to be released during the spawning season, is assumed to be defined prior to the spawning season commence (determinated spawning). Sprat is a serial or protandric spawner, with an asynchronous oocyte development, i.e., the ovaries contain oocytes in different development stages. Each sprat is spawning in batches over a period of 2-3 months (Heidrich 1925). Presence of yolk is used as a criterion for separating immature and developing oocytes. Based on histological studies, Bailey and Pipe (1977) defined oocytes with diameter larger than 144 µm as developing. In the present study oocytes with a diameter of 150 µm or larger are considered as developing. The limit of 150 µm is of practical matter,i.e. eyepiece scale.

Three subsamples for fecundity analysis were taken from each ovary, in the anterior, middle and posterior regions. The total ovary, as well as the subsamples, were weighed in the laboratory. Fecundities were determined by raising each subsample count to the total ovary.

Gonadosomatic Scaling Index (GSI) is here defined as the relation between mean weight of gonads and mean total weight.

The statistical analysis used in the present report are described in Zar (1974).

RESULTS

Age and size of sprat

The sprat ranged in total length from 7 to 15 cm, and in weight from 2.1 to 27.9 g. The biological parameters are summarized in Table 3. There was no difference in the mean length between 1985 and 1986, but the mean weight in 1986 was significantly lower than in 1985. This might be explained by the marked difference in age composition between the two years with 1- and 3- age group each making nearly 40% in 1985 and the 2- age group nearly 60% in 1986 (Fig. 2).

Table 3

Biological parameters of sprat used in fecundity studies.

Year	L (cm)	SD (cm)	Range (cm)	W (g)	SD (g)	Range (g)	N
1985	11.13	2.23	7-15	11.03	6.40	2.1-27.9	125
1986	10.91	1.54	8.5-15	8.88	4.45	3.3-23.5	105

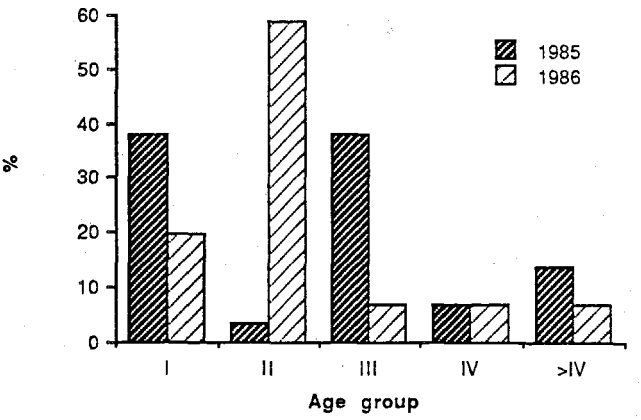

Fig. 2. Age composition of sprat from Frierfjorden in 1985 and 1986, used in the fecundity studies.

Ovary weight

The sprat ovary is elongated and consists of right and left parts. The two parts were weighed separately, and the analysed ovary weights are the sum of the two. In general the left ovary was bigger than the right one, but the difference in weight was not statistically significant (p=0.05).

The gonadosomatic index (GSI) increased during the sampling period (Fig. 3 A) to 6.4 and 5.8% at the end of the sampling period in 1985 and 1986, respectively. Both graphs indicate a small decrease in GSI during the sampling period in late March1985 and April 1986, which might be related to initiation of main spawning season (Fig. 3 B).

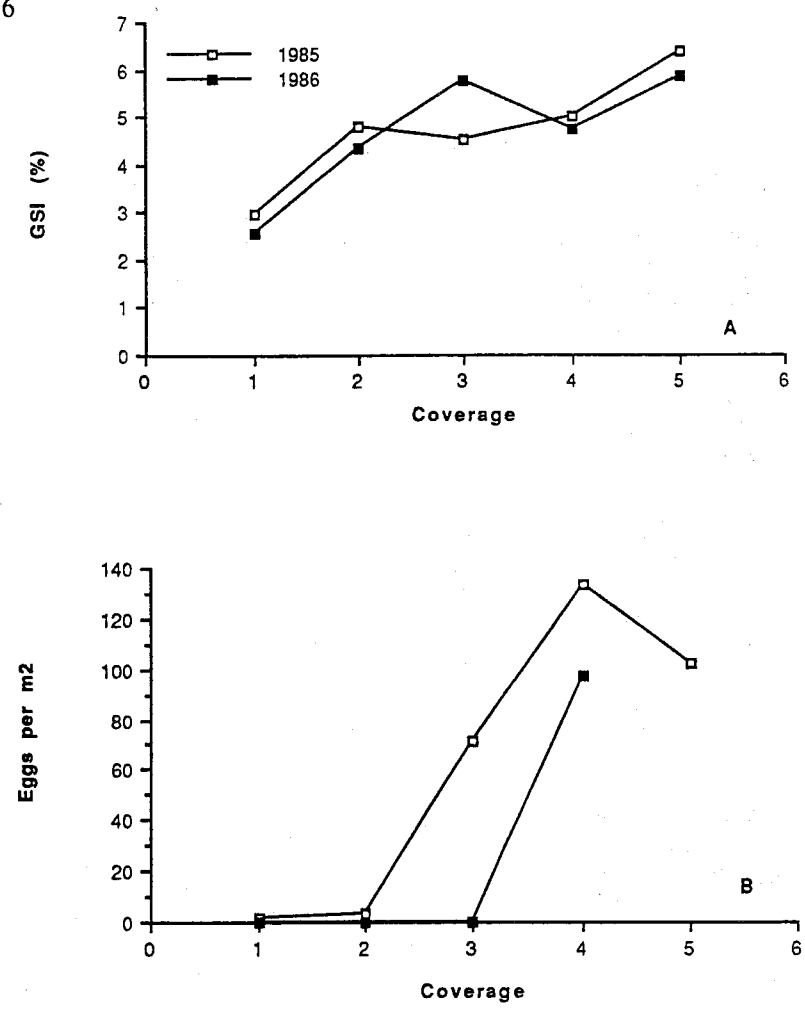

Fig. 3. A): Gonadosomatic index with SE in January-May 1985 and 1986, B): Abundances of newly spawned sprat eggs.

Oocyte size distribution

The relative size frequency distribution of the developing oocytes in the ovaries are presented in Fig. 4, where the patterns symbolize the different coverages. Of the total number of oocytes in the ovaries, 30-35% were developing i.e > 150 µm. Analysis of variance of the size distribution in each subsample gave no significant differences (p= 0.05), i.e. within each size-group the number of oocytes is the same in the three subsamples. It is thus reasonable to conclude that there is an even distribution of oocytes in the ovary.

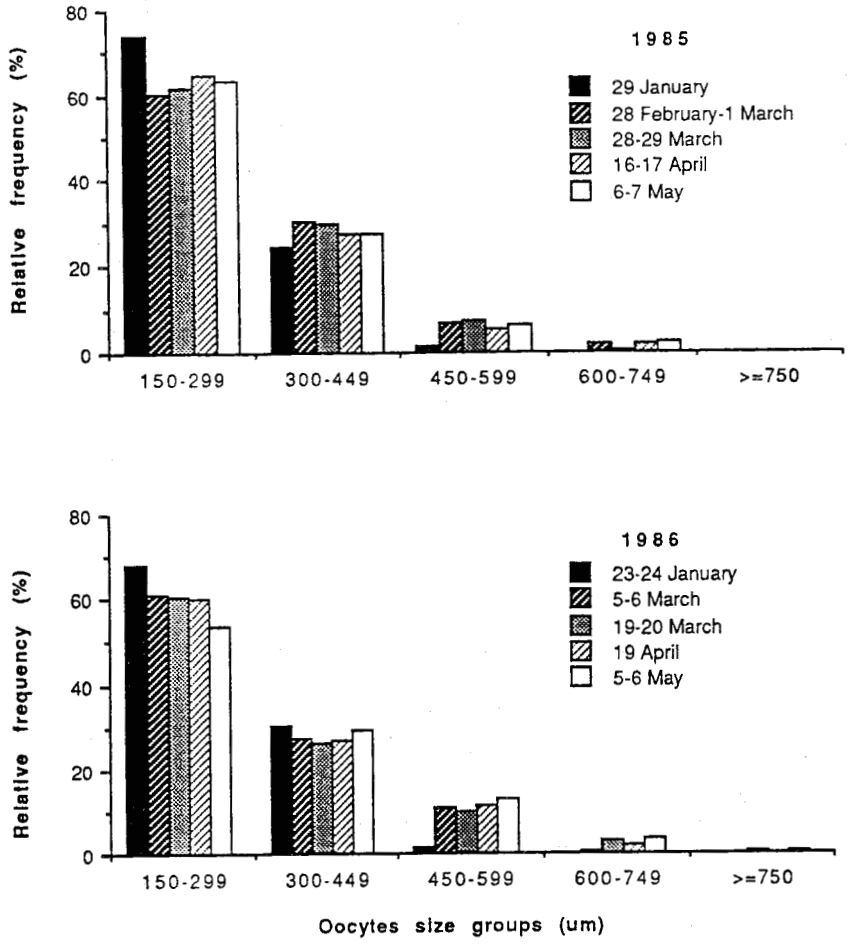

Fig. 4. Size frequency distribution of developing oocytes.

Absolute fecundity

From a single-factor analysis of absolute fecundities, there were no significant differences between the three subsamples (p = 0,05). Absolute fecundities, calculated from the mean of the three subsamples, varied from 3825 to 78955 in 1985 and 2939 to 42822 in 1986. The average values were 21134 and 12260 respectively, with great variation within each size group (Fig. 5).

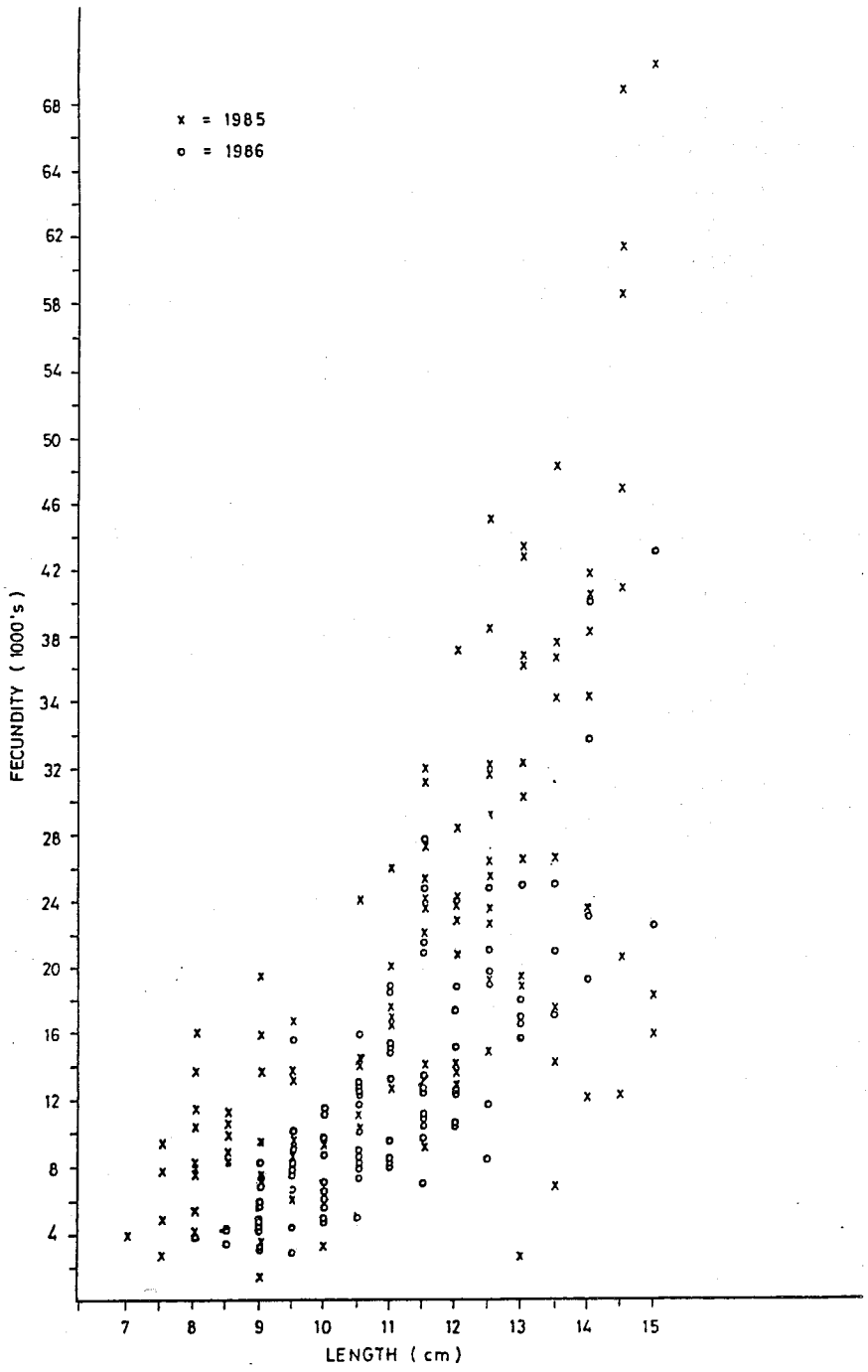

Fig. 5. Relationship between absolute fecundity and length of sprat in Frierfjord, in 1985 and 1986.

Linear regressions were fitted to logarithmic transformations of data of fecundity and length, weight and age, respectively, with regression coefficients in the range of 0.72-0.83. To analyse which of the variables (length (L), weight (W), age (A)) have significant effects on fecundity, stepwise multiple regressions were fitted to the variables (Zar 1974). The statistics yields from multiple regression analysis, are given in Table 4.

The final regression models were:

1985: $\log F = 2.40 + 1.61 \log L + 0.40 \log A$ $(r = 0.75)$

1986: $\log F = 0.32 + 3.57 \log L$ $(r = 0.83)$

Table 4

Statistics of the multiple regression of logarithmic transformed data of absolute fecundities on length (cm), weight (gram) and age of sprat in 1985 and 1986.

1985

Variable	Value	Std.Err	t-value	df
Intercept	1.581			
log(L)	2.754	1.171	2.352	124
log(W)	-0.416	0.389	1.071	124
log(Age)	0.476	0.172	2.768	124

1986

Variable	Value	Std.Err	t-value	df
Intercept	1.519			
log(L)	2.145	1.074	1.997	104
log(W)	0.231	0.305	0.758	104
log(Age)	0.223	0.136	1.647	104

* age is assessed to age group, relative to 1 January

Relative fecundity

Mean relative fecundity, i.e. mean number of oocytes per gram body weight, is considered as a more convenient index for comparing productivity than total number per female. The relative fecundity in 1985 was higher than in 1986 ($p < 0.001$), when the mean weight of the females was significantly lower than in the previous year:

	1985	1986
N	125	105
Mean	1993	1381
SD	870	508

The trend in relative fecundity in the two years (Fig. 6), increased towards a maximum in the end of March, which, according to Fig. 3, is in the early beginning of the spawning season. Relative fecundities at that time were 2044 and 1801, respectively, which do not differ significantly (p=0.05). A mean relative fecundity for the two years is thus estimated to 2034 oocytes per gram (SD= 962), which is twice the value estimated by De Silva (1973).

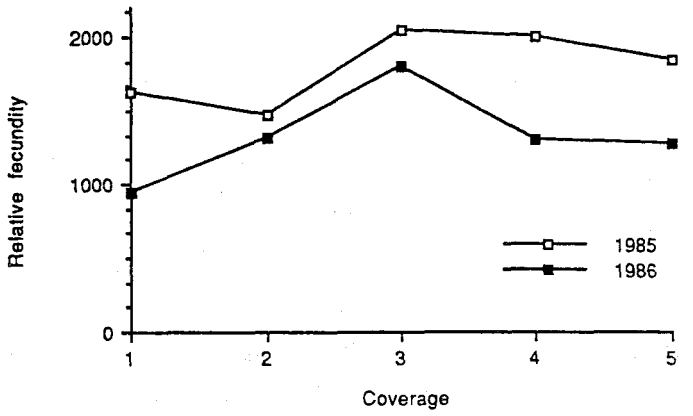

Fig. 6. Mean relative fecundity of sprat in 1985 and 1986.

Relative fecundity varied within each age group through the season, with a tendency to a peak in March-April (Table 5). Comparing the relative fecundity among the different age groups gave no evidence of higer values in the older than in the younger specimens. However, the numbers are low, especially in the higher age groups. Mean relative fecundity in each age group for the two periods shows no differences between the age groups, but between the years.

Table 5

Relative fecundity in each age group per month in 1985 (left) and 1986 (right)

Year	Age group	Month	Relative fecundity	N	Year	Age group	Month	Relative fecundity	N
1985	1	February	1528	13	1986	1	January	801	1
		March	2080	13			February	1073	4
		April	2763	8			March	1455	6
		May	3001	10			April	1210	5
							May	1232	2
	2	February	1369	2		2	January	917	8
		March	2170	2			February	1287	18
							March	2090	12
							April	1405	5
							May	1293	16
	3	January	1517	16		3	February	1156	3
		February	1508	16			April	1107	1
		March	2077	2			May	1428	4
		April	2464	6					
		May	2107	4					
	4	January	1925	4		4	January	1065	3
		February	549	2			February	1564	3
		April	2995	1			May	1131	2
		May	4900	1					
	> 4	February	1549	7		> 4	February	1800	2
		March	2086	6			March	1449	3
		April	2580	2			May	1156	
		May	3523	2					

DISCUSSION

There are variations in absolute and relative fecundities within and between years. A variation in fecundity up to a factor of five, is detected in sprat from the German Bight (Alheit 1987). However, the differences in weight and age composition in the two years complicate the analysis. It has been pointed out that feeding conditions might exert a considerable influence on the growth of oocytes and the fecundity, with a positive correlation between fecundity, fatness and feeding (Blaxter and Holliday 1963). Absolute fecundities estimated for 1985 and 1986 are higher than those published by Bailey and Pipe (1977) for the North Sea sprat (Fig. 7), with De Silva's estimates from inshore waters of the west coast of Scotland lying within the present values. Bailey and Pipe's samples were, however, taken from the end of May to mid July and the possibilities that eggs had already been shed, could thus not be ruled out.

The present estimates of fecundity are based on the assumptions that the standing stock of developing oocytes are separated from the resting

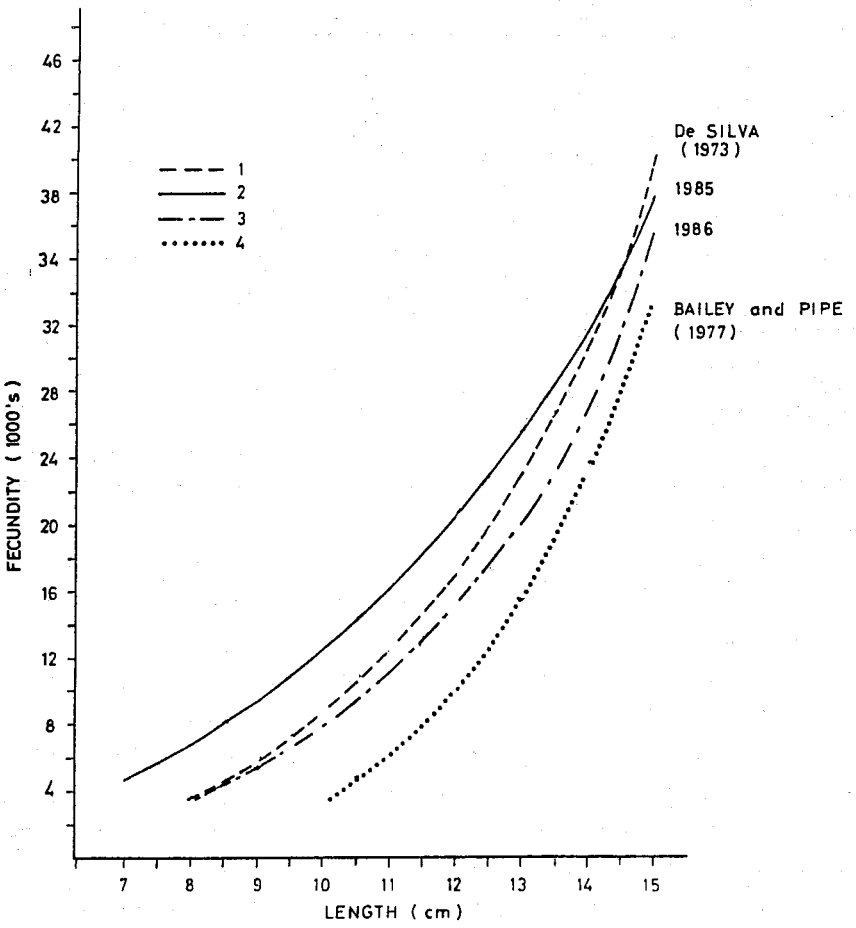

Fig. 7. Fitted curves for relationship between fecundity and length for sprat: 1) Inshore waters off the west coast of Scotland (de Silva 1973), 2) Frierfjord 1985, 3) Frierfjord 1986, 4) NW North Sea (Bailey and Pipe 1977).

ones (previtellogenic oocytes) early in the season, and that the spawning potential is thus defined before the start of the spawning season (determinate spawning). This is the traditionally or total fecundity method used for estimation of fecundity, which was also used by De Silva (1973) and Bailey and Pipe (1977). According to the relative size distribution of oocytes (Fig. 4), small oocytes made a great part (60-70%) of the defined

stock of developing oocytes. This might indicate a continuous separation of developing oocytes from the reservoir (<150 µm) during the current spawning season, i.e. an indeterminate spawning. It should be pointed out, however, that the sampling did not cover the whole spawning season in the fjord, which has a duration from January/February to July (Ellingsen 1979). Main season is from April to June, with peak in egg abundances in April and June. Successive influx of smaller fish to the spawning stock during the spawning season is another complicating factor.

Indeterminat spawning has been demonstrated for northern anchovy, *Engraulis mordax*, by Hunter and Leong (1981), with oocytes smaller than 0,1 mm matured and spawned during the current spawning season. Using hydrated oocytes in ripe-running specimens, Hunter and Goldberg (1980) introduced a new method for fecundity estimation in serial spawners with indeterminate fecundity.

Oocyte size frequency from females with highly advanced oocytes is a method which might give similar results for fecundity as those from the batch fecundity method described by Hunter and Goldberg (1980). Hydration of the sprat oocytes started when the diameter reached about 700 µm. All oocytes with a diameter of 850 µm were translucent. As oocytes with a diameter equal to or larger than 750 µm are poorly presented in the sampled ovaries, the results give evidence for a rapid recruitment into a maturing batch. The most advanced size group present is thus represented by oocytes having a diameter of 600-749 µm. From the development of spawning batches in the German Bight sprat (George and Alheit 1987) it seems reasonable to consider this group as a spawning batch. The "batch fecundities" are estimated and the values presented in Fig. 8. Most of the figures are small and not considered as spawning batches, but merely representing early stages in the development of new batches. There are two relative consentrated groups of points which can be looked upon as separate "clusters". Considering the encircled points as representative batches, the mean batch sizes of 1880 and 1280 oocytes in 1985 and 1986, are calculated, which are significally different ($p=0.05$). Alheit (1988) estimated average batch sizes from 1230 oocytes in age group I to 3560 in age group III, which gives a mean batch size of 2084 oocytes. The relative batch fecundities, 170 and 144 oocytes, are lower than presented by Alheit (1989). However, these are average values, estimated from a low number of values and not taken into account either intraseasonal variations (Heidrich 1925, Alheit 1987) or size - age

structure (Parrish et al. 1986). As indicated by the stepwise multiple regression analysis some of the differences might be related to differences in age composition of the stock. The values for 1985 are

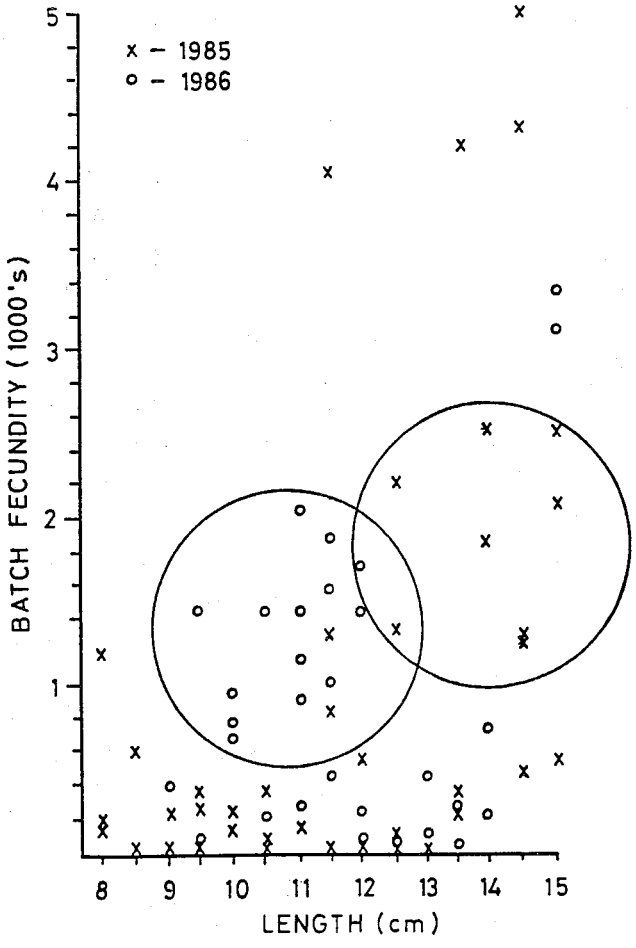

Fig. 8. "Batch fecundity" as given by number of oocytes in size group 600-749 µm.

mainly represented by fish of 3-5 years and 1986 by mainly 2-year-old fish.

Heidrich (1925) estimated that sprat spawn 9-10 batches of eggs during a spawning season of about 2.5 months, releasing a new batch every 8-10 days. From the present values of absolute fecundity, the mean number of batches are calculated as 11.3 (1985) and 9.4 (1986). Both

estimates are based on the assumption that sprat is a determinate spawner. However, from what has been indicated above, the sprat spawning seems to be indeterminated as has been asserted for anchovies, mackerel and sardines (Hunter and Macewicz 1985, Hunter et al. 1989). In case of indeterminate spawning, a defined, size-related spawning potential will induce an underestimation of fecundity. The traditional method or "The total/potencial fecundity" used in the present studies, takes no allowances either to atresia or *de novo* formation of developing oocytes.

It seems obvious that the current methods are not very useful in estimating a general fecundity index for production estimates in sprat, which support the conclusions drawn by Alheit (1988). A survey based on analysis of ripe-running sprat for estimating batch fecundity and spawning frequency as described by Hunter and Goldberg (1980), might be an alternative method as it does not take either the type of spawning (determinate or indeterminate) or the problem represented by atresia into consideration. From the marked interannual variation in growth and interannual and seasonal variations of fecundity, fecundity estimates for spawning stock assessment from egg surveys, should be performed annually.

A comparison of the two methods "Total fecundity" and "Batch fecundity" of estimation of spawning stock biomass of the western mackerel, *Scomber scombrus* , gave similar estimates (Priede 1990). There was a difference between the two estimates of about 15%, indicating an underestimation of 15% in the biomass by the "Total fecundity method". This loss might be accounted for by loss through atresia.

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