ON THE PATTERN OF DECREASE IN THE ABUNDANCE OF MACKEREL IN THE INSHORE WATERS OFF KARWAR WITHIN A FISHING SEASON

BY S. K. BANERJI

(*Central Marine Fisheries Research Institute*)

It is a well known fact that the mackerel fishery in India shows wide fluctuations from year to year. This intra-seasonal fluctuation is generally reflected by the mean seasonal index of abundance which is obtained by dividing the total catch (either in number or by weight) by the total effort in the season. Apart from this intra-seasonal fluctuation, there is the inter-seasonal variation in the abundance of mackerel. While there is no pattern in the intra-seasonal fluctuations in abundance, a definite pattern is noticed in the variation of abundance of mackerel within a season. In the inshore waters off Karwar, the mackerel fishery starts generally in the month of October ; then the fishery reaches its peak when the maximum abundance of mackerel is noticed in the inshore waters and thereafter the abundance of mackerel begins to the fall down till the mackerel population completely disappears from the inshore waters by about the month of April or May. This decrease in abundance of mackerel population in the inshore waters during a season is due to several factors *viz.*, (a) decrease due to fishing, (b) decrease due to migration away from the fishing grounds, (c) decrease due to natural mortality etc. It is of interest to examine if the rate of inter-seasonal decrease in abundance of mackerel stock is in any way dependent on the seasonal abundance of mackerel or it is independent of the seasonal abundance of mackerel. This aspect of the mackerel fishery has been examined in this paper with reference to fishery data of Karwar from 1948-49 to 1958-59 and the implications of the findings have been discussed. It is felt that the same aspect of the fishery needs examination with respect to data of other regions.

MATHEMATICAL THEORY

Let there be N_t fish in the inshore waters at any time t, where t is counted from the time of maximum abundance of the fish. Let the decrease in the population number in a small unit of time dt be proportional to the number present. Then we get

$$\frac{dN_t}{dt} = -iN_t$$

which on solution gives:--

$$N_t = N_o e^{-it} \qquad \ldots\ldots (1)$$

where i is the instantaneous rate of decrease and No is the initial number of fish at the beginning of the time-scale.

Taking the time unit as a month, the equation (1) can be re-written as:--

$$\text{Log } N_t = \log N_o - {}^{it} = a - it \qquad \ldots\ldots (2)$$

where $a = \log N_o$. Thus if log N_t is plotted against time, the slope of the regression line of log N_t on t, *i.e.*, the regression coefficient will furnish an estimate of the total instantaneous rate of decrease.

The actual population number N_t is not known. Hence instead of using N_t, an index of abundance which may be considered as proportional to the population number will be used in finding the regression line similar to equation (2). If n_t is the number of mackerel caught in a month with E_t units of effort, the number caught per unit effort *viz.*, n_t / E_t will be considered as an index of the actual number N_t present. Hence instead of fitting the regression of log N_t on t, we may find the regression of the logarithm of monthly index of abundance on time.

The comparison of the regression lines for different years will permit answering the question if the regression coefficients differ significantly among years, and if the difference bears any relation to the levels of initial abundance in a year.

SOURCE OF MATERIAL

The data used in this paper are either from already published papers or from the unpublished quarterly and annual reports of the Central Marine Fisheries Research Institute. The table I shows monthwise from 1948-49 to 1958-59, the number of mackerel caught at Karwar (n_t) and also the effort E_t expended in a month t. The unit of effort expended is a piece of Rampan net. The last column also shows log n_t / E_t *i.e.*, the logarithm of the monthly index of abundance.

The data for the years 1948-49 to 1952-53 are taken directly from Pradhan (1956). The data for the years 1954-55 and 1955-56 are compiled from Radhakrishnan (1958). The data for other years are compiled from the quarterly and the annual reports of the Institute (unpublished).

ANALYSIS OF THE DATA

Even though the fishery started in October at Karwar in all the years under consideration, it is only in November that the highest abundance (*i.e.* n_t/E_t) was usually noticed. In some years, however, there was departure from this usual condition. The maximum abundance in 1948-49 and 1957-58 was noticed in December only, whereas the same was noticed in October in the years 1951-52, 1955-56 and 1956-57. Though the mackerel population begins to appear in the fishing grounds off Karwar by October every year, it may be assumed that it is fully recruited to the fishing ground from the month of highest abundance. Thus the origin of the coded time has been taken at the month of highest abundance and is shown in Column 2 of Table I.

TABLE I

Showing the number of mackerel landed at Karwar, the effort spent, the apparent index of abundance etc.

Season & month	Coded time=x	No. of fish (n_t) (in '000)	Effort (E_t) (pieces of Rampan)	(n_t/E_t)	log $n_t/E_t = Y$
1948-49					
October	..	816	1,851	441	6·09
November	..	6,294	8,506	740	6·61
December	0	10,102	9,101	1,110	7·01
January	1	2,051	8,006	256	5·55
February	2	39	7,840	5	1·61

TABLE I—*contd.*

Season & month	Coded time-x	No of fish (nt) in ('000)	Effort (Et) (pieces of Rampan)	log nt/Et	-Y
1949-50					
October	..	44	861	51	3·93
November	0	6,650	9,110	730	6·59
December	1	3,696	8,213	450	6·11
January	2	63	1,211	52	3·95
1950-51					
October	..	2,855	6,000	475	6·16
November	0	9,015	9,006	1,001	6·91
December	1	4,704	8,355	563	6·33
January	2	4,423	7,594	582	6·37
February	3	448	8,058	56	4·03
March	4	1,344	5,508	244	5·50
1951-52					
October	0	355	700	507	6·23
November	1	3,592	9,233	389	5·96
December	2	3,671	7,825	469	6·15
January	3	759	5,750	132	4·88
Februry	4	4,328	10,378	417	6·03
March	5	853	2,253	379	5·94
1952-53					
November	0	5,669	10,306	550	6·31
December	1	1,315	10,779	122	4·80
January	2	538	8,276	65	4·17
February	3	477	8,241	58	4·06
March	4	219	3,188	69	4·23
1953-54					
November	0	6,895	12,495	548	6·31
December	1	5,586	14,460	386	5·96
January	2	995	8,940	111	4·71
February	3	76	2,600	29	3·37
March	4	24	1,000	24	3·18
1954-55					
November	0	8,692	19,230	452	6·11
December	1	1,801	9,505	189	5·24
January	2	69	13,665	5	1·16
February	3	91	7,195	13	2·56

TABLE I—contd.

Season & month	Coded time-x	No of fish (nt) in' (000)	Effort (Et) (pieces of Rampan)	(nt/Et)	log nt/Et = y
1955-56					
October	0	2,414	6,200	389	5·96
November	1	1,460	11,050	132	4·88
December	2	866	12,275	71	4·26
January	3	760	10,875	70	4·25
February	4	39	6,100	6	1·79
March	5	169	4,850	35	3·56
1956-57					
October	0	1,465	5,260	279	5·63
November	1	628	5,570	113	4·73
December	2	205	910	225	5·32
January	3	1,336	11,145	120	4·79
February	4	502	10,980	46	3·83
March	5	118	2,510	47	3·85
1957-58					
October	..	334	5,160	65	4·17
November	..	12,948	18,522	699	6·55
December	0	10,899	15,248	715	6·57
January	1	595	8,236	72	4·28
February	2	30	475	63	4·14
1958-59					
October	..	398	1,200	332	5·81
*November	0	8,213	18,800	437	6·08
December	1	7,540	18,300	412	6·02
January	2	2,943	11,500	256	5·55
February	3	6,776	17,500	387	5·96
March	4	5,139	15,350	335	5·81
April	5	1,604	9,225	173	5·15

The Table II gives the sum of squares and products for the two variables *viz.*, $\log_e n_t/E$ which we represent by y and the coded time t which is represented by x. The table also gives the value of the regression coefficient which is an estimate of i for each fishing season. The last column furnishes the sum of squares of the deviations from the regression line of y on x.

TABLE II

Corrected sum of squares and products of y and x for different years, and the deviation from regression

Years	d.f.	y^2	xy	x^2	b	$y^2 - \frac{(xy)^2}{x^2}$	d.f.
1948-49	2	15·6051	—5·40	2	—2·70	1·0251	1
1949-50	2	3·9552	—2·64	2	—1·32	0·4704	1
1950-51	4	5·0569	—5·12	10	—0·51	2·4355	3
1951-52	5	1·2266	—1·25	17·5	—0·07	1·1366	4
1952-53	4	3·5125	—4·90	10	—0·49	1·1115	3
1953-54	4	8·2589	—8·85	10	—0·88	0·4267	3
1954-55	3	13·7178	—7·14	5	—1·43	3·5219	2
1955-56	5	9·7422	—10·64	17·5	—0·61	3.2731	4
1956-57	5	2·7373	—6·06	17·5	—0·35	0·6354	4
1957-58	2	3·7229	—2·43	2	—1·21	0·7705	1
1958-59	5	0·6287	—2·43	17·5	—0·14	0·2899	4
Within years	41	68·1641	—56·86	111·10	—0·51	39·0374	40
Between years	10	23·6453	2·7166	15·98	—0·17	23·1835	9
TOTAL	51	91·8094	—54·1434	126·98	—0·43	68·7230	50

The Table III presents the analysis of covariance for comparing the regressions of different years and also for testing difference in adjusted means. Comparison of the mean square for linear regression within years with that of differences among regressions gives the value of F=4·76. The 5% value of F with 10 and 30 degrees of freedom is 2·16. Hence the regression coefficients in different years are significantly different. Similarly, comparison of the mean squares of average regressions within years and differences in adjusted means shows significant differences in adjusted means in the different years.

TABLE III

Analysis of covariance for testing the adjusted means and the regressions for the years 1948-49 *to* 1958-59

Sources of deviation	d.f.	s.sq.	m.sq.
Linear regressions within years	30	15·0966	0·5032
Differences among regressions	10	23·9408	2·3941
Average regression within years	40	39·0374	0·9759
Defferences in adjusted means	10	29·6856	2·9686
TOTAL REGRESSION	50	68·7230	

When there are significant differences in the regression coefficients between different years, there is no physical meaning in the differences between adjusted means of different years. But if the regression coefficients *i.e.* the slopes between years are not significantly different the physical significance of the difference in adjusted means is that the levels of abundance of mackerel in different years are different. In a pelagic fish population like mackerel, the abundance in the inshore fishing grounds may vary from year to year on account of environmental and other conditions. Granting such variations in levels of abundance, the regression coefficients between different years may either be significantly different or not. If the regression coefficients are not significantly different between years, we may take it as a measure of instantaneous rate of decrease, whatever be the levels of abundance. On the other hand, if they are significantly different these differences may be either due to differences in the levels of abundance or due to environmental factors or abnormal fishing conditions. It has been shown below that environmental factors and abnormal fishing conditions resulting from these, rather than varying levels of abundance, may be the likely causes which affect the regression coefficients. If the fishing conditions remain normal no significant differences are observed in the regression coefficients, even though the levels of abundance in these years may be significantly different. In fact, Ketchen (1961) discussing on pacific cod has cautioned against using catch per unit effort as indices of abundance when there are environmental imbalance. He says "if cod are adapted to a fairly narrow temperature range, then presumably, they will respond by moving away when confronted with intrusions of waters having temperature much above or below this range. Frequently, fishermen report the sudden disappearance of cod from fishing banks. If these disappearances are of long duration in a fishing season, then obviously, fishing success (average catch/effort) would be inaccurate reflections of abundance................".

The analysis of covariance presented in Table III shows that there is significant difference in the regression coefficients of different years. From Col. 6 of Table 2, it is observed that the regression coefficient varies from —0·07 to —2·70. Rather extreme values are observed in the years 1948-49, 1951-52 and 1958-59. In fact, the fishery conditions during these 3 years were not normal. Pradhan (1956) states that in 1948-49, the fishing season was fairly good, but there were frequent interruptions in fishing due to unprecedented weather conditions like cyclones and heavy rains. Similarly, he states that in 1951-52, the fishing season was characterised by the erratic appearance of shoals in the inshore waters off Karwar. In 1958-59 season, there was a bumper landings of mackerel, creating a glut condition and thereby preventing fishermen from normal fishing. As stated by Ketchen (1951) in case of cod, these unusual conditions probably distorted the monthly indices of apparent abundance and thereby also affected the regression coefficients in these particular years. In other years, the fishing conditions were more or less stable. So it is worthwhile to examine the data of only those year when the conditions were normal.

The Table VI presents the analysis of covariance for the data relating to the years 1949-50 to 1950-51 and 1952-53 to 1957-58. The analysis shows that while there was no significant difference in the regression coefficients between different years, the adjusted means show significant difference. This means that during the 8 years, under examination, even though the level of abundance of fish population varied from year to year, there was no significant difference in the regression coefficient between y ($= \log_e n_t/E_t$) and χ ($= t$). Since the levels of abundance were different, the best estimate of b is obtained by considering the average regression line, which gives $b = +\cdot 645$.

TABLE IV

Analysis of covariance for testing adjusted means and regression coefficients for data relating to 1949-50 *to* 1950-51 *and* 1952-53 *to* 1957-58

Sources of deviation	d.f.	s.sq.	m.sq.
Linear regressions within years	21	12·6450	0·6021
Difference among individual regressions	7	7·2083	1·0298
Average regression within years	28	19·8533	0·7090
Difference in adjusted means	7	12·9394	1·8484
TOTAL	35	32·7927	

$$F(7,21) = \frac{1\cdot0298}{0\cdot6021} = 1\cdot71 \quad \text{N.S.}$$

$$F(7,28) = \frac{1\cdot8484}{0\cdot7090} = 2\cdot61 \quad *$$

The variance of b is given by

$$V(b) = \frac{\left(y^2 - \frac{(xy)^2}{x^2}\right) / (n-2)}{x^2} = .0096$$

where x^2, y^2 and xy denote the corrected sum of squares and products respectively.

The 95% confidence limits of b are therefore given by $b \pm t_o V(b)$ *i.e.* $\cdot645 + \cdot20$, where t_o is taken from student's distribution.

Thus the best estimate of instantaneous rate of decrease of the population under normal fishing conditions, whatever be the levels of abundance of the population is 0·645 *i.e.*, 0·64 and its 95% upper and lower confidence limits are 0·44 and 0·84.

The total monthly rate of decrease is given by $1-e^{i}$. The best estimate of the total monthly rate of decrease is 0·47 and its confidence limits are 0·36 and 0·56.

DISCUSSION

In the section on the mathematical theory it was assumed that the decrease in population number was proportional to the number present at any instant and was independent of the age structure of the population. If it could now be assumed that all the fish present in the population are of the same age group, the estimate of instantaneous rate of decrease will in fact be equivalent to an estimate of instantaneous rate of total mortality. Both Pradhan (1956) and Sekharan (1958) have stated that the mackerel fishery on the West Coast depends mainly on one age group *viz.*, the second year class. After making its contribution to the fishery in the inshore waters, the residual portion of this age group migrates away from the fishing ground and most probably is not available again in the next fishing season for commercial exploitation. What happens to this age group subsequent to its migration away from the inshore fishing ground after it has been exploited by a commercial fishery in the fishing season, will probably remain a matter of conjecture unless more facts are known about the fish but from the point of view of commercial fishery, this loss due to migration has got to be considered as a major component of the natural mortality. The best estimate of instantaneous total mortality rate under the assumption of only one age group being fished can therefore be taken as 0·64.

The analysis of covariance had shown that in normal years the total instantaneous rates of decrease (mortality) do not show significant variation over years even inspite of difference in levels of seasonal abundance. When there is a high abundance of fish in a limited area like the inshore waters it means that denser shoals are available for commercial exploitation and the coefficient of fishing mortality would be higher than when the shoals were thinner and the fish scarcer due to low abundance. But since the total instantaneous rate remains unaffected by changes in the levels of abundance, it is likely that fishing has very little effect on the instantaneous total rate. The major component of the total rate must be therefore due to natural loss including loss due to migration. Ketchen (1961) discussing Pacific Cod states that in a fishery "with a high natural mortality rate (with short life span), annual fishing success would depend heavily on the numerical strength of the incoming year-class and would therefore be relatively unstable. This will be exhibited by great fluctuation in the catch per unit effort among different years". This is exactly the situation with the mackerel fishery in India. The natural mortality is perhaps relatively very high compared to the fishing mortality and there is consequent fluctuation in the abundance and catch of mackerel from year to year.

SUMMARY

In spite of variations in the levels of abundance of mackerel from year to year, the instantaneous rate of decrease remains constant. If the hypothesis that mackerel fishery mainly depends on only one age group is valid, then the instantaneous rate of decrease is an estimate of the coefficient of instantaneous total mortality, the best estimate of which is found to be 0·64. It has been postulated that the component of fishing mortality is relatively negligible and the component of natural mortality is predominant. As such the mackerel fishery depends mainly on the numerical strength of the incoming age group and is therefore highly unstable from year to year.

REFERENCES

Ketchen, K. S. (1961) . . . . . . Pacific cod in Canadian waters. Jour. fish. Res. Bd. Canada **18** (4).

Pradhan, L. B. (1956) . . . . . . Mackerel fishery of Karwar. Indian J. Fish **3**(1).

Radhakrishnan, N. (1958) . . . . . . Observations on Mackerel fishery at Karwar for the seasons 1954-55 and 1955-56. *Ibid.*, **5**(2).

Sekharan, K.V. (1958) . . . . . . On the South Kanara coastal fishery for mackerel *Rastrelliger Canagurta* (cuvier) together with notes on the biology of the fish *Ibid.*, **5**(1).