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Possibilities Raised by a Study of the Size Distribution in a Sample of a Shoal of Sprats, *Sprattus antipodum* (Hector)

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Abstract

A shoal of small fishes driven ashore near Kaikoura in May consisted largely of sprats, but included at least a few pilchards and yellow-eyed mullet in addition to predators. Several size groups of sprats were evident. Statistical analysis of the large sample (N = 2,165) strongly suggests that observed frequency distribution cannot be reasonably accounted for in terms of component groups of normal distribution: it is concluded that the species has a prolonged breeding season overall. The sample is dominated by fishes of mean S.L. 77.8mm and a small component of mean S.L. 60.3mm is recognisable. Comparison of our species with *S.s. phalericus* suggests that these fish groups are aged 4 and 3 years respectively. A group of mean S.L. 98.1mm is considered to contain fishes aged 6 years and more.

Measurement of the fishes was done by students and provides a nice example of bias towards round numbers.

INTRODUCTION

INFORMATION on the New Zealand Sprat is scanty, repetitious and inconclusive. A shoal was found at Goose Bay, south of Kaikoura, on 5 May 1962, and a bucketful of fishes was collected by various means from the teeming mass amongst the rocks off the beach. The shoal was marked by flocks of gulls and was self-evident from the agitated water. The sea was calm and the weather fine. Much of the shoal was pressed ashore into the extreme shallows and Kahawai were darting amongst the small fishes, actively feeding in water no more than knee-deep. Larger fishes were discernible further offshore.

Most of the small fishes were sprats, but the sample contained one *Sardinops neopilchardus* (Steind.) and one *Aldrichetta forsteri* (C. and V.), proving that the shoal was mixed.

I follow Svetovidov (1963) in placing this sprat in the world-wide genus *Sprattus* Girgensohn, but follow Phillipps (1927) and Whitley (1937) in presuming there to be only the one species here (although the former suggests that the species *mülleri* Klunzinger may be valid). These sprats were used to give a practical example of the length-frequency method of examining fish populations to the students of the current field course at the Edward Percival Marine Laboratory, Kaikoura. No more than that was attempted, but the results are amenable to a detailed analysis.

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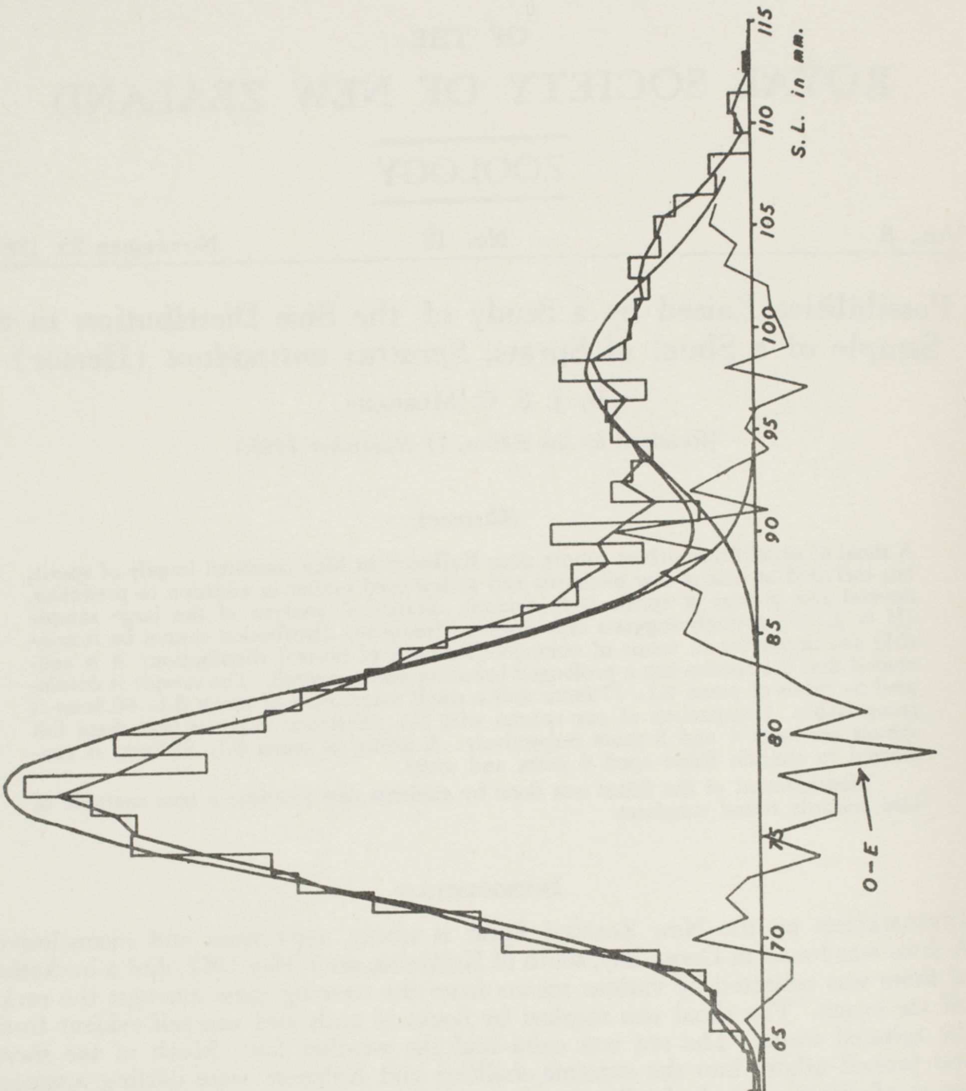

Fig. 1.—Length-frequency distribution of the sample (N = 2,165) shown by histograms and a smoothed curve. Normal distributions of the two main groups have been calculated from parameters in Table I and are shown separately and combined. Curve "O–E" shows the discrepancy between Observed and Calculated frequencies.

Since the fishes were scooped from the water, and not netted, the sampling efficiency can be regarded as uniform throughout their size range. Whether the sample is properly representative of the whole shoal it is impossible to say.

The standard length (chin to base of median caudal rays) was measured to the nearest mm and the length-frequency distribution of the total of 2,165 fishes is given in the Appendix and shown in fig. 1. It is likely that errors in measurement would assign a proportion of fishes to neighbouring size-classes therefore a smoothed curve has been prepared for the frequency polygon (fig. 1) by averaging frequencies in paired adjacent classes. The histograms strongly suggest observers' bias towards " round " numbers (ending in 0 or 5) e.g.—the 79mm class was probably robbed and some fishes wrongly allocated to the 80mm class; similarly, the 69, 74, 89 and 94mm classes were probably robbed. (Peaks in curve " O–E " in fig. 1 clearly show the effect of this observational bias.)

It appears that there are two main groups of fishes, the majority having a modal length of 77.5mm and a lesser group having a modal length of 98.5mm. There are puzzling irregularities of the smoothed curve between these two groups; and there are suggestions of a group of fishes at each extreme of size, i.e., at 60.5mm and 110.5mm although the numbers of fishes concerned are very small.

To investigate the size distribution further the original data (unsmoothed) have been analysed by Harding's (1949) probability paper method using Cassie's (1950, 1954) development. The curve (fig. 2) shows two major inflexions, at approximately 0.65% and 82% so that this method of analysis suggests three significant size-groups in the catch. Ignoring the four smallest fishes, that constitute less than 0.185% of the catch, it is possible to fit a curve (straight line) quite neatly to the points just below the 0.65% inflexion to indicate the parameters of group A (fig. 2, line A). Similarly, curves (straight lines) can be fitted as shown for groups B and C, comprising 81.35% and 17.632% of the catch leaving only 0.368% of the catch, the eight largest fishes, as beyond the scope of reasonable analysis. Straight lines A, B and C in fig. 2 reveal group parameters as shown in Table I. The lines may be variably fitted so that means and standard deviations are probably ± 0.5mm. The means of groups B and C match the corresponding modes in fig. 1 and this probability paper analysis provides parameters for the small group A that was tentatively recognised in fig. 1 (but such analysis cannot unequivocally confirm the validity of this group).

TABLE I.—*Apparent Groups in the Catch*: **Means and standard deviations of the Standard Lengths are derived from fig. 2 and appear to be accurate ± 0.5mm.**

Group	% of Catch	Corresponding Number of Fishes	Mean S.L. (mm)	Standard Deviation (mm)
Smallest fishes	0.185	4.0	—	—
A	0.465	10.1	60.3	1.1
B	81.35	1761.2	77.8	4.7
C	17.632	381.7	98.1	4.7
Largest fishes	0.368	8.0	—	—
Total:	100	2165		

Curves of normal distribution for groups B and C are shown in fig. 1 calculated (Fisher and Yates, 1948) from the parameters in Table I. They show too poor a fit to observed distribution to be acceptable. This is confirmed by a Chi^2 test on observed and expected frequencies in the sixteen classes from 67mm to 103mm that are least likely to be affected by the observational bias mentioned, i.e., classes ending in the numbers 2, 3, 7 and 8: a Chi^2 value of 48 results, with 10 degrees of freedom for the combined distributions of groups B and C. The discrepancy between observed and expected frequencies for each class is shown by the curve " O–E " in fig. 1.

Clearly, it is worthwhile to investigate whether the catch could be interpreted better in terms of a more complex arrangement of groups of normal distribution. A great asset of the probability paper method of analysis is that it suggests likely starting points for investigation not only by the inflexions of the cumulative curve but by the discrepancies of the fitted curves. As it turned out, considerable investigation of the data led to no recognition of a series (or even of a dual series) of clearly defined groups that fitted the results more plausibly than the groups suggested.

One can only conclude that the bad match of the observed distribution with the expected is due to distribution within each group that is not normal. Fig. 1 shows that both group B and group C are platykurtic and positively skewed in comparison to normal distributions and therefore it does not seem unlikely that the nature of the non-normal distribution in these groups is of similar type.

Discussion and Conclusions

The word " group " has been used instead of the tempting phrase " year-class " to avoid an unwarrantable assumption. Nikol'skii (1961) observed of the North Sea sprat, *Sprattus sprattus,* that feeding fishes in the Baltic stay in individual shoals consisting chiefly of fish of similar age. Svetovidov (1963) remarked similarly on the Mediterranean and Black Sea sprat (*S.s. phalericus*). In strong contrast, the Goose Bay shoal was certainly mixed in that it not only contained pilchards and yellow-eyed mullets but also sprats of at least two, possibly several size-groups.

The different groups of sprats could be due to several causes, e.g. (a) mixed species; (b) mixed populations of one species (the geographical range of movement of a sprat shoal is undetermined, here); (c) mixed year-classes; (d) mixed broods; (e) disparate growth rates of the sexes in combination with previous possibilities.

We should assume, for the present, that there is only one species of sprat in our catch and that it is represented by different year-classes of a regional population. We may look to knowledge of sprats elsewhere as a guide to interpretation of the data.

Svetovidov quoted lengths (not always defined) of *Sprattus sprattus* at certain ages as determined by various workers. Apparently varieties grow at very different rates but *S.s. phalericus* reaches a maximum length of 130–160mm and is most common at 60–80mm. These are much the same as extreme and average lengths of our *S. antipodum* (Hector in Hutton, 1872; Parrott, 1957) and it is therefore reasonable to suppose the two species to have similar rates of growth.

Lengths quoted by Svetovidov for *S.s. phalericus* are as follows (assumed to be " total lengths ") :—

Age 1 year	Length 27.9mm	
2	48.1mm	∴ Increment = 20.2mm
3	71.9mm	23.8
4	83.5mm	11.6
5	90.9mm	7.4

Fishes of group A of our sample therefore seem likely to be aged 3 years. Fishes of group B show an increment of 17.5mm (in S.L.) which is much greater than the 4th year increment in (T.L.?) of *S.s. phalericus* but not too great for us to regard our group B to consist predominantly of fishes aged 4 years. However, the increment between groups B and C is 20.3mm which is inconceivable as one year's growth.

The lengths given by Svetovidov indicate a sigmoid growth curve in contrast to the generality of Beverton and Holt (1959) that: "Growth in length nearly always [for most fishes] follows a simple curve without an inflexion". The inflexion in the growth of *S.s. phalericus* appears to be at about age 3 years and, if *S. antipodum* has a similar growth curve, our group A fishes would be at or beyond the point of inflexion of post-larval growth. Thinking in terms of simple year-classes fig. 1 suggests that a year-class lies between groups B and C, but comparison with the growth of *S.s. phalericus* suggests not one, but several, classes to be overlapping between these groups and within group C. As has been mentioned, these classes cannot be identified in our catch.

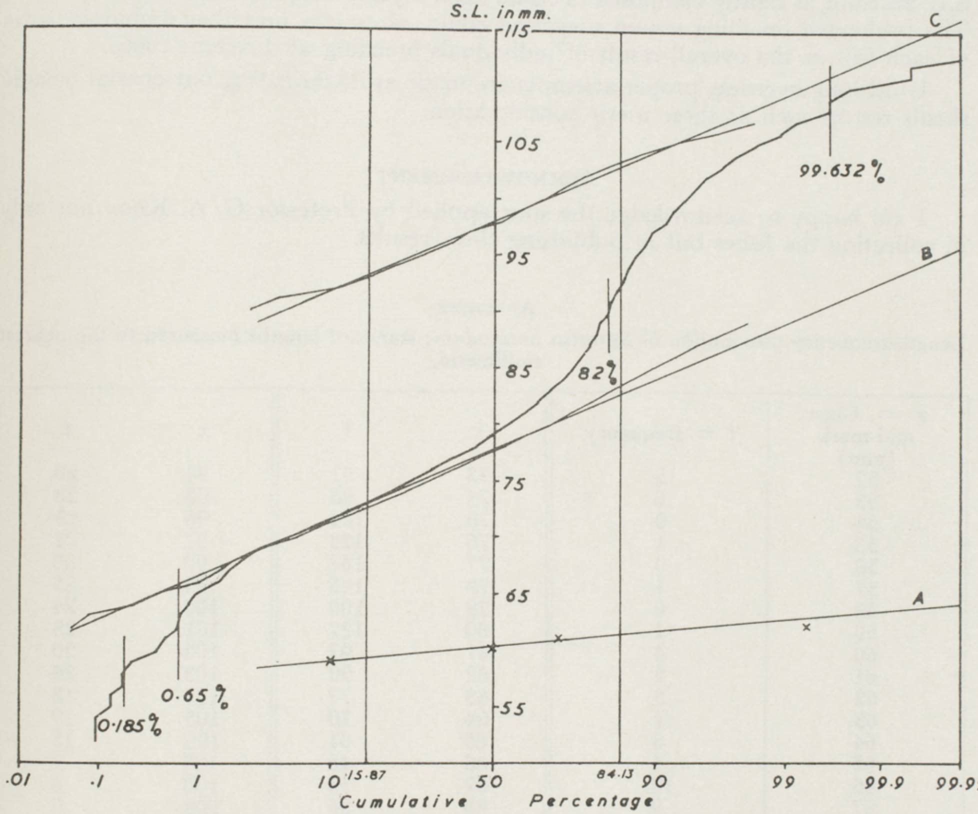

FIG. 2.—Probability paper analysis of the sample. Vertical dashes show where the cumulative curve was subdivided in analysis. Fitted lines A, B and C reveal the parameters for these groups (points for curve A marked with *x*; wavy lines show the actual distributions of the points of curves B and C to which straight lines are fitted).

It is known that in some Clupeids females grow faster than males: a sex ratio other than unity is not uncommon (e.g., Svetovidov noted that females outnumber males in *S.s. balticus*). The data in fig. 2 have also been exhaustively examined with these phenomena in mind but none of the several possible solutions reasonably meets the criteria of a constant sex ratio coupled with likely growth rates for each sex. No reasonable series of groups can be discovered commensurate with two series of year-classes of males and females growing at different rates. Further, the cumulative curve gives no indication of a recognisable series of broods each season.

It seems reasonable to abandon attempts to account for observed distribution in terms of a series of size-groups each of normal distribution.

European and Black Sea sprats may have lengthy spawning periods or produce several broods a year. Little more seems to be known of the breeding characteristics of *S. antipodum* than that ripe and spent females have been recorded in May (Phillipps, 1927; Parrott, 1957). If the breeding season of our sprat is prolonged then this provides probably the simplest explanation of year-classes made up of non-normal length distribution. I suggest that this sample indicates that *S. antipodum* has a prolonged breeding season: that the fishes of group A (mean standard length 60.3mm) are aged 3 years, that the major group in the sample is chiefly composed of fishes aged 4 years (mean S.L. 77.8mm) and that the minor group, of mean S.L. 98.1mm, is mostly composed of fishes aged 6 years with older fishes also present. The prolonged breeding season suggested could, of course, be either a characteristic of each fish or the overall result of individuals breeding at different times.

Until long overdue, proper attempts are made at investigating our coastal pelagic shoals results such as these merit consideration.

Acknowledgment

I am happy to acknowledge the spur applied by Professor G. A. Knox not only in collecting the fishes but in publishing these results.

Appendix

Length-frequency distribution of *Sprattus antipodum;* standard lengths measured to the nearest millimetre.

x = Class mid-mark (mm)	f = frequency	x	f	x	f
52	2	73	91	94	20
53	0	74	96	95	28
54	0	75	124	96	29
55	1	76	123	97	21
56	0	77	132	98	38
57	1	78	145	99	25
58	0	79	109	100	24
59	1	80	127	101	23
60	4	81	97	102	20
61	2	82	90	103	24
62	3	83	77	104	18
63	1	84	70	105	19
64	3	85	61	106	15
65	4	86	46	107	7
66	10	87	35	108	8
67	9	88	36	109	0
68	11	89	22	110	3
69	20	90	40	111	4
70	51	91	11	112	0
71	55	92	28	113	1
72	76	93	24	Total N = 2,165	

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