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Population Dynamics and the Management of the Hardtail Scad *Megalaspis cordyla* from the Bay of Bengal

M G Mustafa[*a] *and M Shahadat Ali*[b]

[a]*Bangladesh Fisheries Research Institute, Marine Fisheries & Technology Station, Cox's Bazar, Bangladesh*

[b]*Department of Zoology, Dhaka University, Dhaka, Bangladesh*

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FiSAT program was used to estimate population parameters of *Megalaspis cordyla* from length frequency data. L∞ and K were found to be 38.5 cm and 0.54 year^{1}, respectively. The Wetherall plot provided an estimate of L∞ and Z/K as 38.12 cm and 3.902, respectively. The annual rates of natural and fishing mortality were estimated as 1.17 and 1.11, respectively. The exploitation rate was 0.51. The selection pattern L_{50} was 22.32 cm. Recruitment pattern suggests of one main pulse in May-August. Maximum yield could be achieved simultaneously decreasing length at first capture to 18.0 cm. The relationship between total length and body weight was found to be $W = 0.01794\ L^{2.8184}$. Highest yield and price could be achieved by increasing the fishing mortality to 1.25 coefficient rate.

Key words: *Megalaspis cordyla*, Population dynamics, Bay of Bengal.

Introduction

Megalaspis cordyla Linnaeus is one of the most common fish species of Bangladesh and fetches about 3.2% of the total stock along with other Carangidae in the Bay of Bengal (Lamboeuf 1987). This species is distributed in waters of 10 to 80 m depth (Khan *et al* 1989; Lamboeuf 1987). The importance of this fish in the fishery of Bangladesh coast has been indicated by several authors (Chowdhury *et al* 1979; Lamboeuf 1987; Mohiuddin *et al* 1980; Mustafa *et al* 1987; Mustafa and Khan 1993; Saetre 1981; Shafi and Quddus 1982). The supply of this fish in the market comes mainly from the offshore trawl fishery as its distribution is limited to only greater depths. Fishes of this family usually move in schools. Its highest catches were reported during the months of March, April, May and June (Lamboeuf 1987).

Management issues such as determination of the state of fishing and the optimum number of trawlers is related to the question of how the abundance of various fin fish species fluctuates with time and how they are distributed within the shelf area. Knowledge of life cycle pattern and population dynamics of the commercially important fish species is bessential when determining a management strategy and subsequent recruitment of the offspring to the fishery. Recruitment to the fishery expresses itself by an increase in the catch per unit of effort and by a decrease in the average size of the fin fishes.

*Author for correspondence

Materials and Methods

The study was conducted from April 1995 to March 1997. Length-frequency and length-weight data were collected for the present study from commercial fishing trawlers immediately after return from trips and from research vessel R/V Anusandhani within the continental shelf of Bangladesh. Sampling was done monthly and all length-frequency data for each month were pooled and entered in computer through ELEFAN 0 program. Trawling depth varied from 20m to 90m. Total length from the tip of the notch to the tip of the tail at two centimeter intervals for total of 3244 specimen were measured on board immediately after the catch were made as well as at the landing center. Length frequency data used for population dynamics analysis are given in Table 1.

FiSAT (FAO-ICLARM Stock Assessment Tools) as explained in detail by Gayanilo *et al* (1994) is the software which resulted from the merging of its predecessors. The complete ELEFAN package developed at ICLARM and LFSA developed by FAO were used to analyze the length frequency data. FiSAT was developed mainly for the detailed analysis of length frequency data. Length-frequency based computer programs ELEFAN I and ELEFAN II were used to estimate population parameters L∞ and K (Pauly and David, 1981; Saeger and Gayanilo 1986). Additional estimate of L∞ and Z/K value was obtained by plotting L-L' on L (Wetherall 1986) as modified by Pauly 1986).

The growth performance of *Megalaspis cordyla* population in terms of length growth was assessed on the basis of the ϕ' index of Pauly and Munro (1984).

Table 1

Length-frequency data used for estimating population parameters in Hard tail scad (*Megalaspis cordyla)* caught in the Bangladesh EEZ (April 95- March 97).

Length (cm)	Apr 95	May	June	Jul	Aug	Sept	Oct	Nov	Dec	Jan 96	Feb	Mar
15												
16								1				
17	1				1		1	1	1			
18	2	1			1	2	3	3	3			
19	2	1			4	19	8	4	1			
20	3	4	1		2	34	11	7	4			
21	5	5	2		5	16	23	8	7		1	1
22	7	4	3		5	12	18	8	11	2	2	2
23	10	14	7		8	6	21	4	6	5	13	7
24	14	18	6	3	7	3	13	8	5	3	12	39
25	12	22	9	3	6	2	15	7	2	1	10	32
26	3	25	18	2	4	4	4	8	8	2	9	22
27	2	20	10	4	6	6	6	5	11	9	7	6
28	1	10	3	1	2	8	0	7	15	12	4	4
29	0	4	2	1	1	3	2	16	21	13	11	1
30	1	1	2	1		1	3	20	13	7	10	2
31							0	8	17	3	8	1
32							2	12	9	1	4	
33							1	1	3		3	
34							0	2	2		4	
35							0	1	1		2	
36							1				1	

Length (cm)	Apr 96	May	June	Jul	Aug	Sept	Oct	Nov	Dec	Jan 97	Feb	Mar
15						1						
16					1	1						
17					2	2						
18					4	6	1					1
19		4			7	9	0	1	2		1	3
20	1	1		1	3	11	3	2	3		5	6
21	0	4	2	4	1	7	15	5	8	2	10	8
22	1	7	3	3	1	5	10	10	10	5	17	13
23	12	8	6	3		3	9	7	38	8	21	15
24	32	13	8	5		2	12	6	28	5	35	18
25	35	22	9	4		2	12	8	24	3	12	7
26	20	25	13	6			10	7	20	2	6	2
27	8	16	8	5			4	5	8		3	1
28	3	7	3	2				4	3		1	2
29	2	3	1	1							6	2
30	1	2									12	4
31											4	3
32											1	1
33												
34												
35												
36												

$\phi' = \log_{10}K + 2\log_{10}L\infty$ .... (1)

The ELEFAN II estimate Z from catch curve is based on the following equation:

$$Z = \frac{K(L\infty - \bar{L})}{\bar{L} - L'} \quad \text{.......................................} (2)$$

where $\bar{L}$ is the mean length in the sample, computed from L' (upper) and L' (lower) limit of the smallest length class used in the computation of L (Beverton and Holt 1956). The parameter Z of equation 2, estimated using the routine ELEFAN II (Pauly 1983; Saeger and Gayanilo 1986), is based on the methods of catch curve analysis (Robson and Chapman 1961) and an extract solution was found using the recursive model, i e;

$\ln(Ni/(-e^{-zj\ dti})) = a - zj + 1 * ti$ .... (3)

where dti is the time needed to grow through class i, ti the relative age corresponding to the lower limit of class i, zj is an initial value of Z and Ni is the number of fishes (Pauly 1984). The parameter M was estimated using the empirical relationship derived by Pauly (1980), i.e.;

$\log10M = 0.0066 - 0.279\log10L\infty + 0.6543\log10 + 0.463\log10T$ .... (4)

Where L∞ is expressed in cm, T (°C) is the mean annual environment temperature (here it was taken as 28°C). The estimate of F was taken by subtraction of M from Z. An additional estimate of Z value was obtained by ELEFAN II (Jones and Van Zalinge 1981). The exploitation ratio E was then computed from Gulland's (1971) expression:

$E = F/Z = F/(F+M)$.

"Selection pattern" was determined using the routine ELEFAN II i.e. plots of probability of capture by length (Pauly 1984) by extrapolating the catch curve and calculating the number of fish that would have been caught. Recruitment pattern was obtained by backward projection of the length axis of a set of length frequency data (seasonally growth curve) according to the routine ELEFAN II. The separation of normal distribution (NORMSEP) program for the separation of mixture of normal distributions into their components have been accessed within ELEFAN II.

Relative yield-per-recruit (Y'/R') and relative biomass-per-recruit (B'/R') was obtained from the estimated growth parameter and probabilities of capture by length (Pauly and Soriano 1986). Here, yield (Y) per recruit (R) was calculated as relative yield-per-recruit (Y'/R') and relative biomass-per recruit (B'/R').

The analysis provides estimates of B'/R' for specified values of the exploitation ratio (E=F/Z) and size at entry to the fishery (Lc) in % of B'/R' in the unfished population; thus a value of (B'/R') = 100% implies that the population is unfished. Values of B'/R' < 100% imply that the biomass-per-recruit has decreased due to of fishing.

Yield-per-recruit analysis provides a series of biomass-per-recruit for specified values of the natural mortality (M). Yield-per-recruit isopleths were studied using this biomass-per-recruit of same value against exploitation rate and selectivity (Lc/L∞) to get isopleths line of maximum yield-per-recruit.

Length-weight relationship. Total length (cm) and total weight (g) were recorded. The relationship between length-weight was calculated by a computer program followed after Sparre (1985). The intercept (a) and slope (b) of regression line were calculated by using the following formula:

$W = a.\ L^b$.

Virtual population analysis (VPA). The total landings were distributed over length groups. The predictive counterpart of VPA and cohort analysis published by Thompson and Bell (1934) and applied by Gulland (1965) were used. It is reviewed by Jones (1984) and Pauly (1984). An estimated length structured Virtual Population Analysis of *Megalaspis cordyla* was carried out.

Yield and stock prediction. Thompson and Bell (1934) routine were used to analyze yield and stock prediction for *Megalaspis cordyla.* This model combines features of Beverton and Holt's (1957) Y/R model with those of VPA, and are used to analyze single or several species for single or several fleet.

Results and Discussion

Growth parameters. The extreme value theory was applied to predict L∞ from extreme values. Predicted extreme length was found as 38.54 cm. At 95% confidence interval the predicted extreme length lies between 35.51 cm and 41.57 cm. A scan of K values was performed to predict growth constant K ($year^{-1}$). The growth parameters, L∞ and K of the *M. cordyla* have been estimated for 1995-97. L∞ and K were found to be 38.5 cm and 0.54 per year respectively. For these estimates through FiSAT the response surface (ESP/ASP) was 0.283 for main line (solid line). The growth curves with those parameters are shown over its restructured length distribution in Fig 1. The t_o value was taken as 0. L∞ and K value has been reported for *M. cordyla* as 39.2 cm and 0.34 by Mustafa and Ahmed (1992).

Estimation of L∞ and Z/K. The modified Wetherall plot (1986) analysis incorporated in the FiSAT yielded the regres-

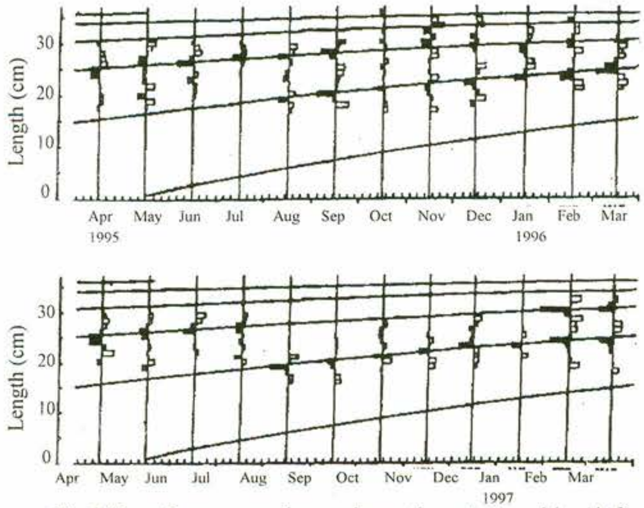

Fig 1. Growth curve superimposed over the restructured length frequency data of *Megalaspis cordyla* from the Bay of Bengal, Bangladesh.

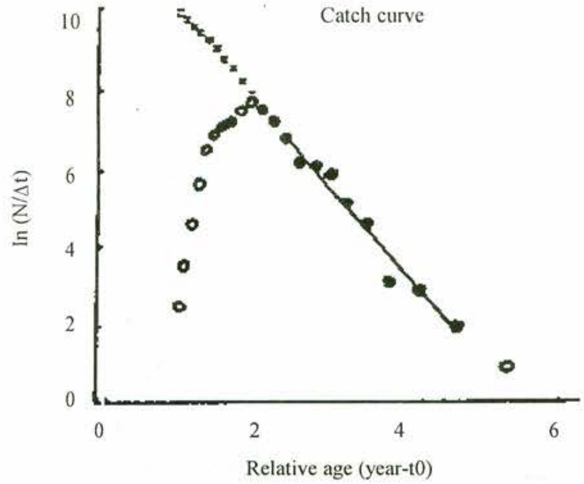

Fig 3. Length-converted catch curve of *Megalaspis cordyla*.

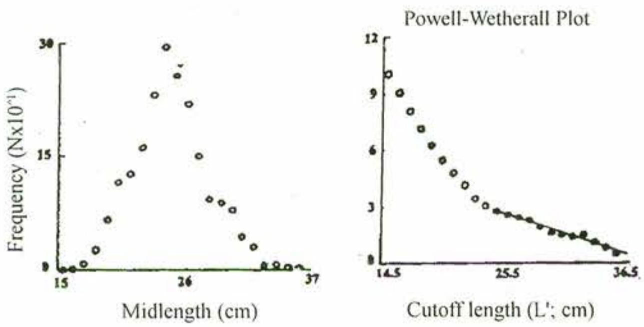

Fig 2. Estimation of L∝ and Z/K using the methods of Wetherall for *M. cordyla;* the estimated L∝ = 38.13cm and Z/K =3.90.

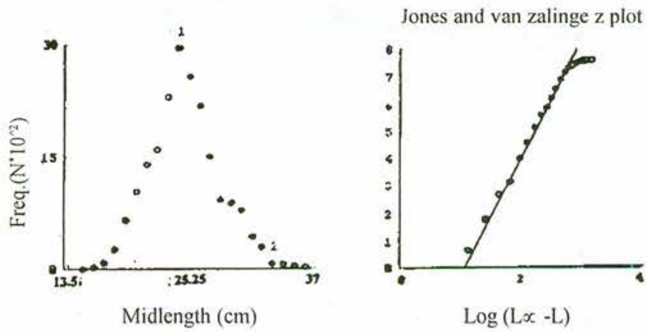

Fig 4. Jones and van Zaling Plot of *Megalaspis cordyla*.

sion line Y = 7.78 + (-0.204)*X and r = 0.983. Based on these points, L' from 24.5 cm show a good linear relationship and the points of lengths below 35.5 cm smoothly approach the extended line from which L∝ = 38.125 cm and Z/K = 3.902 were obtained (Fig 2).

Growth performance. Growth performance for *Megalaspis cordyla* was found to be 2.90.

Mortality. The mortality rates M, F and Z were found to be 1.11, 1.17 and 2.28 respectively. Figure 3 presents the catch curve utilized in the estimation of Z. The darkened quadrilateral represent the points used in calculation of Z via least squares linear regression. The correlation co-efficient for the regression was 0.991 (a = 11.98 and b = - 2.28). The Jones and Van Zalinge plot (1981) yielded the regression line Y = -4.49 + (4.327)* X and r = 0.998. Based on these points, L' from 24.25 cm shows a good linear relationship and the points of lengths below 33.25 cm smoothly approach the extended line from which Z = 4.327 was obtained (Fig 4).

Exploitation rate. The exploitation rate E has been estimated from Gulland's (1971) equation E = F/F+M. Thus from the range of values F and F+M it can be shown that the rate of exploitation, E was 0.51. Mustafa and Ahmed (1992) have stated that the rate of exploitation for the stock of hardtail scad in Bangladesh marine water was 0.41 on the basis of length frequency data. From these values, the stock of hardtail scad of Bangladesh cost appears to be lower fishing.

Selection pattern. The lengths at the first capture (Lc) from "Selection curve" were found to be 21.165, 22.329 and 23.493 for escapement factor L_{25}, L_{50} and L_{75} respectively. Selective curves are shown in Fig 5. Mustafa and Ahmed (1992) reported that the selection (L_{50}) was 20.10 cm on the basis of the net used by the research vessel (Anusandhani) from the Bay of Bengal, Bangladesh.

Recruitment pattern. Recruitment pattern is suggestive of only one even seasonal pulse in May-August. It appears from the original pattern of recruitment with superimposed normal distribution (Fig 6) that this species is recruited in the fishery mainly during May-August.

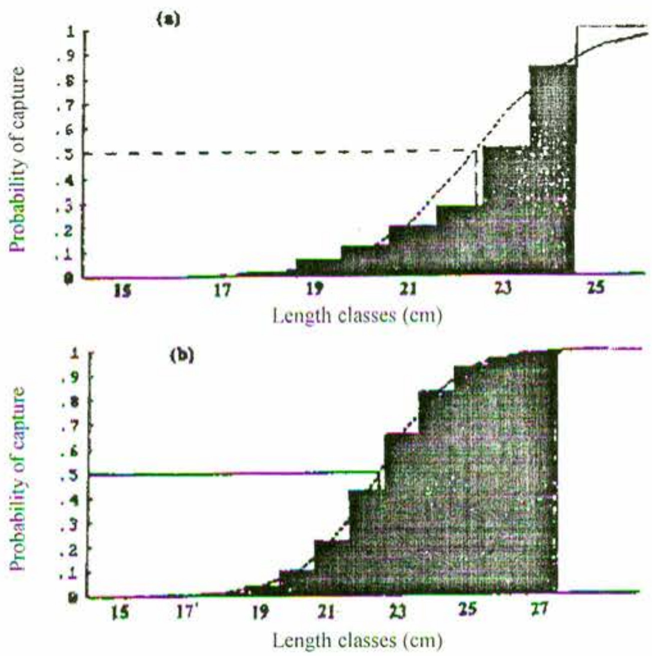

Fig 5. Selection pattern of *Megalaspis cordyla* (a), Logistic (b).

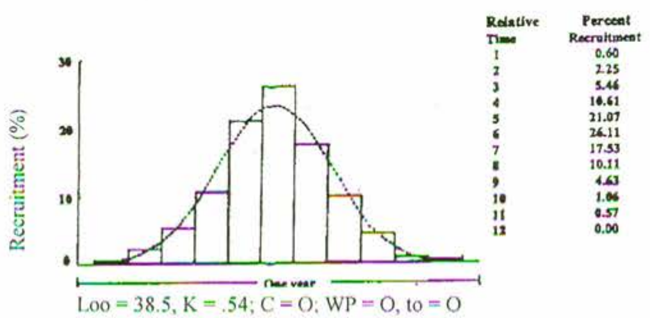

Fig 6. Recruitment pattern showing recruitment season for *Megalaspis cordyla*.

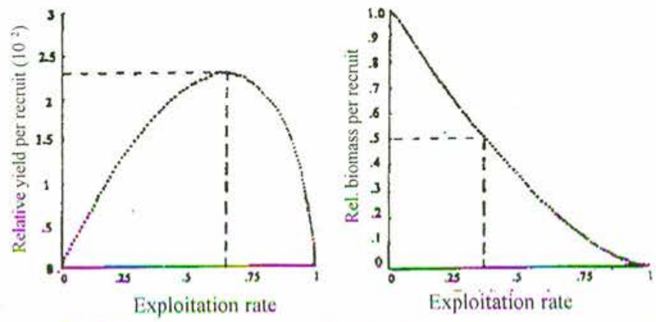

Fig 7. Relative yield per recruit and relative biomass per recruit of *Megalaspis cordyla* (Lc/L∞ = 0.58 and M/K = 2.06).

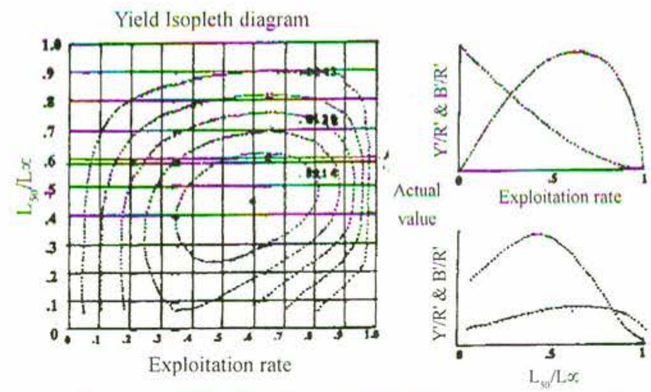

Fig 8. Yield per recruit isopleths diagram of *Megalaspis cordyla*.

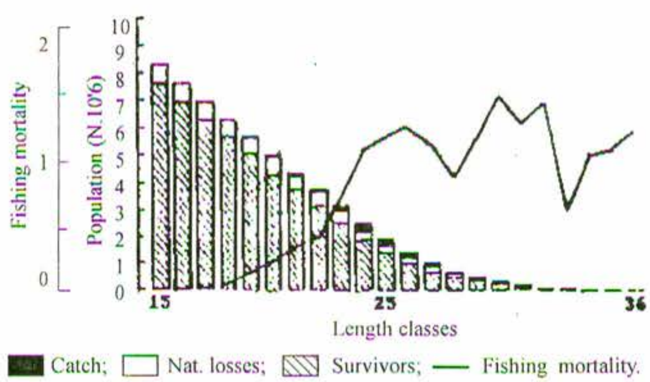

Fig 9. Length-cohort analysis of Polled data of *Megalaspis cordyla*.

Yield-per-recruit and biomass-per-recruit. The yield-per-recruit and biomass - per- recruit were determined as a function of the exploitation rate assuming Lc/L∞ = 0.58 and M/K = 2.06. Figure 7 shows that the present exploitation rate 0.51 was not exceeding the optimum exploitation (E_{max}) 0.6.

Figure 8 shows the yield-per-recruit isopleth diagrams of various lengths for *Megalaspis cordyla* at entry into the fishery which are based on different values of E and a constant value of M = 1.11. The discontinued curves indicate the range which produced the maximum yield-per-recruit. The maximum value of relative-yield-per-recruit at the meeting point of the eumetric yield curve with the maximum sustainable yield (MSY) curve at E = 0.6 and Lc = 18.0 cm in the yield-per-recruit diagram was so called potential yield-per-recruit. Hence, the value of Lc = 18.0 for 1.32 year should be considered as the optimum age of exploitation at which the biomass (standing stock) attains its maximum size. The curve suggests that the maximum yield-per-recruit could be achieved simultaneously decreasing both Lc and F. However this might cause a significant depletion of spawning stock. Hence, about 1.0% of the unripe female species entered into the fishery (TL<18.0 cm). Present length at the first entry was 15.0 cm, this fishery being running at the MSY level.

Length-weight relationship. From the regression analysis of the length and weight the relationship was found to be $W = 0.01794\ L^{2.8184}$.

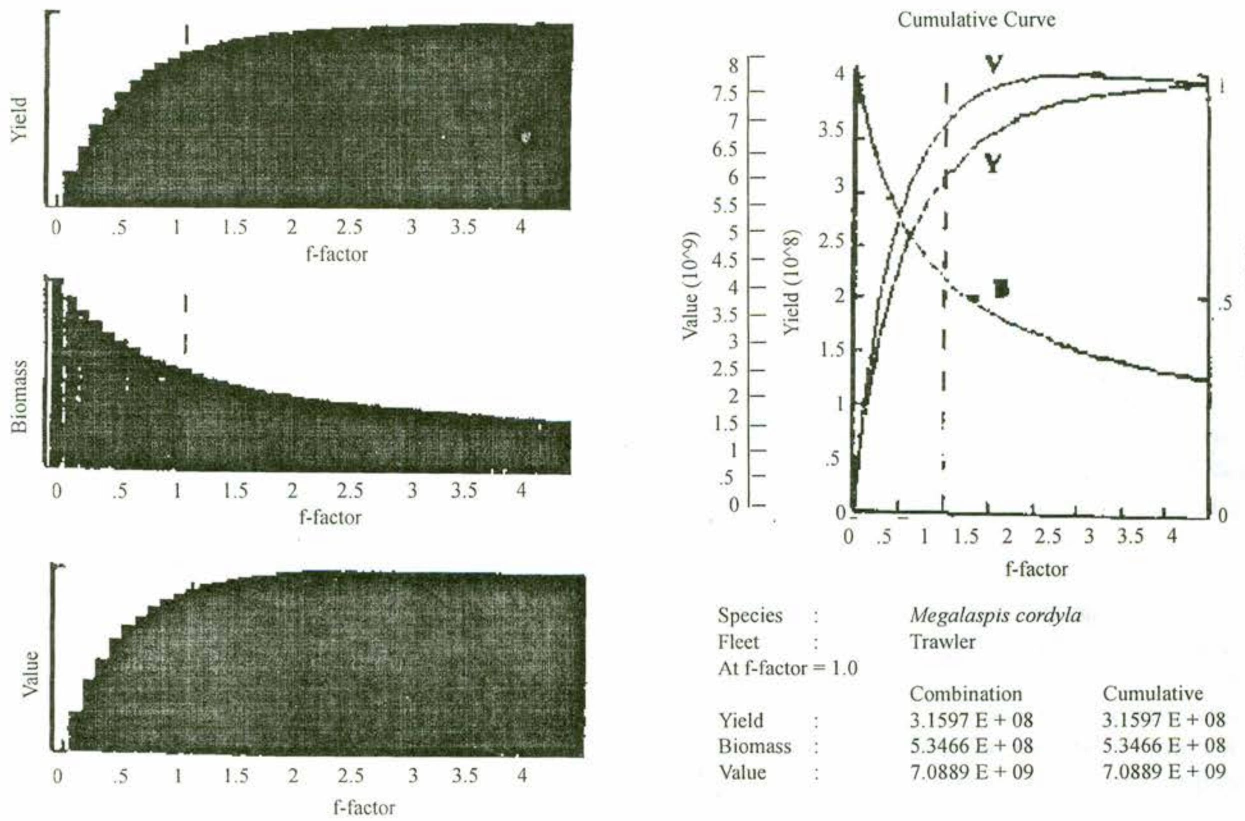

Fig 10. Thompson and Bell yield stock prediction analysis of *Megalaspis cordyla*.

Virtual population analysis. An average value of F (L>15.0 cm) and E were obtained as 0.358 and 0.244 respectively. L∝ = 38.5 cm, K = 0.54, M = 1.11, F = 1.17, a = 0.01794 and b = 2.8184 were used as inputs to a VPA. The t_0 value was taken as 0. The virtual population analysis produced for *M. cordyla* with those parameters is shown in Fig 9. Highest exploitation was observed between 21.0 cm and 31.0 cm length class.

Yield and stock prediction. Yield, biomass and value were determined as a function of the growth parameters (L∝ and K), mortality rates (M and F), recruitment size, length-weight relationship (intercept and slope) and price (class length) respectively. Yield and stock prediction analysis showed that the highest yield and price could be attained by simultaneously increasing the fishing mortality to 1.25 coefficient rate (Fig 10).

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