VARIATIONS IN VERTEBRAL NUMBER OF YOUNG *SARDINELLA AURITA* IN RELATION TO TEMPERATURE DURING SPAWNING SEASON

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INTRODUCTION

Several workers (SCHMIDT, 1917 ; HUBBS, 1922 ; WISNER, 1961 ; HEMPEL and others) found that in fishes the average number of vertebrae is affected by the prevailing water temperature at the time of egg development. Negative correlation between the vertebral number and the water temperature was observed in nature. In some of the experimental work (TANING, 1952 ; SEYMOURE 1959 and others) it was found that not only high temperatures, but also low temperatures cause a decrease in vertebral number. The influence of temperature is restricted to a certain sensitive stage in embryonic development. Relating to his experiments TANING (1952) writes : "The plastic period for the vertebrae was soon found to be early in ontogeny, long before the hatching of the egg, in gastrulation period".

Vertebral counts of *Sardinella aurita* from different countries (BEN-TUVIA, 1960 a) show a certain amount of variation being the lowest in Angola (47.44) and Israel (47.46) and the highest off Rhodes Island (48.38) and other parts of Aegean Sea (48.28). The differences seem to depend on sea temperatures ; in colder areas the average number of vertebrae tends to be higher.

Studies in Israel previous to 1961 brought to light a great deal of variation which could only be attributed to heterogeneity in the investigated material. In the present study an attempt was made to test the hypothesis that a considerable month — to — month variation in vertebral number of young fish of the same size can be expected even in the same locality as a result of changing thermal conditions during the spawning season. Also a study was made on the vertebral variations between fish of different sizes, taken at the same time and place, to see whether this variation can be attributed to the same cause.

Materials and methods.

Samples of young sardinella (0 age group), 7-15 cm in total length were taken for vertebral counts at irregular intervals between july and november 1961 and june and october 1962. Most of the fish ranged in length from 7,5 to 11,5 cm (fig. 1). These juvenile fish appear in considerable quantities in commercial catches from the end of June until the end of the light fishing season in november. The 18 mm mesh size (stretched) of Cianciola purse seine does not usually retain fish smaller than 7 cm.

Of the total of 19 samples, 16 were obtained from Haifa bay, one from Dor and two from Jaffa. The distance between Haifa in the north and Jaffa in the south is only 60 miles and it is assumed that the same stock is available to the fishery in both areas.

Fish in each sample were measured for total length and grouped in 5 mm intervals. A total of 1020 specimens were examined for vertebra in 1961 and 2801 in 1962.

Skeletons were prepared from fresh fish and counted under binocular. The urostyle was included as a part of the last vertebrae. Vertebral numbers thus obtained were analysed for differences between samples taken at various dates. In addition, the 1962 samples were analysed for differences between length groups.

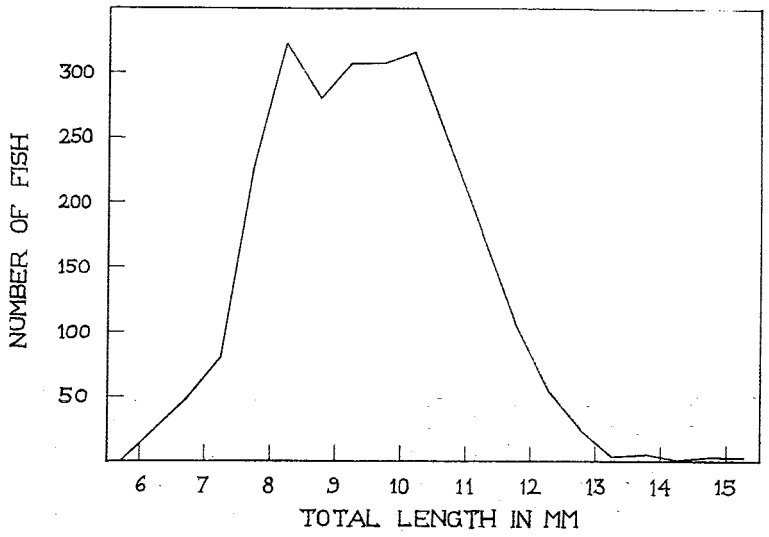

FIG. 1. — *Length distribution of juvenile* Sardinella aurita *used for vertebral counts in* 1962.

Variation in vertebral number.

It was found (BEN-TUVIA 1960a and unpublished data) that *Sardinella aurita* spawns more than once during the spawning season. There is no indication of separate spawning populations migrating along the Israeli coast and adapted for spawning during different months. Therefore it is presumed that eggs of the same parental population are hatched in various months, from april or may until september, within a wide range of temperatures.

The temperature of the sea varies greatly during this period. The average surface temperature of the Mediterranean coast of Israel for years 1947-1956 (OREN, 1957):

Month:	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Temp. (°C):	17°41	17°19	16°97	19°74	21°80	25°61	28°19	28°59	29°07	26°26	23°01	20°04

After the winter interpause spawning starts in spring when the surface temperature rises over 20°C. This occurs along the Mediterranean coast of Israel usually in may and occasionally in april.

The gradual increase in temperature during the spawning season is considered as the cause of the progressive decrease in the number of vertebrae among the juvenile sardinella caught between june-july and november. It is suggested that fish which reached a length of 8-10 cm in one of those months were born approximately two months earlier. Thus fish obtained in july were born in may, those of august were born in june, etc. Fish of november with the lowest vertebral number were born apparently during the second half of august or in september when the temperatures are highest.

Considerable year-to-year variations in the sea temperatures were recorded during these months (OREN, 1957 ; BEN-TUVIA, 1960 b). This period seems to be extremely important for the reproductive processes of the population. Low temperatures of the sea water

in april and may cause a late spawning and on extreme occasion this may occur as late as the second half of may. High temperatures, on the other hand, induce spawning as early as the end of april. This difference may be responsible for the year-to-year fluctuations in the strength of the year classes of sardinella (BEN-TUVIA, 1960 b).

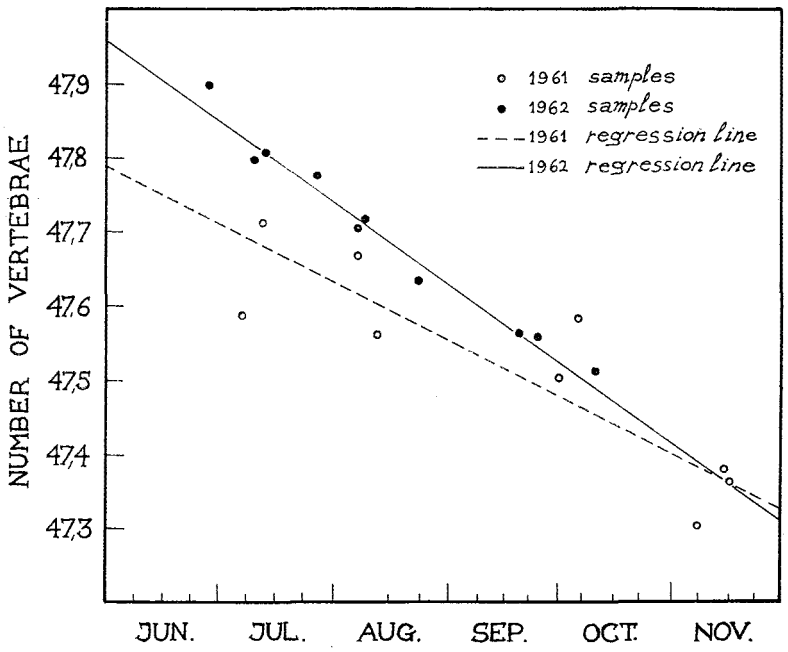

FIG. 2. — *Dependence of the average number of vertebrae on the date of sampling.*

Variations in temperature may also explain why samples taken in july and august of 1962 show significantly higher vertebral counts than those taken in corresponding months of 1961. As seen in figure 2 the difference between two points on the regression lines for the 15 of july is 0.13 vertebrae. Presumably young fish collected in july-august were born early in the spawning season; they would be influenced by the sea temperatures prevailing during april-may, which was higher in 1961 than in 1962 (table 1.)

Month	Year	
	1961	1962
April	19°32	18°54
May	22°73	20°01

TABLE 1. — *Average surface temperatures along the coast of Israel* (OREN, unpublished data).

Statistical treatment of data.

The data for 1961 and 1962 are shown graphically in figure 2, each point representing the average number of vertebrae in each sample. This graph indicates that a linear relationship exists between Y, the number of vertebrae and T the time when the sample was collected, i.e.

$Y = mT+C$. Taking june 28th as the zero for T, this being the earliest date, either in 1961 and 1962 for which a sample was collected, the least squares estimates of m and C are as follows :

1961	m	— 0.0025	C	47.723
1962	m	— 0.0036	C	47.867

The statistical significance of the estimates of m were tested using a two sided t — test. The resultant values of t were :

1961	t = 4.48
1962	t = 32.29

In both cases the values of this greater than the tabulated 0.001 level of t establishing that a negative correlation exist between the number of vertebrae and the time of sampling.

It should be noted that the above equation is only valid for the period from june to november, this being the period during which fish of the o group, spawned from may to september, appear in the catch.

Date	Locality	Number of Vertebrae				Total	Mean
		46	47	48	49		
7.7.1961	Haifa	—	24	34	—	58	47.586
12.7	"	—	50	94	7	151	47.715
7.8	"	—	63	106	6	175	47.674
12.8	"	—	73	92	1	166	47.566
1.10	"	—	53	51	1	105	47.505
6.10	"	—	64	84	2	150	47.587
7.11	"	3	79	38	—	120	47.294
14.11	Jaffa	—	47	29	—	76	47.382
15.11	Dor	—	12	6	1	19	47.368
28.6.1962	Haifa	—	40	150	20	210	47.905
10.7	"	—	43	128	8	179	47.803
13.7	"	—	13	46	2	61	47.819
27.7	"	—	104	254	17	375	47.768
8.8.	"	4	139	269	20	432	47.706
9.8	Jaffa	—	150	280	20	450	47.711
22.8	Haifa	3	67	112	6	188	47.644
19.9	"	6	191	237	10	444	47.565
24.9	"	7	114	159	3	283	47.558
10.10	"	3	82	93	1	179	47.514

TABLE 2.- *Vertebral counts of* 1961 *and* 1962 *samples.*

Variation between length groups.

Juvenile fish of each sample collected in 1962 were divided into 5 mm length groups. Vertebral counts obtained for each length group in a sample show a great deal of variation, usually with a trend toward higher counts in larger fish.

Five samples out of ten exhibit a positive correlation between the length of fish and the average number of vertebrae. In the other five samples there is no such correlations ; however the graphed data show a slight upward trend. In general there are indications that positive correlation exists between the length of the young fish and their vertebral number. This could

be explained assuming that the larger fish are older and were born in the early period of spawning when the temperatures were low. A similar explanation was briefly suggested for juvenile *Clupea pallasii* by HUBBS (1925) who found that small fish, apparently born late in the season exhibit lower vertebral counts than larger one.

The fact that 50% of the 1962 samples do not show correlation between the length of fish and the number of vertebrae could be caused by several factors such as bias of sampling, migrations of sardinella, variability in growth rate, etc.

Further studies are greatly needed to clarify the part played by various biotic and abiotic factors in determining the average number of vertebrae in sardinella of the eastern Mediterranean.

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SUMMARY

Vertebral counts of *Sardinella aurita* from the Mediterranean coast of Israel were made from samples taken at irregular intervals through the summer and fall of the years 1961 and 1962. The fish examined all belong to 0 age group and ranged from 7-15 cm in total lengths.

The average number of vertebrae decreases gradually being the highest for june sample (47.9) and the lowest for november (47.3).

This can be attributed to the changes in temperature of the sea water during the time when the fish were born. There is evidence that young fish, which appear for the first time in commercial catches towards the end of june, were born at the beginning of the spawning season i.e. at the end of april or the first half of may, when the prevaling average surface temperature is about 20 °C. The temperature rises quickly during june and reaches over 28 °C in july or august or september. The young sardinella born late in the season are characterized by a low average number of vertebrae as shown in samples collected in october-november. Thus a negative correlation exists between the sea temperature at hatching time and the average vertebral number. Apparently fish born throughout the spring and summer in the same area arise from the same parental population.

Part of the 1962 samples demonstrate a positive correlation between size class and average vertebral number. It is assumed that the larger fish are older than the smaller fish within the same sample and therefore their higher vertebral number reflects the thermal conditions at an earlier time of spawning.

1962 — year samples have higher vertebral counts than those of year 1961 taken in corresponding months. It is possible that these differences are due to lower temperatures prevailing in april and may 1962 as compared with 1961.

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