Annexure 4

RESULTS OF THE ANALYSIS OF *HILSA ILISHA* LENGTH FREQUENCIES

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1. INTRODUCTION

In March 1985, a survey program commenced in the Upper Bay of Bengal under the regional UNDP/FAO project for "Marine Fishery Resources Management in the Bay of Bengal". The main purpose of the programme was to determine the relative abundance of *Hilsa* species, their distribution in the different environments, spawning areas and seasons, migration patterns and the state of the *Hilsa* fishery.

Catch and effort and length frequency data are not available over a reasonable number of years to attempt to fit production models or to apply the Virtual Population Analysis. In view of this the ELEFAN method of analysis was applied to the length frequency data of *Hilsa ilisha,* collected during 1985/86, for preliminary indication of the characteristics of this exploited population.

2. MATERIALS AND METHODS

Gillnetting is the primary method of fishing for *Hilsa* and mesh sizes ranging from 7.6 to 12.6 cm are used by the fishermen in all environments, in different periods of the year. Length frequencies (1 cm length classes, males and females combined) were collected during the period March 1985 to April 1986. Commercial landings were sampled regularly and also fish caught by experimental gears were measured. In all cases the total length was taken. Samples taken were weighed and the length frequencies were raised to the total catch of the boat sampled. Wherever possible, the mesh size of the gillnets used was measured.

The length frequencies (with 2 cm intervals) were analyzed in the project's headquarters in Colombo using an Apple IIe computer and the ELEFAN I program written by Pauly and David (1981). As suggested by Pauly (1985), the program should be improved by counting the positive point values in the restructured samples only once during the compilation of the explained sum of peaks (ESP) instead of several times as in the original version. This problem could be solved by "flagging" out any peak hit by the growth curve. The project's system analyst provided the necessary amendments, which resulted in the so-called "post-Sicily version".

The parameters thus obtained were used in the ELEFAN II program and the results were used in the relative yield per recruit analysis.

The Bhattacharya method (after Pauly and Caddy, 1984) was applied to the length frequency data as well. The project's system analyst rewrote the program for use on the Apple IIe computer (Goonetilleke and Sivasubramaniam, 1986, manuscript).

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3. RESULTS

3.1 Length frequencies

All samples from the four sampling centres were combined and attempts were made to find growth parameters. Due to the absence of a well defined modal progression (in fact a negative progression was observed) in the restructured samples, further analysis was suspended. Separation of the length frequencies by mesh size was possible only for the Chittagong data. Time series of reasonable length were available for the 10.1, 11.4 and 12.6 cm mesh sizes.

A preliminary analysis of the length frequencies was initially carried out using the original ELEFAN I program, followed by a more precise determination of the growth parameters with the post-Sicily (PS) version. In all cases the WP, C and D parameters in the ELEFAN analyses were 0, 0 and 1 respectively. It appeared that the PS version strongly reduces the number of parameter combinations which results in the best fit of a growth curve to the available length frequencies (i.e. the highest ESP/ASP ratio). Using the original version numerous combinations with the same ESP/ASP ratio were observed, bringing in a subjective element in the choice of parameters. This problem was only partly solved by the PS version because in some cases still more than one combination could be obtained. Starting points were searched not only by the computer, but also by eye, using the restructured samples. Several starting points and numerous parameter combinations were tried out before the final growth parameters were decided upon.

The analysis of the length frequencies from the 10.1 cm mesh sizegearresulted in two growth curves, passing through the majority of the peaks. The two growth curves represent two different broods. The L_∞ values for the two curves were more or less equal (56.4 and 56.8 cm). A difference may be found in the k-value and in the ESP/ASP ratio; the two k-values were 0.91 and 1.15 respectively. The restructured frequencies and the two growth curves are presented in Figure 1 a. The growth parameters are summarized in Table 1.

The analysis of the data from the experimental fishing gear (12.5 cm mesh size), however, allowed the plotting of three growth curves, representing three broods. The L_∞ values varied from 56.2 to 56.7 and the k-values from 0.95 to 1.10. These values were of the same order of magnitude as the parameters from the commercial data. The sum of the three ESP/ASP ratios was reasonably high, although it should be taken into account that some peaks are hit by more than one curve, especially the peaks in the part close to L,. The growth curves are presented in Figure 1 b.

The length frequencies for two other mesh sizes, 11.4 and 12.6 cm, also presented two growth curves with comparable parameters (cf Table 1). However, the combination of the frequencies from the several mesh sizes did not result in the same parameters as those obtained by the analysis of the data for each mesh size separately. When the ELEFAN I program was run with the above meant parameters as input, either the fitness of the growth curve was very poor or even negative, or there was a certain fit but with very high L_∞ or low k-values; this fit was considered to be a “forced” one.

The analysis of the Chandpur length frequencies irrespective of the mesh sizes resulted in a relatively poor fit. Two growth curves (for two broods) could be drawn, connecting the majority of the peaks. However, the two ESP/ASP values obtained were rather low: 0.197394 and 0.145611 respectively. The k-values for the two broods were considerably lower (0.78 and 0.825) than those from the individual Chittagong data series (cf Table 1). Results of the analysis of the length frequency data from Chandpur or Chittagong, combined without respect to different mesh sizes used, suggest larger longevity for *Hilsa ilisha* than that indicated by the results from the analysis of the data for different mesh sizes.

The length frequencies used in the analyses figure in Appendix 1.

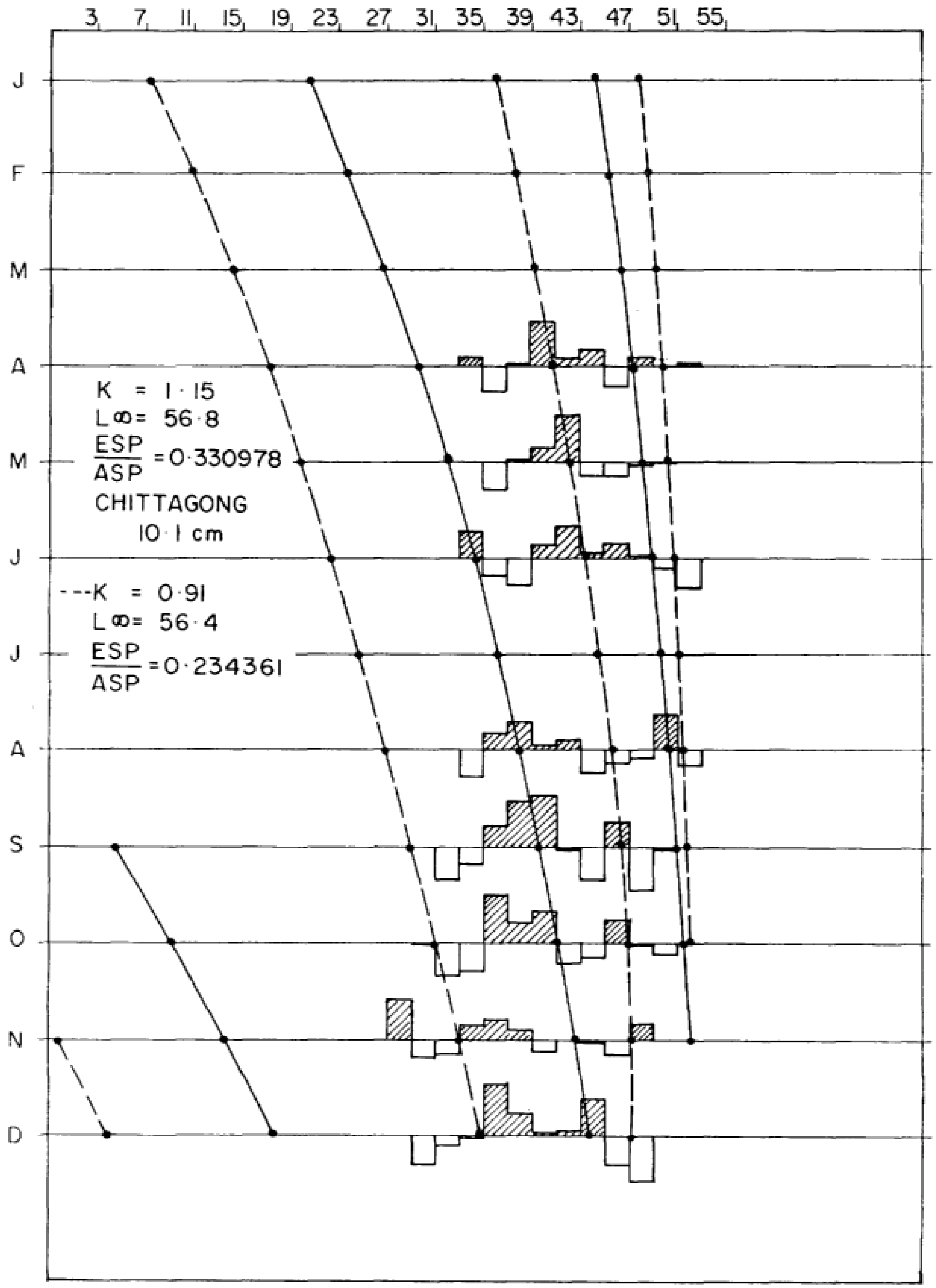

Fig. 1a Restructured length frequency distribution of *Hilsa ilisha* caught in 10.1 cm mesh gillnets at Chittagong and the growth curves fitted.

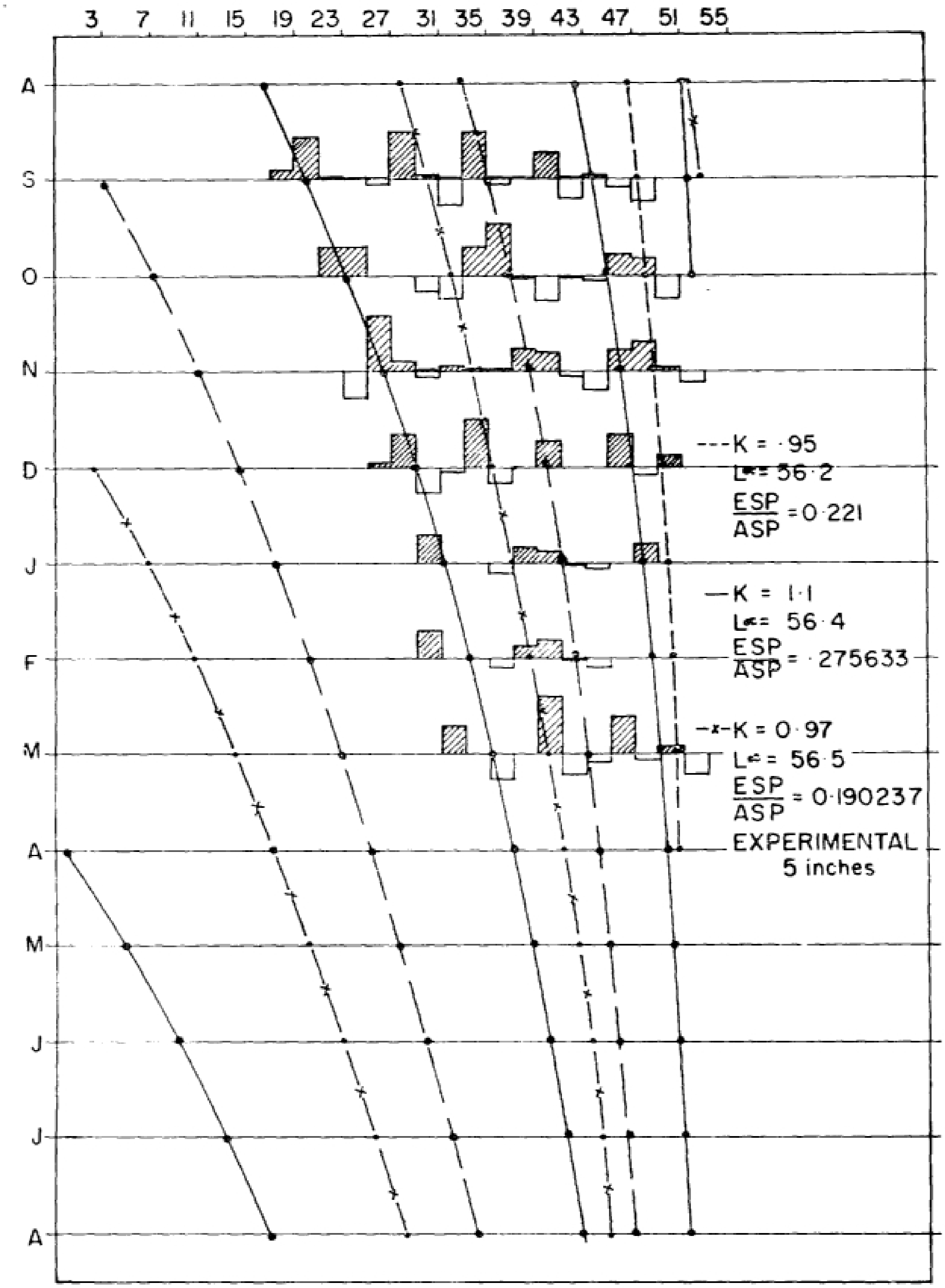

Fig. 1b Restructured length frequency distribution of *Hilsa ilisha* caught in the 5" mesh experimental net and the growth curves fitted.

3.2 Recruitment

In Figure 2a, the recruitment pattern, determined through the ELEFAN II analysis (Pau!y ct a/., 1981) for the length frequencies from the 10.1 cm mesh size gillnet, is shown, with the separation of the normal distributions of the peaks by means of the NORMSEP program (Pauly et al., 1986). The pattern clearly shows two peaks. As may be derived from the growth curves also, two spawnings appear to take place, one in August, and the other in November; in the case of the separated normal distributions the time lapse between the two peaks is around four to five months, which corresponds with the period between two spawnings.

The ELEFAN II analysis, using the parameters obtained from the analysis of the length frequencies from the different mesh sizes, resulted in similar recruit patterns. In all cases at least two peaks of recruitment were observed (in some cases small skews were found). The combination of length frequencies from the different mesh sizes (Chittagong and Chandpur data), indicated only a single annual recruitment.

Three peaks were observed in the recruitment pattern of the experimental data, which is presented in Figure 2b. One peak is of a rather small size, but the probability of fitness for the three peaks is vary good, of the level of 0.1%. The intervals between the peaks are 3 and 5.4 months. The origins of the growth curves are around April, August and November, which correspond with the intervals between the recruitment peaks.

3.3 Mortality and exploitation rate

By means of the ELEFAN II program the total mortality (Z) could be estimated from a length converted catch curve and from the mean length in the samples. Natural mortality (M) could be calculated from Pauly's empiric formula (Pauly, 1980) and subsequently the fishing mortality (F) could be obtained. In Table 2 the parameters obtained from the ELEFAN II analysis are summarized for the growth parameter combinations of Table 1. Natural mortality varied between 1.23 and 1.63; total mortality for the brood with a k-value of 1.15 varied between 3.1 and 4.7 and for the other brood (k: 0.90-1.05) between 2.2 and 3.7. The Chandpur and experimental gear data indicated low total mortality rates.

The exploitation rate gives an interesting picture: the exploitation rate for the 10.1 and 11.4 mesh sizes is higher than 0.50 (i.e. $F>M$), viz. 0.53-0.66, while the exploitation rate for the 12.6 cm mesh is lower than 0.50 ($F<M$), viz. 0.42-0.48. The E-values for the experimental and Chandpur data are much lower: 0.27-0.41 (Table 2). The exploitation rates for the experimental and 12.6 cm mesh size gears are low, because only a part of the population is being exploited, while the low E-value for Chandpur may be explained by the low total mortality rate.

3.4 IVIean length at first capture

The mean lengths at first capture for the 10.1, 11.4 and 12.6 cm mesh sizes are 38.9, 39.0 and 39.2 cm respectively. The L_e value for the experimental data (mesh size 12.5 cm), however, is considerably lower: 34.5 cm probably because of the poor catches made with this gear. The L_e value for the Chandpur data is 38.1 cm, but in this case the data are obtained from various mesh sizes.

3.5 Bhattacharya method

The Bhattacharya method was applied to the total length frequencies (1 cm intervals) by mesh size and also to the total of all mesh sizes combined. The total length frequencies from the other stations and the experimental data were analyzed in the same way. All mean lengths obtained from this analysis were compiled and grouped. Of each group the average was calculated, which resulted in the following modal lengths: 22.1, 36.8, 40.7, 47.2 and 49.9 cm total length, of which 22.1, 40.7 and 49.9 cm would represent one brood and 36.8 and 47.2 cm the other. The expected length frequency was calculated and subtracted from the observed frequency which resulted in the so-called residuals. The latter were analyzed using the Bhattacharya method again and there were indications that modal lengths appear at 31.8, 42.3 and 51.7 cm of which one or two may be assigned to a possible third brood. Some other modal lengths were found

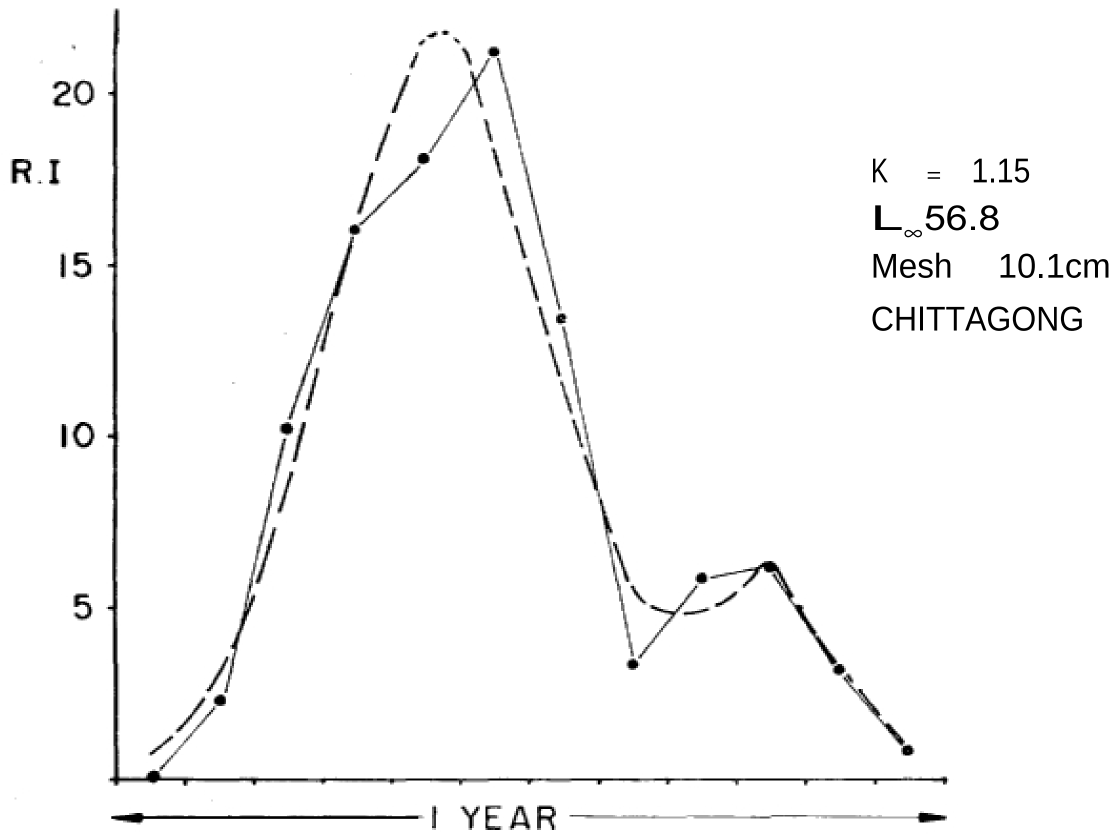

Fig. 2a Recruitment pattern for Hilsa. Data from 10.1 cm mesh gear (R. I. = Recruitment Intensity). Normal distributions of the recruitment peaks after separation by the NORMSEP program (dotted line).

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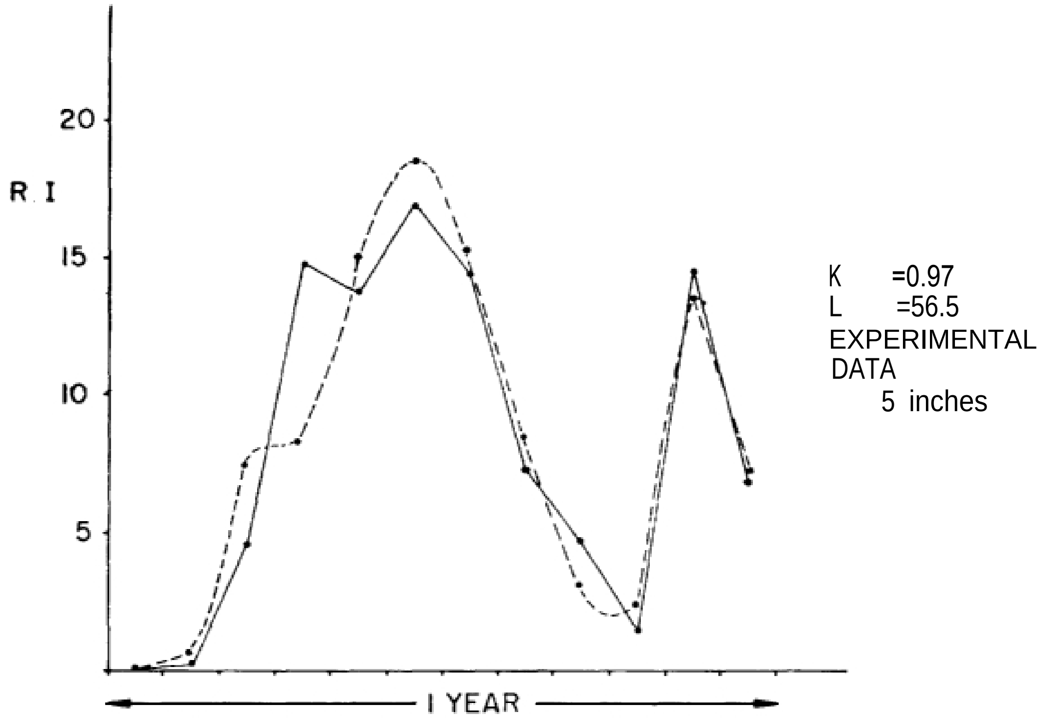

Fig. 2b Recruitment pattern from the length frequencies of *Hilsa ilisha* caught with 5" mesh gilinets. Normal distribution of the recruitment peaks after separation by the NORMSEP program (dotted line).

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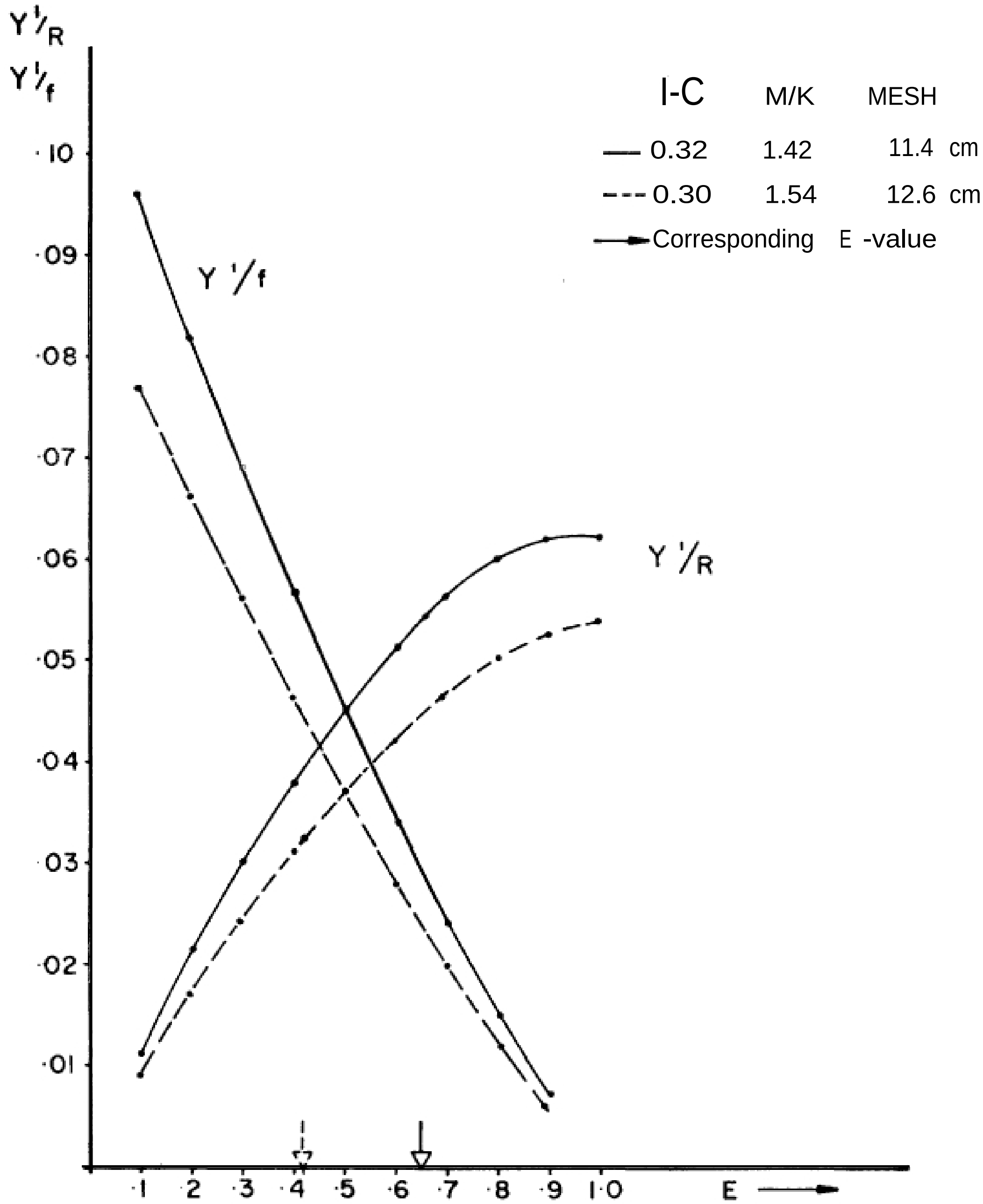
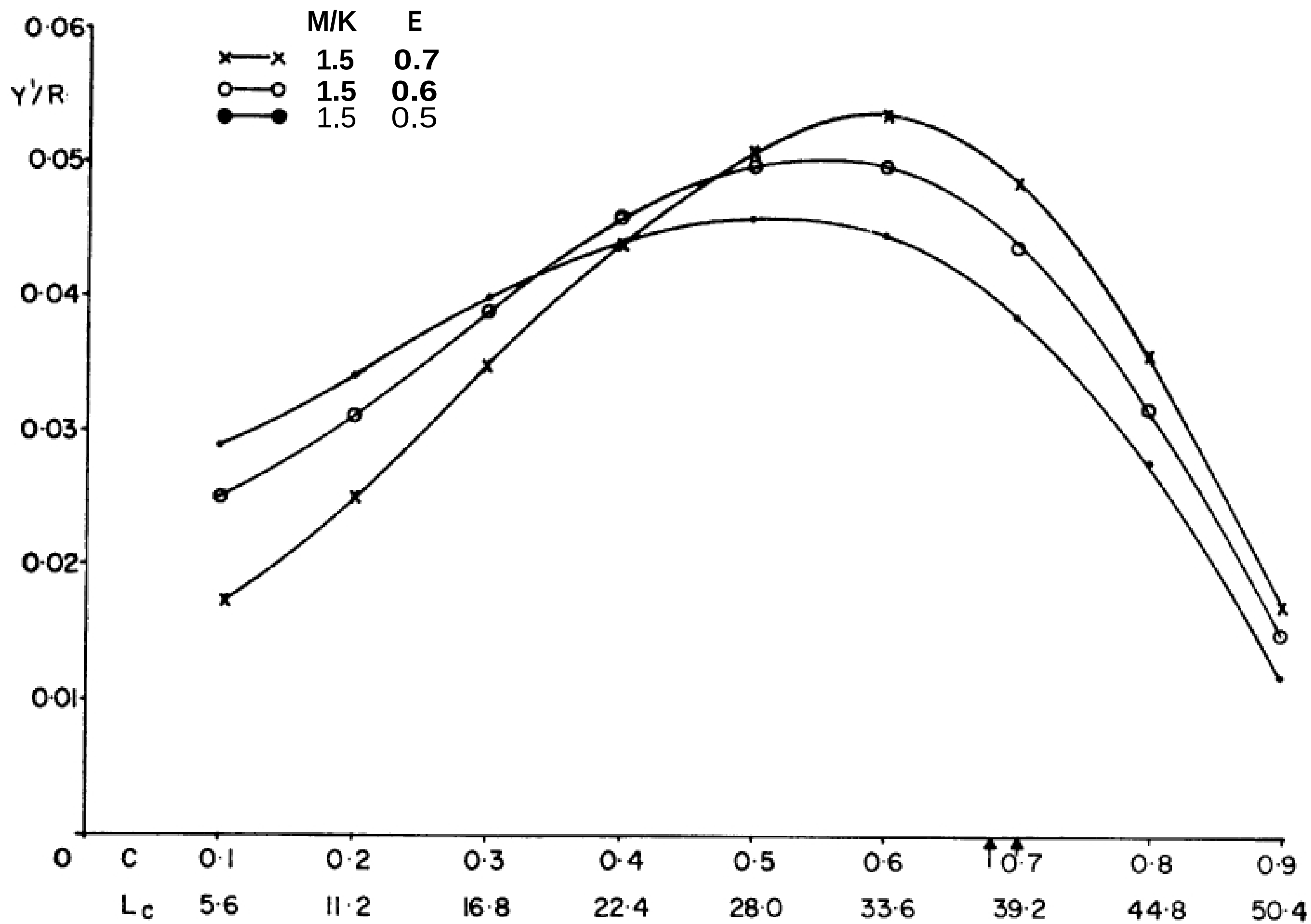


Fig. 3 Relative yield per recruit and per effort, curves for *Hilsa ilisha* as a function of the exploitation rate (E).

Annexure 4, Fig. 4



Relative yield per recruit curves for three levels of exploitation for Hilsa as a function of C(Lc/Lω) and Lc (L∞= 56)

In the several data series which confirmed the modes found in the analyses of the original length frequencies.

The Gulland-Holt, Ford-Walford and Von Bertalanffy plots were applied to the modal length data for the two broods. The results are presented in Figs. 5, 6 and 7.

In Figure 5 two Gulland-Holt plots are presented : one using a time interval of one year (Δ_t=1.0) and the other six months (Δ_t=0.5). In the case of Δ_t=1.0, two points were derived for one brood and one point only for the other. Linear regression analysis applied to these points resulted in an L_∞ and k-values of 57.7 cm and 0.52 respectively. This L_∞ value is slightly higher than the one which was found through the ELEFAN I analysis, while the k-value is very much lower. In the case of Δ_t=0.5, the modal length data were considered to represent one virtual brood. A straight line was fitted to the four points obtained through linear regression analysis, which resulted in L_∞ and k-values of 55 cm and 0.94 respectively. These parameters are fairly close to the ELEFAN I results.

Figure 6 shows a Ford-Walford plot, resulting in an L_∞ of 57.7 cm and a k of 0.73. The plot fits two points for one brood and one point for the other. The modal lengths obtained from the analysis of the residual frequencies do not fit very well in this plot.

The logarithmic generalized Von Bertalanffy growth formula, where $(-l_n((L_\infty-L_t)/L_\infty))$ was plotted as a function of t, resulted in an L_∞ value of 55 cm with a corresponding k-value of 0.90. For the time intervals between the modal lengths six months were chosen. The L_∞ was obtained by applying linear regression analyses to the data and by selecting the highest r^2 value, corresponding to the most appropriate L_∞ (after Pauly, 1984). It must be pointed out that the data for the assumed two broods were combined in this analysis and thus resulted in parameters somewhat different from those found through other methods. An estimation was made for t,, which appeared to be positive and of a rather high value: 0.40. This value may change when other ages are being chosen for the modal lengths. The modal lengths obtained through the Bhattacharya method represent age groups and not absolute age.

3.6 Relative yield per recruit

Using the k and L_∞ values obtained with ELEFAN I and the Z, M and L_c values (and subsequently F, E and C) with ELEFAN II (cf Table 2), a relative yield per recruit analysis was accomplished (it must be noted that this analysis is entirely based on the length frequencies from Chittagong, separated by mesh size). Three sets of data with various exploitation rates (E=F/Z) were chosen for the analysis. The relative yield per recruit and per effort have been plotted as a function of the exploitation rate and are presented in Figure 3. In Figure 4 the relationship between the relative yield per recruit and the mean length at first capture is presented.

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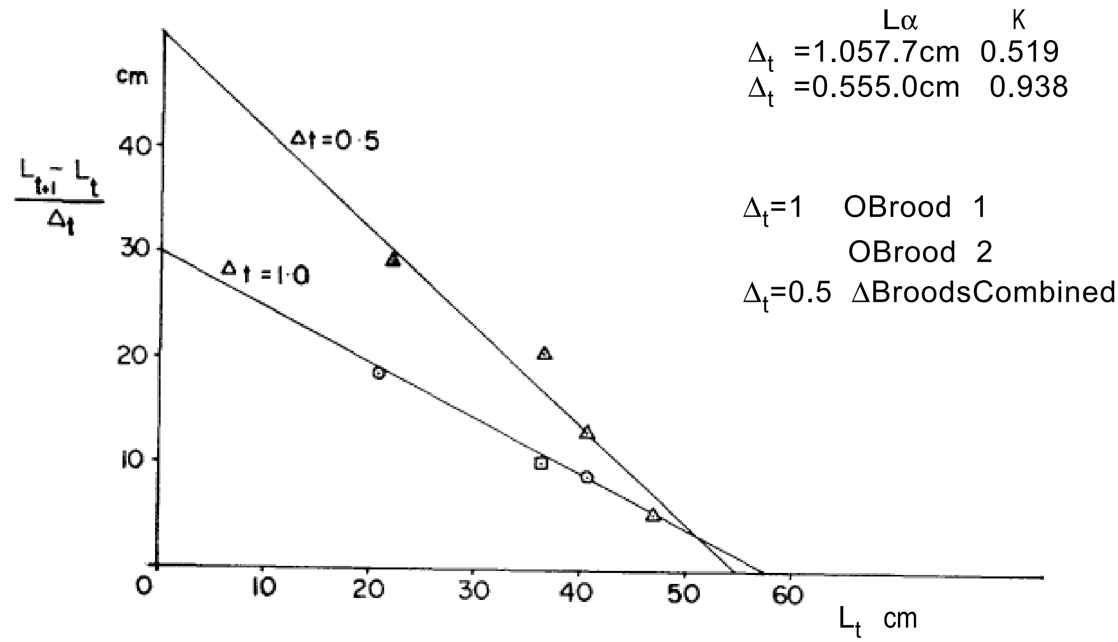

Fig. 5 A Gulland-Holt plot with points derived from Bhattacharya method on length frequency distribution of *H/lsa ilisha.*

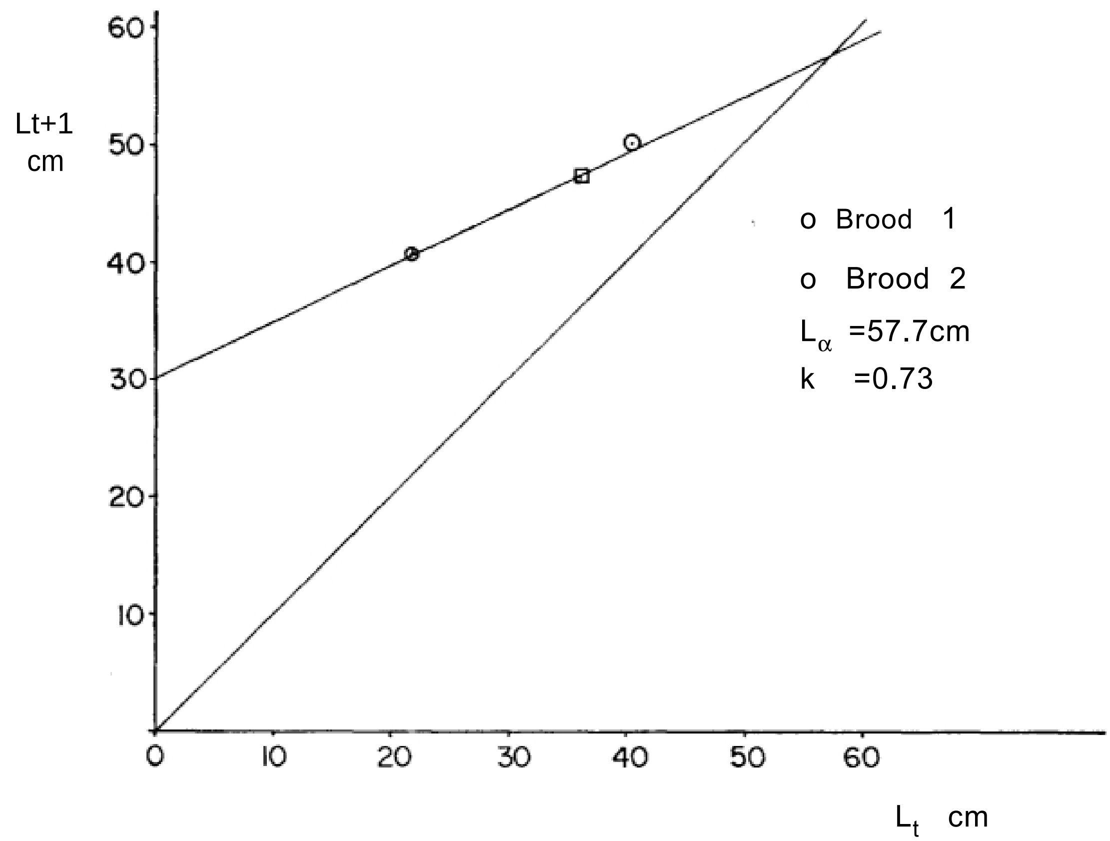

Fig. 6 A Ford-Walford plot with points derived from Bhattacharya method on length frequency distribution of *Hilsa ilisha.*

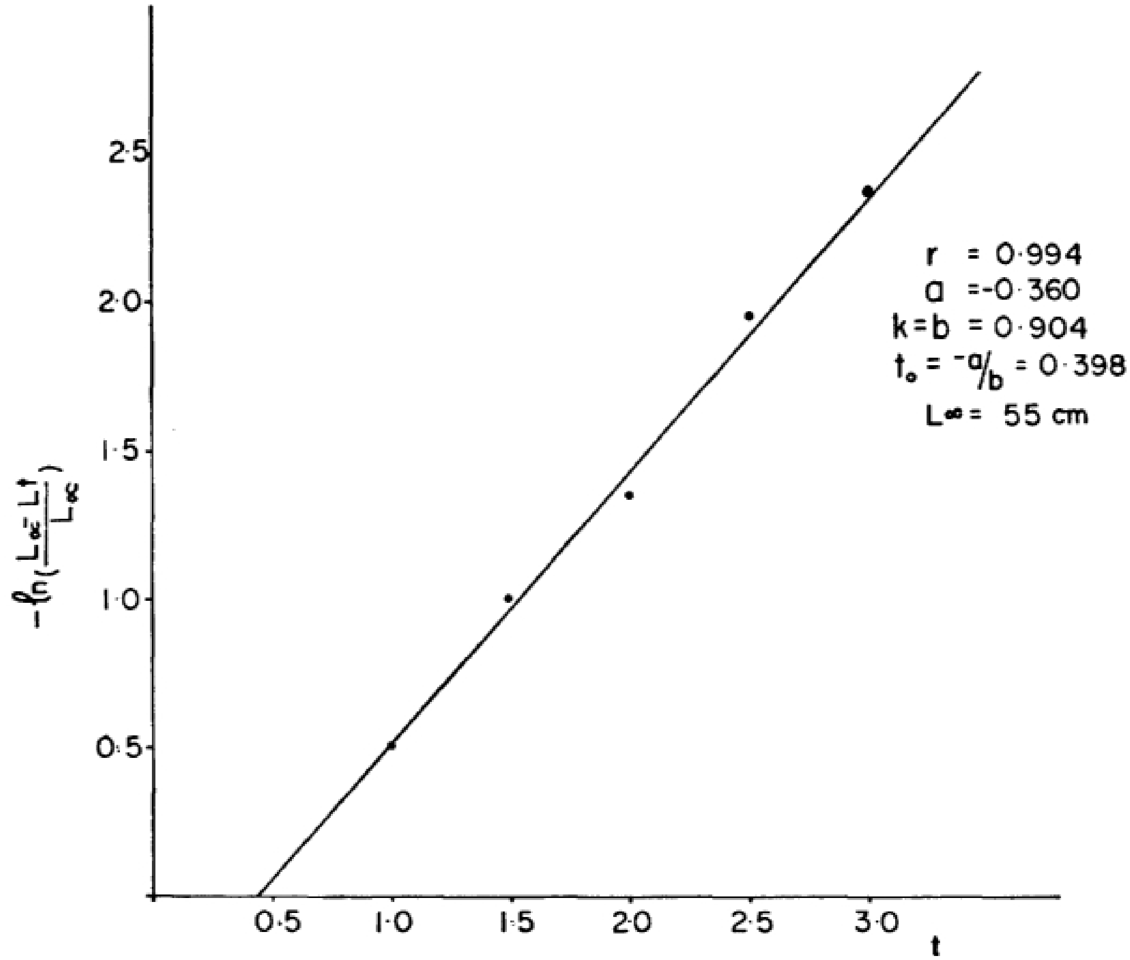

Fig. 7 Von Bertalanffy plot of points derived from Bhattacharya method on the length frequency distribution of *Hilsa iisha.*

4. SUMMARY AND DISCUSSION

For the analysis of growth parameters of *Hilsa ilisha* the data sets from Chittagong are being considered the most appropriate. Of all commercial fishery length frequency data collected during the survey program, only these could be raised to the total catch per boat sampled, and also the frequencies are known by mesh size. Two broods could be observed in all sets of commercial data. From the Chittagong frequencies two recruitments may be found, in August and in October/November. The experimental data permitted the fitting of three growth curves; the recruitment appeared to take place in April, August and November/December. The commercial data did not allow a third growth curve. The gonad somatic index values for *Hilsa* show peaks in February/March, June/July and October/November (Islam et al., 1986). These results would indicate recruitment in April, August and November; however, regarding the points of origin of the growth curves, the selectivity effect of the mesh sizes may influence the positions of the modes resulting in a possible shift of the points of origin.

The L_∞ is estimated to be between 56 and 57 cm total length and the k-value (annual basis) between 1.05 and 1 .1 5 for the main brood and between 0.90 and 0.95 for the second brood. When studying Table 1, it should be noted that for the three data series from Chittagong the first brood (August or summer brood) has a k-value of 1 .15, while the k-value for the winter brood (October/November) is of the order of 0.90-0.91. On the other hand the summer brood from the experimental data has a lower k-value: 0.95 ; the winter (November) and spring broods (April) have k-values of 0.97 and 1.05 respectively. The difference between the results from the commercial and experimental data may be due to sampling errors or the selective character of the gears, which may cause shifts in the positions of the peaks. Another reason might be a possible seasonality in the growth, which may be expressed in the growth parameters because the periods of sampling did not entirely overlap (April to December for the commercial data and from September to March for experimental data) (Figures la and 1 b). Quddus et *al.* (1984) determined the Von Bertalanffy growth equation for two races of *Hilsa ilisha.* In these equations the L_∞ value is of the order of 642 and 680 mm and the k-values of the order of 0.19 and 0.16 respectively. The age and growth determinations are based on otolith readings; the longevity would be about five years. The results from the ELEFAN analysis presented in this paper differ considerably from Quddus' results.

If, however, the length frequencies for the several mesh sizes are being combined (in the case of the Chittagong data series), the results from the individual mesh size analysis cannot be obtained any more. This observation indicates that length frequencies combined for several different mesh sizes are not suitable for the ELEFAN growth parameter analysis. The results from the combined Chittagong data analysis resemble those from the Chandpur data, i.e. relatively high L_∞ and low k-values. In this study it is believed that length frequencies obtained from different mesh sizes disturb the modal progression and that length frequencies may only be analyzed when data from a specific mesh size is used. The modal progression, however, may be biased due to the entangling capacity of the gear, resulting in a large range of sizes that is being caught. Nevertheless, the results of the analyses of the frequencies by mesh size are of the same order of magnitude, which is a justification for the use of the ELEFAN analysis of length frequencies obtained from a selective gear like a gillnet.

The growth parameters estimated by the analysis of the data from commercial catches match considerably with the results of the experimental data analysis, although the number and time of recruitment show some differences.

Concerning the 2 cm intervals, the following observation was made: in the case of Chandpur the largest length class with midlength 55 cm resulted in a minimum analyzable L_∞ of 57 cm (i.e. the minimum input value for L_∞ in the ELEFAN I analysis must be 57 cm), while the L_∞ values from the Chittagong data indicate an L_∞ smaller than 57. In the other environments no fish of the 55 cm (mid-length) length class were recorded; this phenomenon might influence

It should be noted that the length frequencies were not adjusted for mesh selection, because data needed for analysis of the mesh selectivity of the different mesh sizes were only available for a small number of overlapping months.

The post-Sicily version of ELEFAN I appeared to strongly reduce the number of growth parameter combinations with the best fit or highest ESP/ASP ratio. Due to "flagging out" of any peak hit by the growth curve, the ESP/ASP ratio could have a lower value than the ESP/ASP ratio obtained by the original ELEFAN I version, and this observation may be very important in the choice of the best fitting growth parameters for a set of length frequency data.

During finalization of the report, ICLARM's latest version of ELEFAN reached the project's headquarters. Analyses were carried out using this version and the results appeared to be of the same order of magnitude as obtained with the project's post-Sicily version. In the latest version, however, the ESP/ASP ratios tended to be slightly higher, because ASP values have been lowered by adjustment of peaks surrounded by "zero-neighbours" (Brey and Pauly, 1986).

The Bhattacharya method gives interesting results, which may be compared with the results of other researchers, compiled by Raja (1985). Estimates of 217 and 357 mm were obtained for fish 1 and 2 years old in one case. In another case, modal groups were identified as 247, 343 and 393 mm for males and 265, 391 and 436 mm for females. The series identified from the present study, in combination with the growth parameter results, would indicate modal lengths of 22.1, 40.7 and 49.9 cm for one brood and 36.8 and 47.2 cm for the other. Analysis of these results, using Gulland-Holt, Ford-Walford and Von Bettalanffy plots results in growth parameters well comparable with those obtained from the ELEFAN analysis. The obtained t_o value, however, is considered to be unusually high. This result should be interpreted cautiously.

If tha highest exploitation rate obtained in Chapter 3.3 is accepted, the optimum exploitation rate for the maximum relative yield per recruit has not yet been reached. This would indicate that the Hilsa resources are not being overexploited and some degree of increase of fishing effort may be realized. A significant increase in effort will not result in a much higher production due to the lower catch rates that may be realized closer to the optimum yield level. It may also be stated that the yield curves show signs of levelling off beyond the optimum values which may give the wrong impression that the exploitation rate could be increased indefinitely without a decline in yield. This is not the case and such abnormal situations are commonly met with in tropical fisheries. The validity of the results of the relative yield per recruit analysis in this case appears to be questionable.

The relative yield per recruit in relation to the mean length at first capture (L_c) indicates that the optimum mean size is smaller than the values observed (Figure 4, arrows), for the 10.1, 11.4 and 12.6 cm mesh sizes (no data available for smaller mesh sizes). The L_c values may be higher due to entanglement of fish and the absence of smaller size groups on the fishing grounds (Azad et al., in press). The L_c values given in Table 2 were calculated from the Chittagong data only. Due to the lack of length frequencies by mesh size for other areas, no L_c values could be estimated. The L_c values for other areas, however, may differ from the values observed in Chittagong area because the exploited size ranges may differ from place to place and also from season to season due to the migratory character of *Hilsa.*

Theoretically the relative yield per recruit may be improved by catching more of the smaller sizes (by the use of nets with smaller mesh sizes). However, non-availability of smaller sizes of fish on the fishing grounds and entangling of fish besides gilling will create practical difficulties in implementing this. In general, the hilsa fishery in Bangladesh, by virtue of the behavioural factors of the fish and the gear, have regulated the exploitation in a unique way. It is emphasized once more that the results are based on the ELEFAN analysis of the Chittagong length frequencies only and so are of a tentative nature.

5. LITERATURE

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Table 1

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Summary of the results of the ELEFAN I analysis of
Hilsa ilisha **length frequencies**

Source	Brood	L_∞	k	ESP/ASP	Origin of growth curve
Chittagong 10.1 cm	1	56.8	1.15	**0.330978**	August
	2	56.4	0.91	0.234361	October/November
Chittagong 11.4 cm	1	56	1.15	0.429422	August
	2	56	0.90	0.110465	November
Chittagong 12.6 cm	1	56.1	0.91	0.317996	October
	2	56.8	1.15	0.181985	August
Experimental data	1	56.7	1.05	0.312734	April
	2	56.2	0.95	0.22187	August
	3	56.5	0.97	0.190237	November
Chandpur	1	58	0.825	0.197394	January
	2	57	0.78	0.145611	October/November

Table 2

Parameters obtained from the ELEFAN II analysis of *Hilsa* frequencies and some derived parameters used in the relative yield per recruit analysis (for the source of the L_∞ and k-values (see Table 1) C = L_c/L_∞

Mesh Size(cm)	L_∞	k	Z	L	Lmean	Z from mean L	M	F	E=F/Z	L_c	T	C=L_c/L_∞	I-C	M/k
10.1	56.8	1.15	3.89	40	43.8	3.997	1.62	2.27	0.58	38.9	27.4	0.68	0.32	**1.41**
10.1	56.4	0.91	2.98	40	43.8	3.065	1.39	1.59	0.53	38.9	27.4	0.69	0.37	**1.53**
11.4	56	1.15	4.73	41	42.2	4.964	1.63	3.10	0.66	39.0	27.4	0.70	0.30	**1.42**
11.4	56	0.90	3.65	41	43.6	4.210	1.39	2.27	0.62	39.0	27.4	0.70	0.30	**1.54**
12.6	56.1	0.91	2.39	40	44.4	2.453	1.40	1.00	0.42	39.2	27.4	0.70	0.30	**1.54**
12.6	56.8	1.15	3.12	40	44.4	3.285	1.62	1.50	0.48	39.2	27.4	0.69	0.31	**1.41**
12.0	56.7	1.05	2.53	36	41.8	2.718	1.49	1.04	0.41	34.5	26	0.61	0.39	**1.42**
12.0	56.2	0.95	2.23	36	41.8	2.377	1.40	0.82	0.37	34.5	26	0.61	0.39	**1.47**
12.0	56.5	0.97	2.31	36	41.8	2.477	1.42	0.90	0.39	34.5	26	0.61	0.39	**1.46**
Mixed	58	0.825	1.89	40	45.7	1.760	1.27	0.62	0.33	38.1	26	0.66	0.34	**1.54**
Mixed	57	0.78	1.68	40	45.7	1.529	1.23	0.45	0.27	38.1	26	0.67	0.33	**1.58**