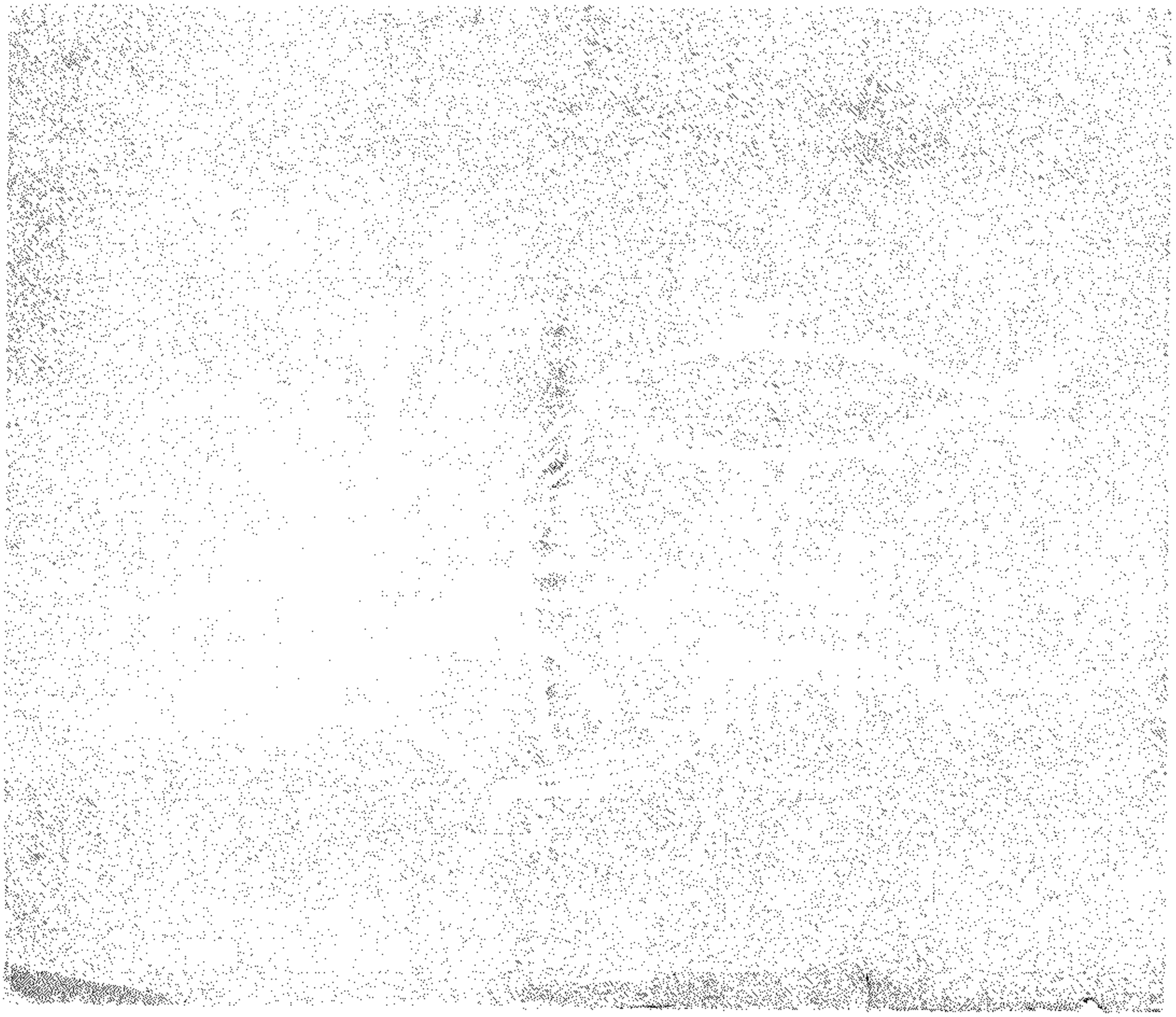
PROCEEDINGS OF THE SYMPOSIUM

ON

LIVING RESOURCES
of
THE SEAS AROUND INDIA



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ACCELERATION OF ASSESSMENT OF FISH POPULATIONS AND COMPARATIVE STUDIES OF SIMILAR TAXONOMIC GROUPS

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ABSTRACT

Proper assessment of the impact of fishing on the various fish populations is essential for the efficient management of the fishery resources of the country. Three types of assessment have been distinguished. A preliminary assessment just indicates if fishing is affecting the stock. The second type of assessment predicts long-term effect of fishing on a stock without taking into consideration the effect of fluctuating environmental factors. The final type, which is obviously the ultimate objective of all assessments, takes into account changing environment in forecasting the effect of fishing on a stock. Various diagnostic characters and parameters needed to be estimated for each type of assessment are indicated. Quicker methods of estimating some of the parameters are indicated. The role of comparative study of similar taxonomic group for such estimation of some of the parameters has been mentioned.

1. INTRODUCTION

A PROPER assessment of the impact of fishing on the fishery resources is essential for the efficient management of the fishery resources of the country. The existing procedures for a fairly realistic assessment of a fish population, based on reliable estimates of various parameters involved, need a large amount of basic data for many years and consume considerable amount of time. For an efficient management of the fishery the requirement is not only to have a proper assessment of the population but also to have it done as quickly as possible. This goal may be approached in two different ways. Either new methods in which the time factor involved is considerably small, has to be discovered or the existing methods can be developed and the time factor may be reduced by using short-cuts, approximations and other methods.

Further approach to this problem will depend on the type of population assessment required which in turn falls according to the nature of information to be obtained. The types of population assessments can be broadly put under two heads, namely, (1) Rough assessment and (2) Detailed assessment. The method of detailed assessment can itself further be divided into two groups, one considering the resource without reference to its dynamic habitat and the other considering the same with reference to the dynamic habitat in which it lives along with other communities. When it is required to know whether the fishing intensity is affecting the stock and the yield significantly or not the methods of rough assessments can be made use of. This will also indicate the nature in which the population is affected by the fishing intensity. When our need is for a detailed diagnosis of the present position of the fishery and a prediction of the long-term effects of the fishing intensity or selectivity on the population, the first method of detailed assessment is employed, whereas the second method of detailed assessment can be adopted when the necessity arises to assess and predict the year-to-year changes in stock and yield and also to know as early as possible whether a particular method of regulation brought into force is producing the desired result or not. The basic data needed and the parameters to be computed in order to expedite the calculations of various types of population assessments differ to a considerable extent

2. ROUGH ASSESSMENT

An examination of some features of fish population may help in the discrimination between lightly exploited stock from the heavily exploited ones. In a lightly exploited or virgin stock, the fish are usually old, on the average, large in size and have the appearance of heavy headedness of slow-growing fish. The density of fish in a lightly exploited fish population being high, the catch per unit effort is usually high. In a heavily exploited stock on the other hand, the density of fish is comparatively lower and so also the catch per unit effort and the catch consists of mostly smaller and younger fast-growing fish. Thus these discriminating features may be gainfully employed in making rough assessments of the general level of exploitation of a stock, particularly if data on the same features are available from another stock of the species for comparison. This method of rough assessment has been demonstrated by Graham (1929) in the case of *Tilapia esculenta* by comparing the taxonomic features of the species for two areas. Two useful synoptics derived from the above considerations are very useful. One is the synoptic $\bar{l}/\bar{l}_e$, where $\bar{l}$ is the average size of the catch and $\bar{l}_e$ is the minimum size of the fish at first capture. In a lightly exploited fish, the value of the synoptic will be higher than the value in a heavily exploited stock where the value of the synoptic will be nearer 1. The other useful synoptic is C/f which is catch per unit effort. In a heavily exploited stock, the value of C/f will be smaller than in a lightly exploited stock. If values of C/f and f are available for a fishery for several years and fishing exerts predominant influence on the stock, it is well known that the following relation holds good:

$$C/f = a - bf.$$

The yield curves are thus given by

$$C = af - bf^2$$

showing that the catch increases with the initial stages of increase in effort, reaches a maximum at a particular fixed amount of effort and then decreases with further increase in the effort. Therefore in a steady population if both C/f and C are seen to be having a downward trend it can be concluded that the increased fishing activity effects a reduction in the yield and hence the fishing effort in operation has to be reduced. Whereas if C is seen increasing with decrease in C/f, it can be said that the fishing effort does not produce any adverse effect on the yield and that the effort in operation can be increased. Since the above curve is seen to have the maximum point at $f = a/2b$, that will be the critical point on the effort line, where the maximum equilibrium yield will be obtained and the maximum equilibrium yield itself will be $a^2/4b$. These optimum values of C and f compared with the figures of annual or seasonal catch and effort on hand will supply us with bettter information regarding the position of the fishery. To illustrate by an example the data pertaining to the annual sciaenids landings in Gujarat together with annual input of effort are given below.

Catch, effort and catch per 1,000 units of effort of sciaenids in Gujarat

Year	Catch (tonnes)	Effort 10^6 m.hr.	Catch in kg. per 1,000 m.hr.
1960	2291	21	109·09
1961	1335	25	53·40
1962	4380	19	230·52
1963	2389	25	95·56
1964	2448	24	102·00
1965	1913	12	134·41
1966	1543	14	110·21
1967	1417	18	78·72

The relation between C and C/f is seen to be

$$C/f = 187{\cdot}274 - 3{\cdot}698 f$$

which leads to the result that a maximum equilibrium yield of 2371 m. tonnes can be obtained with a maximum effort of $23{\cdot}6 \times 10^6$ m. hrs. Looking into the data on catch and effort one finds that in the earlier years there have been some over-exploitation and the present intensity of fishing could be raised to some extent.

It must be mentioned, however, that the discriminating features mentioned above are not only affected by fishing but also by a host of natural factors. The interpretation of these features in terms of exploitation alone can, therefore, be sometime very risky. For example, the stock may increase or decrease due to some fishery-independent factors like availability of rich food or unfavourable condition for survival of young ones and in such cases either the linear relation between C/f and f does not exist or it may sometimes give a linear relation with a positive b.

Another simplified procedure used in the field of stock assessment employs, the rate of exploitation

$$E = \frac{F}{Z}(l - e^{-z})$$

where F and Z denote the instantaneous rates of fishing and total mortalities respectively. There exists a known relation that

$$W_0 = E\bar{W}$$

where W_0 is the weight at first capture and W is the mean weight of all the fish whose weight is greater than W_0 in the catch. So the yield from a given fishery can be increased when

$$E > (W_0/\bar{W}) \quad \text{(Allen, 1953)}.$$

This is known as the breakeven value of E and has been made use of in the ICNAF area. When W_0 and $\bar{W}$ are stipulated this procedure will supply us with a range of values of E within which an increase in yield can be expected. Further when F and M are not known the conditions under which the yield shall increase can also be estimated. In the case of the oil-sardine fishery in the west coast of India, the average weight W_0 of the new recruit class is about 12 gm. and the average weight of the fish above the recruit size in the commercial catch is about 32 gm. Thus the rate of exploitation is

$$E = W_0/\bar{W} = 0{\cdot}40.$$

The rate of exploitation can be made greater than this either by increasing W_0 or by reducing $\bar{W}$ or by a suitable combination of both. W_0 can be increased by raising the size of first capture and $\bar{W}$ can be reduced by increasing fishing effort. From the detailed analysis of oil-sardine resource in another paper, the following values are obtained:

$$M = 0{\cdot}67 \text{ and } F = 0{\cdot}75$$

so that,

$$E = \frac{F}{F+M}(l - e^{-z}) = 0{\cdot}40$$

a result already obtained, by a simple consideration above. If the present size of first capture is kept fixed as at present, F has got to be increased so that $E > 0{\cdot}40$. It has been shown elsewhere that the maximum catch is obtained at $F = 1{\cdot}40$.

3. DETAILED ASSESSMENT

Long-term assessment

For long-term assessment of the effect of fishing on yield, various mathematical models containing parameters of recruitment, growth and mortalities have been built up. Various models are fundamentally the same but they differ from one another in the assumptions made regarding the growth pattern of the fish. The most widely used model is that of Beverton and Holt, who assume the growth of fish to conform to Bertalanffy's growth equation. The yield equation developed by them contain seven parameters R, W_∞, F, M, t_0, K and t_ρ. Fairly accurate estimates of these parameters are necessary for estimating the long-term yield corresponding to particular F or t_ρ. Beverton and Holt (1957) and Parrish (1957) examined the effect on long-term yield prediction of variations in values of growth and mortality parameters and particularly of K. They noted that W_∞ and R appear as factors of proportionality and that if predictions are to be made in relative terms and if it is assumed that W_∞ and R do not change with changes in the intensity or selectivity of fishing, these two parameters in their model could be reduced. Holt (1957) further showed that the number of parameters can further be reduced by one by writing the coefficients of mortalities expressed as ratios of K. This reduces the computational labour a great deal particularly since Tanaka (1958) has pubilshed tables for Z/K from 0·0 to 15·0 and $K(t_\rho - t_0)$ from 0·0 to 6·0. But, while all these manipulations relate to easing heavy computational labour, the basic fact remains that fairly accurate estimates of growth and mortality rates are necessary for employing these types of assessments. The estimates of growth parameters can be fairly easily obtained if ages of fish could be determined. When age determination is difficult, attention is directed to the possible use of length frequency distribution of catch samples. Beverton and Holt (1956) has proposed an approximate formula for calculating

$$\frac{Z}{K} = \frac{l_\infty - \bar{l}}{\bar{l} - l_c}$$

where $\bar{l}$ is the mean length of all fish greater than l_c, the length of the fully recruited group in catch. Thus even in the absence of age composition of the catch, Z/K can be estimated if some estimates of l_∞ are available. An approach found useful in estimating the growth parameters is from the recovery of tagged fish. Gulland and Holt (1959) have shown that the length increment per unit time and average of initial length and length at recapture are linearly related and the line cuts the x-axis at l_∞ and has a slope $(-K/b)\tanh b$ which is equal to $-K$ for small values of b, where $b = Ka/2$ and $a =$ time interval.

Applying this method to the recovered tagged lobster on the south-west coast of India, the growth parameters for male and female lobsters were separately calculated as follows:

Estimates of parameters

	K	l_∞	t_0
Male ..	0·717	312·3711	−0·094
Female ..	0·601	303·1656	−0·117

The estimate of natural mortality M poses the greatest difficulty for the fishery biologists. As has been stated before, usually the estimates of total mortality rates are made from age distribution of commercial catch for every season and for separation of the natural mortality component from the total mortality rate, estimates of total mortality rates are required for several years when fishing effort varied markedly. Thus for estimation of M, data for several seasons are necessary. Apart from the time factor involved, the most disturbing factor is that environmental conditions may change a great deal thereby invalidating the estimation procedure of natural mortality. Le Cren (1958) has therefore suggested the desirability of investigating other ways of estimating mortality and other vital rates: ways which do not rely so much on variations in factors related with time. Beverton and Holt (1956) suggested several such methods. One of the suggestions was to make possible use of variations in fishing effort on different age groups, different sub-stocks or different sexes within one stock over a fairly short period of time. In fact, this suggestion can be very usefully used for estimating M for several fisheries in India. Venkatasubba Rao (1961) has made application of this method to Ghol fishery in Bombay waters. There is an extensive Ghol fishery in the inshore waters but recently the same fishery was exploited by trawling in the offshore waters. The age-groups exploited by trawl fishery was different from that of the inshore waters. From an analysis of the catch data of the trawl fishery, he estimated Z and this he assumed as equivalent to M, since F for the age-groups exploited by the trawl fishery was considered negligible. Reference may be made to the mackerel fishery in India in this connection. There is a big commercial fishery of mackerel existing on the west coast, but there is also a small fishery of the same along the east coast. In view of the limited fishery, the Z calculated from the fishery data of the east coast may be taken as an estimate of M which may ultimately be employed to assess the fishery of the west coast. There is very wide scope of employing the above method in calculating M for many of the Indian fisheries which are nearly all restricted to coastal waters and where only certain age-groups are being exploited at present. Then there are possibilities of marking experiments, estimations of total stock from egg production and estimation of area swept by fishing gear, etc. Many of these possibilities have to be tried and developed for accelerating the assessment of stocks and much fundamental research and experimental fishing are required towards the development of these methods. But the most important and promising suggestion towards estimation of many parameters by the application of comparative population studies to fisheries biology came from Holt (1959). Follwing his suggestions, an attempt has been made in this paper to examine the possibility of empolying methods of comparative studies to the Indian fisheries.

For the above purpose, collecting from published accounts all available information of lengths at different ages on various species of fish from Indian waters, the two growth parameters K and l_∞ were calculated. The minimum length at first maturity l_m was also noted down, wherever available. These data are summarized in Table I and the reference to the corresponding published accounts is also given alongside.

Svardson (1943) has stated that l_m/l_∞ is usually constant. Holt (1959) listing the informations available to him has found l_m/l_∞ to be varying between 0·25 and 0·90. From Table I, for the ten species belonging to three different orders for which the values of both l_m and l_∞ are available, it was found that l_m/l_∞ ranges from 0·31 to 0·72, majority of the values being round about 0·5 or 0·6. This rough relation may be of use to get an approximate idea of the magnitude of l_∞ of any species when l_m of that species which can be easily measured by observation is known. Instead of taking the proportional relation between l_m and l_∞, it was thought that they may be linearly related. The ten values of l_m and l_∞ available in Table I were plotted one against the other and it was found that a straight line would adequately fit the data. A straight line fitted by the method of least squares is seen to be

$$l_\infty = -90{\cdot}706295 + 2{\cdot}78095\, l_m.$$

The validity of the regression has also been tested by F test and found to be highly significant. The analysis is given in Table II.

TABLE I

The values of K, and l_m l_∞

Species	K	l_∞ mm	l_m mm	Source
Hemirhamphus georgii	1·33	236	..	Talwar, P. K. (1962)
Chanos chanos	2·31	315	..	Tampi (1960)
Sardinella longiceps	0·50	207	150	Hornell and Naidu (1924)
Sardinella albella	1·44	133	90	Sekaran (1955)
Sardinella gibbosa	1·08	171	88	Sekaran (1955)
Hilsa ilisha	0·49	511	190	..
Raconda russellina	0·40	247	..	Verghese (1961)
Anchoviella baganensis	..	..	50	George (1958)
Anchoviella batanensis	..	..	75	George (1958)
Coilia borneensis	0·70	185	..	Verghese (1961)
Setipinna phasa	..	..	150	Jingran (1961)
Thrissocles mystax	0·76	236	130	Venkataraman (1962)
Mugil cephalus	0·15	1400	..	Gingran and Mishra (1962)
Mugil dabula	0·13	1006	..	..
Mugil cunnesius	0·31	292	131	Sarojini (1958)
Mugil parsia	0·32	307	95	Sarojini (1957)
Salaroides leptolepis	..	..	88	Tandon (1961)
Psammoperda waigiensis	..	..	210	Prabhu (1954)
Otolithoides brunneus	0·19	1836	..	Narayanan Kutty (1961)
Pseudosciaena diacanthus	0·84	1046	..	Venkatasubba Rao (1961)
Sillago sihama	0·75	281	130	Radhakrishnan (1957)
Rastrelliger kanagurta	0·60	316	190	Sekaran, Devanesan and John (1940)
Scomberomorus guttatus	..	..	240	Krishnamurthy (1958)
Trichiurus haumela	0·20	980	370	Prabhu (1955)
Cynoglossus semifasciatus	..	..	100	Seshappa and Bhimachar (1955)
Psettodes erumei	..	..	331	Pradhan (1962)
Polydactylus indicus	..	..	700	Karekar and Bal (1960)

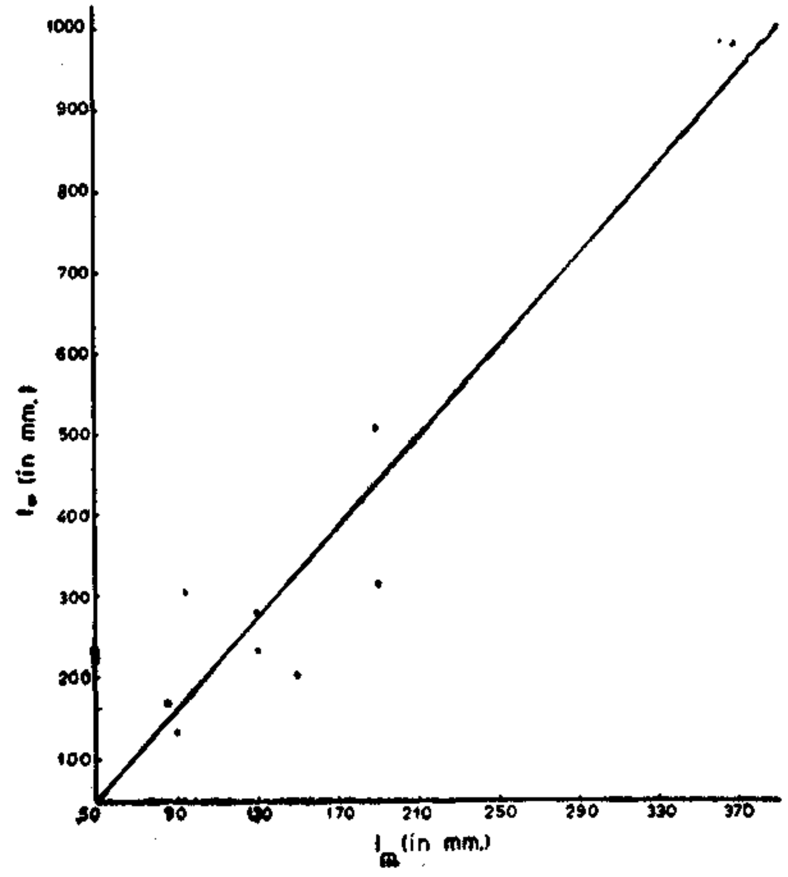

FIG. 1

TABLE II

Analysis of variance to test the significance of the linear regression between l_∞ *and* l_m

Source of Variation	D.F.	S.S.	M.S.	F
Due to Regression ..	1	489,071	489,071	68·6
Deviations ..	8	57,019	7,127	..
TOTAL ..	9	546,090	..	..

It is seen that about 90 per cent of the total variation in l_∞ is explained by the regression of l_∞ on l_m. Though there are not enough data for group-wise study, the five pairs of values available for the different species belonging to the order clupeiformes have been subjected to a statistical analysis and found to have a significant regression at 5 per cent level of probablity. The regression line is given by the equation

$_{\infty} = -\ 138\cdot496 + 3\cdot0240\ l_{m}$ and the fitted line shown in Fig. 2.

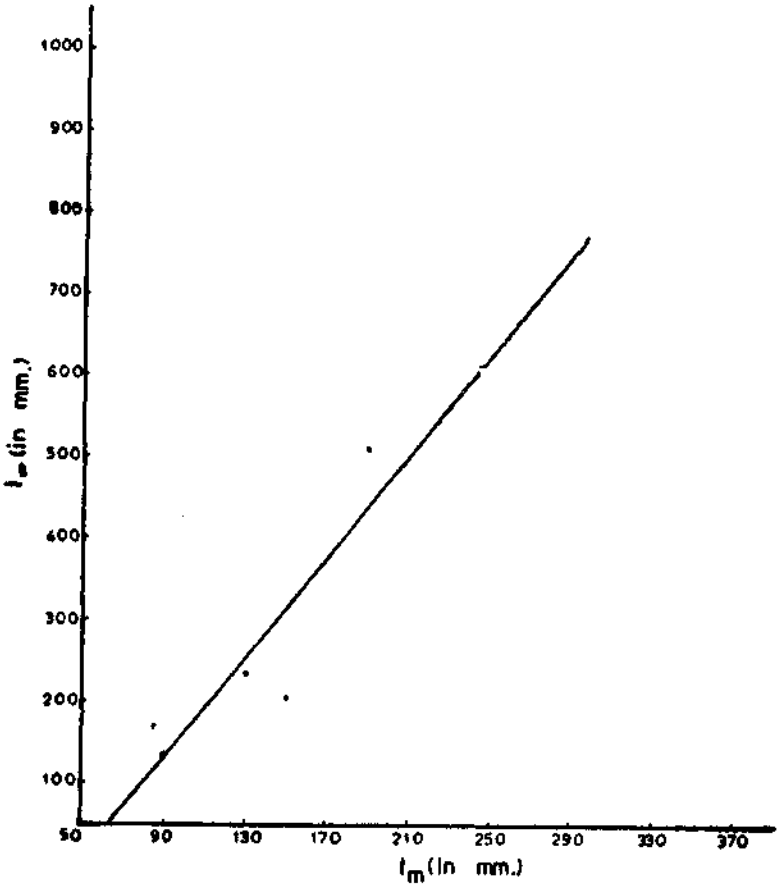

FIG. 2

The relevant analysis is given in Table III.

TABLE III

Analysis of variance to test the significance of the regression of l_{∞} on l_m for Clupeiformes

	D.F.	S.S.	M.S.	F
Source of Variation				
Regression ..	1	69,682	69,682	10·2
Deviations ..	3	20,401	6,800	..
TOTAL ..	4	90,083	..	..

The regression in this case removes nearly 77 per cent of the variations in l_∞. These results seem to be promising and may help in obtaining the estimate of l_∞ with a knowledge of l_m obtainable from direct observation. It will be worthwhile estimating such relations for different groups of fish of the Indian waters.

The values of K listed in Table I, show a clear change from group to group. The values for the order Cupeiformes are fairly high whereas those for the order Mugiliformes are fairly low. The values of K for Perciformes are in between the above two. This suggests the possibility of the dependence of K on different orders, families or genera. Research in this direction may reveal the pattern of dependence and may help in indicating the range in which K must lie for a particular species.

It is generally known that big fish tend to have small values of K and small fish to have higher values of K. Thus a relation between K and l_∞ is to be expected. To examine the type of relation existing between these two parameters, the values of K and l_∞ available for 18 different species belonging to 4 different orders have been considered. First it was tried to see if a linear relation exists between these two parameters. No significant linear regression was observed between these two parameters within each order, probably due to the small number of species for which the values are available. When the values for all the species irrespective of the order were considered, a linear relation given by the equation

$$l_\infty = 839 \cdot 5978 - 443 \cdot 2590 \text{ K}$$

and just significant at 5 per cent level of probability was seen to exist. The fitted regression removed however only 25 per cent of the total variation in l_∞, and is therefore considered to be not a very good fit (see Fig. 4). The analysis pertaining to the above is presented in Table IV.

TABLE IV

Analysis of variance to test the significance of the regression of l_∞ *on K*

	D.F.	S.S.	M.S.	F
(*a*) *Clupeiformes*—				
Variance due to:				
Regression ..	1	1,208	1,208	..
Deviations ..	6	97,344	16,224	..
TOTAL ..	7	98,552	..	..
(*b*) *Mugiliformes*—				
Variance due to:				
Regression ..	1	768,505	768,505	12·24
Deviations ..	2	125,539	62,770	..
TOTAL ..	3	894,044	..	..
(*c*) *Perciformes*—				
Variance due to:				
Regression ..	1	1093,060	1093,060	6·13
Deviations ..	3	534,633	178,211	..
TOTAL ..	4	1627,693	..	..
(*d*) *All fish combined*—				
Variance due to:				
Regression ..	1	1045,639	1045,639	5·3
Deviations ..	16	3134,277	195,892	..
TOTAL ..	17	4179,916	..	..

The negative regression obtained above indicates an inverse relation between l_∞ and K and therefore a direct relation between Kl_∞ and l_∞ or between Kl_∞ and K. Taylor (1959) has established linear regressions between Kl_∞ and K considering several populations of a number of fish

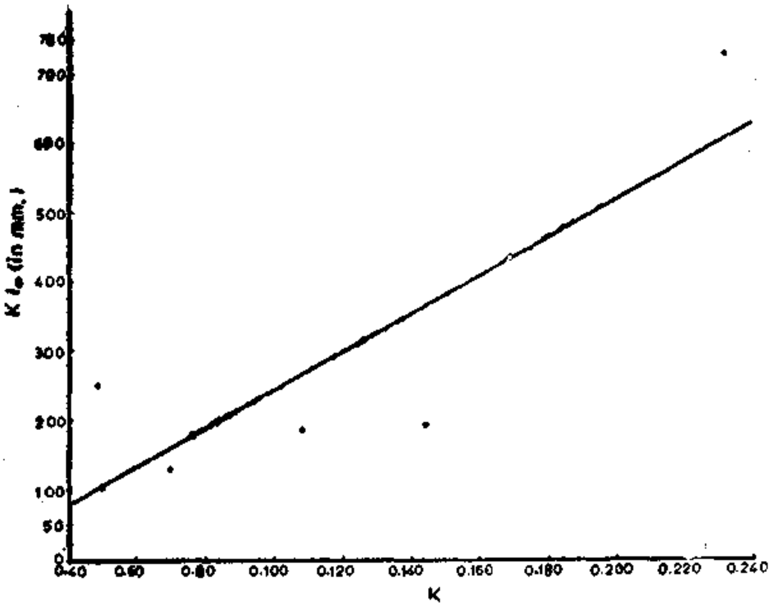

FIG. 3

species. In the present study also a significant linear regression was noticed between these values for the species belonging to the order Clupeiformes. The fitted line is given by the equation

$$Kl_\infty = -31{\cdot}8045 + 276{\cdot}0203\ K.$$

There was no significant linear relation within the other two orders, Mugiliformes and Perciformes. A significant regression line was noticed between the two parameters when the values of all species belonging to different orders were considered together. The fitted line in this case is given by the equation

$$Kl_\infty = 113{\cdot}9814 + 177{\cdot}6381\ K.$$

The last relation between K and Kl_∞ can be rewritten as

$$l_\infty = (113{\cdot}9814/K) + 177{\cdot}6381$$

This is a curvelinear relation between l_∞ and K and has been plotted in Fig 4. This relation has been found to remove nearly 50 per cent of the variation in l_∞. The analysis of variance relevant to the above is presented in Table V.

Next the relation between $\log_e l_\infty$ and $\log_e K$ was considered. Holt (1959) has stated that a linear relation between $\log_e l_\infty$ and $\log_e K$ will be more suitable. He has specified, however, that the regression equation so obtained cannot be applied to the unrelated species with the assumption that the constants involved in the regression remain the same for all the species. From the data in table it is seen that in the case of the species belonging to the order Mugiliformes there is a singificant linear relation given by the equation

$$\log_e l_\infty = 3{\cdot}8448 - 1{\cdot}6277 \log_e K$$

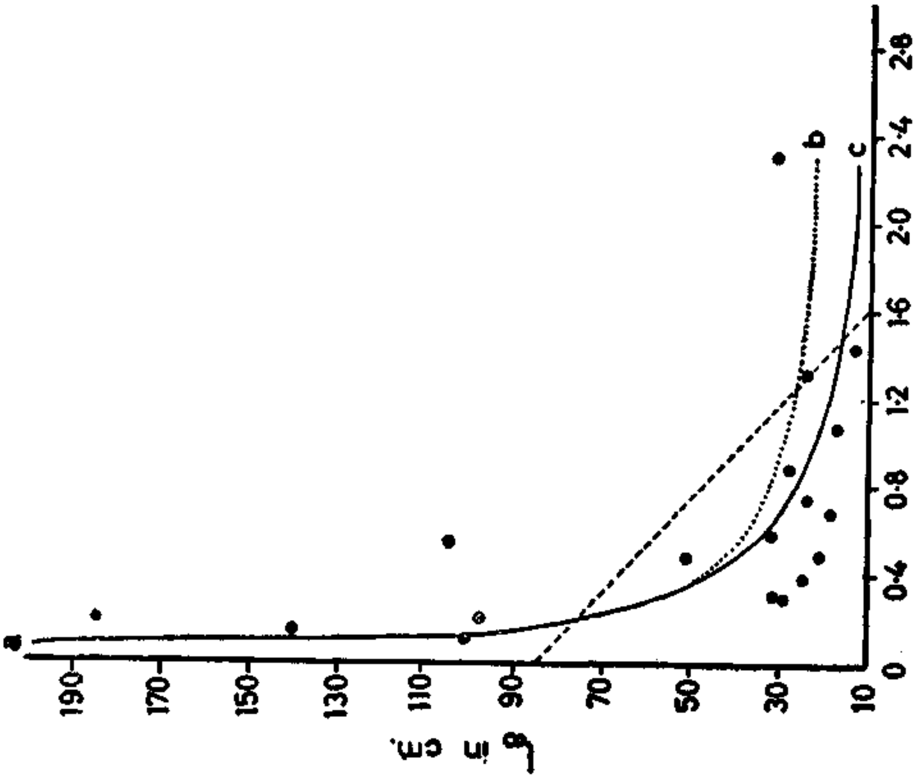
l_e in cm.
190
170
150
130
110
90
70
50
30
10
0
0·4
0·8
1·2
1·6
2·0
2·4
2·8
K
a
b
c

FIG. 4

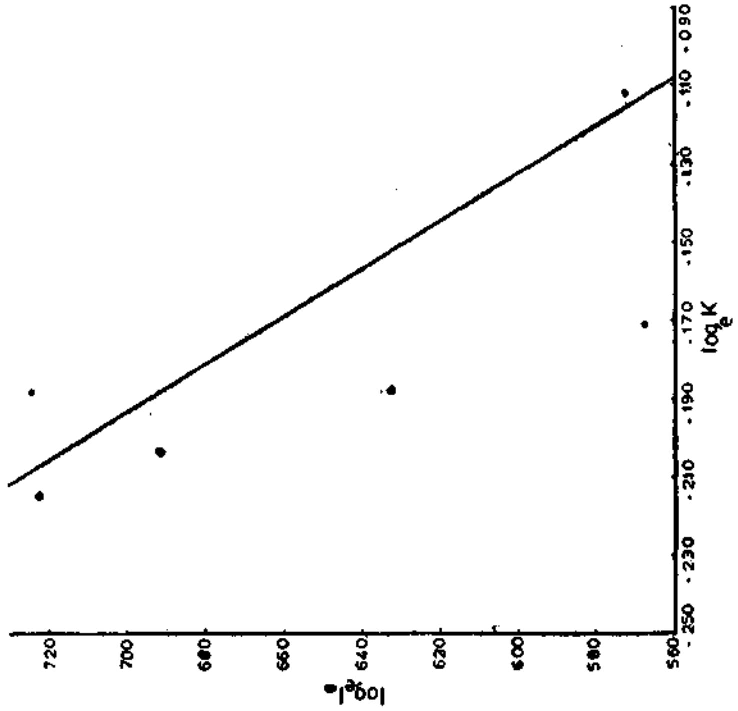
$\log_e l_e$
720
700
680
660
640
620
600
580
560
·250
·230
·210
·190
·170
·150
·130
·110
·090
$\log_e K$

FIG. 5

TABLE V

Analysis of variance to test the significance of the linear regression of Kl_{∞} *on K*

	D.F.	S.S.	M.S.	F
(*a*) *Clupeiformes*—				
Variance due to:				
Regression	1	222,543	222,543	17·84
Deviations	6	74,863	12,477	..
TOTAL	7	297,406	..	..
(*b*) *Mugiliformes*—				
Variance due to:				
Regression	1	5,033	5,033	2·6
Deviations	2	3,912	1,956	..
TOTAL	3	8,945	..	..
(*c*) *Perciformes*—				
Variance due to:				
Regression	1	156	156	..
Deviations	3	103,319	34,440	..
TOTAL	4	103,475	..	..
(*d*) *All fish combined*—				
Variance due to:				
Regression	1	167,934	167,934	8·59
Deviations	16	312,702	19,544	..
TOTAL	17	480,636	..	..

and that there is no such significant relation within the other two groups. However, a highly significant linear relation is observed in the case when the species belonging to different orders are clubbed together and their regression line in that case is given by

$$\log_e l_{\infty} = 5\cdot4645 - 0\cdot7230 \log_e \mathrm{K}.$$

This relation is again another curvelinear equation of the form

$$l_{\infty} = a\mathrm{K}^{-p}$$

and the fitted curve has been shown again in Fig 4. This relation also has been found to explain for about 50 per-cent of the variations in l_{∞}. The analysis pertaining to the above is given in Table VI.

From Fig. 4, it is clear that the relation of the type

$$l_{\infty} = a\mathrm{K}^{-p}$$

or a linear relation between $\log_e l_{\infty}$ and $\log_e$ K seems to fit the data best.

TABLE VI

Analysis of variance to test the significance of the linear regression of $\log_e l_\infty$ on $\log_e K$

	D.F.	S.S.	M.S.	F
(a) Clupeiformes—				
Variance due to:				
Regression	1	0·0773	0·0773	..
Deviations	6	1·1107	0·1851	..
TOTAL	7	1·1880	..	..
(b) Mugiliformes—				
Variance due to:				
Regression	1	1·7856	1·7856	21·44
Deviations	2	0·1666	0·0833	..
TOTAL	3	1·9522	..	..
(c) Perciformes—				
Variance due to:				
Regression	1	1·7730	1·7730	5·93
Deviations	3	0·8971	0·2990	..
TOTAL	4	2·6701	..	..
(d) All fish combined—				
Variance due to:				
Regression	1	5·7313	5·7313	18·56
Deviations	16	4·9412	0·3088	..
TOTAL	17	10·6725	..	..

Next it was dicided to examine if any significant linear relation between Kl_∞ and l_∞ exists. No significant linear relation was noticed in any case between Kl_∞ and l_∞. The relevant analysis is shown in Table VII.

TABLE VII

Analysis of variance to test the significance of linear regression of Kl_{∞} *on* l_{∞}

	D.F.	S.S.	M.S.	F
(*a*) *Clupeiformes—*				
Variance due to:				
Regression ..	1	10,194	10,194	..
Deviations ..	6	88,358	13,060	..
TOTAL ..	7	98,552	..	..
(*b*) *Mugiliformes—*				
Variance due to:				
Regression ..	1	795,186	795,186	16·1
Deviations ..	2	98,857	49,429	..
TOTAL ..	3	894,043	..	..
(*c*) *Perciformes—*				
Variance due to:				
Regression ..	1	370,737	370,737	..
Deviations ..	3	1256,956	418,985	..
TOTAL ..	4	1627,693	..	..
(*b*) *All fish combined—*				
Variance due to:				
Regression ..	1	255,465	255,465	1·04
Deviations ..	*16*	3924,451	245,278	..
TOTAL ..	17	4179,916	..	..

More detailed studies of this nature are indicated.

Again as the variations in the ratio l_m/l_{∞} is depending upon, to a certain extent, on the differences on growth rate upto the onset of maturity and that the growth rate itself is given by the parameters K and l_{∞}, an attempt to correlate l_m/l_{∞} either with l_{∞} or with K is worth studying. Holt (*op. cit.*) has shown that there exist no indication of a relationship between l_m/l_{∞} and l_{∞} for the partial compilation of l_m/l_{∞} (Beverton and Holt, 1959, Holt 1959 *a* and *b*). The available data from the Indian fishes also showed no significant linear relation as can be seen from the analysis given in Table VIII.

TABLE VIII

Analysis of variance to test the significance of linear regression of l_m/l_{∞} *on* l_{∞}

	D.F.	S.S.	M.S.	F
(*a*) *Clupeiformes—*				
Variance due to: ..				
Regression ..	1	52,324	52,324	4·16
Deviations ..	3	37,759	12,586	..
TOTAL ..	4	90,083	..	..
(*b*) *All fish combined—*				
Variance due to:				
Regression ..	1	159,427	159,427	3·30
Deviations ..	8	386,663	48,333	..
TOTAL ..	9	546,090	..	..

Also as can be seen from Tables IX and X, neither l_m/l_∞ nor $\log_e (1-l_m/l_\infty)$ showed any significant linear relation with K, though such a relation has been observed by Holt (*op. cit.*).

TABLE IX

Analysis of variance to test the significance of linear regression of l_m/l_∞ *on K*

	D.F.	S.S.	M.S.	F
(*a*) *Clupeiformes*—				
Variance due to: ..				
Regression ..	1	0·0064	0·0064	..
Deviations ..	3	0·0738	0·0246	..
TOTAL ..	4	0·0802	..	..
(*b*) *All fish combined*— ..				
Variance due to:				
Regression ..	1	0·0506	0·0506	3·5
Deviations ..	8	0·1158	0·0145	..
TOTAL ..	9	0·1164	..	..

TABLE X

Analysis of variance to test the significance of linear regression of $\log_e (1-l_m/l_\infty)$ *on K*

	D.F.	S.S.	M.S.	F
(*a*) *Clupeiformes*—				
Variance due to:				
Regression ..	1	0·0205	0·0205	..
Deviations ..	3	0·4257	0·1419	..
TOTAL ..	4	0·4462	..	..
(*b*) *All fish combined*—				
Variance due to:				
Regression ..	1	0·2090	0·2090	2·8
Deviations ..	8	0·6014	0·0752	..
TOTAL ..	9	0·8104	..	..

The absence of such relations may again be due to the small number of values available for study.

The methods of comparative studies can be adopted to study the parameters concerning mortality also. As the bigger fishes are expected to live longer a direct relation between $T_{max.}$, the maximum age of the fish and l_∞ can naturally be expected. Such relations have been established for the fishes belonging to the families Clupeoidei, Pleuronectoidei, Salmoraonoidei and the order Gladiformes (Beverton and Holt, 1959). Again when the longevity of the fish is more, that is, the period of life T_{max} is high, the death can naturally be expected to be low and hence an inverse relation between Z or M and T_{max} may be obtained. So if the maximum age is known by direct observation both l_∞ and Z or M can be obtained by these two relations respectively. Otherwise if l_m is obtained by observation of the fishery, T_{max} and hence Z or M can be obtained by the successive applications of these two relations. Further as longevity can be expected to be inversely related to the mortality as well as the rate at which the growth to the asymptote decreases a direct relation between the later two factors can be expected, and such relations between M and K have also been established by Beverton and Holt (1959) for the families and the order mentioned earlier. As M and K can be seen to be positively correlated within a particular taxonomic group M/K is less variable within the group and can be considered as a constant for each group and M can be directly got when K is known by other means. The values of M and K for the oil sardine along the west coast of India are seen to be 0·65 and 0·50 respectively. Hence the value of M/K is 1·3. On the basis of this value for oil sardine, the values of M for the related species *Sardinella albella, Sardinella gibbosa, Hilsa ilisha* and *Racconda russellina* for which the K values have been given as 0·50, 1·44, 1·08, 0·49 and 0·40 can be roughly and easily estimated to be 0·65, 1·87, 1·40, 0·64, and 0·52 respectively. It has further been observed that for many clupeid families M/K and l_m/l_∞ tend to be inversely related. This type of relation if established will help us to know the value of M/K when l_m/l_∞ is known.

A few results of the comparative study presented here are based on a limited data available. For a true and better understanding of the types of relations existing between various factors, and for a more accurate appraisal of the relations a detailed study of a large number of values of the parameters for many different species has to be carried out. Once such a study is carried out, they will be of immense help in reducing the time required for determining the long-term average yield corresponding to a particular level of fishing intensity.

Year-to-year assessment and forecasting

The estimation of long-term effect of fishing on a fish stock has been considered. This does not take into consideration a multitude of other fishery-independent oceanographic and ecological factors that are also likely to affect a fish population. In fact if their effect on the stock is not taken into consideration in addition to the interaction generated by fishing, it is difficult to make any short-term forecast about fishery prospects which is so essential for fishery industry. Till now, the only method available for this purpose is to find out from a long-term series the relation between abundance and the other factors either singly or jointly and then effect corrections for change in these factors for estimating the effect of fishing on the stock. This procedure requires a long series of data accumulated over years. A great deal of fundamental research is necessary to understand the behaviour and the effect of each of these fishery-independent hydrological and ecological factors on the recruitment, natural mortality, growth rate and behaviour of a fish stock, before any short-cut could be suggested leading to accurate short-term forecasting.

4. SUMMARY

Quick assessment of the status of a fish population is an imperative need for fishery management. First, some rough methods of assessment have been discussed in this paper with illustrations from Indian fisheries. Assessment methods to determine the long-term effect of fishing on stocks have next been discussed. Quicker methods of estimating some of the vital parameters required for such assessment have been indicated with illustrations from Indian fisheries. The role of comparative studies for the estimation for some of these parameters has been explored with reference to the available data from Indian fisheries. It was seen that there was a linear relation between the asymptotic length l_∞ and the minimum length at maturity l_m, so that if l_m is known from observation estimation of l_∞ is possible. Next, studies were made to find out if any relation exists between l_∞ and K. A linear and two curvilinear relations were considered. The relation of the type

$$l_\infty = aK^{-b}$$

or

$$\log_e l_\infty = a - b \log_e K$$

was found to be highly significant. No significant relation was observed between Kl_∞ and l_∞. Similarly, no significant relation was found between l_m/l_∞ and l_∞. A relation seems to exist between T_{max} and Z, where T_{max} is the maximum longevity observed and Z the rate of total instantaneous mortality. M/K was found more or less constant within an order so that if K is known, M can be estimated. The need for a systematic comparative studies on a wider scale among the Indian fisheries is emphasized in order to accelerate the assessment of long-term effect of fishing intensity or selectivity on the fish stock. Regarding short-term forecasting, factors other than fishing have to be taken into consideration, and no quicker method seems to be available at the present stage of knowledge.

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