LENGTH-WEIGHT RELATIONSHIP IN THE OIL-SARDINE, *SARDINELLA LONGICEPS* VAL.

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INTRODUCTION

The study of the length-weight relationship in fishes by fishery biologists has been mainly directed towards two objectives, namely, to provide a mathematical relationship between the two measurements as a means of interconversion and secondly, to calculate the 'condition factor' (Le Cren, 1951). In a species of commercial importance, the former object has been found essential to convert the catch statistics of that species from weight to numbers in order to obtain the abundance of stock in space and time. However, the question that has to be answered first for both the above objects is whether a single equation will suffice or separate equations are required to describe the relationship between length and weight at various times of the year and phases of life history.

In spite of the great economic importance of the Indian oil-sardine, *Sardinella longiceps*, in the marine fishery resources of India and in spite of the fact that investigations on this fish date back to 1910 with Hornell's report, there has been, except for a brief account by Dhulkhed (1963) on an year's data, no attempt to study this biological aspect of the fish. The present report deals with the length-weight data of oil-sardine collected from Calicut region in the years 1959 to 1964.

METHODS

Random samples, each consisting of twenty-five fish, were collected from the local fish landing place. Although samples were taken sometimes from gill net returns, in view of their selective nature, and to have uniformity, only the boat seine data were utilised for the present analyses. The total length recorded in mm was from the tip of the snout to the tip of the lower caudal fluke extended along the median axis. The weight was taken nearest to 0.1 g after removing the surface moisture on the fish between foldc of filter paper.

Since the regression coefficient 'b' in the allometric formula, $W=aL^b$, may differ between years, sexes or maturity groups and this difference may or may not be statistically significant, the data were analysed after classifying the fish into 7 groups,

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namely, indeterminate, immature male, immature female (Stage I), mature male, mature female (Stages IIa, III, IV, V and VI), spent male and spent female (Stages IIb, VIIa and VIIb). The stages of maturity followed were according to Antony Raja (1971). Under each of these main groups, the seasons of capture were treated as sub-groups. It was assumed that a linear relationship exists between the logarithm of length and the logarithm of weight from examination of a sample scatter diagram made on a logarithmic plot and confirmed by tests for linearity. The statistical comparisons were done by analysis of covariance (Snedecor, 1955).

RESULTS

Table 1 gives the statistics for the regression of logarithm of weight on logarithm of length for different groups and seasons. Table 2 shows the analyses of covariance to test the significance of differences among seasons within the different groups. (The detailed regression data have been omitted for the sake of brevity of the report.) It is seen from Table 2 that in all the groups, except mature female, significant differences are declared in the regression coefficients between seasons, the degree of significance being at 5% level in the case of immature male and spent male and at 1% in the others. In the case of mature female, while the slopes of the regression line may be comparable, there are high significant differences in the adjusted means.

The results of analyses of covariance to test the significance of differences among sexes within groups in each season are tabulated in Table 3. This study reveals that except for the immature group of 1961-62 and mature group of 1962, there are no significant differences in the regression coefficient between the sexes in any other year. In the adjusted means also, no significant differences could be detected except for the mature group of 1959. It is interesting to note that the immature groups of 1961-62, which have differing relationships between the sexes, exhibit differences in the mature state also in 1962.

So, broadly speaking, while pooling the data relating to sexes may be justified to a large extent, the significant differences seen in the regression coefficients among seasons, clearly demonstrate that it is not advisable to combine the data of different seasons even for the same maturity group. The conclusion that emerges from this study, thus, is that different length-weight regressions have to be used to convert the statistics of catches from weight to numbers.

The regression lines for the different groups during the different seasons are shown in Fig. Ia to Id.

An attempt was made to find the differences, if any, in the length-weight relationships between indeterminate and immature fish of the same season in view of the fact that both belong to the same year's recruitment. In this analysis, the data relating to immature male and female are pooled for all those seasons wherein no significant differences in the coefficients of regression between the sexes are declared.

TABLE 1. *Statistics for the regression of logarithm of weight on logarithm of length for different groups and seasons along with 't' test for significance of deviation from cube law.*

Groups/ Seasons	Size range(mm)	N	$\bar{X}$	$\bar{Y}$	log *a*	*b*	M.S.	't' test for *b*
Indeterminate								
1959	92—118	36	2.0086	0.9893	—5.1120	3.0376	0.000547	N.S.
1960	84—116	68	2.0113	0.9512	—4.0941	2.5085	0.001778	**
1961	88-121	150	2.0436	0.9810	—3.4880	2.1871	0.002125	**
1962	54-115	50	1.8986	0.6004	—4.9786	2.9385	0.004750	N.S.
1963	91-101	13	1.9786	0.8419	—4.9172	2.9107	0.000111	N.S.
Immature male								
1959—1960	125—161	155	2.1474	1.3785	—4.5256	2.7494	0.001041	N.S.
1960—1961	130—162	247	2.1620	1.4029	—5.7881	3.3261	0.002430	N.S
1961—1962	110—143	158	2.0923	1.1096	—5.0012	2.9206	0.001518	N.S.
1962—1963	110—147	160	2.0940	1.1968	—4.8842	2.9040	0.001578	N.S.
1963—1964	110—161	101	2.1451	1.3685	—4.4411	2.7083	0.000707	**
Immature female								
1959—1960	128—158	114	2.1516	1.3902	—3.7844	2.4050	0.001210	**
1960—1961	112—163	321	2.1584	1.4057	—5.1515	3.0380	0.002726	N.S.
1961—1962	105—140	170	2.0880	1.1097	—3.4856	2.2008	0.002983	**
1962—1963	106—153	158	2.0991	1.2165	—4.5050	2.7257	0.001241	N.S.
1963—1964	106—162	93	2.1462	1.3712	—4.1430	2.5693	0.000753	N.S.
Mature male								
1959	165—184	47	2.2454	1.7555	—2.7627	2.0122	0.000582	**
1960	157—184	45	2.2322	1.7019	—4.0040	2.5562	0.000363	*
1961	150—189	59	2.2112	1.5871	—4.1213	2.5816	0.000585	*
1962	140—183	88	2.1928	1.5381	—6.3935	3.6171	0.002314	**
1963	141—188	41	2.2150	1.6328	—4.5987	2.8133	0.000577	N.S.
Mature female								
1959	166—190	28	2.2525	1.7791	—3.7843	2.4699	0.000897	**
1960	155—193	64	2.2443	1.7270	—4.9155	2.9597	0.000842	N.S.
1961	152—188	57	2.2146	1.5955	—4.5511	2.7755	0.000667	N.S.
1962	142—187	90	2.2083	1.5943	—5.0918	3.0277	0.001805	N.S.
1963	151—185	34	2.2276	1.6583	—4.6683	2.8401	0.000881	N.S.
Spent male								
1959—1960	162—183	13	2.2398	1.6569	—6.6015	3.6871	0.000656	N.S.
1960—1961	166—191	48	2.2472	1.6743	—9.2844	4.8766	0.008664	N.S.
1961—1962	150—192	112	2.2148	1.5165	—4.6389	2.7792	0.001737	N.S.
1962—1963	155—190	40	2.2275	1.6157	—3.8927	2.4729	0.007013	N.S.
1963—1964	166—181	21	2.2475	1.6669	—4.9632	2.9500	0.001353	N.S.
Spent female								
1959—1960	161—188	12	2.2347	1.6362	—3.6889	2.3829	0.000690	N.S.
1960—1961	169—191	53	2.2552	1.7211	—5.1888	3.0640	0.001588	N.S.
1961—1962	154—179	115	2.2203	1.5460	—5.5963	3.2168	0.001861	N.S.
1962—1963	160—182	29	2.2329	1.6182	—10.3345	5.3530	0.007815	*
1963—1964	164—191	22	2.2493	1.6713	—3.2963	2.2085	0.000779	*

N=Number of fish; $\bar{X}$=mean value of length variate; $\bar{Y}$=mean value of weight variate; *a*=y-intercept; *b*=regression coefficient; M. S.=mean square deviation from regression; N. S.=not significant; **significance at 1% probability; * significance at 5% probability.

TABLE 2. *Analyses of covariance, linear regressions of logarithm of length and weight, to test the significance of differences among seasons within groups.*

Source of variation	D.F.	sum of squares	mean square	F
Indeterminate				
Due to regression within season	307	0.67963	0.00221	
Difference between reg. coeff.	4	0.06925	0.01731	7.83**
Immature male				
Due to regression within season	811	1.31057	0.00162	
Difference between reg. coeff.	4	0.01595	0.00399	2.46*
Immature female				
Due to regression within season	846	1.76816	0.00209	
Difference between reg. coeff.	4	0.06454	0.01614	7.72**
Mature male				
Due to regression within season	270	0.29668	0.00110	
Difference between reg. coeff.	4	0.04298	0.01075	9.77**
Mature female				
Due to regression within season	263	0.29928	0.00114	
Difference between reg. coeff.	4	0.00297	0.00074	0.65
Due to average regression within season	267	0.30225	0.00113	
Difference between adj means	4	0.09455	0.02364	20.92**
Spent male				
Due to regression within season	224	0.88900	0.00397	
Difference between reg. coeff.	4	0.04210	0.01053	2.65*
Spent female				
Due to regression within season	221	0.65778	0.00298	
Difference between reg. coeff.	4	0.09391	0.02348	7.83**

Among the 4 seasons thus examined, it is seen that while in 1959-60 there are no differences either in the regression coefficient or the adjusted means, in 1962-63 and 1963-64 the significant differences are limited to the adjusted means only. On the contrary in 1961-62 alone even the slope of the regression line is significantly different between the groups (Table 4). Thus, although no uniformity could be noticed running through all the years, it can be generally assumed that while the slope of relationship does not differ between the indeterminate and immature fish of the same season, the elevation may be significantly different, which may, perhaps, be attributed to the difference in size groups examined.

Discussing the merits of allometric formula with cube formula in expressing the length-weight relationship, Beverton and Holt (1957, p.279 *et seq.*) state that the values of a and b may vary within wide limits for very similar data and are sensitive to quiet unimportant variations in the latter. They further proceed to remark that instances

TABLE 3. *Analyses of covariance, linear regression of logarithm of length and weight, to test the significance of differences among sexes within groups in each season.*

Source of variation	D.F	sum of squares	mean square	F
	Immature			
1959—1960				
Due to regression within sex	265	0.29475	0.00111	
Difference between reg. coeff.	1	0.00267	0.00267	2.41
Due to average regression within sex	266	0.29742	0.00112	
Difference between adj. means	1	0.00003	0.00003	0.03
Total	267	0.29745	0.00111	
1960—1961				
Due to regression within sex	564	1.46484	0.00260	
Difference between reg. coeff.	1	0.00369	0.00369	1.42
Due to average regression within sex	565	1.46853	0.00260	
Difference between adj. means	1	0.00972	0.00972	3.74
Total	566	1.47825	0.00261	
1961—1962				
Due to regression within sex	324	0.73782	0.00228	
Difference between reg. coeff.	1	0.03011	0.03011	13.21**
1962—1963				
Due to regression within sex	314	0.44280	0.00141	
Difference between reg. coeff.	1	0.00210	0.00210	1.49
Due to average regression within sex	315	0.44490	0.00141	
Difference between adj. means	1	0.00276	0.00276	1.60
Total	316	0.44766	0.00142	
1963—1964				
Due to regression within sex	190	0.13852	0.00073	
Difference between reg. coeff.	1	0.00102	0.00102	1.40
Due to average regression within sex	191	0.13954	0.00073	
Difference between adj. means	1	0.00009	0.00009	0.12
Total	192	0.13963	0.00073	
	Mature			
1959				
Due to regression within sex	71	0.04952	0.00070	
Difference between reg. coeff.	1	0.00075	0.00075	1.07
Due to average regression within sex	72	0.05027	0.00070	
Difference between adj. means	1	0.01749	0.01749	24.99**
Total	73	0.06776	0.00093	
1960				
Due to regression within sex	105	0.06783	0.00065	
Difference between reg. coeff.	1	0.00096	0.00096	1.48
Due to average regression within sex	106	0.06879	0.00065	
Difference between adj. means	1	0.00176	0.00176	2.71
Total	107	0.07055	0.00066	

TABLE 3 (*Contd.*)

Source of variation	D. F.	sum of squares	mean square	F
1961				
Due to regression within sex	112	0.07002	0.00063	
Difference between reg. coeff.	1	0.00050	0.00050	0.79
Due to average regression within sex	113	0.07052	0.00062	
Difference between adj. means	1	0.00004	0.00004	0.06
Total	114	0.07056	0.00062	
1962				
Due to regression within sex	174	0.35787	0.00206	
Difference between reg. coeff.	1	0.01344	0.01344	6.52*
1963				
Due to regression within sex	71	0.05072	0.00071	
Difference between reg. coeff.	1	0.00002	0.00002	0.03
Due to average regression within sex	72	0.05074	0.00070	
Difference between adj. means	1	0.00042	0.00042	0.60
Total	73	0.05116	0.00070	
	Spent			
1959—1960				
Due to regression within sex	21	0.01412	0.00033	
Difference between reg. coeff.	1	0.00355	0.00355	10.76**
1960—1961				
Due to regression within sex	97	0.47954	0.00494	
Difference between reg. coeff.	1	0.01545	0.01545	3.13*
1961—1962				
Due to regression within sex	223	0.40130	0.00180	
Difference between reg. coeff.	1	0.00290	0.00290	1.61
Due to average regression within sex	224	0.40420	0.00180	
Difference between adj. means	1	0.01853	0.01853	10.29**
Total	225	0.38567	0.00171	
1962—1963				
Due to regression within sex	65	0.47749	0.00735	
Difference between reg. coeff.	1	0.04470	0.04470	6.08*
1963—1964				
Due to regression within sex	39	0.04127	0.00106	
Difference between reg. coeff.	1	0.00171	0.00171	1.61
Due to average regression within sex	40	0.04298	0.00107	
Difference between adj. means	1	0.00001	0.00001	0.01
Total	41	0.04299	0.00105	

of important deviations from isometric growth in adult fishes are rare. Hence, it appears advisable to test the regression coefficients against the isometric growth value of 3 to find whether there are any significant departures. For purpose of this comparison, the differences between the observed regression coefficient and the value 3, divided by the standard error of the regression coefficient, yields values of 't' which may be compared with the tabulated value of this statistic (Snedecor, *op. cit.* p. 119). It is seen from Table 1 that out of 35 values of *b*, 12 are found to depart significantly from 3 of which 8 do so at 1 % probability level and 4 at 5 % level. Among the adult

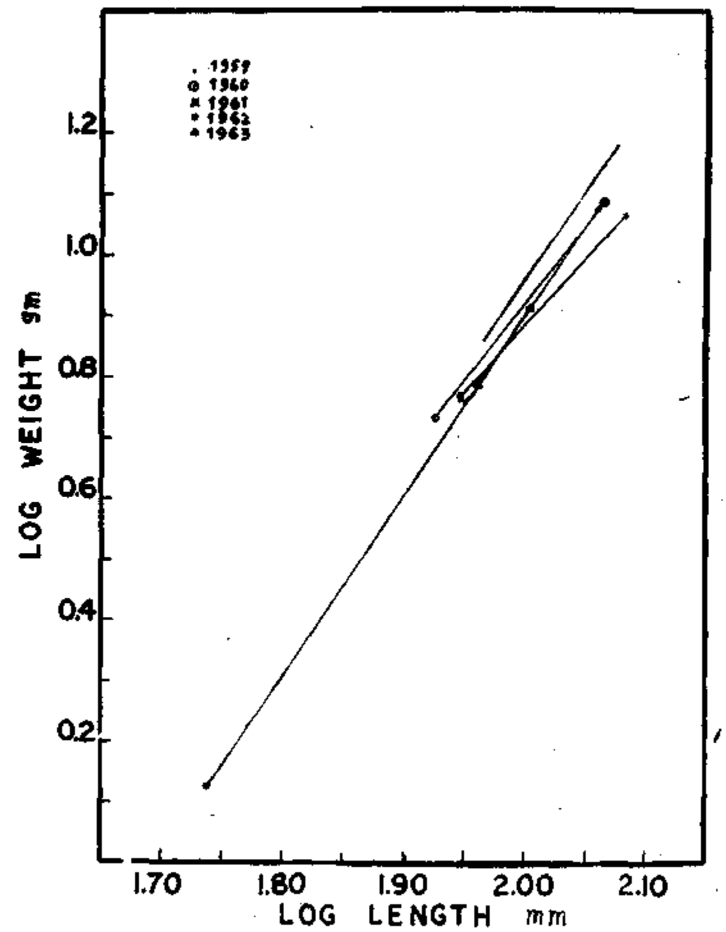

FIG. 1a. Length-weight regressions of indeterminate oil-sardine.

fish to which the remarks of Beverton and Holt (*loc. cit.*) relate, 3 are found significantly different at 1 % level and 4 others at 5 %. The group that registers markedly deviating values of regression coefficient is mature male and it is interesting to note that the males in spent condition have showed no significant deviations in their regression coefficient from 3 in any of the seasons.

It is seen from Table 1 that in the groups, indeterminate, immature and mature, although the values of *b* range from 2.0122 to 3.6171, the majority are found between 2.5 and 3.0. All the values that are below 2.71 and the most extreme value on the

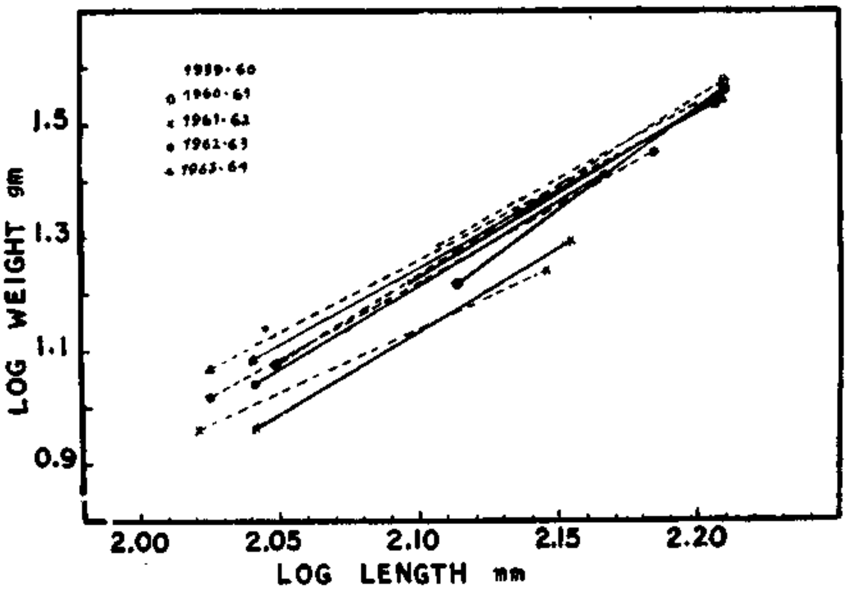

FIG. 1b. Length-weight regressions of immature oil-sardine (Broken lines refer to females)

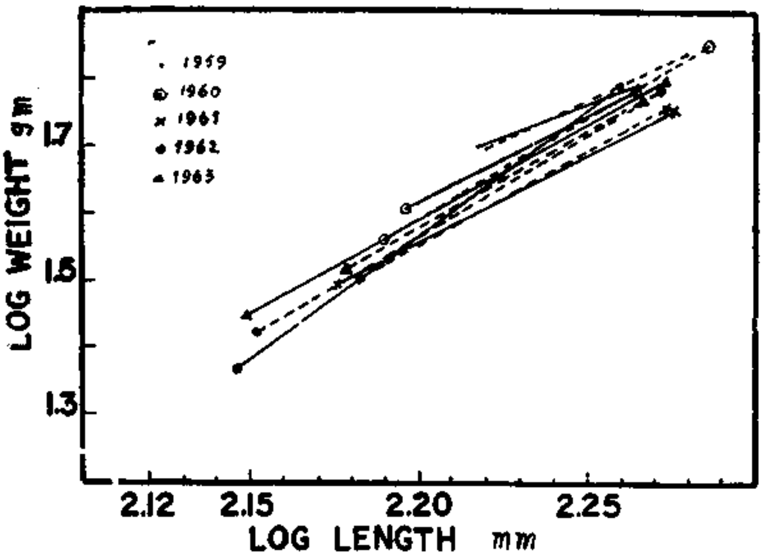

FIG. 1c. Length-weight regressions of mature oil-sardine.

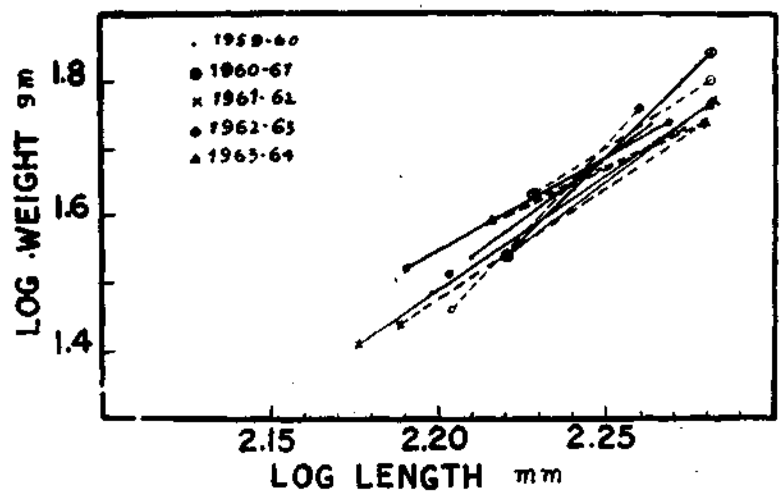

FIG. 1d. Length-weight regressions of spent oil-sardine.

TABLE 4. *Analyses of covariance, linear regression of logarithm of length and weight, to test the significance of differences between indeterminate and immature fish of the same season.*

Source of variation	D.F	sum of squares	mean square	F
1959—1960				
Due to regression within groups	301	0.31600	0.00105	
Difference between reg. coeff.	1	0.00323	0.00323	3.08
Due to average reg. within groups	302	0.31923	0.00106	
Difference between adj. means	1	0.00179	0.00179	1.69
Total	303	0.32102	0.00105	
1960—1961				
Due to regression within groups	632	1.59559	0.00252	
Difference between reg. coeff.	1	0.01907	0.01907	7.57**
1962—1963				
Due to regression within groups	364	0.67565	0.00186	
Difference between reg. coeff.	1	0.00312	0.00312	1.68
Due to average reg. within groups	365	0.67877	0.00186	
Difference between adj. means	1	0.01543	0.01543	8.30**
Total	366	0.69420	0.00190	
1963—1964				
Due to regression within groups	203	0.14085	0.00069	
Difference between reg. coeff.	1	0.00016	0.00016	0.23
Due to average reg. within groups	204	0.14101	0.00069	
Difference between adj. means	1	0.03483	0.03483	50.48**
Total	205	0.17584	0.00086	

higher side are declared significantly different from isometric growth. Although the values for the spent groups vary widely between 2.2 and 5.4, it is seen that only these two extreme values are found departing significantly from 3, whereas all the other intermediate values do not.

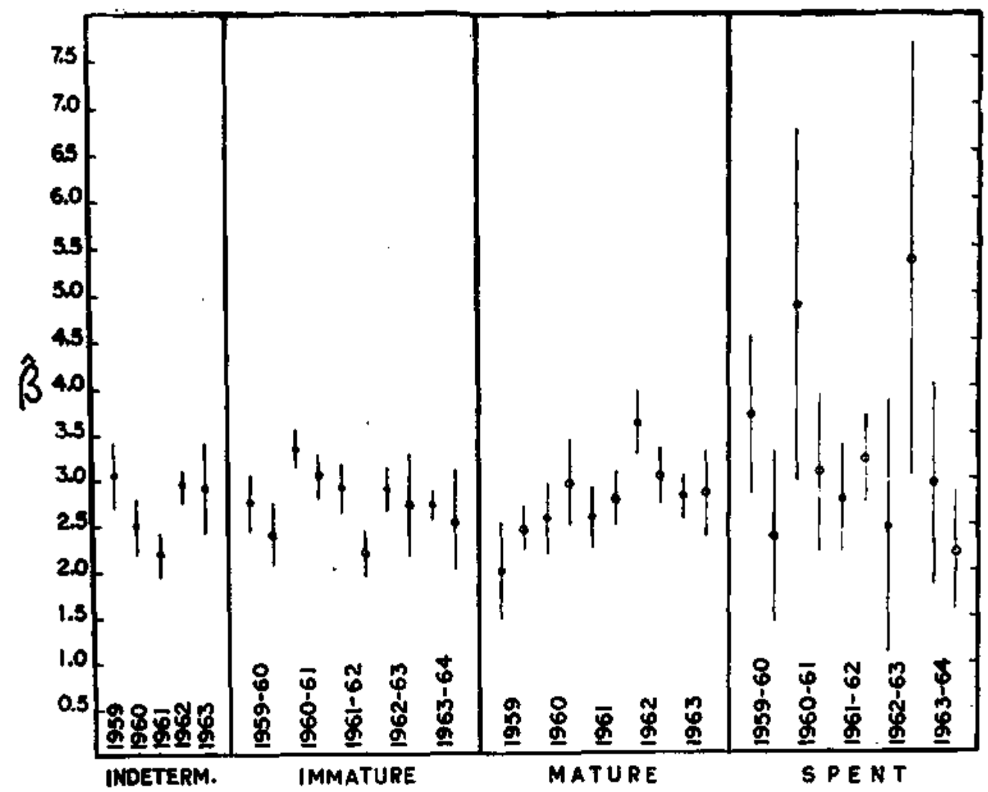

FIG. 2. Regression coefficients with their 95% confidence limits for different groups during different seasons. (Solid circles in the sexed fish refer to males and open circles to females).

The individual regression coefficients of the different sub-groups are shown in Fig. 2 with their 95% confidence limits. An interesting feature noticed from this illustration is that while in the immature group, the females have recorded a slightly lower value of *b* than the males uniformly in all the seasons, the converse is true when the fish become mature (except in the mature group of 1962). Generally speaking, it may be said that the females are slightly thinner in the immature state but with the attainment of maturity, they become fatter and slightly more rotund than the males. In the spent group such a clarity could not be noticed, for both cases are recorded during the 5-year period. Between the indeterminate and immature fish also, no clear trend is seen, for while in 1959-60 and 1963-64, the indeterminates have a higher value of *b*, the reverse is the case in 1960-61 and 1961-62. Thus, the observations of Dhulkhed (1963) that the indeterminates have the highest values followed by the females and males are not borne out by the present study. Perhaps his data being limited to only one year, it is possible that some trend showed up which may not be a true index of the real biological phenomenon. Dhulkhed (*loc. cit.*) has also combined his data relating to the indeterminate, female and male of *Sardinella longiceps* on the inference that there were no significant differences between the regression coefficients. However, an analysis of covariance attempted on his data reveals that the differences between the groups are significant at 5% level but not at 1%. The variance ratio of 4.16 is rather nearer 1% than 5%. Hence, while statistically it would not be correct to have pooled the data, it also appears rather premature to conclude, based on an year's data which relate to different year-classes, that the samples belong to a homogeneous population.

From Fig. 2 it is also seen that the regression coefficients for the immature groups, which form the commercial fishery, show peak value in 1960-61 followed by a steady fall in the values through the subsequent years. Whether this trend in any way reflects the steady fall in the oil-sardine fishery from 1960-61 through 1963-64 can only be vaguely indicated with no other evidence at present to substantiate the doubt.

SUMMARY

A total of 2,739 fish caught during 1959-64 was examined for length-weight relationship of the Indian oil-sardine, *Sardinella longiceps* through analyses of covariance, after classifying the fish according to seasons of capture, sex and maturity.

In view of the length-weight relationship differing significantly among fish of different seasons and maturity groups, different length-weight regressions may have to be used to convert the statistics of catch from weight to number of fish.

Generally, the differences between sexes in the immature and mature categories were not significant. Between the indeterminate and immature groups of the same season, the slope of the relationship may be comparable but the elevation was significantly different, which may be due to differences in the size groups examined.

Out of 35 values of regression coefficients for different groups which ranged from 2.0 to 5.4, 12 were found to depart significantly from the isometric growth value of 3. The majority of the values lie between 2.5 and 3.0.

The females are slightly thinner than the males in the immature state but with the attainment of maturity, they become fatter and slightly more rotund than the males.

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