SOME ASPECTS OF THE BIOLOGY AND DYNAMICS OF THE BLUE-SPOTTED SEA BREAM,

Sparus caeruleostictus

IN GHANAIAN WATERS.

BY

KWAME OWUSU-BOATENG B.Sc

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UNIVERSITY OF GHANA,
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DECLARATION

I declare that this M.Phil thesis was written after a year long research under the main supervision of Prof. C.J. Vanderpuye, Head of the Department of Oceanography and Fisheries, University of Ghana, Legon. It has not been presented anywhere, either in part or whole, for a degree.

KWAME OWUSU-BOATENG

APPROVED:

Prof. C.J. Vanderpuye
(Supervisor/Head of Department)

Prof. J.S Djangmah
(Supervisor)

K.A. Koranteng
(Supervisor)

A.K. Armah
(Supervisor)

UNIVERSITY OF GHANA
LEGON
MAY, 1994

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ABSTRACT

This study, undertaken during the period March,1992 - March,1993, investigated the distribution, growth, population parameters, dynamics, food habits and reproduction of *Sparus caeruleostictus* in Ghanaian coastal waters. *S. caeruleostictus* show a distinctive size distribution by depth; bigger fish are found in deeper waters. There are two spawning periods in a year and new recruits come into the exploited population in their first year of life. *S. caeruleostictus* mature in their second year of life. Crustaceans are the main diet for the species. Growth and mortality parameters, as estimated with the Electronic Length Frequency Analysis (ELEFAN) methods are: L_{∞} = 44.3 cm (fork length), K = 0.48/yr, Z = 2.480/yr, M = 0.856 and F = 1.621/yr. The mean length at first capture, Lc_{50} was estimated to be 10.75 cm (fork length) and the rate of exploitation E, 0.65. The lengths at first maturity for the males and females, were 18.4 cm and 17.2 cm (fork length) respectively. Fecundity ranged from 40,000 - 400,000 (size range:17.5 - 24.8 cm fork length). Length and fecundity relationship was exponential and described by the equation: Log F = 1.3671 + 2.9479 Log L . Analysis of the relative yield per recruit (Y/R)' showed that to achieve the maximum sustainable yield (MSY) it will be necessary to reduce the level of the present fishing effort.

INTRODUCTION

Sparus caeruleostictus, commonly called the Blue-spotted Sea Bream, belongs to the Family Sparidae of the sub-order Percoidea and the order Percomorphii. Under this Family nineteen species belonging to 10 genera have been recorded in Ghanaian waters (Ofori-Adu, 1989). These include *S. caeruleostictus*, *Pagellus bellotii* and *Dentex canariensis*, which are commonly called red fish. Because of its delicious flesh, red fish is graded A1 on the local market (Ofori-Adu,1989). Next to shrimps and lobsters, grade A1 fish fetches the highest price. During a general survey of fish distribution in the Gulf of Guinea by the Spanish Fishing Vessel, Lagoapesca, in April 1990, *S. caeruleostictus* was shown to be the most abundant member of the group in Ghanaian waters (FAO,1991). Out of 380 kg of sparids caught, *S. caeruleostictus* contributed 146.43 kg (38.53%). The rest was made up of *P. bellotii*, 129.05 kg (33.96%) and *D. canariensis*, 104.52 kg (27.51%) (FAO, 1991).

The adult *S. caeruleostictus* is easily identified by its colour: pink with silvery reflections on the upper part of the belly; fine blue spots on the back and sides; dark blotch at the base of the last dorsal soft ray; and bluish spots which glitter giving it the name Blue-spotted Sea Bream (Irvine, 1947;Fischer et. al.,1981; Ofori-Adu, 1989)(Plate 1).

S. caeruleostictus has a wide geographical distribution. It occurs along the West African Coast to as far as the coastal waters of Northern Africa, where it is fished in

Plate 1. Freshly landed *S. caeruleostictus*

Scale 1 cm : 3.93 cm

Moroccan waters (Williams,1968;FAO,1987). The species generally has a preference for cold waters (temperature range:17 - 25°C) and hence its distribution on the continental shelf depends on the depth of the thermocline and on the position of the fronts separating the warm and cold waters (Rijavec, 1973). Results of trawl surveys have shown that seasonal vertical migrations take place in areas where there are marked seasonal temperature differences; for example: off the coasts of Mauritania and Senegal (FAO, 1987). By contrast, off the coasts of Cote d'Ivoire, Ghana and Togo, seasonal temperature variations are less pronounced and hence seasonal differences in vertical migrations are limited (Rijavec, 1973).

In Ghanaian waters, S. caeruleostictus prefers water temperatures below 20°C and a salinity range of 35.5% - 36% (Rijavec, 1973; Ofori-Adu, 1989). Preference for these conditions is believed to be responsible for the occasional inshore - offshore movement which the species makes within the continental shelf of Ghana (Ofori-Adu, 1989).

There is no organised fishery for S. caeruleostictus alone; it is usually caught with other demersal species. The traditional method of capture is with canoes in which fishing is done with hook-and-line or bottom set gill nets on rocky coral grounds (Kwei, 1973; Ofori-Adu, 1989). A Modern method of capture is by otter-trawling, which results in substantially higher catches than by the traditional methods (Bernacsek, 1986).

Considerable work in the areas of growth and mortality has been done on S. caeruleostictus in the North western coast of Africa (Lim,1987). Along the South western coast, work done on S. caeruleostictus has mostly been on its distribution (Troadec, Bouillon, Burro, 1967, cited by Rijavec 1973; Williams, 1968) and biology (Matta, 1965; Williams 1968, cited by Rijavec, 1973, Lim, 1987). In Ghanaian waters, in particular, most work accomplished has been in the areas of reproduction, growth, distributon and abundance (Rijavec,1973). Areas little covered include: population dynamics (especially mortality and growth) and food and feeding habits. The present study was undertaken with a view to providing more information on the most deficient areas; this will no doubt assist in the rational exploitation of such a highly valued commercial species.

2. MATERIALS, METHODS AND DATA ACQUISITION

Data were collected as part of the bottom trawl survey programme of the Fish Stock and Statistics Section of the Research and Utilization Branch of the Fisheries Department (F.R.U.B.), Tema. This involved a trawling survey once a month from March 1992 to March 1993, aboard the research vessel R/V 'Kakadiamaa'which is a 29 m, 700 Hp multipurpose vessel, equipped with two steel V-type otter boards. The fishing gear used was an Engel High Opening Balloon bottom trawl with 380 meshes around the fore-end of the belly and 40 mm stretched meshes in the cod-end (Koranteng, 1984) (Fig.1).

The sampling design adopted for the trawl surveys was the stratified systematic type with a certain amount of randomisation with regard to trawling depth within a stratum (Koranteng,1980). An element of randomization was introduced to reduce the potential for biases in systematic sampling. The area for the study of the distribution and dynamics of _S. caeruleostictus_ is bounded in the East by the 1° 10' and in the West by the 3° 0' longitudes, and the 15 m and 75 m water depth contours (Koranteng,1980) as shown in Fig.2. This area is divided into zones, strata, substrata, sectors and blocks as shown in Fig.2. The total area is about 5,400 square nautical miles along a 250 nautical mile long coastline. There are 40 sampling stations distributed among the sectors.

There are 3 main strata namely A, B, and C, with the following depth ranges:

Fig.1 Diagram of Engel High Opening bottom trawl.

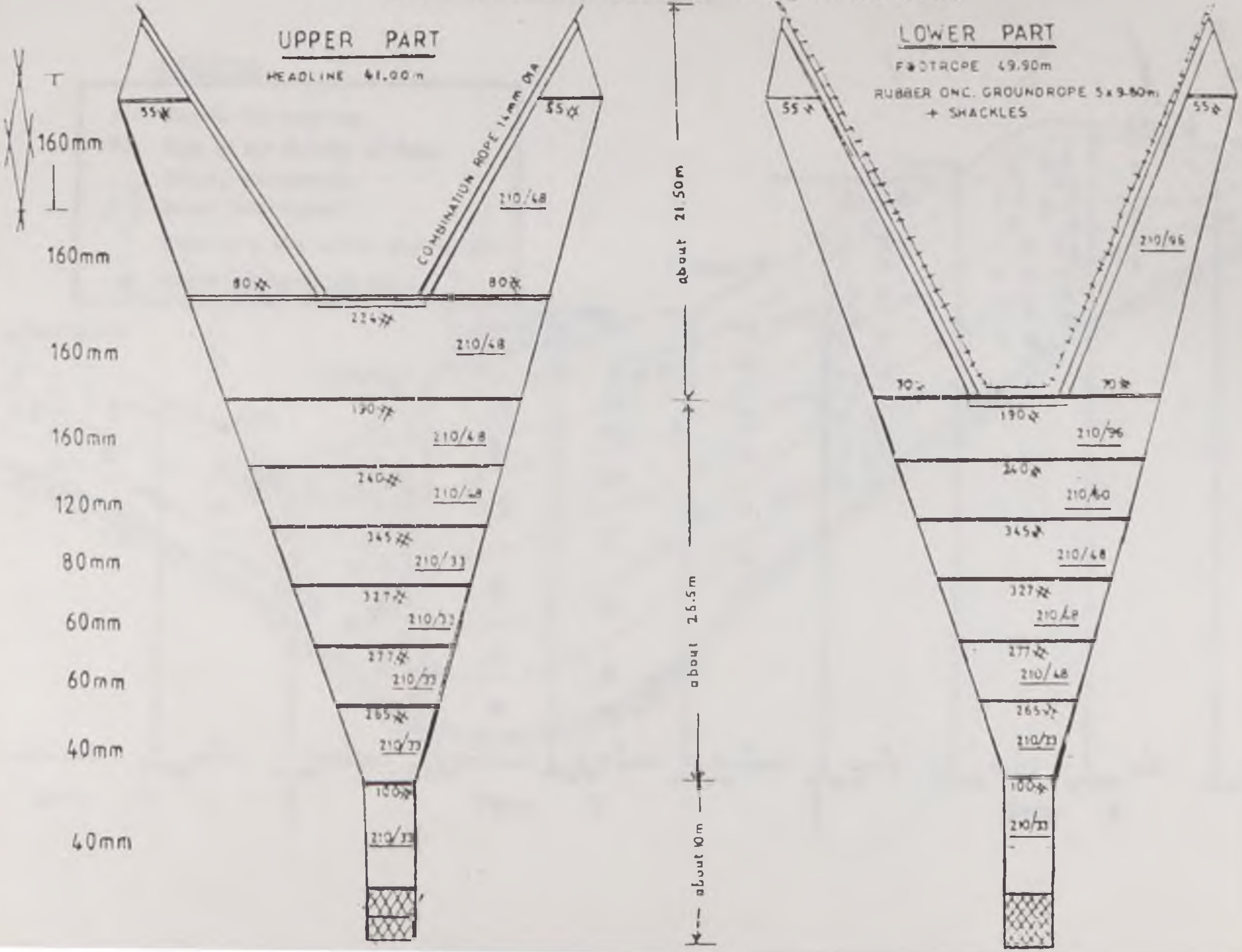
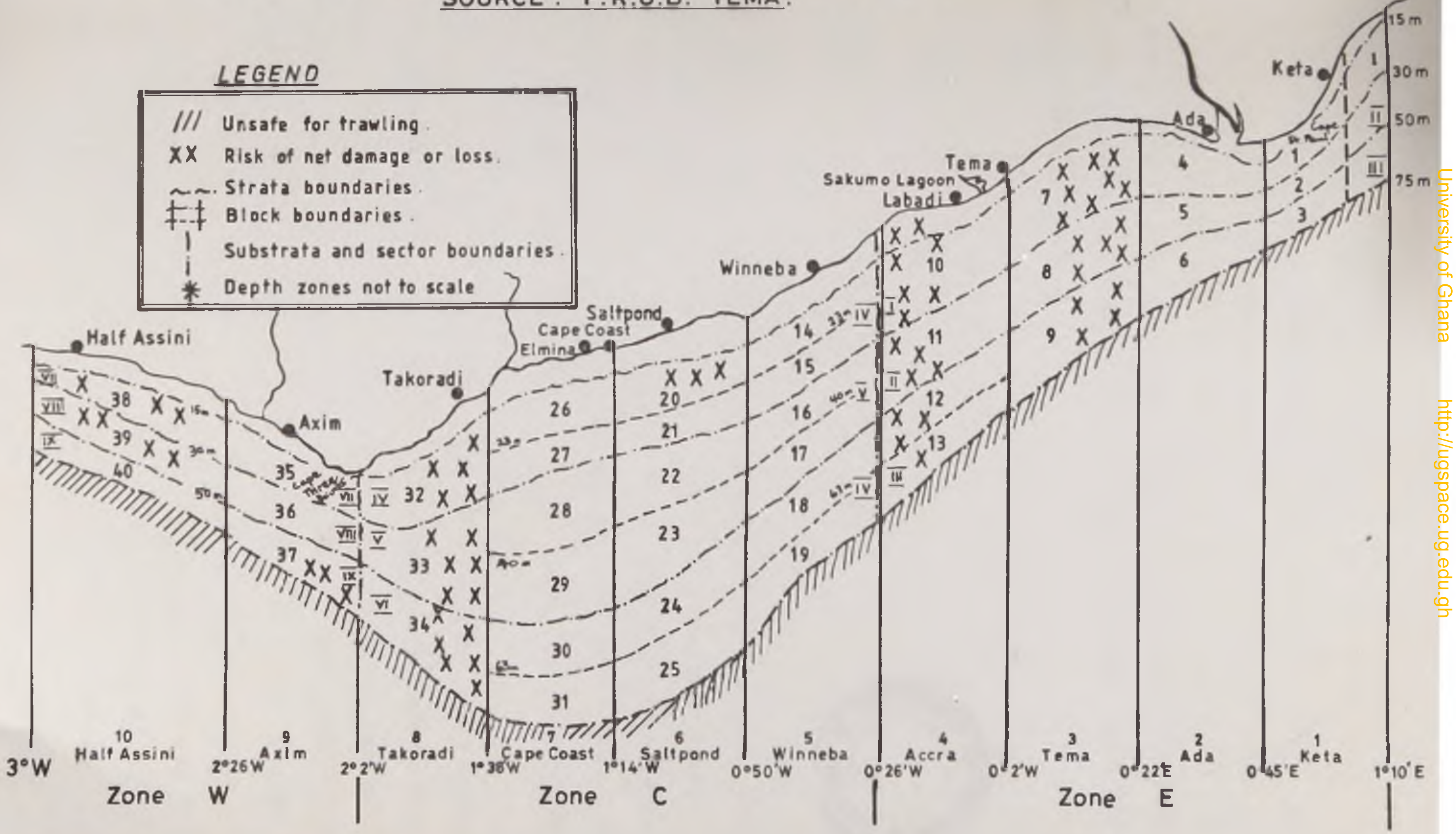


Fig. 2 DEMERSAL FISH SURVEY : SAMPLING DESIGN

SOURCE : F.R.U.B. TEMA.



A 15 m - 30 m

B 31 m - 50 m

C 51 m - 75 m

Two substrata occur in each stratum between longitudes 0°26' W and 1°38' W and stratum C of the Accra sector with the following depth ranges:

1(A) 15 m - 23 m

2(A) 24 m - 30 m

1(B) 31 m - 40 m

2(B) 41 M - 50 m

1(C) 51 m - 63 m

2(C) 64 m - 75 m

The stations are not at fixed positions but indicate the vessel's location within a block or area in a specific sector. Each block corresponds to a depth range within a stratum or substratum. Trawling takes place at any position within a block provided that position is safe for trawling (Koranteng,pers.comm.).

Since the author undertook the investigation with staff of F.R.U.B., the sampling design for trawling followed that designed by the F.R.U.B. When a sampling station was reached, the depth and trawling track were selected by the captain of the vessel, in collaboration with the Scientist - in - Charge. The net was shot and each haul lasted for 30 minutes at a speed of about 3 knots (5.56 km/h). Trawling time was cut short only when the sea bed was observed to be full of snags or the gear got stuck to the sea bed. All hauls were carried out between 0600 hours and 1800 hours G.M.T.

Data for the population dynamics study were collected by recorders of the Fish Stock and Statistics section of F.R.U.B. covering the period June 1990 to May 1991. The data covered all the sectors on the continental shelf. Monthly samples of S. caeruleostictus, representative of the stock as a whole, were obtained by pooling daily samples within each month across all the forty (40) sampling stations within the survey area.

Data involving catch rates, catch per month and per year from June 1990 to May 1991 were extracted from the files of F.R.U.B. Data on total catches of canoes, shrimpers, industrial and inshore vessels, and bottom and surface temperature readings were also extracted from these files. Bathymetric readings were extracted from trawl survey worksheets.

Biological data were collected by the author with the assistance of staff of the Fish Stock and Statistics section of F.R.U.B. during trawl surveys between the Accra and Winneba sectors. A sample of about fifty (50) fish specimens was taken at each sampling station. Each specimen was weighed to the nearest 0.1 g and measured (fork length) to the nearest cm. Samples for stomach content analysis, reproductive biology and length-weight relationship were preserved on ice for later study in the laboratory. Data analyses were mostly executed with the following PC softwares for stock assessment studies: ELEFAN (Electronic Length-Frequency Analysis) (Gavanilo et. al.,1989); LFSA(Length-based Fish Stock Assesment)

(Sparre,1987); and STATGRAPHICS (Statistical Graphics,1989).

3. DISTRIBUTION AND ABUNDANCE

3.1 Material And Methods

Data for the study period: June 1990 to May 1991, were extracted from files of the Fish Stocks and Statistics section of F.R.U.B., Tema. Length frequency distributions in the 3 strata and 10 sectors were investigated. The relationship between the temperature and the catch was also analyzed.

3.2. Results

Length - Frequency Distribution Within Strata

Fig. 3 shows the line polygons of the length-frequency distributions in the 3 strata displayed on the same axis. The skewed distributions show a shift from the left to the right of the modal length for strata A, B, and C in that order. Table 1 gives the length ranges, modal lengths, abundant length groups and numbers caught in the 3 strata.

In terms of abundance stratum B had the highest catch , followed by stratum A and then stratum C (Table 1).

Length-Frequency Distribution Within Sectors

Of the 10 sectors studied, catches were made in 8, namely Keta, Tema, Accra, Winneba, Saltpond, Cape Coast, Takoradi and Half-Assini. Fig.4 shows the Length-frequency distributions in these sectors. The Keta, Tema, Accra, Winneba, Cape coast and Saltpond sectors had fish of lengths ranging from about 6 - 30 cm. Takoradi and Half-Assini sectors had narrower

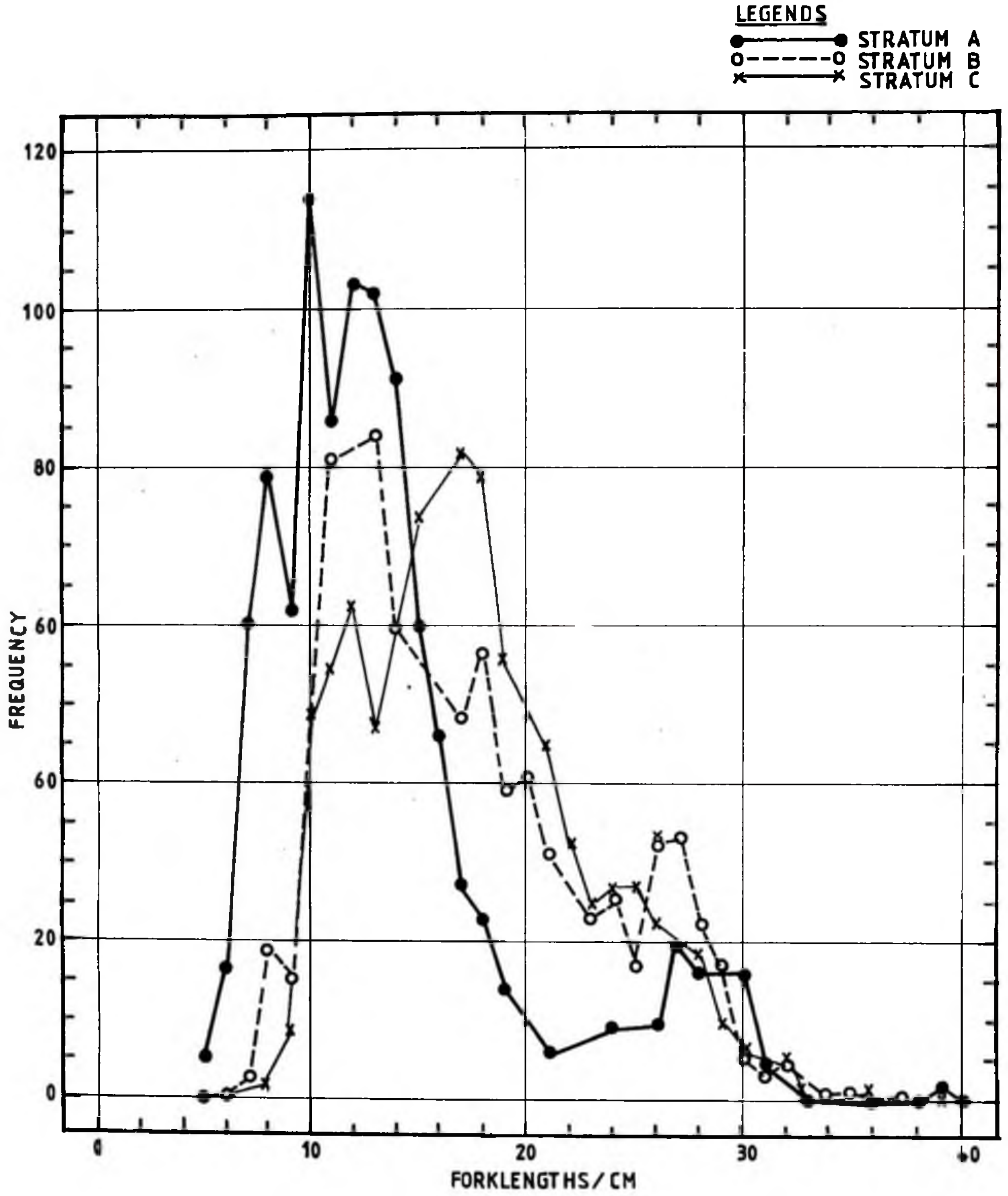
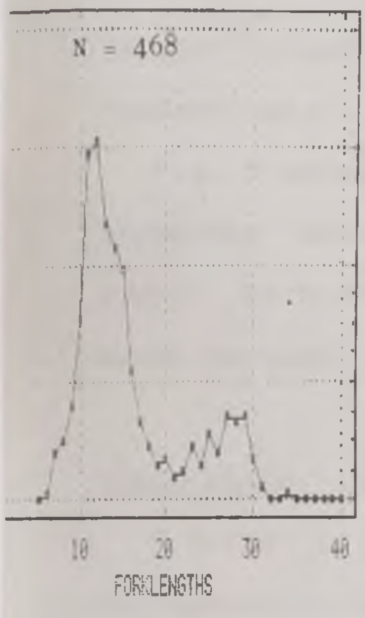
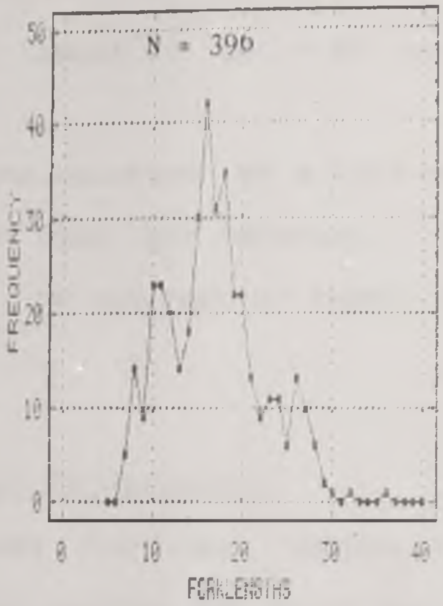


Fig. 3. Length-frequency distributions of *S. caeruleostictus* in strata A, B and C.

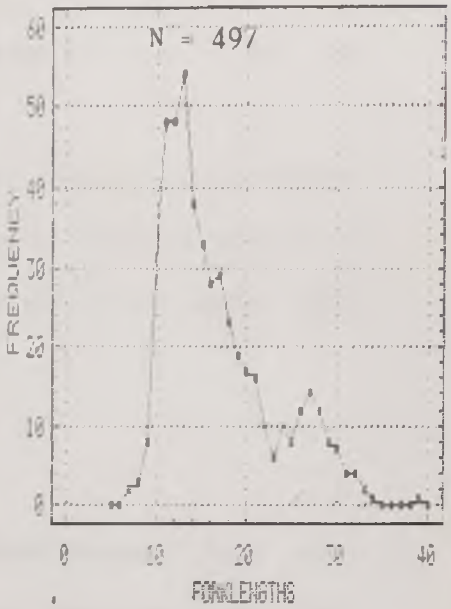
L/F DIST.OF S.CHERULEOSTICTUS
IN KETA SECTOR



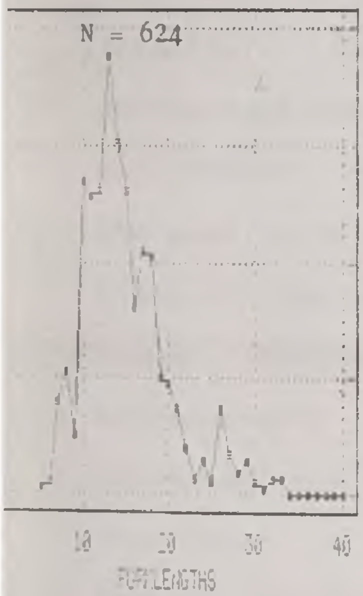
L/F DIST OF S.CAERULEOSTICTUS
IN ACCRA SECTOR



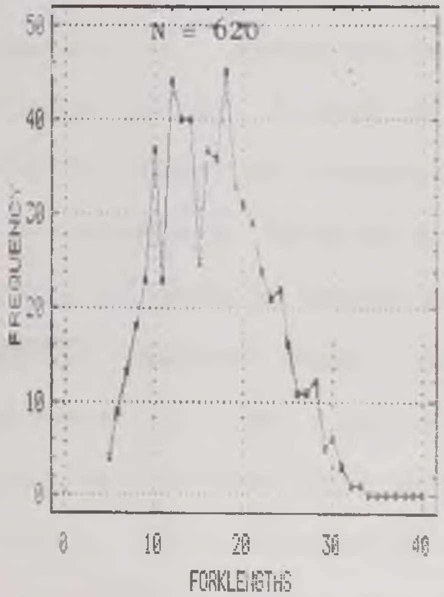
L/F DIST OF S.CHERULEOSTICTUS
IN TEMA SECTOR



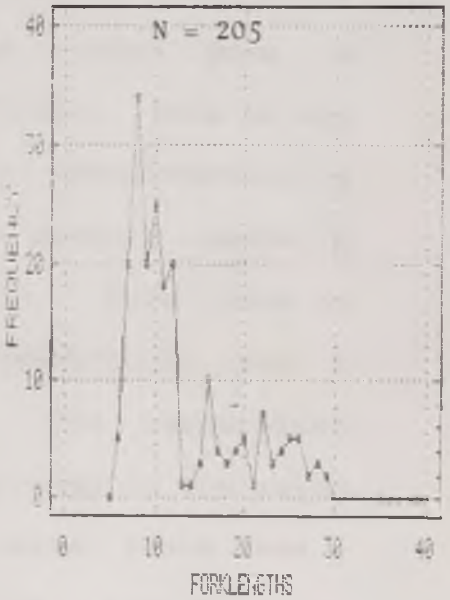
L/F DIST. OF S.CHERULEOSTICTUS
IN WINNEBA SECTOR



L/F DIST OF S.CHERULEOSTICTUS
IN SALTPOND SECTOR



L/F DIST OF S.CAERULEOSTICTUS
IN CAPECOAST SECTOR



L/F DIST.OF S.CAERULEOSTICTUS
IN TAKORADI SECTOR

L/F DIST. OF S.CAERULEOSTICTUS
IN HALF-ASSINI SECTOR

length ranges of about 11 cm - 26 cm and 17 cm - 30 cm respectively.

Fig. 5 shows the location of a hard rocky substratum which stretches between Tema and Takoradi. This covers strata B and C. Stratum A is composed of mostly a mixture of sandy and muddy bottoms.

Temperature - Catch Relationship

Table 2 gives the mean bottom temperatures and the corresponding total catches per month for the period June 1990 to May 1991. These have been combined and presented together as shown in Fig.6. These results cover the area under study (Fig.2). Regression of temperature on catch gave a correlation coefficient (r) of 0.3463 ($p > 0.05$). This is not significant at the 5% level of probability (Notwithstanding the poor correlation which was determined on monthly basis, a trend in the two sets of data is discernible). From June to August there was a marked drop in temperature and a corresponding decrease in the catch. The temperature increased from August to October with an increase in the catch from August to November. From October to December there was a fall in temperature with the catch decreasing from November to December. January to March showed a slight increase in temperature with catch increasing slightly between January and February. From March to April the temperature fell and the catch also decreased around this period.

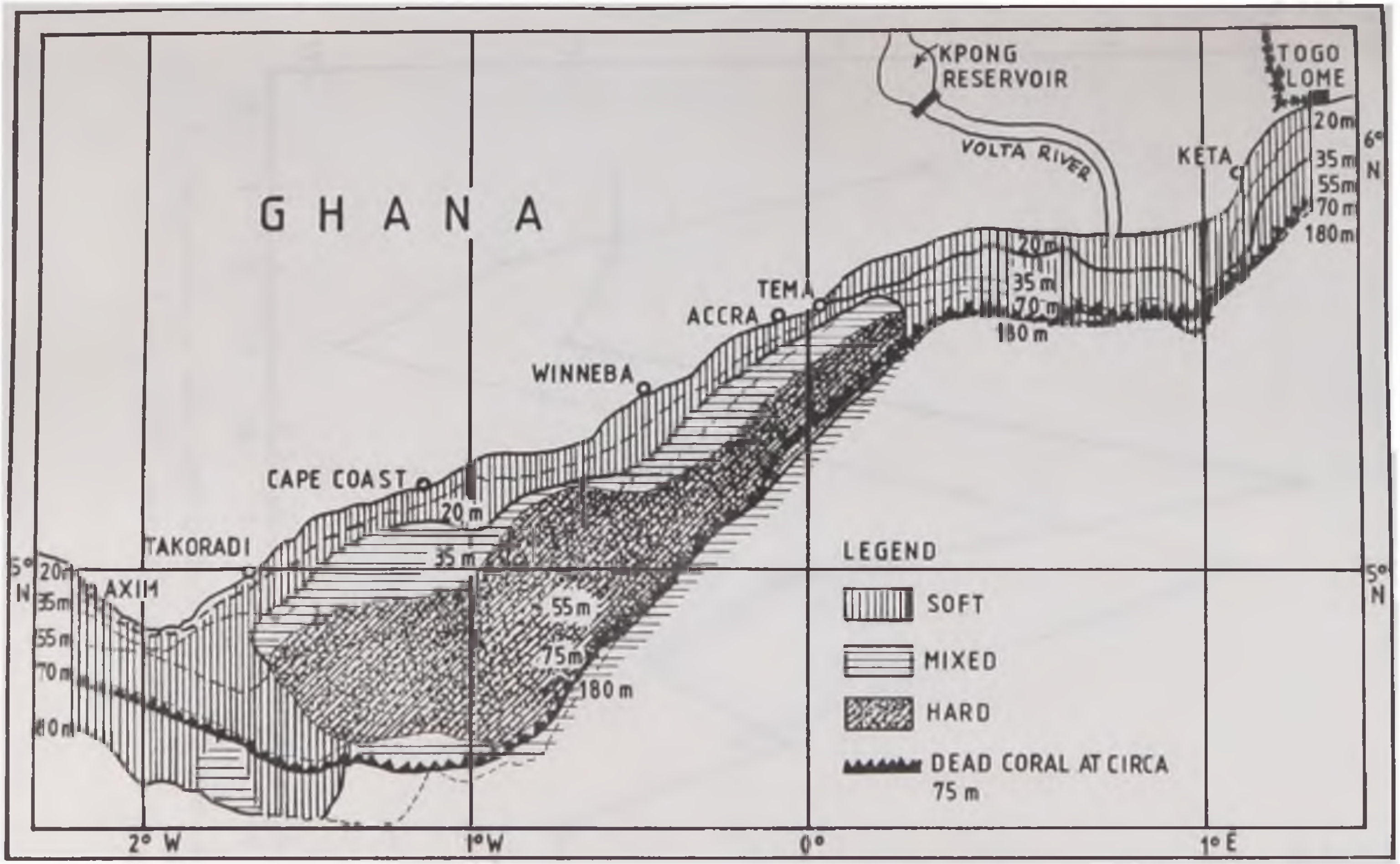


Fig. 5 Bathymetry and sedimentology of the continental shelf of Ghana.
(Source : Bernacsek, 1986).

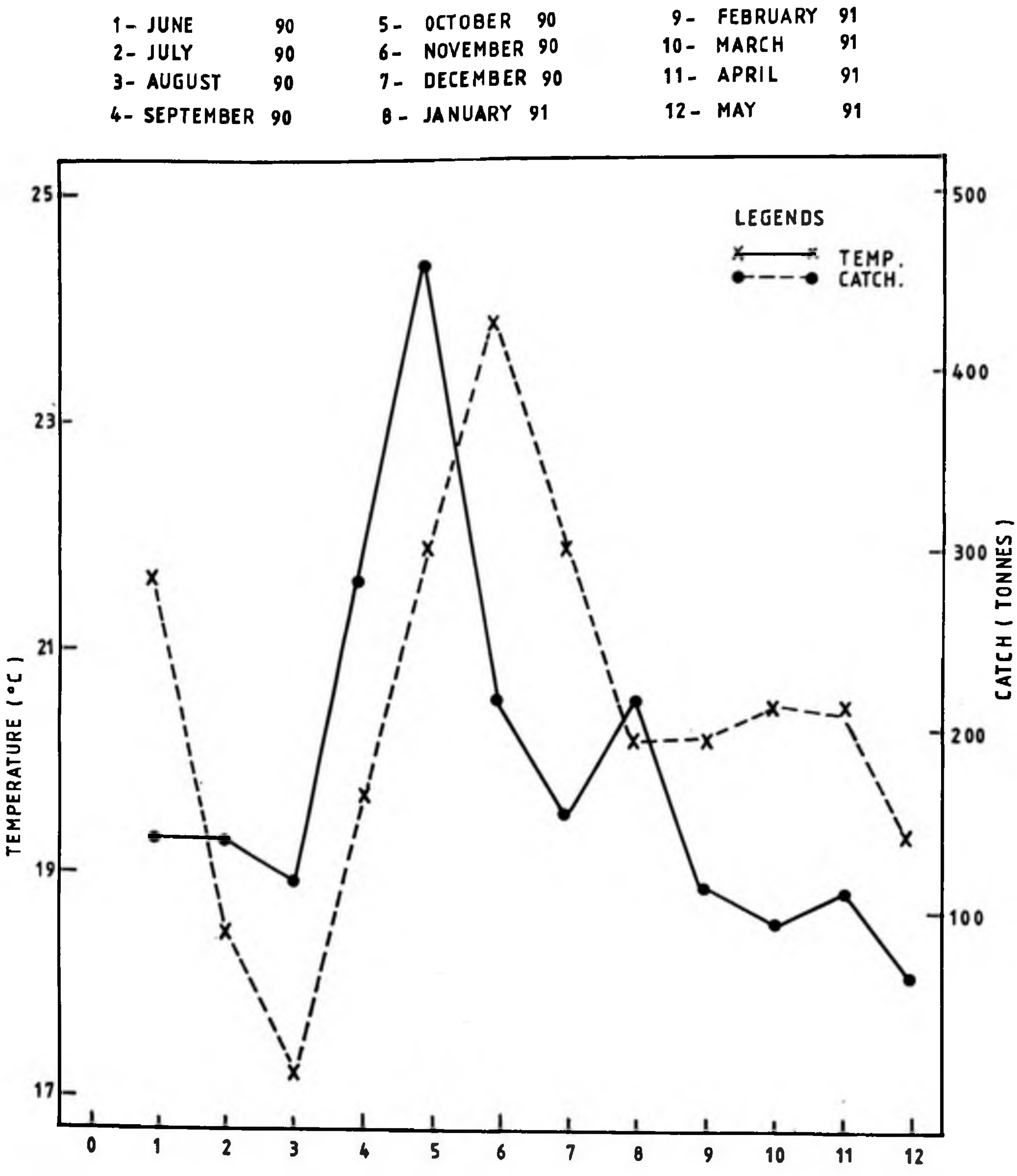


Fig. 6 Variations in mean monthly bottom temperatures and total catches (June, 1990 - May, 1991).

4. GROWTH

4.1 Materials and Methods

4.1.1 Bhattacharya Analysis

This method is based on the assumption that fish belonging to the same cohort show lengths that are normally distributed. It is useful for splitting a composite distribution of a sample into separate normal distributions when several cohorts of fish are contained in it. Details of the method are presented in Sparre et al.(1989) and incorporated into the ELEFAN V programme.

Length-frequency distribution of eleven samples of S.caeruleostictus, collected from June 1990 to May 1991 shown in appendix 6, were separated according to this method.

4.1.2. Body - Scale Relationship

Scale samples of S. caeruleostictus were removed with tweezers on the left side of the body, at approximately the same point below the lateral line and in line with the first spiny ray of the anal fin. This step was taken to reduce the variation in scale size for fish of any given length (Bagenal and Tesch, 1978). Scales were stored in paper envelopes with the following information written on them: weight, length of radii and the date of collection.

Five scales were removed from each fish and the average lengths of their radii were determined by measuring to the nearest 0.1 mm, the distance from the focus to the anterior edge for each scale. This was performed using an eyepiece graticule and the vernier scale on an Olympus CH2 research microscope. Each scale was then examined under a magnification of x 400, and the number of circuli from the focus to the anterior edge were counted along the primary radius (there was no evidence of growth rings). The average number of circuli for each set of scales per fish were determined. Regression of (1) fork length (cm) on average scale length (mm) and (2) the logarithm of the average number of circuli on the logarithm of fork length were determined.

4.1.3. Weight - Length (W/L) Relationship

Each fish specimen was weighed to the nearest 0.1 g and the corresponding fork length determined to the nearest 0.1 cm.

In fishes, the weight-length relationship is usually represented by the exponential equation:

$$W = aL^b$$ (Bagenal and Tesch, 1978)

where,

W = weight of fish

L = length of fish

a = intercept on weight axis

b = exponent, b having a value between 2 and 4.

A value of $b = 3$ infers isometric growth (growth with unchanging body proportions and specific gravity). When b is greater or less than 3 growth is said to be allometric (changing body proportions and specific gravity).

A logarithmic transformation of the exponential equation gives:

$$\text{Log } W = \text{Log } a + b \text{ Log } L.$$

Regression analysis of log W on log L were executed for the males and females. This was done for either sex to determine if their regression coefficients (slopes) were significantly different by calculating their confidence limits to determine if there was any overlap between them.

Ricker, (1975) and Sparre et al., (1989), indicated that one of the assumptions behind linear regression analysis is that the independent variable cannot be a random variable but a predetermined parameter. In fishery biology studies, however, both weights and lengths are random variables and this poses a problem. A way out, suggested by Ricker (1975), is the use of the Geometric Mean (GM) regression. The parameters in the GM regression are determined as follows:

(1) $b' = b/r$

where b = regression coefficient

r = correlation coefficient

(2) $a' = y - b'x$.

where a' = GM regression intercept

x = mean of x variables

y = mean of y variables

After determining that there was no statistically significant difference between the slopes of the separate sexes, their weight - length data were pooled. GM regression coefficients were then determined from the results.

4.1.4 Condition

Fulton's Condition Factor (CF) which measures the plumpness or well-being of a fish is expressed by the formula:

$$K = 100W/L^3$$

where, W = weight of fish in g.

and L = length of fish in cm.

This equation is used only where the power of L in the weight length relationship is not significantly different from 3.

The formula was used to calculate the condition factors of the combined sexes since their separate growths were not statistically different. CF was calculated for each fish and the values obtained were averaged for each month. A mean monthly condition against month was then plotted.

4.2. Results

Bhatthacharya Analysis

Length-frequency distributions of 11 monthly-samples (appendix 6) were analyzed. Bhattacharya plots for June, 1990, December, 1990, and May, 1991 are shown in Figs.7 - 9. The mean length (cm), the standard deviation and the separation indices for each normal distribution in a monthly sample are shown. The composite normal distributions were drawn over the total length-frequency distribution of each sample (Figs.7 - 9) . A total of 6 cohorts were extracted from the 11 monthly samples. The results are given in Table 3. From these results, there were possibly 6 cohorts or age-groups present in the fishery. This number of cohorts were determined from the 6 average length groups extracted from the monthly samples by the analysis.

Bhattacharya's Method

Cohort No.	Population (N)	Mean (cm) Length	Standard Dev. (s.d)	Separation Index (S.I.)
1	62·77	7·971	0·93656	--
2	169·73	12·392	1·66928	3·3936
3	214·10	17·683	1·81902	3·0332
4	130·54	24·157	2·19221	3·2282

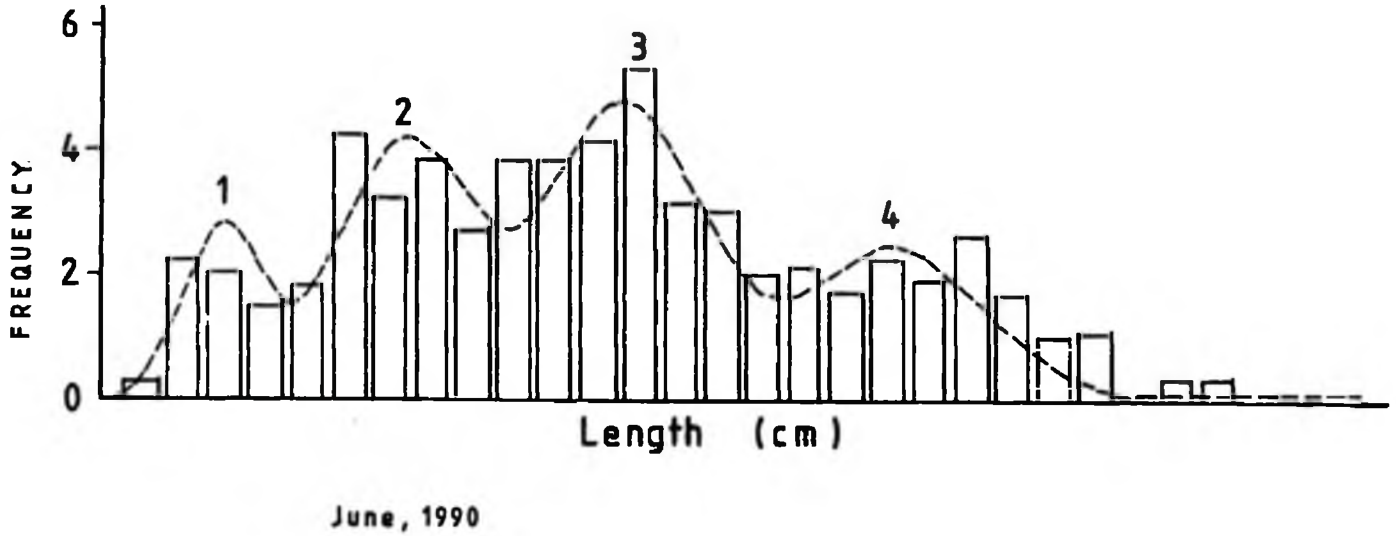


Fig. 7 Bhattacharya plot for June, 1990

Bhattacharya's Method

Cohort No.	Population (N)	Mean (cm) Length	Standard Dev. (s.d.)	Separation Index (S.I.)
1	31·56	14·679	1·36134	- -
2	9·61	18·928	0·79488	3·9408
3	8·96	23·001	0·84846	4·9576

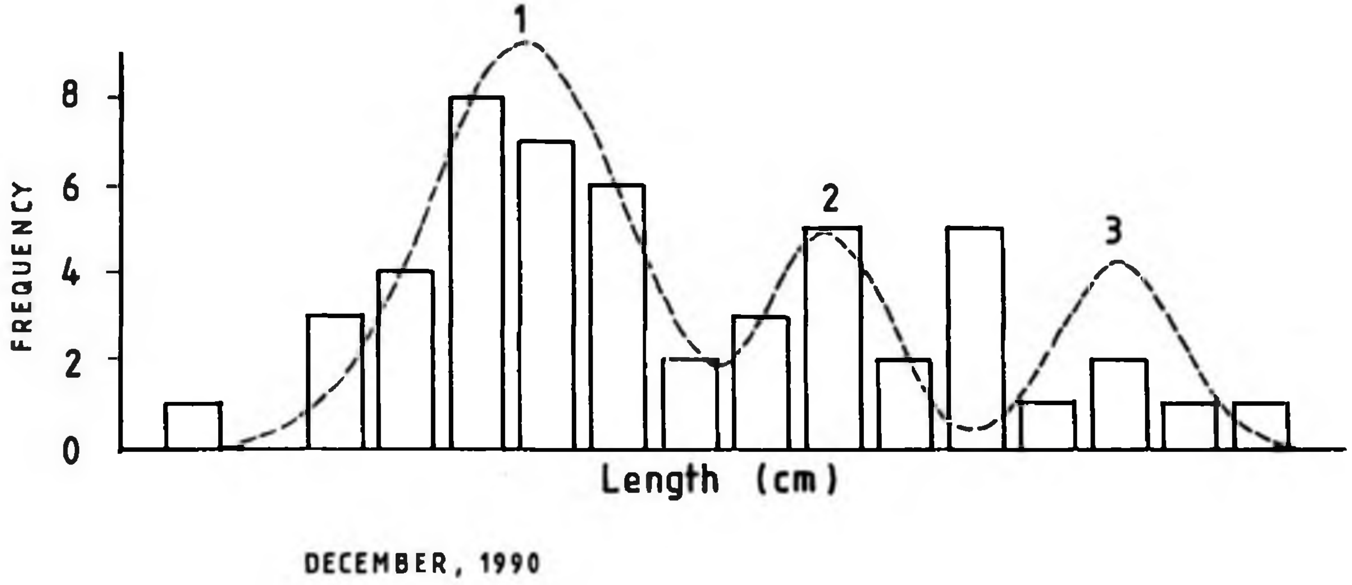


Fig. 8 Bhattacharya plot for December, 1990.

Bhattacharya's Method

Cohort No.	Population (N)	Mean (cm) Length	Standard Dev. (S.D.)	Seperation Index (S. I.)
1	28·41	10·500	1·85143	- -
2	28·37	16·445	0·90184	4·3186
3	24·23	25·833	2·19294	6·0671

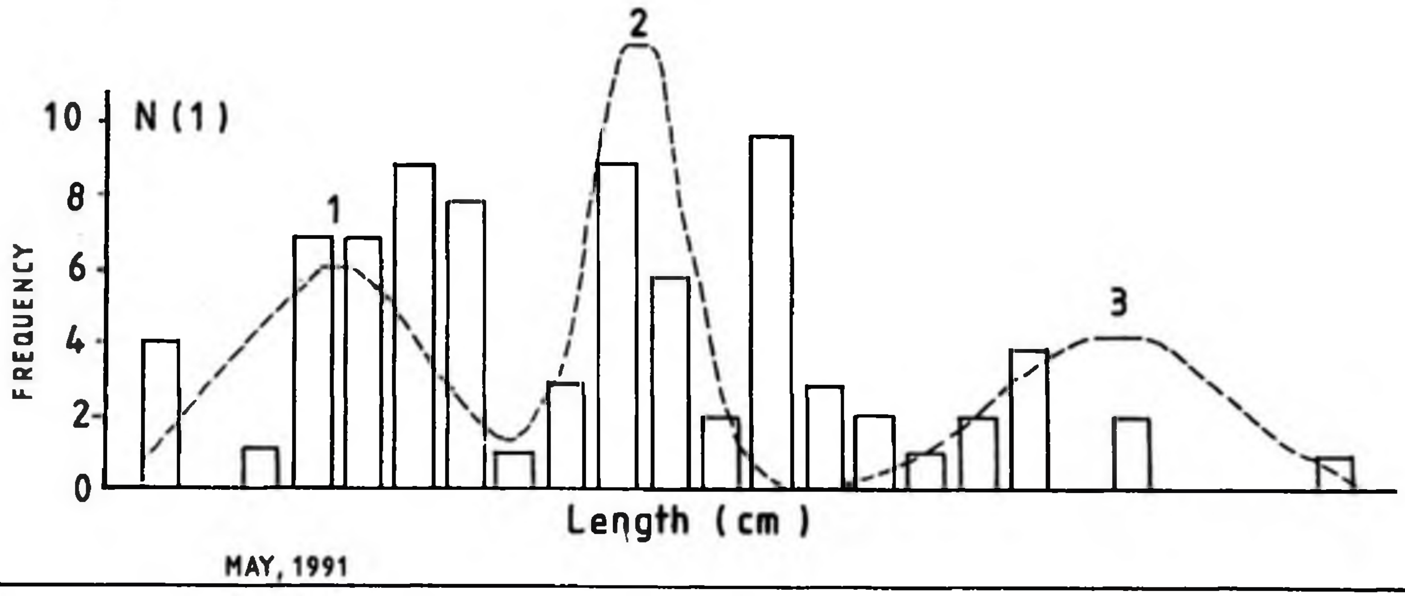


Fig. 9 Bhattacharya plot for May, 1991

These cohorts can be assigned approximate ages by comparing their average lengths with values calculated from the growth model, using the growth parameters (chapter 5).

Body-Scale Relationship

The following regression equation given by the Lee method (Lagler,1966) was fitted:

$$L = a + b\ I$$

where, L = length of fish in cm

a = intercept on the length axis

b = slope or regression coefficient

l = radius of scale in mm

A plot of body-length against scale-length is shown in Fig.10. The relationship is curvilinear. But since for mathematical purposes rectilinear equation is preferable, the Log. transformation is relationship is given as as follows:

$$\text{Log } L = -3.88 + 3.63 \text{ Log } l$$

Fig.11 shows the body-length/number of circuli relationship. The curve depicts a relationship of the form:

$$C_n = al^b$$

C_n-number of circuli on scale

l- body-length in cm

a and b are parameters

The logarithmic transformation of the above formula gives the folowing relationship:

$$\text{Log.} C_n = \text{Log } a + b \text{ Log } l.$$

Fig.10 Regression of fork length on scale length for S.caeruleostictus

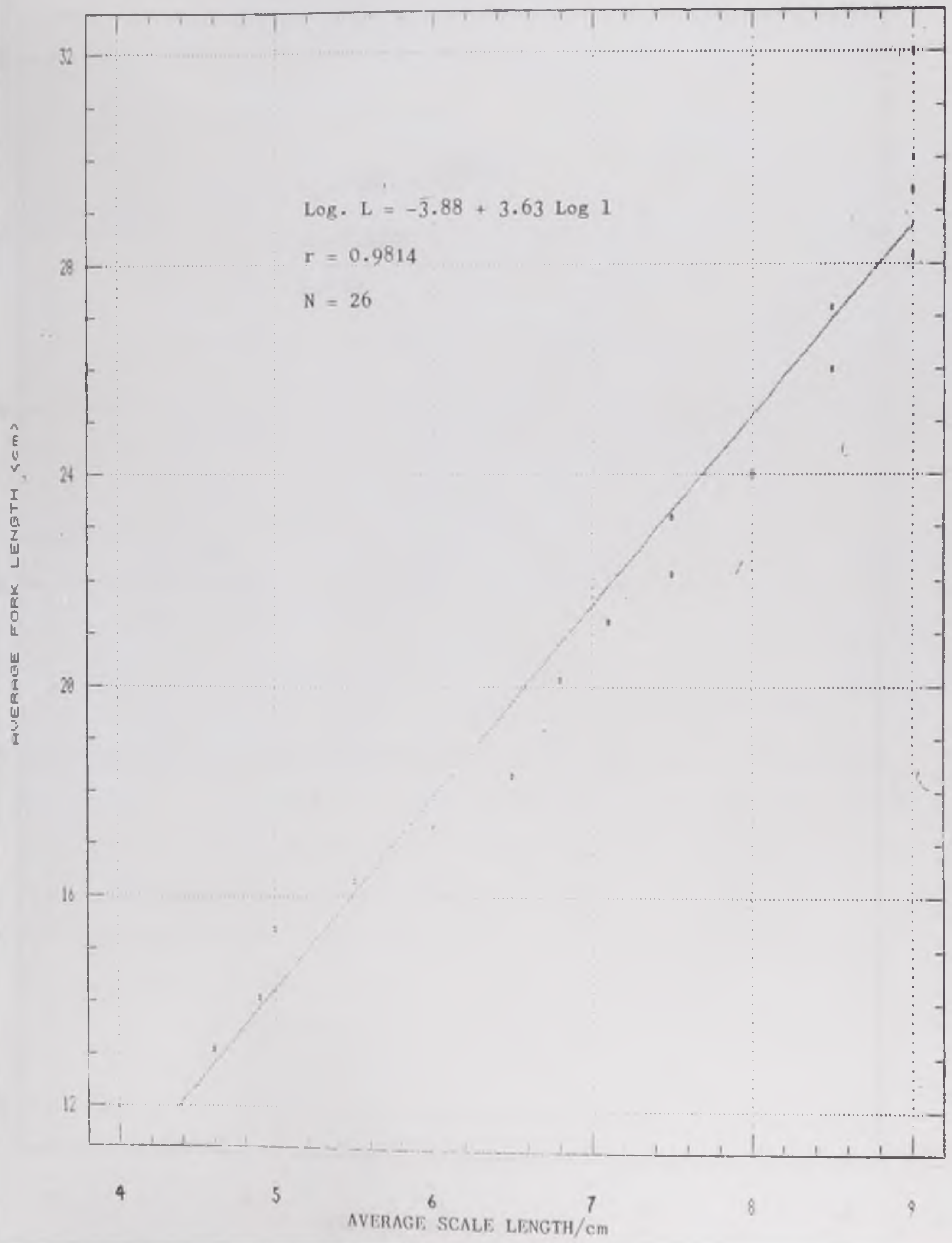
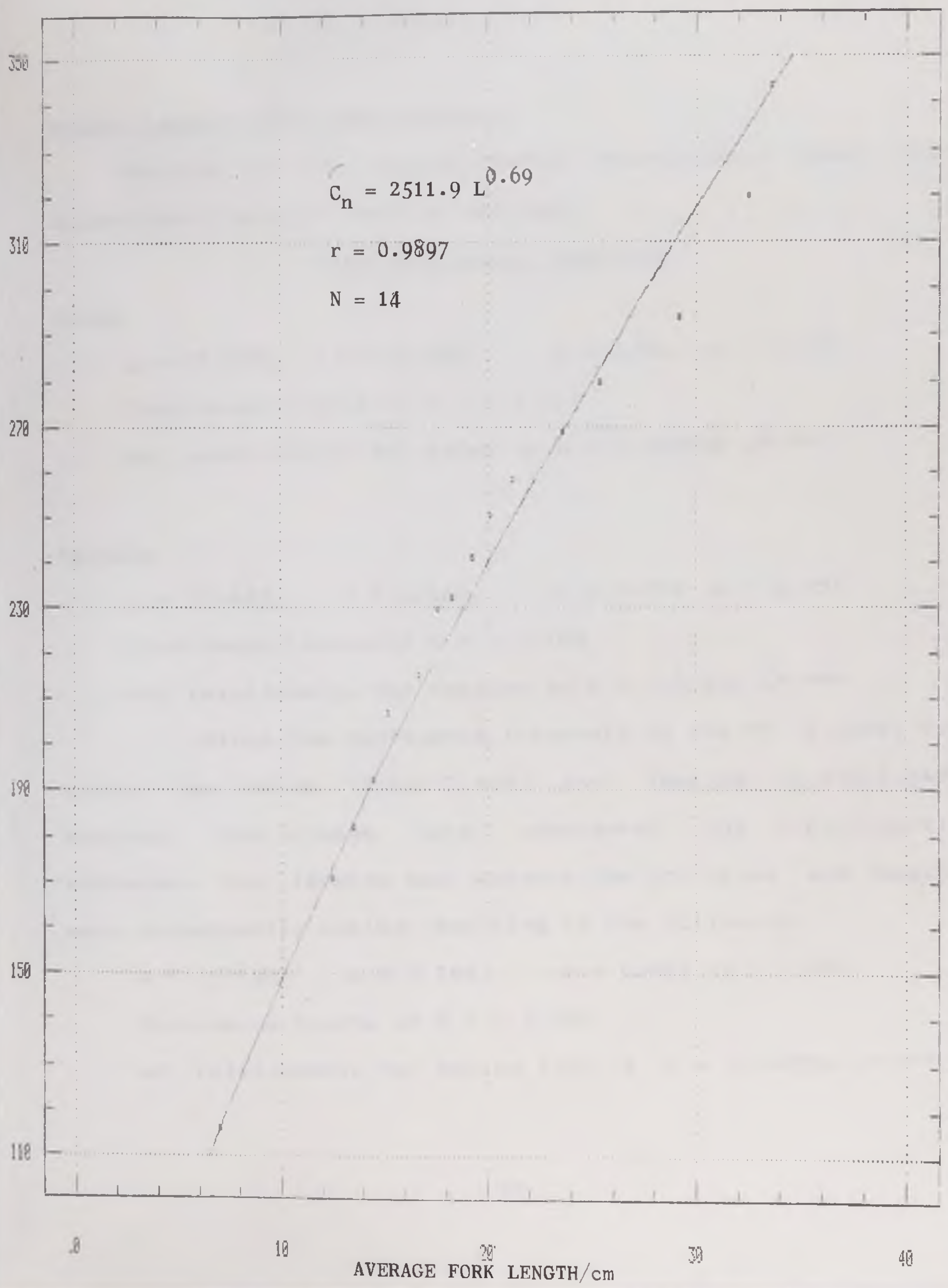


Fig.11 Regression of numbers of circuli on body length for S.caeruleostictus.



The regression of Log C_n on Log L gave the linear relationship:

$$\text{Log } C_n = 3.40 + 0.69 \text{ Log } L$$

$$\text{or} \quad C_n = 2511.9\ L^{0.69}$$

Weight-Length (W/L) Relationship.

Results of the weight-length relationship taken from appendices 9 and 10 were as follows:

From Regression Analysis

Males

$a = -3.028$, $b = 2.787$, $r = 0.967$ ($p < 0.05$)

Confidence limits of b = ± 0.117

W/L relationship for males is $W = 0.000938\ L^{2.787}$

Females

$a = -2.643$, $b = 2.660$, $r = 0.919$ ($p < 0.05$)

Confidence limits of b = ± 0.188

W/L relationship for females is $W = 0.00228\ L^{2.660}$

Since the confidence intervals at the 95 % level for slopes for males (2.670-2.904) and females (2.472-2.848) overlap, the slopes were considered not significantly different. The lengths and weights for the males and females were consequently pooled resulting in the following:

$a = -3.260$, $b = 2.780$, $r = 0.969$ ($p < 0.05$)

Confidence limits of b = ± 0.084

W/L relationship for pooled fish is $W = 0.000550\ L^{2.870}$

G.M.Regression

In terms of GM regression the value of the parameters are as follows:

$b' = 2.870/0.969 = 2.962$

$a' = 5.130 - (2.962*2.921) = -3.52$

Therefore the W/L relationship for the G.M regression is

$$W = 0.000295\ L^{2.962}$$

The value "b" is less than 3. The growth of S. caeruleosticus could hence be said to be allometric.

Figs.12 - 14 show graphs of the W/L relationship for the males, females and the pooled results.

Condition

Since both slopes for males and females were about 3 and also not statistically different, condition factors were calculated with combined values. Fig.15 shows the graph of mean monthly condition against the months. It can is observed from the graph that there were two peaks of average CF, one in August and the other in January. The lowest value of"K" occurred in July. There was a short decline from September to October. These results are almost similar to those of Rijavec (1973) shown in (appendix 11).

Fig. 12 Regression of log.weight on log.length

for male S.caeruleostictus

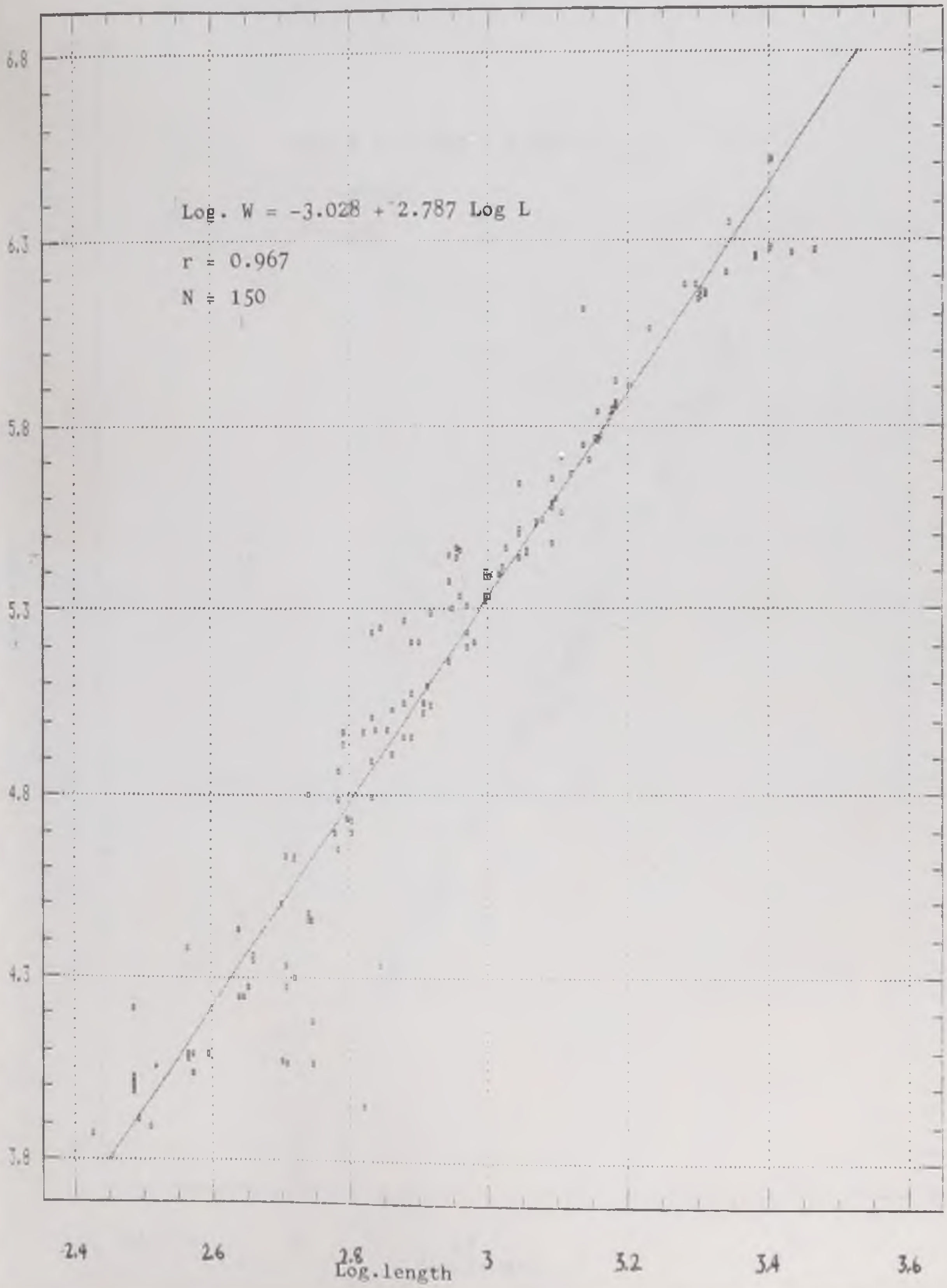


Fig.13 Regression of Log.weight on Log.length for female *S. caeruleostictus*.

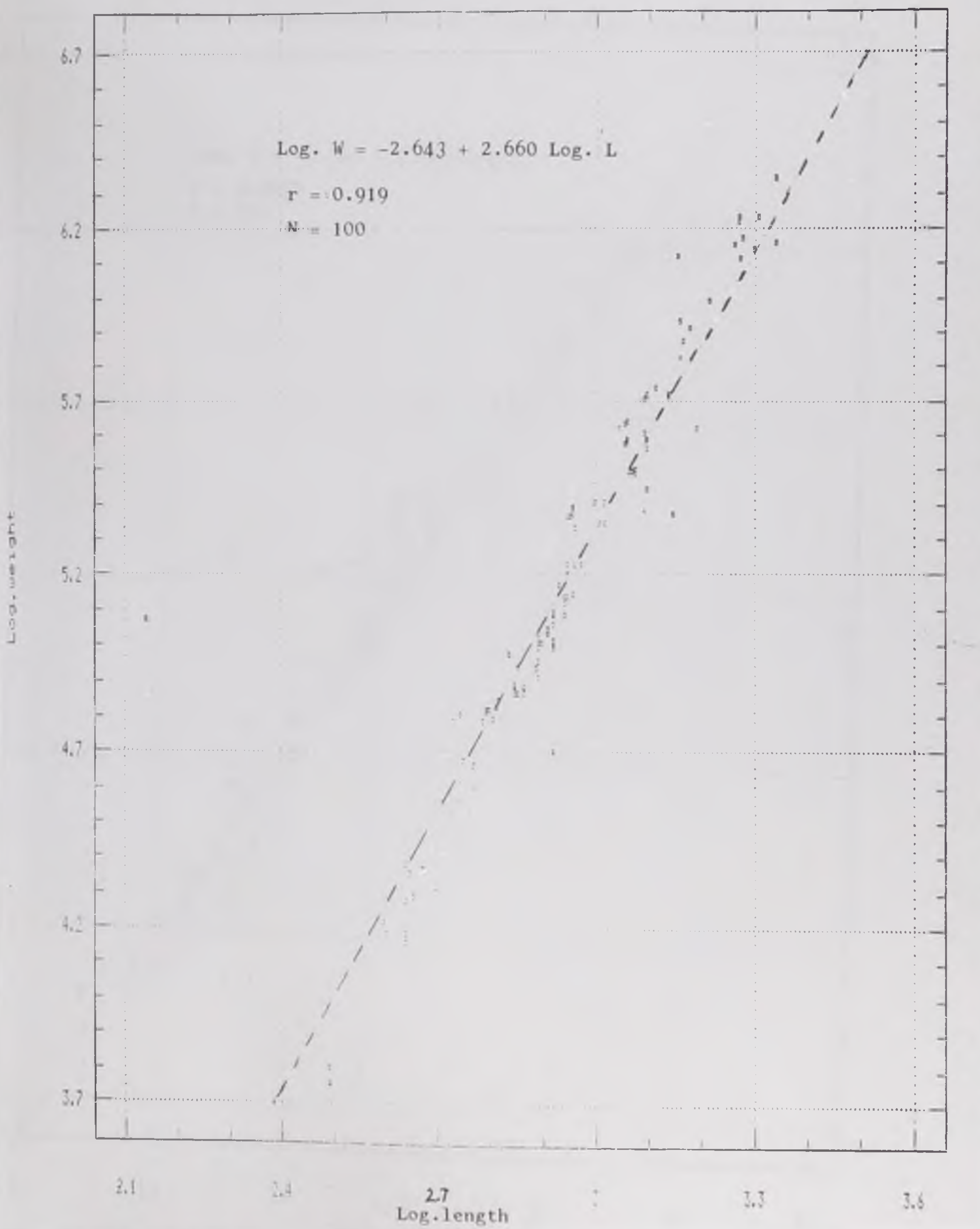


Fig.14 Regression of Log.pooledweights on Log.pooledlengths for S.caeruleostictus

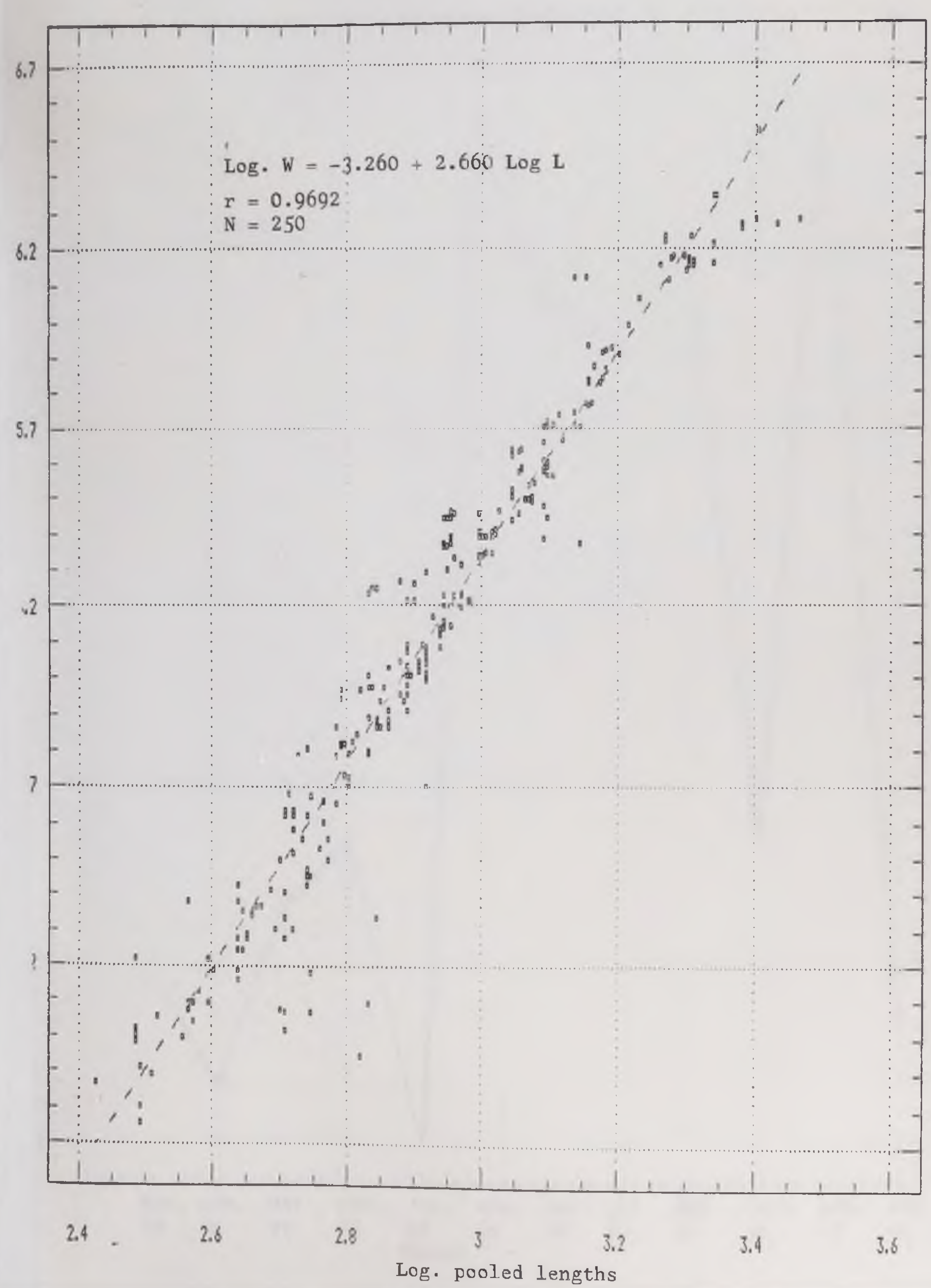
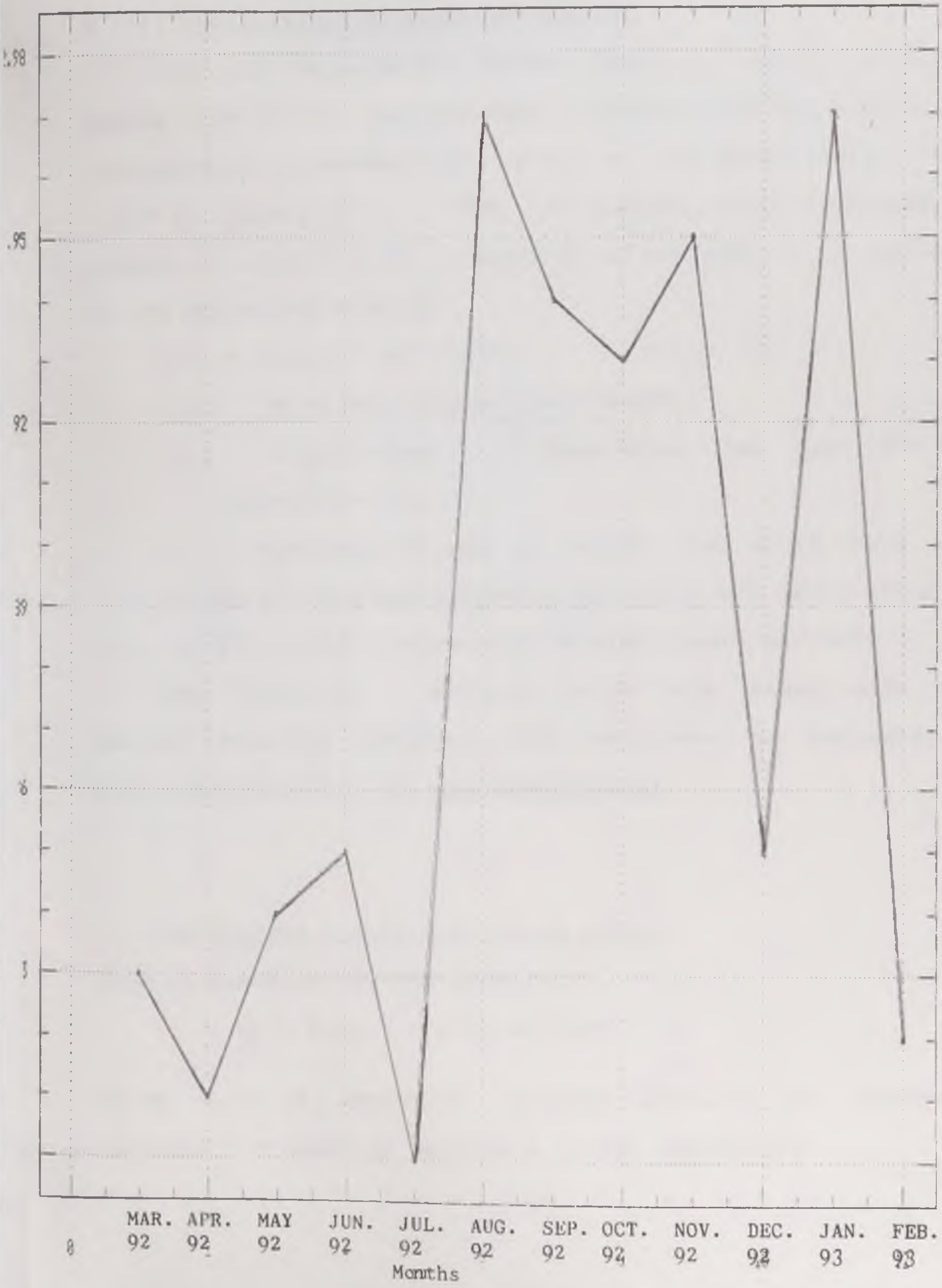


Fig.15 Changes in the mean monthly condition factor of *S. caeruleostictus*

(present study)



5. POPULATION PARAMETERS

5.1. METHODS

5.1.1. Estimation of Growth Parameters

The Von Bertalanffy Growth Equation (VBGE) which has become one of the cornerstones in fishery biology studies was developed as a mathematical model by Von Bertalanffy, 1934; cited by Sparre et al., 1989. This model, which expresses the length, L, of a fish as a function of its age, t, is expressed by the following formula:

$$L_{(t)} = L_{\infty} [1 - e^{-k(t-t_o)}] \qquad ......(1)$$

L_{∞} = the maximum theoretical length.

K = Growth rate. It determines how fast the fish approaches L_{∞}

t_o – hypothetical age at which fish would have zero length if it grows according to the growth model above.

L_{∞} , K, and t_o are referred to as fish growth parameters.

The following methods which have essentially been derived from the original VBGE were used to estimate the growth parameters of S. caeruleostictus:

(i) The Gulland – Holt Plot for K and L_{∞}

This is expressed by the equation:

$$\frac{dL}{dt} = KL_{\infty} - K\ L(t)\ \text{cm/year}$$

Using dL/dt as dependent variable and L(t) as independent variable the equation becomes a linear regression:

$$dL/dt = a + b\,L(t)$$

where $a = KL_{\infty}$; $b = K$ hence $L_{\infty} = -a/b$

Data for relative age and relative lengths were taken from the results of the Bhattacharya analysis (Table 3). Various age intervals were tried and an interval of 0.5 yrs. gave the best results. Consequently, the first cohort was assigned an age of 0.5 yrs based on the assumption of 2 cohorts per year.

(ii) Von Bertalanffy Plot for t_o.

The growth equation (1) can be re-written as:

$- \mathrm{Ln}\,(1 - L(t)/L_{\infty}) = K\,t_o + Kt$ (Sparre et. al., 1989)

where Ln = natural logarithm.

't' = independent variable

$- \mathrm{Ln}\,(1 - L(t)/L_{\infty})$ = dependent variable

A linear regression of $- \mathrm{Ln}\,(1 - L(t)/L_{\infty})$ on 't' can be defined with $b = K$ and $Kt_o = a$.

Data for relative ages and lengths, were taken from the results of the Bhattacharya analysis (Table 3) with the exception of L_{∞} which was obtained from the Gulland and Holt plot.

Hence from the regression;

$$t_o = -a/b$$

(iii) Ford - Walford Plot for K and L_{∞}

Ford (1933) and Walford (1946), rewrote equation (1) to give the following:

$$L(t + dt) = a + b\,L(t)$$

A regression of $L(t + dt)$ on $L(t)$ was performed using the results of relative lengths at relative ages from the Bhattacharya analysis.

The intercept $a=L_{\infty} (1-b))$ and the slope $b = \exp (-kdt)$ Hence the parameters K and L_{∞} are given as:

$$K = -1/dt \ln b \text{ and } L_{\infty} = a/1-b$$

(iv) ELEFAN I

This method restructures monthly length-frequency samples to form peaks and troughs above and below a running average. It aims at obtaining the best goodness of fit (Rn) for a curve running through the samples, giving the best L_{∞} and K values. Details of the method are presented in Pauly (1987).

Length-frequency distributions of 11 samples (Appendix 6) were analysed according to this method.

(v) Pauly's Empirical Formula for t_o

Pauly (1984) related the growth parameters t_o, L_{∞} and K by the formula:

$$\log - (t_o) = 0.392 - 0.275 \log L_{\infty} - 1.038K.$$

The t_o was calculated using the results of L_{∞} and K from the ELEFAN I method.

(vi) Phi Prime Test for Growth Performance

The Growth Performance index ϕ' is expressed by the formula:

$\phi' = \log K + 2 \log L_{\infty}$ (Pauly and Munro, 1984). It is to determine that estimates of growth parameters are not biased due to sampling methods since species within the same family should have similar ϕ' values.

The value "ϕ'" was then used to compare the reliability of the estimated growth parameters with results obtained by other workers on the same species.

5.1.2. Estimation of Mortality Parameters

The death process or mortality can be described with a model using parameters. These parameters are total mortality (Z), Natural Mortality (M) and Fishing Mortality (F). These are related by the formula:

$Z = F + M$ (Gulland, 1978).

The following methods were used to estimate mortality parameters for *S. caeruleostictus:*

(i) Pauly's empirial formula for M (Pauly, 1984)

This formula was derived from the multiple regression of L_{∞}, K, and temperature, T for several fish stocks (Sparre et al., 1989). It is given by the following:

$\log M = -0.0152 - 0.279 \log L_{\infty} + 0.6543 \log K + 0.463 \log T$

T = mean annual environmental bottom temperature in degrees celsius from June 1980 to May 1991. This was extracted from the Fisheries Research and Utilisation Branch (F.R.U.B.) files. The above formula is incorporated into the ELEFAN II programme.

(ii) Total Mortality Estimation

The catch curve is a graphical representation of numbers of survivors of fish plotted against their absolute ages. Ages from lengths were obtained by using the inverse Von Bertalanffy growth model:

$t(L) = t_o - 1/K \text{ Ln } (1 - L/L_{\infty})$ (Sparre et. al.,1989)

The method is incorporated into the ELEFAN II programme. This includes the calculations for Z, F and E (Exploitation rate) Details of the method are presented in Pauly,(1982, 1987) and Gayanilo et al.(1989).

The 11 length-frequency samples from Appendix 6 were analysed according to this method.

(iii) Estimation of Stock size and Fishing Mortality from Cohort Analysis

Length-based cohort analysis (Jones' 1984, cited by Sparre et al., 1989) was used to estimate stock sizes and fishing mortalities. This was executed with the ELEFAN III and the LFSA (L-COHOR) programmes. Details of the methods are described in Murty, (1987) and Sparre et. al, (1989). Input data for the programmes were L_{∞}, K, catch per month, natural mortality and the exploitation rate.

5.2 RESULTS

5.2.1 Estimation of Growth Parameters

(i) The Gulland - Holt Plot.

Fig. 16 shows the graph of $dL(t)$ vrs $L(t + 1) + L(t)/2$.

The regression analysis gave the following:

$b = -0.462$

$a = 21.153$

$r = -0.755$ $(p > 0.05)$

sample size, $n = 4$

hence $K = 0.462/\text{yr}$

and $L_\infty = \dfrac{21.153}{0.462} = 45.785$ cm.

(ii) Von Bertalanffy Plot

Fig. 17 shows the graph of:

$$-\ \text{Ln}\ (1- \frac{L(t)}{L_\infty})\ \text{vrs.}\ t$$

From the regression analysis

$a = 0.0073$

$b = 0.449$

sample size, $n = 4$

$r = 0.995$ $(p < 0.05)$

hence $K = 0.449/\text{yr}$

$t_0 = \dfrac{0.0073}{0.449} = 0.016$ yr.

Fig. 16 The Gulland and Holt plot for *S. caeruleostictus*

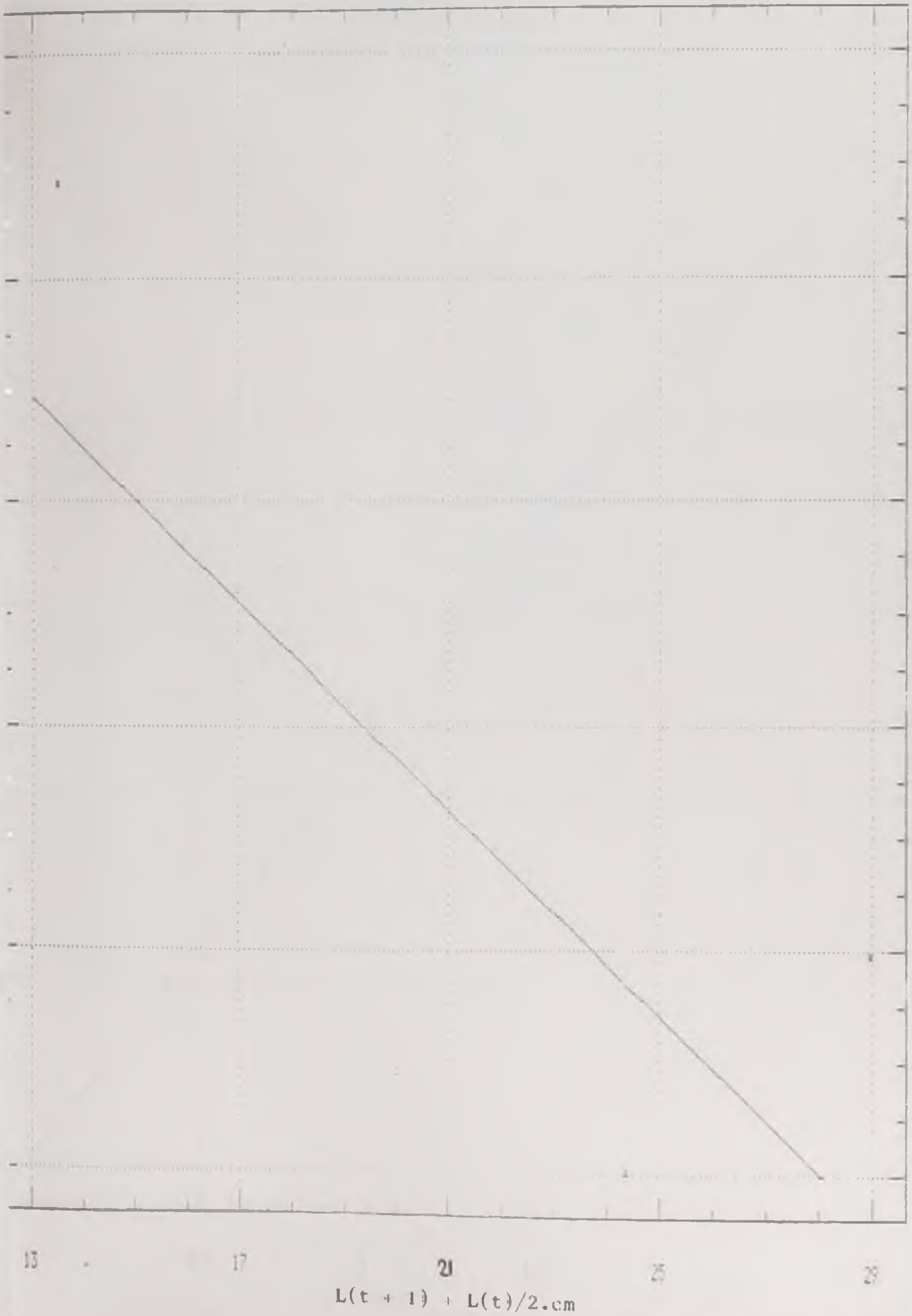
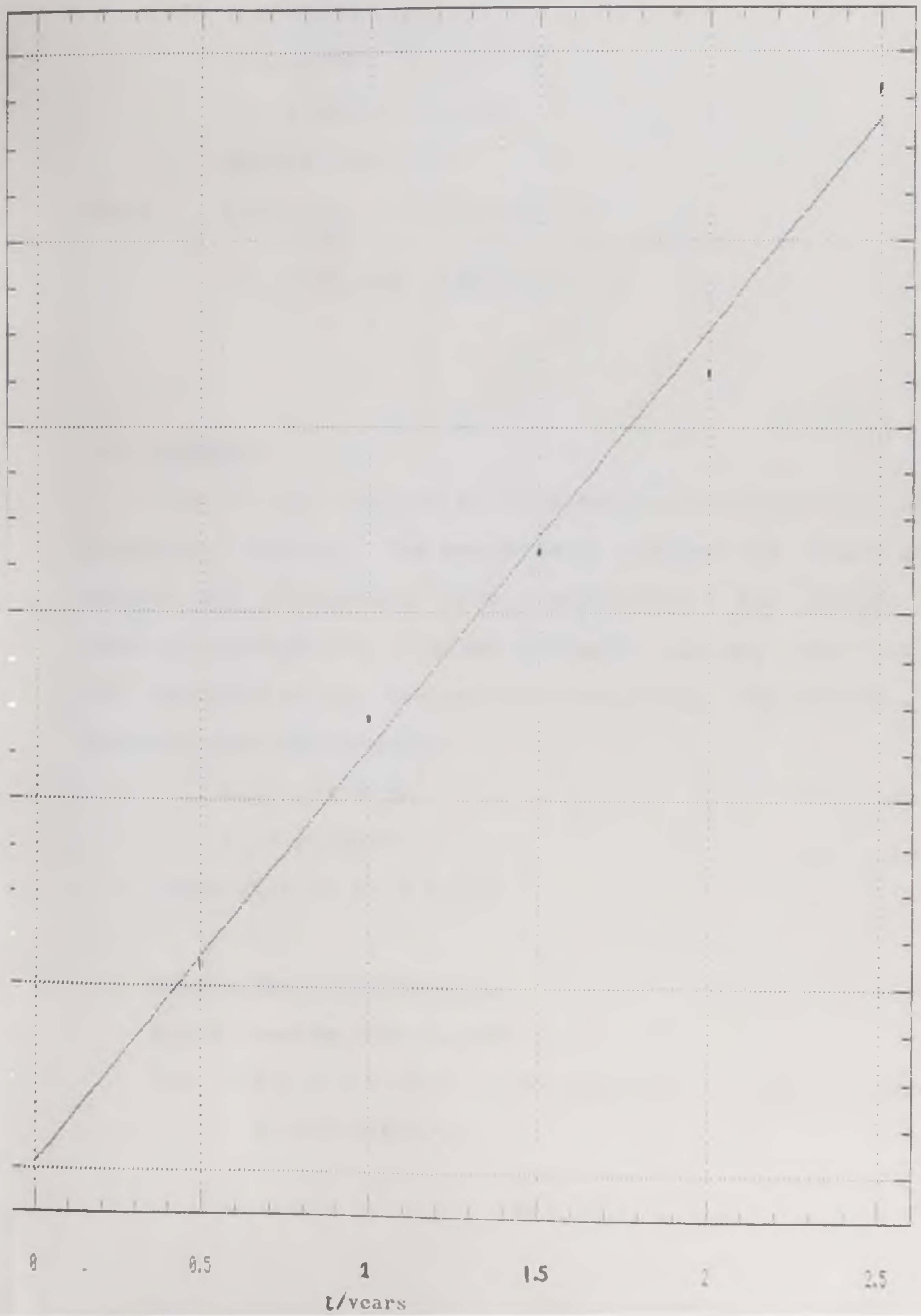


Fig. 17 : The VonBertalanffy plot for *S. caeruleostictus*



(iii) The Ford-Walford Plot

Fig. 18 shows the graph of the Ford-Walford plot. The regression gives:

$a = 9.754$

$b = 0.779$

$r = 0.980$ ($p < 0.05$)

sample size $n = 4$

Hence $L_{\infty} = \frac{a}{1-b} = 44.14$ cm

$K = 1/dt \ln b = 0.50/yr$

(iv) ELEFAN I

Fig. 19 is a display of the restructured monthly length-frequency samples. The peaks and troughs are shown as the shaded and non-shaded bars respectively. The growth curve passing through the highest of peaks was the best one. This was observed to be the second curve from the bottom . The best fit was obtained with

$L_{\infty} = 44.3$ cm

$K = 0.480/yr$

These give an $R_n = 0.174$.

(v) Pauly's Empirical Formula

Using results from ELEFAN I,

$\log -(t_o) = - 0.392 - 0.275 \log 44.3 - 1.038 \times 0.48$

$t_o = - 0.045/yr$

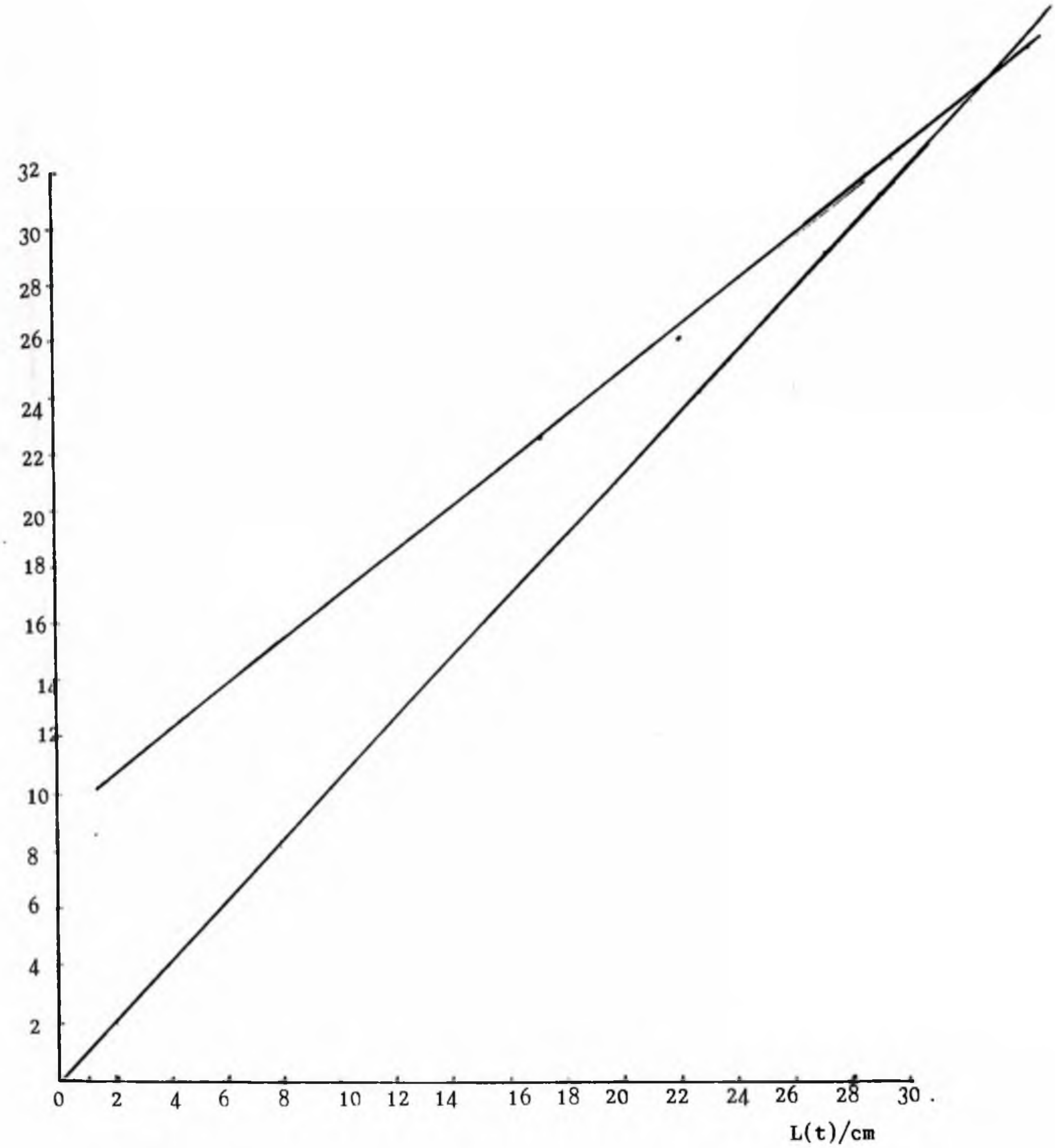
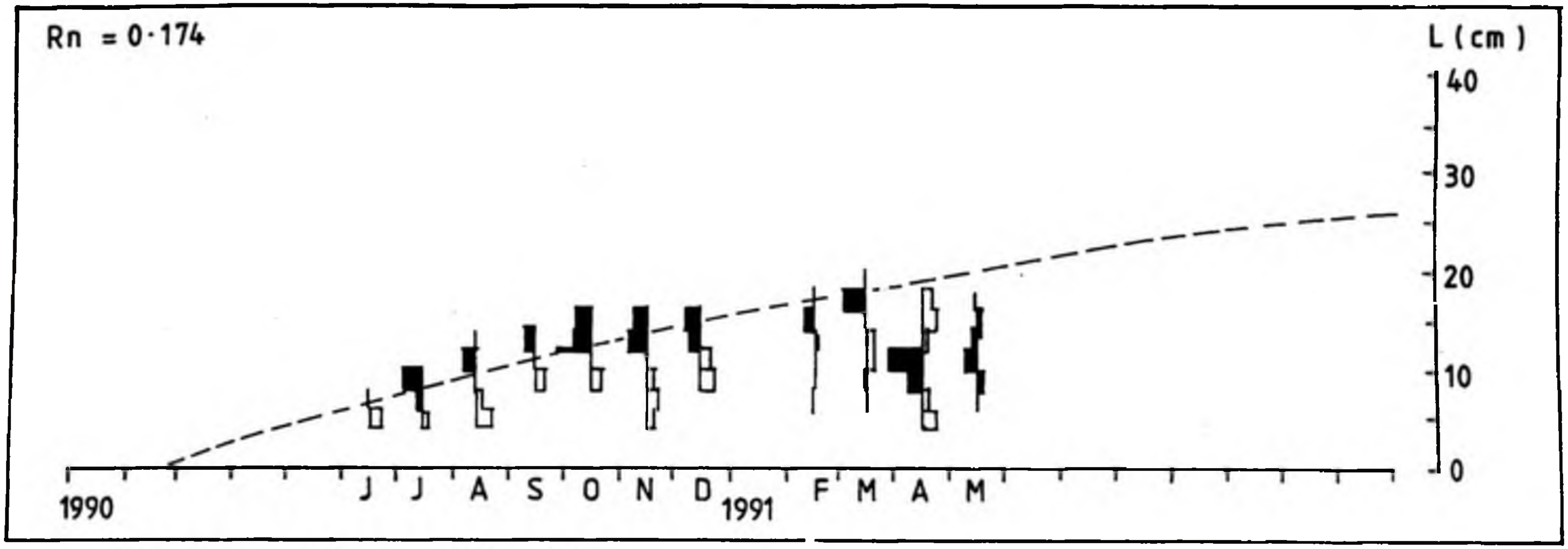


Fig.18 The Ford-Walford plot for S.caeruleostictus



Loo (asymptotic length) = 44.30 cm
K (growth constant) = 0.48/yr

Fig. 19 Graph of the growth curve for: <u>S. caeruleostictus</u> showing restructured length-frequency samples.

A summary of the results from these methods are given below:

	L_∞(cm)	K/yr	t_o(yr)
Gulland and Holt	45.82	0.46	
Von Bertalanffy	-----	0.45	0.016
Ford-Walford	44.14	0.50	
ELEFAN 1	44.30	0.48	-0.045

Further calculations in some aspects of the dynamics of S.caeruleostictus involving L_∞ and K, used the results from ELEFAN I since the method utilises several samples spread over a regular period (Pauly,1987).

The von Bertalanffy growth equation for S. caeruleostictus is given as:

$$L_{(t)} = 44.3\ (1 - e^{-0.48(t + 0.045)})$$

The growth curve is shown in Fig.20.

(vi) Growth performance

Table 4 shows the estimates of growth parameters, and growth performance index for S. caeruleostictus in the present study and those found by other authors in previous studies. These results show that the estimates of the growth parameters are reliable since their growth perfomance indices are comparable.

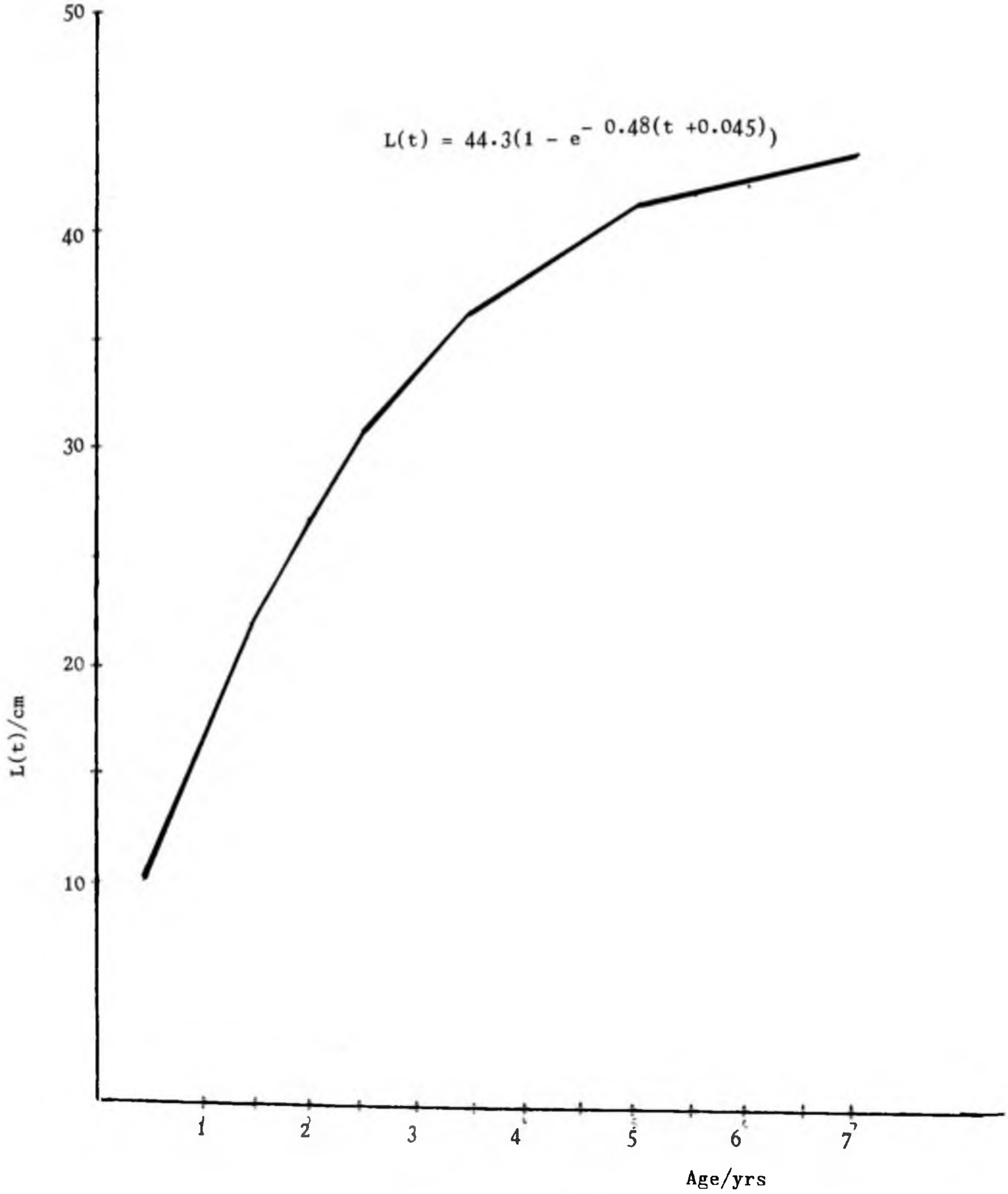


Fig.20 Growth curve for *S.caeruleostictus*

5.2.2 Estimation of Mortality Parameters

(i) Catch Curve

Results of the catch curve analysis are shown in Fig.21

$Z = 2.477/yr$

$M = 0.856$ (from Pauly's Empirical formula with $T = 20.4°C$)

$F = Z - M = 1.621/yr$

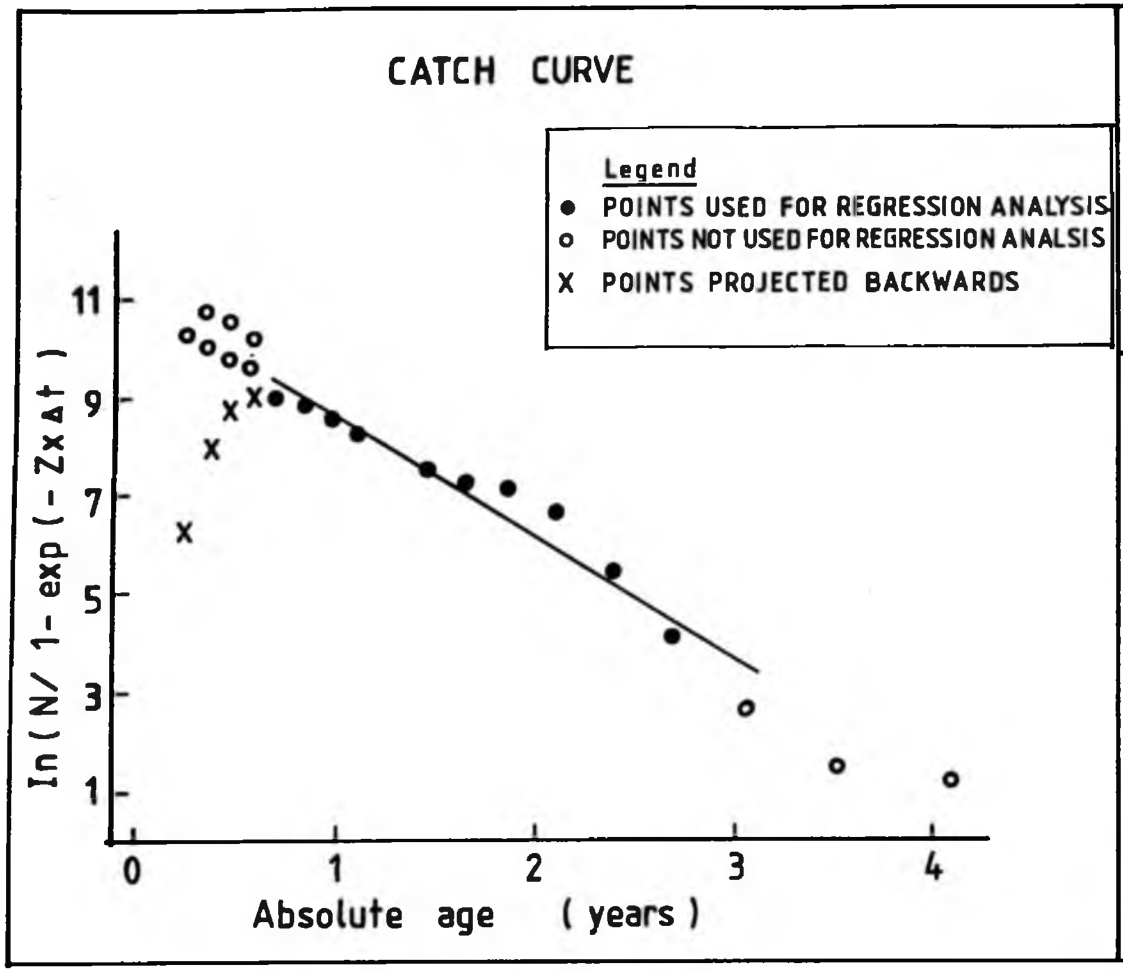
Exploitation rate $E(F/Z) = 0.654$.

$L' = 12.00$ cm. This is the cut-off length. Fishes lower than this length were are not included in the analysis.

Mean length from $L' = 18.393$ cm. This is the mean length of fish longer than L' in the sample. The Z from mean length (1.945) was calculated using Beverton and Holt's Z Equation given as $Z = K (L_{\infty}-L')/(L-L')$ (Sparre et al.,1989).

(ii) Cohort Analysis

The results of the length cohort analysis are shown in Fig.22. The bars show the numbers caught and their corresponding numbers of survivors at each length, while the blank spaces show the natural losses or natural mortalities. The numbers of survivors decrease with each increased length. This is due to the general increase of F with each length group. The estimate of mean $F = 1.093$, the mean $E = 0.561$. The average number recruited to the fishing ground was estimated to be 6689.66×10^7 as shown in Appendix 15. This number reduces with increasing length group. There is a marked increase in fishing mortalities from about 24 cm reaching a peak at 29 cm.



Growth Parameters

Loo : 44 · 300 cm K : 0 · 480
to : 0 · 045

cut off length (L') = 12 · 000
mean length (from L') = 18 · 393
Z from mean length = 1 · 945
Z from catch curve = 2 · 477

Nat. mortality (M. estimated for
T = 20·4 °C) = 0 · 856
M value used = 0 · 856
Fishing mortality (F = Z - M)
(Z & M as entered) = 1 · 621
Exploit , rate (E = F/ Z) = 0 · 654

Fig . 21 Graph of the catch curve for S. caeruleostictus with the estimates of Z, M, F and E.

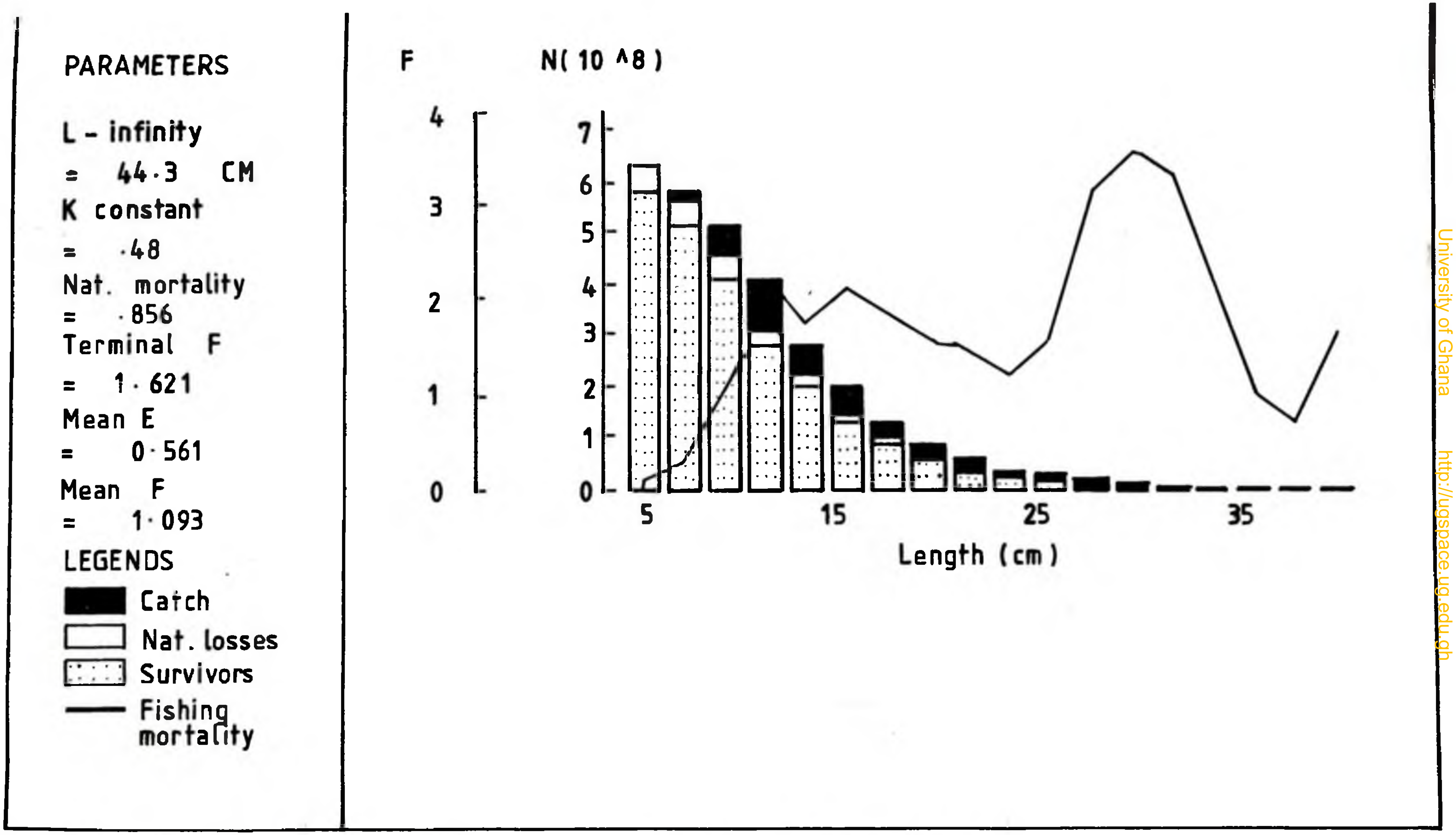


Fig. 22 Graph of the length structure cohort analysis for *S. caeruleostictus*.

6. SOME ASPECTS OF THE DYNAMICS

6.1. Methods

(i) Estimation of mean length at first capture

The mean length at first capture was estimated by extrapolating the descending limb of the catch curve backwards (Fig.21). Fish numbers or 'expected' on the extrapolation represent the actual numbers of fish on the ascending limb. The ratio of 'expected' numbers to actual numbers give the estimates of the probabilities of capture (Pauly, 1987). These probabilities were plotted against the mean lengths and the resultant selection curve was used to determine the L-50 (50% retention length) at 0.5 probability and also the L- 25 and L -75 at probabilities of 0.25 and 0.75 respectively. The L-50 represents the Length at first capture Lc_{50}. The methods are incorporated in the ELEFAN II programme. Details of the methods used for calculations can be found in Pauly, (1987) and Gayanilo et al., (1989).

(ii) Recruitment Pattern

Recruitment is the entry of juvenile fish into the fishery. The pulsed nature of annual recruitment of a fish species generates the peaks and troughs in a length - frequency distribution, enabling the estimation of growth parameters (Pauly, 1987). Hence given a set of length frequency data and its corresponding growth parameters, recovery of the recruitment pulses is possible (Pauly, 1987).

The 11 length - frequency distributions (Appendix 6) were projected backward onto a one year time axis, using the estimated growth parameters from Chapter 5. This produced a recruitment pattern for *S. caeruleostictus.* The method is incorporated in the ELEFAN II programme.

6.1.1. Predictive Dynamics

(i) Forecast of Yield and Stock Biomass

Yield and stock biomass were predicted for *S. caeruleostictus* at various levels of fishing effort, using the length coverted Thompson and Bell analysis (Murty, 1987; Sparre and Venema, 1992). The predictions by the Thompson and Bell method assesses the effect of decreasing or increasing the fishing effort by a certain factor. The analysis is incorporated in the programme MIXFISH in the LFSA software package. Details of the calculations can be referred to in Sparre et al., (1989) and Murty, (1987).

(ii) Relative Yield Per Recruit

The Beverton and Holt's Relative Yield per Recruit model was used to assess the optimum level of exploitation in relation to the mesh size of the gear used to catch *S. caeruleostictus.* Sparre et al., (1992) gives it as:

Relative Yield per Recruit (Y/R)'

$= E.U^{m/k} [1-3u/1+M + 3u^2/1+2M - U^3/1+3M] -$ (1)

Where $m = \frac{1-E}{M/K} = K/Z$

$U = 1-Lc/L_{\infty}$ (the fraction of growth to be completed after entry into the exploited phase)

$E = F/Z$ (exploitation rate).

The values of U and M were calculated from results of previous estimates. Hence for a given Lc_{50}.

$$U^{m/k} [1 - 3u/1+M + 3u^2/1+2M - U^3/3M]$$

is constant. The calculated values of (Y/R)' were plotted against different values of E ranging from 0 to 1. The Lc_{50} was changed and a new plot was done to see if there was a change in the optimum E relative to the actual exploitation rate. Inputs into the ELEFAN II programme were, L_{∞}, Lc_{50}, M and K.

6.2 Results

Estimation of length at first capture

Fig. 23 shows curve of the estimated probabilities capture The regression of mean length on the Log. of probability of capture gives a high r (0.9811 at $p < 0.05$) with intercept a= -7.37 and slope b=0.6858. If logarithm of probability of capture is represented by Log PC and mean length by L, then the regression equation is given as Log PC = - 737 + 0.6858 L. This equation was used to obtain the smooth probabilities in Table 5 and hence the ogive in Fig.23. The slope b is an estimate of the natural mortality M of the fish which were unexploited and which made up the ascending portion of the

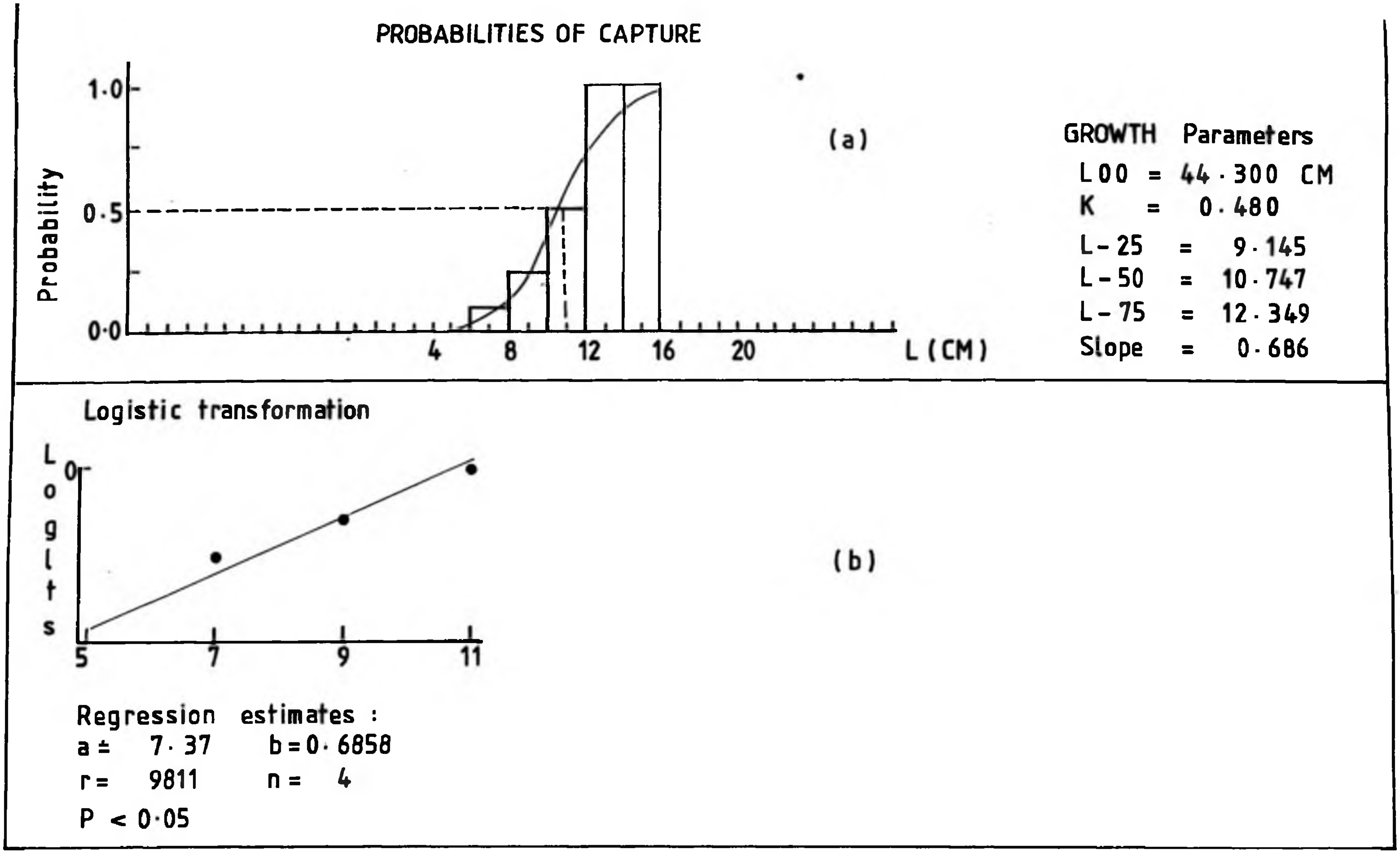


Fig. 23. GRAPHS OF SELECTION CURVE FOR S. caeruleostictus.

curve. Hence L-50 = 10.747 cm, L-25 = 9.145 cm and L-75 = 12.349 cm. The L-50 represents the length at which 50% of the fish are retained by the gear in use.

Recruitment Pattern

Fig. 24 illustrates the pattern of recruitment of S. caeruleostictus in Ghanaian waters. Two recruitment peaks from the curves are indicated in this figure, a large one at January and a smaller one at September, with an interval of about 4 months. Each of the two recruitment curves show two clear modes, possibly corresponding to two cohorts.

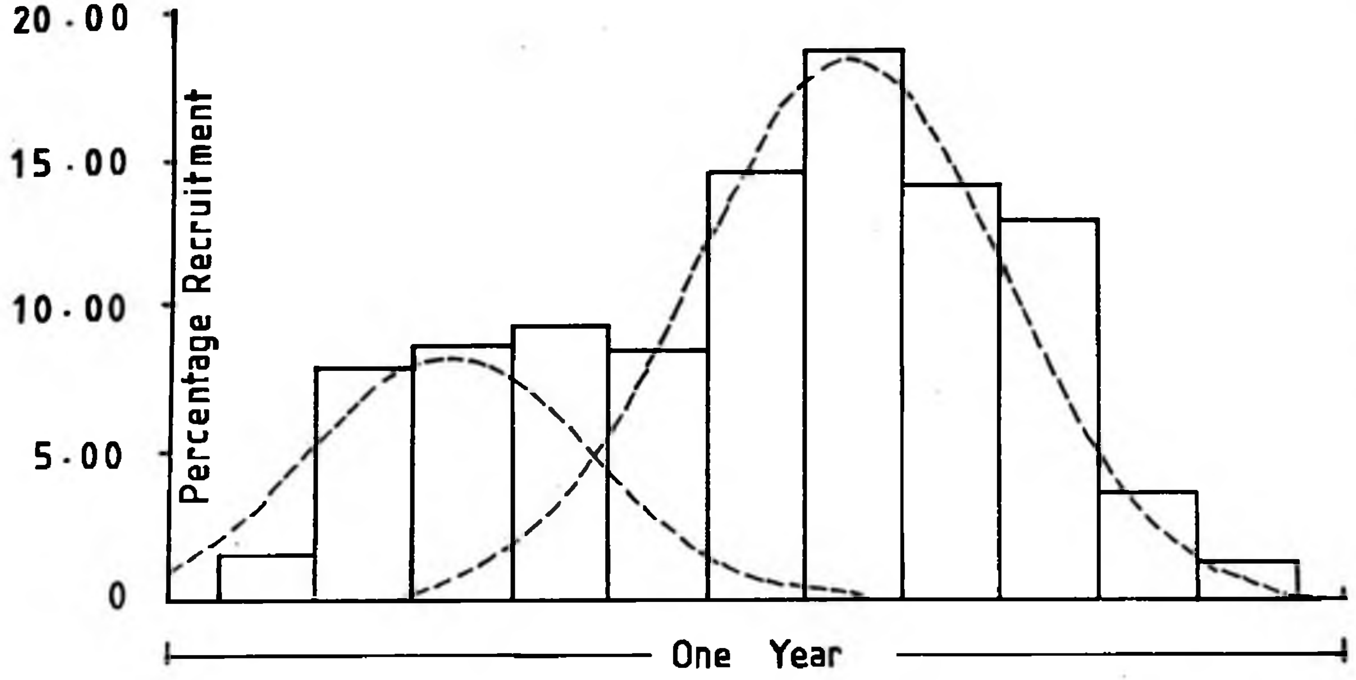
Forecast of Yield and Stock Biomass

The Thompson and Bell analysis for predicting the catches and stock size is presented in Table 6. The yield and biomass in tonnes (t) in relation to the fishing mortality are shown in Fig. 25. The estimated Maximum sustainable Yield (MSY) is 5098.81 t at an effort level of 0.540 which is about half the present level of 1.000. The mean biomass at an effort level of 0.540 is given as 6812.60 t. The present level of effort 1.000 gives a yield of 4608.90 t with a mean biomass of 3629.28 t (Table 6).

Relative Yield Per Recruit

Table 7 gives the calculated values of (Y/R)' from different rates of exploitation (E), for two different Lc_{50}

RECRUITMENT PATTERN



Absolute Time		Percent Recruitment
1	July	1.52
2	Aug	7.81
3	Sept	8.68
4	Oct	9.26
5	Nov	8.30
6	Dec	14.49
7	Jan	18.51
8	Feb	13.94
9	Mar	12.62
10	Apr	3.58
11	May	1.29
12	Jun	0.00

GROWTH PARAMETERS : Loo= 44.300 CM
K= 0.48 to= 0.05

Fig. 24 . RECRUITMENT PATTERN FOR _S. caeruleostictus_.

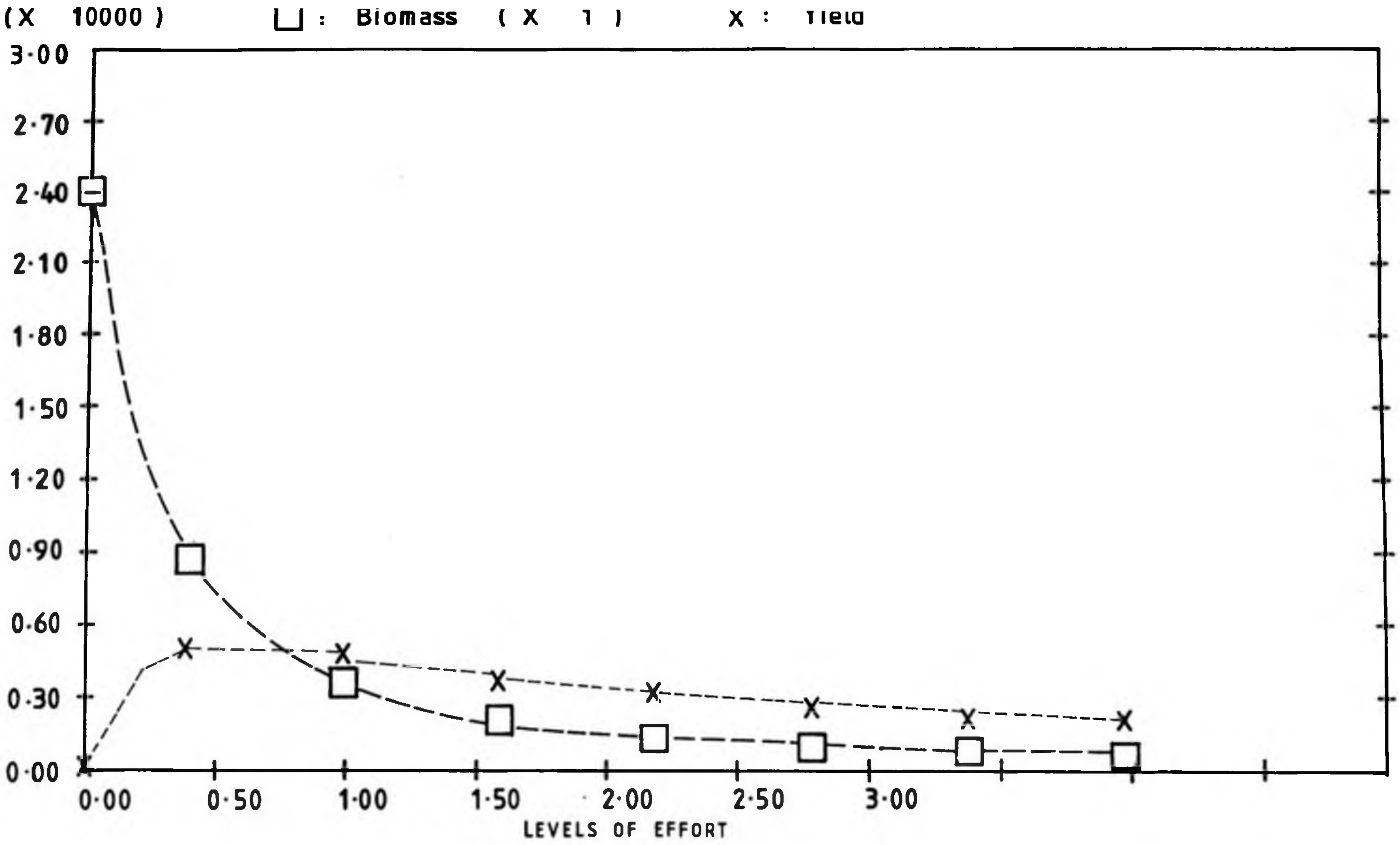
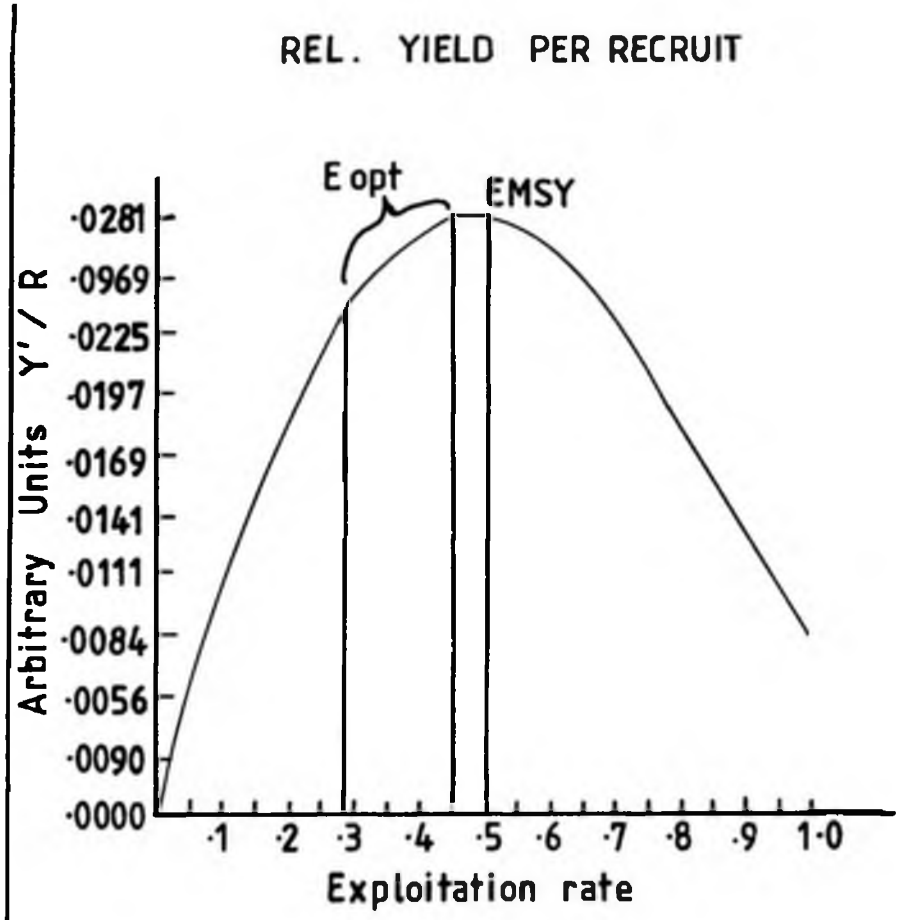


Fig.25 Graph of the length Thompson and Bell analysis for S. caeruleostictus, showing the Biomass and Yield curves .

values of 10.747 cm and 14.619 cm. Fig. 26 illustrates the (Y/R)' curve at the Lc_{50} of the present study which is 10.747 cm from the selection curve. The E for Maximum sustainable Yield (E^{msy}) is given as 0.4784 from Fig.26. The E for optimum yield (E^{opt}) for safe fishing falls between 0.2593 - 0.4575, below the E^{msy}.

Fig. 27 illustrates the position of the present effort, relative to the peak of the dome if the Lc_{50} is increased to 14.6 cm, as a result of an increase in the mesh size of the gear. The E^{msy} from Fig.27 gives 0.5510 whilst the E^{opt} falls between 0.3113 - 0.5130. A comparison of these results with the value of 0.654 obtained from the catch curve show that the fishery is probably being overfished.



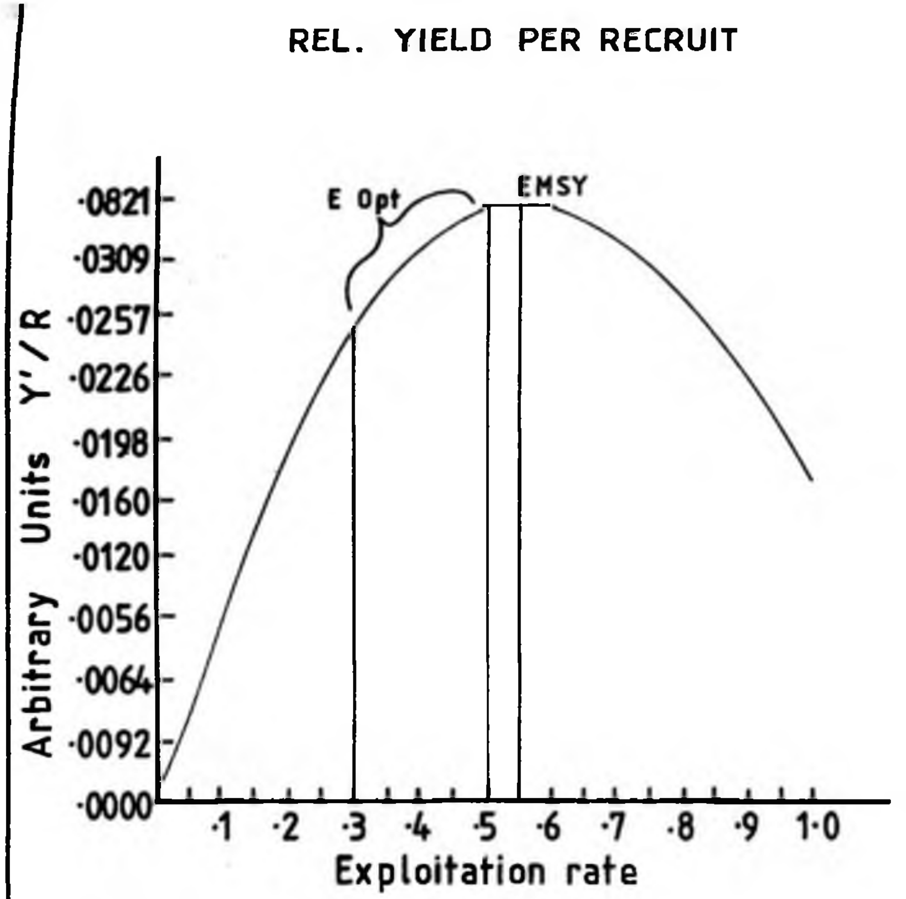
Optima:

Emax : 0·4784 Lc / Loo = 0·24

E- ·1 : 0·4532 M / K = 1·78

E- ·5 : 0·2593

Fig. 26 Relative Yield per Recruit curve for the présent mesh size of the trawl net .



Optima :

Emax : 0·5510

E-·1 : 0·5130

E_ 5 : 0·3113

Lc/Loo = 0·33

M/K = 1·78

Fig. 27. RELATIVE YIELD PER RECRUIT (Y/R) FOR AN INCREASED MESH SIZE OF THE TRAWL NET.

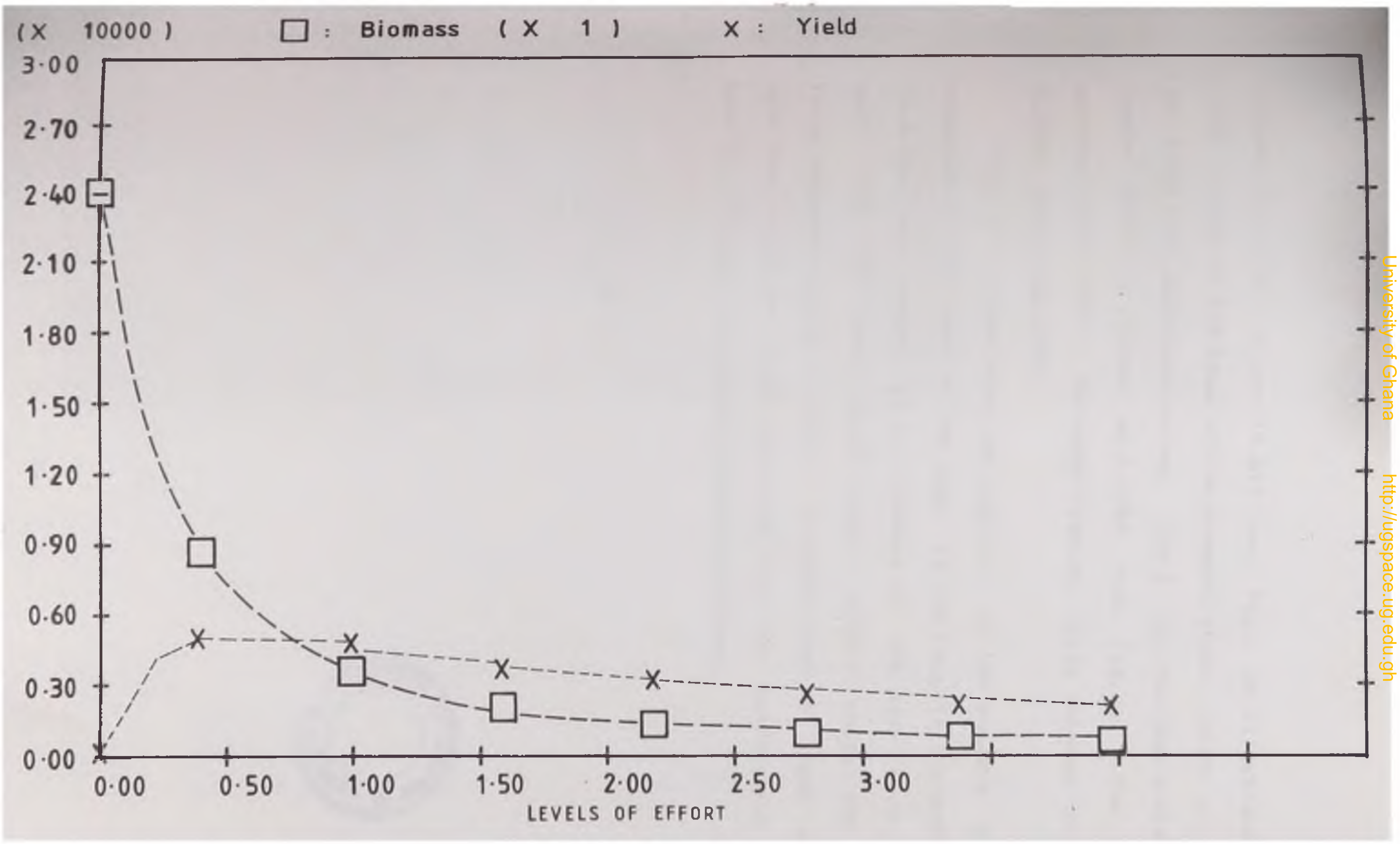


Fig.25 Graph of the length Thompson and Bell analysis for S. caeruleostictus, showing the Biomass and Yield curves .

7. FOOD HABITS

7.1. MATERIALS AND METHODS

Random samples of 20 specimens per month of Sparus caeruleostictus were taken mainly from the catch of R/V 'Kakadiamaa' from November 1991 to December 1992. Owing to insufficient specimens from the vessel in Nov., 1991, Dec.. 1991 and Feb., 1992 twenty-five specimens were obtained from fish caught with the 'hook-and-line' by local fishermen off the coasts of Accra and Tema to make up the number.

The fork lengths of individual fish were measured to the nearest cm., their stomachs removed and stored in specimen tubes containing 8% formalin. Where stomachs could not be removed on deck or from the canoe landings , whole specimens were frozen and preserved in ice. In the laboratory, the stomachs of the fish previously preserved in the formalin were soaked in water for 24 hours to remove excess formalin. Specimens preserved in ice were left to thaw out completely before investigations started. Each stomach was cut open and its contents flushed into a petri-dish with copious water before being examined. The food items were identified with a binocular microscope, using both the low and high powers where appropriate. Food items were sorted out and identified to the genus level. Owing to the shortcomings of virtually all methods for analysing stomach contents, three methods, namely the percentage occurrence, numerical and points methods were used in analysing the stomach contents. The procedure adopted for each of these methods were as follows:

(1) Percentage Occurrence (Bowen 1985; Laevestu, 1965)

i) The different types of food present in the stomach were tabulated into their various taxonomic groups.

ii) The number of individual stomachs in which each kind of food item occurred were totalled.

iii) The occurrence of a food item in a number of fish in a series is expressed as a percentage of the total number of fish.

This method describes the uniformity with which groups of fish select their diet and also estimates the proportions of fish populations that feed on a particular food item. (Windell and Bowen, 1978). The limitations of the method are as follows (Bowen, 1985; Lagler, 1966).

a. The results are biased by the accumulation of remains of certain food items which are resistant to digestion

b. It fails to disclose the number of forage items involved

c. It does not show the importance of the bulk relationships of the various categories of food items

d. High percentage of occurrence does not indicate high nutritional importance of food item to the fish.

(2) Numerical Method (Bowen, 1985; Laevestu, 1965)

(i) The number of individuals of each kind of food item in each stomach were counted. These were summed up to give totals for each kind of food item in the whole sample, and then a grand total of all the items were taken.

(ii) These summed food items were expressed as a percentage of the total number of organisms in all fish.

This method estimated the relative abundance of the different food items in the diet of the fish. It also described the possible diet of an individual fish (Bowen, 1985). By comparing the totals of each food item, limited conclusions as to the relative significance of the different food items are drawn (Lagler, 1966). The Limitations of the method are as follows(Lagler, 1966; Windell and Bowen, 1978):

a. Organisms which occur in large numbers need not constitute the most important food item.

b. The smaller, most numerous organisms are magnified in importance.

c. It provides little information on the food value of the items.

(3) Points Method(Laevestu, 1965; Windell and Bowen, 1978)

i) Each stomach was examined and points were assigned according to degree of fullness. These points were then subdivided among the various food items. The food items were sorted into groups, and each food item was given a point proportional to its size in the group and the number of items in the group.

ii) A food item was given 16 when filling most of the stomach, 8, when half full, 4 when a quarter full and 2 when in small traces.

iii) All the points gained by individual food items in a group were summed up and converted to percentages. This gave the percentage composition of the food on a monthly basis.

The points method was based on size and degree of abundance of food items. It is described as a numerical - volumetric hybrid applied subjectively (Windell and Bowen, 1978). It gives the best approximation of the relative value of the food items in terms of biomass and energy . The limitations of the method are as follows (Windell & Bowen, 1978).

a. Its subjective basis makes it impossible to use statistical analysis for the data

b. It is difficult to compare points data from two different workers.

7.2. Results

During the period: Nov., 1991 to Dec., 1992, 240 stomachs were examined. Out of this number 23 were found to be empty or contained food items in advanced stage of digestion. This number represented 9.6 % of the number of fish examined.

(i) Identification of Food Items

The following five groups of food organisms were identified in their diets aided by the work of Barnes (1974) and Edmunds (1978): molluscs, fish larvae, polychaetes, coelenterates and crustaceans. Table 8 lists these five groups.

Ontogenetic changes in food habits were not evident in *Sparus caeruleostictus*. The lengths of fishes examined in this study ranged from 13.0 cm to 29 cm forklength. All five food items were found in the stomachs of fish in this length range.

(i) Percentage Occurrence

Table 9 shows the results of the percentage of occurence method. The number of fish in each sample was 20. The number of fish that ingested a food item and their percentages per samples are shown under the food items. The most important food item in the diet were the crustacea.

(ii) Numerical Method

Table 10 shows the result of the Numerical method. Numbers of organisms for each group are shown with their percentages per month. The most important food item in the diet were the crustacea.

(iii) Points Methods

Table 11 shows the results of the points method. The most important food item in the diet were the crustacea.

Table 12 is a comparative summary of the results for the three methods. This is further illustrated in Figs. 28 - 30.

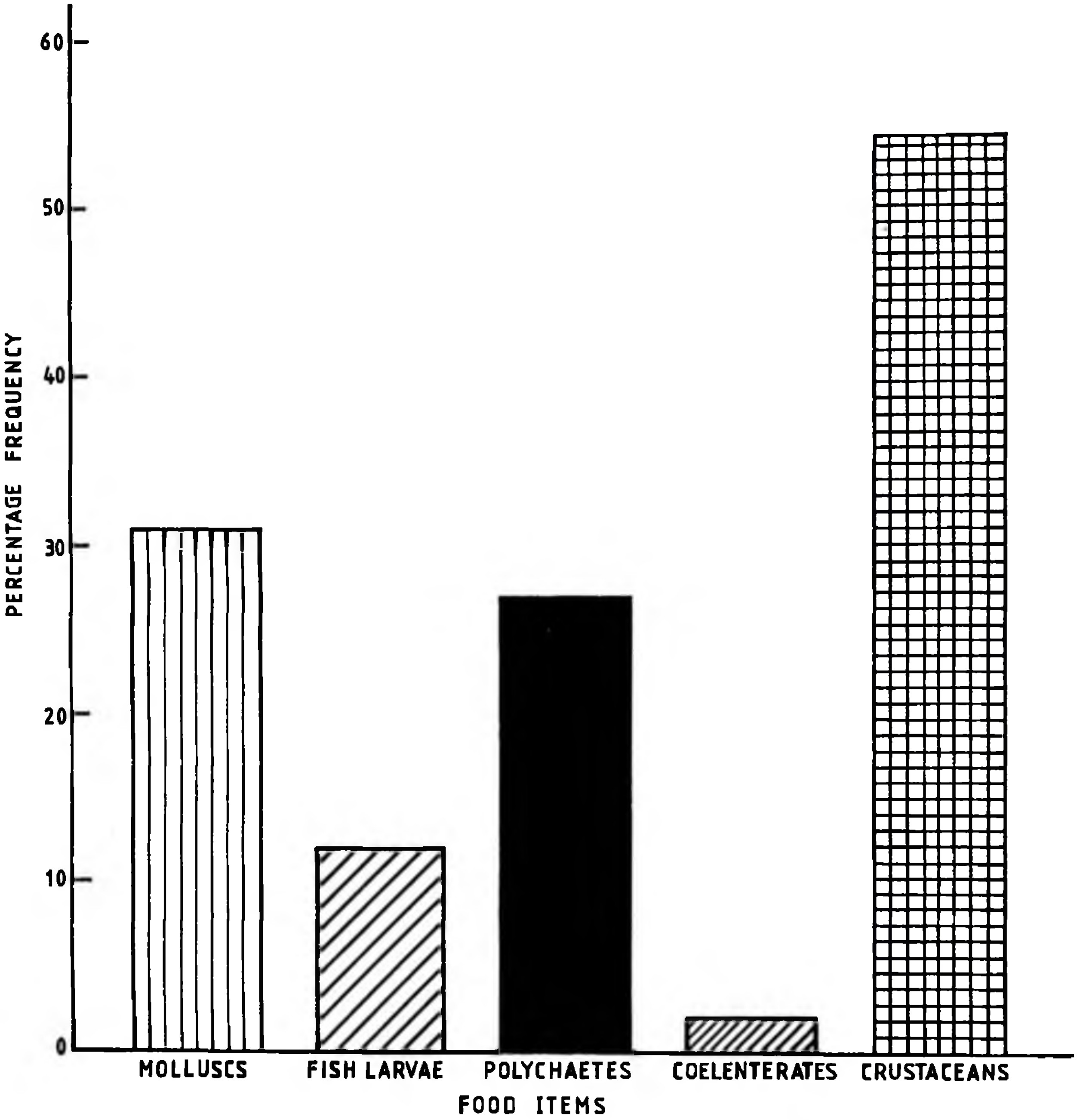


Fig. 28 Percentage frequency of food items in the stomachs of *S. caeruleostictus*.

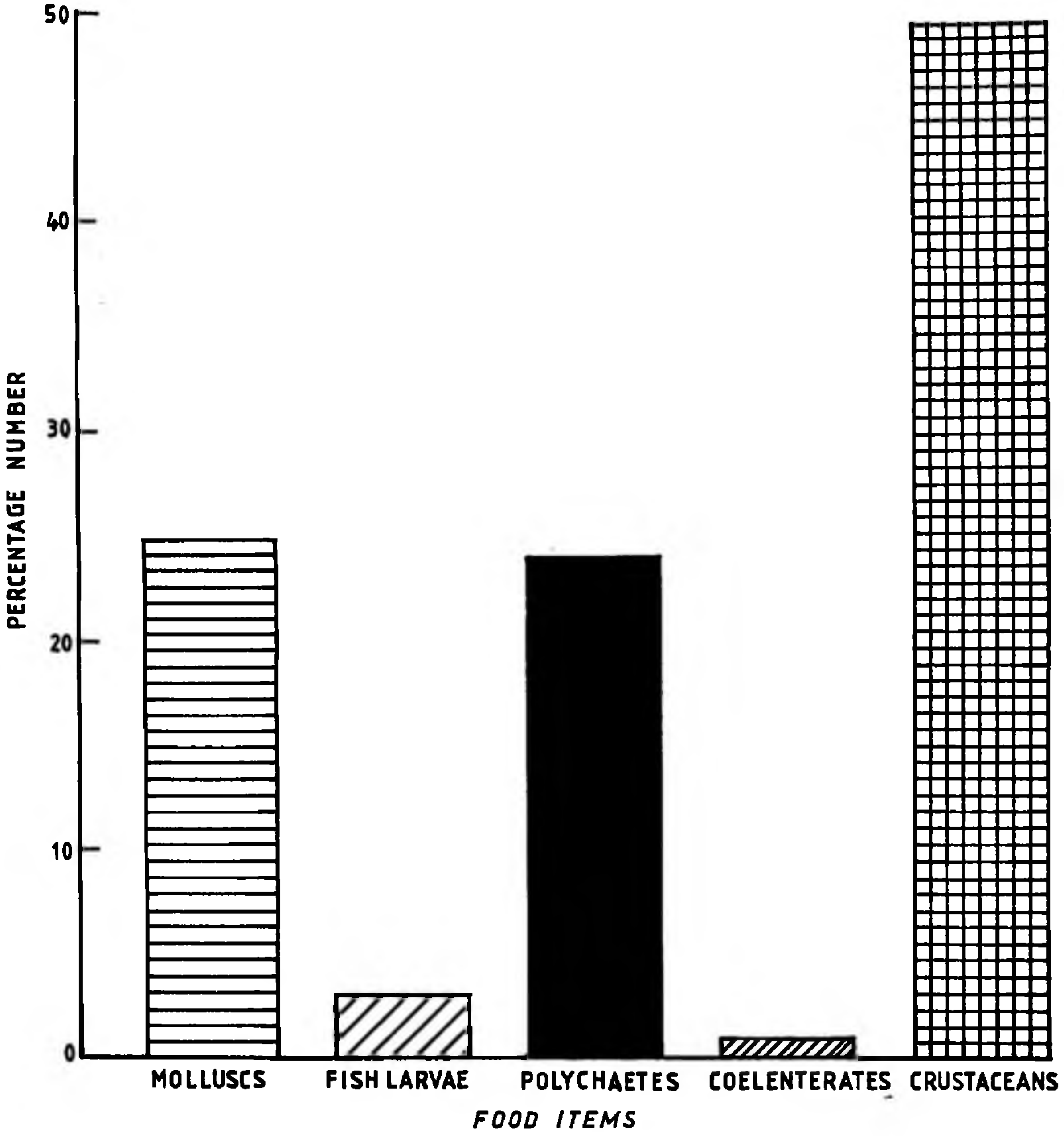


Fig. 29 Percentage Numbers of Food items in the stomachs of _S_. _caeruleostictus_.

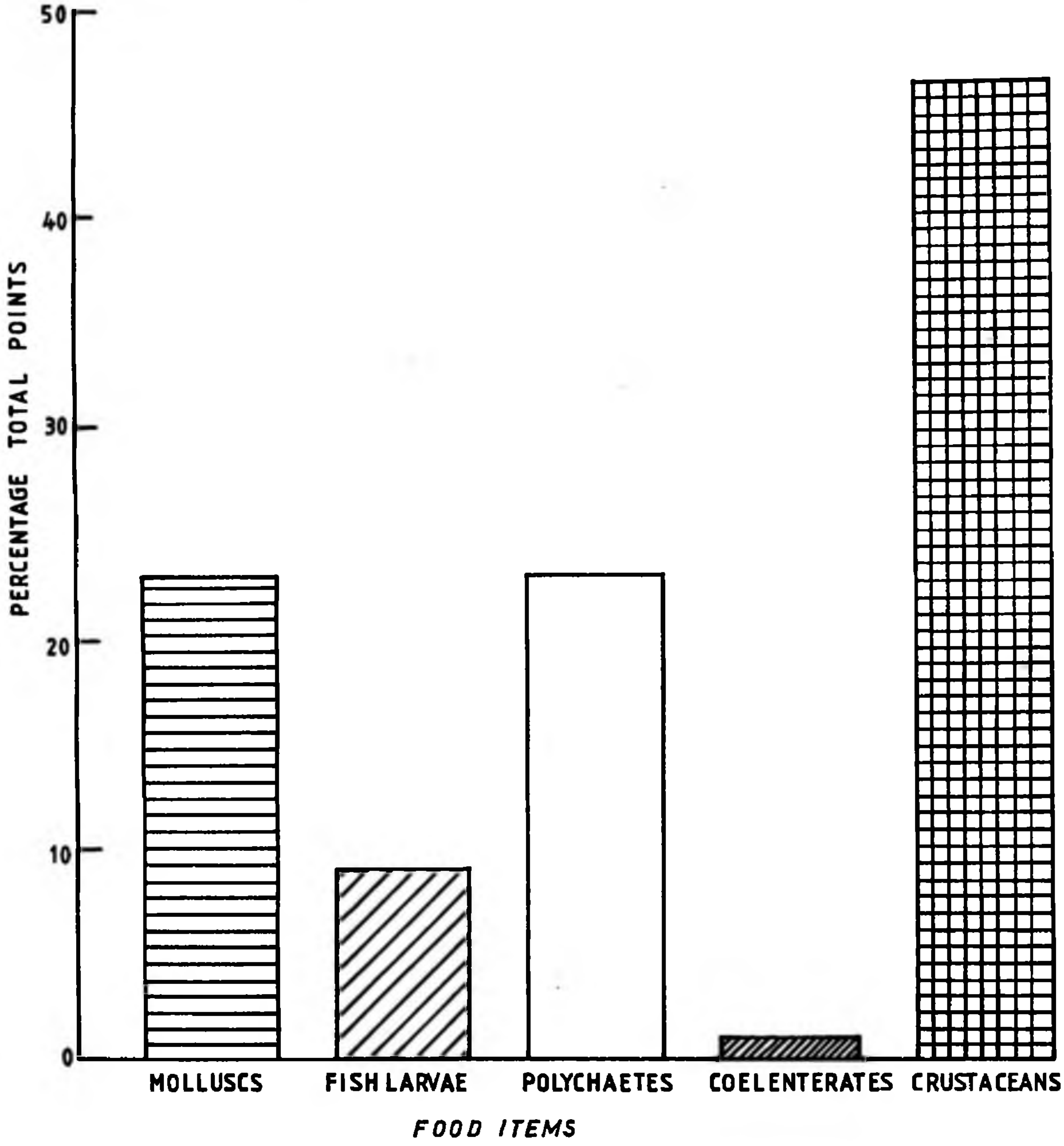


Fig. 30 Percentage total points of food items in the stomachs of S. caeruleostictus.

The three methods give the same order of abundance as listed below for the first method:

Percentage Occurrence Method

Crustaceans, Molluscs, Polychaetes, Fish Larvae, Coelenterates.

Figs. 31 and 32 show the compositions of the food items over a period of one year, the Numerical and Points method. These were drawn to investigate whether there was any evidence of seasonal changes inthe food preference of Sparus caeruleostictus.

(iv) Food size selection

Investigations on the changes in the size of fish larvae consumed, in relation to the length of the fish (Fig.33) showed a correlation coefficient of 0.6929 (not significant at $p < 0.05$) from the regression of the total length (TL) of fish larvae on the fork length (FL) of the fish ingesting them.

Fig.31 SEASONAL PERCENTAGE COMPOSITION OF MAJOR FOOD ITEMS DETERMINED BY THE NUMERICAL METHOD

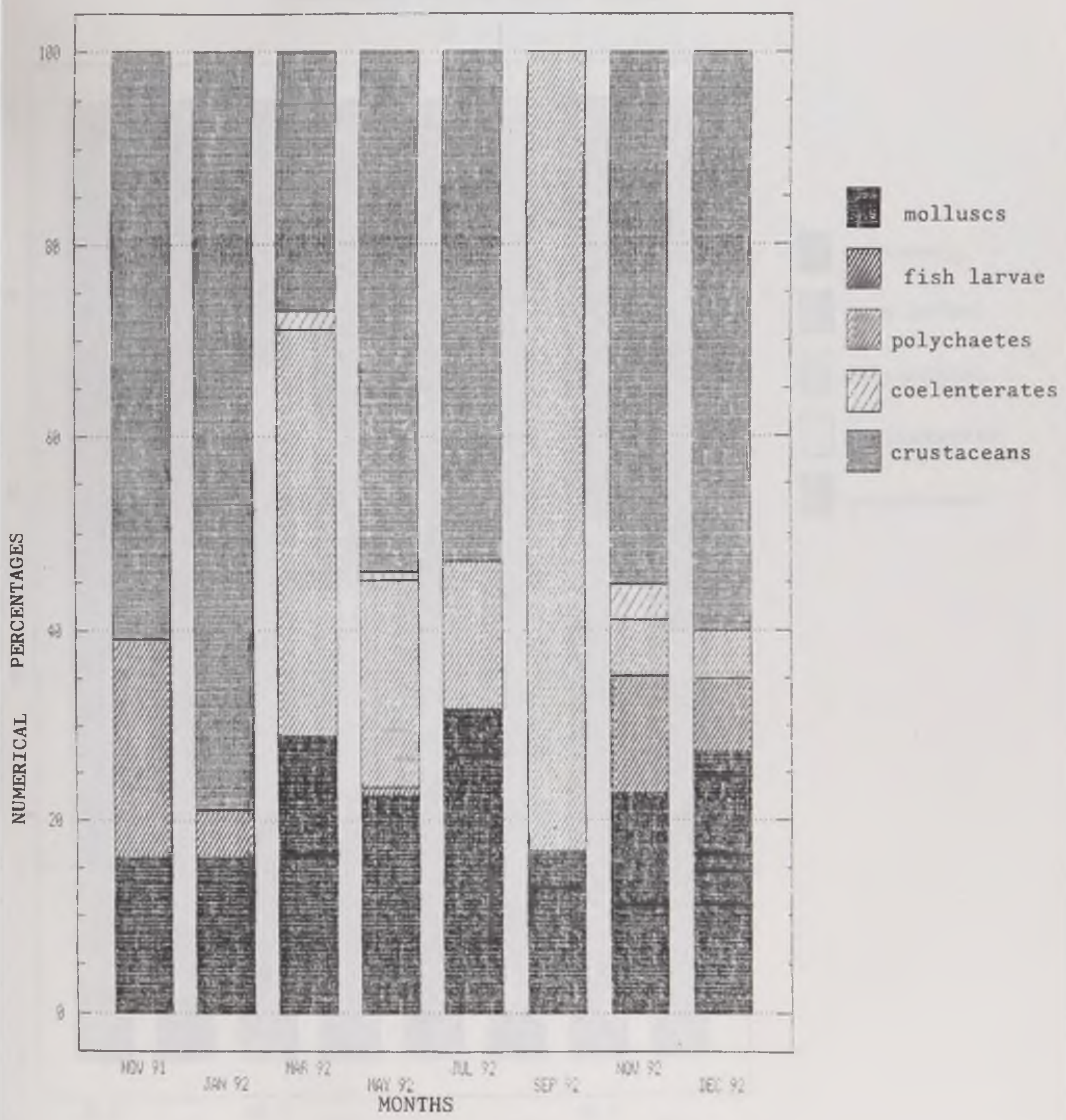


Fig.32 SEASONAL PERCENTAGE COMPOSITION OF MAJOR FOOD ITEMS DETERMINED BY THE POINTS METHOD

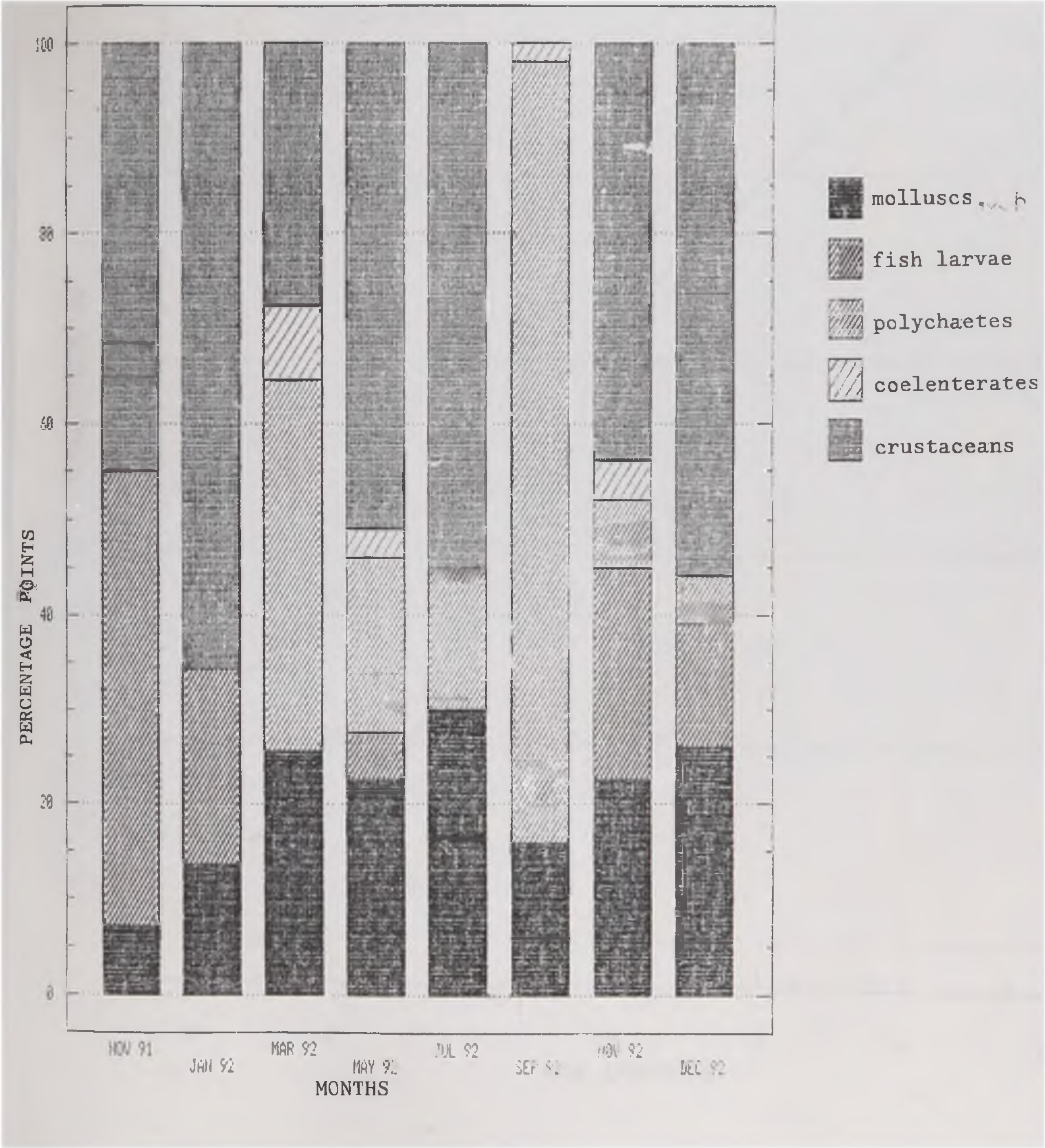
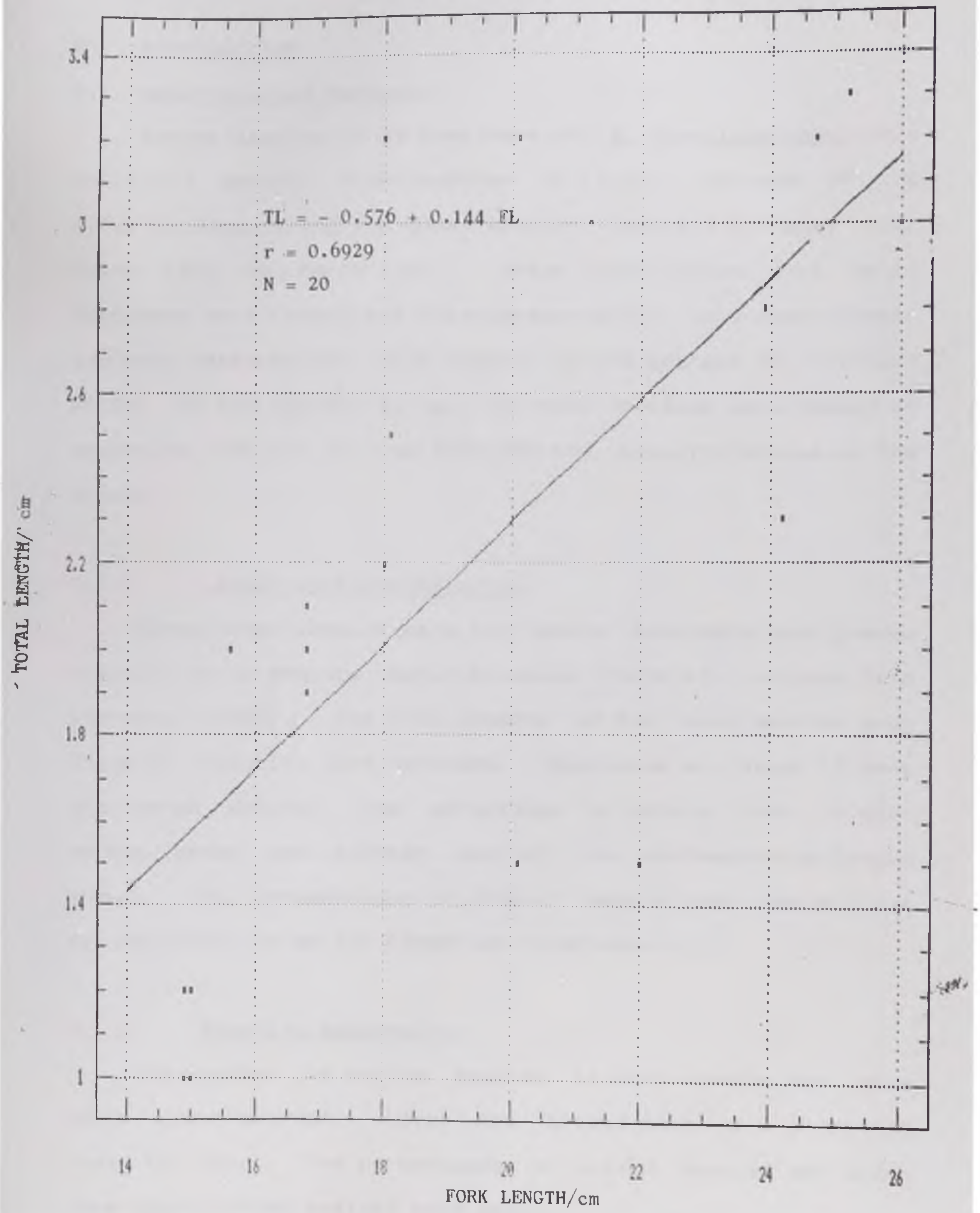


Fig. 33 Regression of the total length of prey fish on fork length of predator fish.



8. REPRODUCTION

8.1 Materials and Methods.

Random samples of 20 specimens of *S. caeruleostictus* were collected monthly from catches of trawl surveys of the F.R.U.B, Tema, along the coast between Tema and Winneba, from March 1992 to March 1993. After each catch in a month specimens were thawed out after preservation in a deep-freezer and were measured for fork length to the nearest cm and body weight to the nearest 0.1 g. The body cavities were opened to determine the sex of the fish and the maturity status of the gonads.

8.1.1. Length-at-First-Maturity

Gonad conditions of male and female specimens were graded visually on an 8-state maturity scale (Table 13) adapted from Laevestu (1965). The fork lengths of the specimens at each stage of maturity were recorded. Specimens at stage II were considered mature. The percentage of mature fish in each length group was plotted against its corresponding length group. The length-group at 50% of mature individuals (L_{50}) was estimated to be the length at first maturity.

8.1.2. Spawning Seasonality

The number of mature females in each sample for each month were recorded. Later the gravid ones were extracted from the data. The percentages of gravid females per month were then plotted against each month.

8.1.3. Fecundity

Fecundity of *S. caeruleostictus* was estimated from the examination of 20 ovaries of stage III and IV individuals collected in August and September 1992. The ovaries were then split longitidinally, turned inside out, placed in specimen tubes and preserved in Gilson's fluid (Bagenal and Braum, 1978). The preservative served as a fixative as well as a medium for breaking down the ovarian tissue. The eggs were thoroughly washed in distilled water and continously decanted until all the ovarian tissue had been removed.

Counts of eggs for each ovary were made by the volumetric sub-sampling method after egg separation (Bagenal and Braum, 1978). Each ovary was placed in a 100 ml measuring cylinder and water added to it up to the 100 ml mark. This was followed by vigorous stirring which resulted in adequate distribution of eggs within the water column. Four aliquot sub-samples of 2 mls each were quickly taken with a dropper and emptied into a petri-dish. The number of eggs in each aliquot was determined with an Electronic Fish Egg Counter (OSK 2100). The average number of eggs from the aliquots was used to estimate the total number in each ovary by the following proportional method:

$$\text{FECUNDITY} = \text{Number in Aliquot (N)} * 100/2$$

8.2. Results

(i) Length-at-first-maturity

Figs. 34 and 35 illustrate the ogives for the length at first maturity for the males and females. The males had L_{50} = 18.4 cm and females, L_{50} = 17.2 cm.

(ii) Spawning seasonality

Spawning seasonality pattern is illustrated in Fig. 36. It shows two peak spawning periods. The main spawning occurred between September and October whilst the other minor spawning occurred between January and February. Gravid females were not found from about March to June 1992. Examination of gonads during this period showed that they were in the stage II condition only. Stage III and IV conditions were encountered from July onwards.

(iii) Fecundity

The number of eggs in each of 20 specimens of *S. caeruleostictus* of various lengths was estimated. The estimated number ranged from 45,204 to 360,128 eggs for fish of fork length between 17.5 to 24.8 cm as shown in Table 14. Fig. 37 shows the regression of fecundity against fork length. The curve was best described by the exponential relationship:

$$\text{Log } F = 1.3671 + 2.9479 \text{ Log } L$$

where F represents the fecundity and L, the fork length in cm.

Fig. 34 :Plot of percentage maturity against average fork length for male *S. caeruleostictus*.

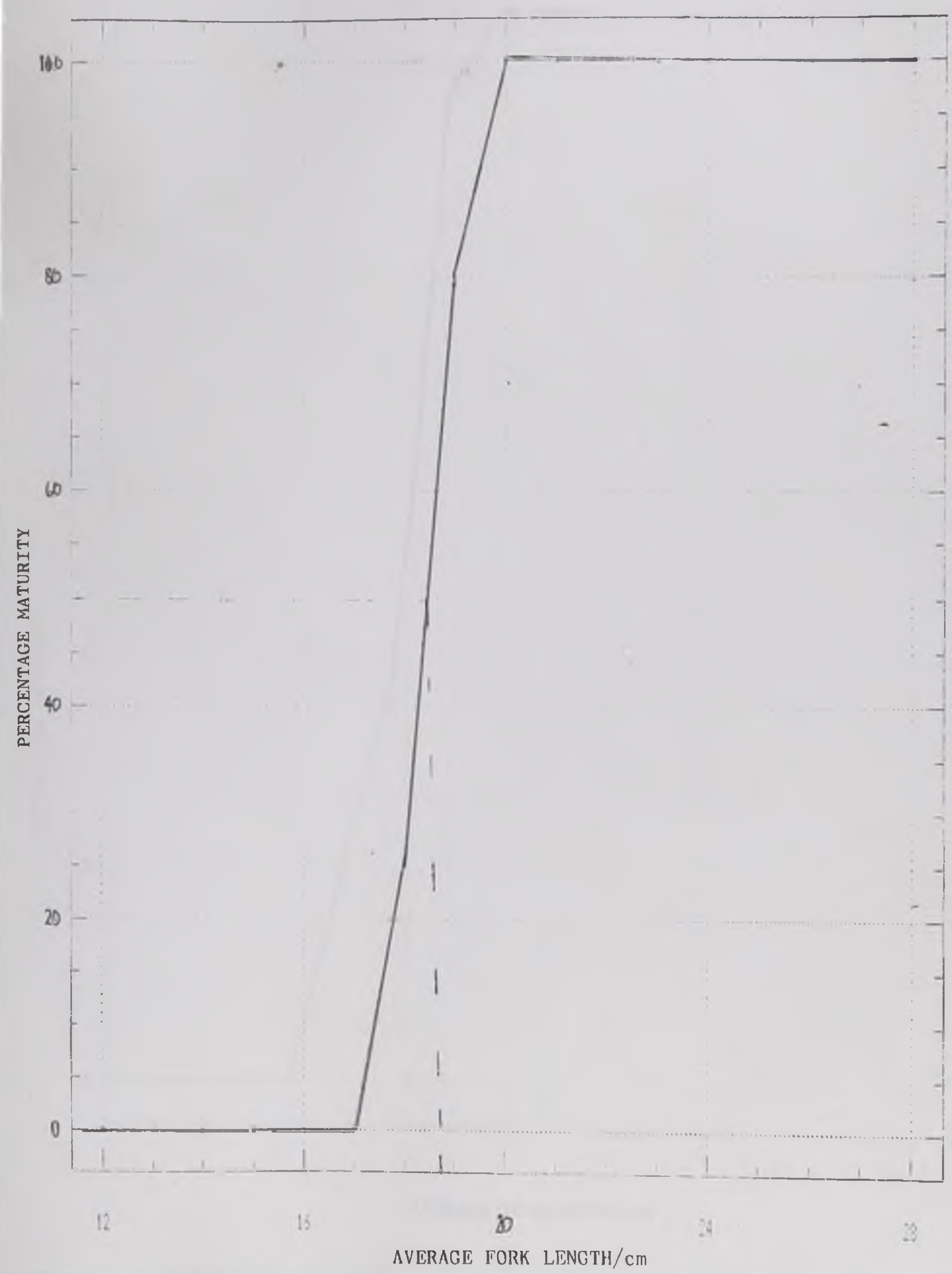


Fig.35 Plot of percentage maturity against average fork length for female *S. caeruleostictus*.

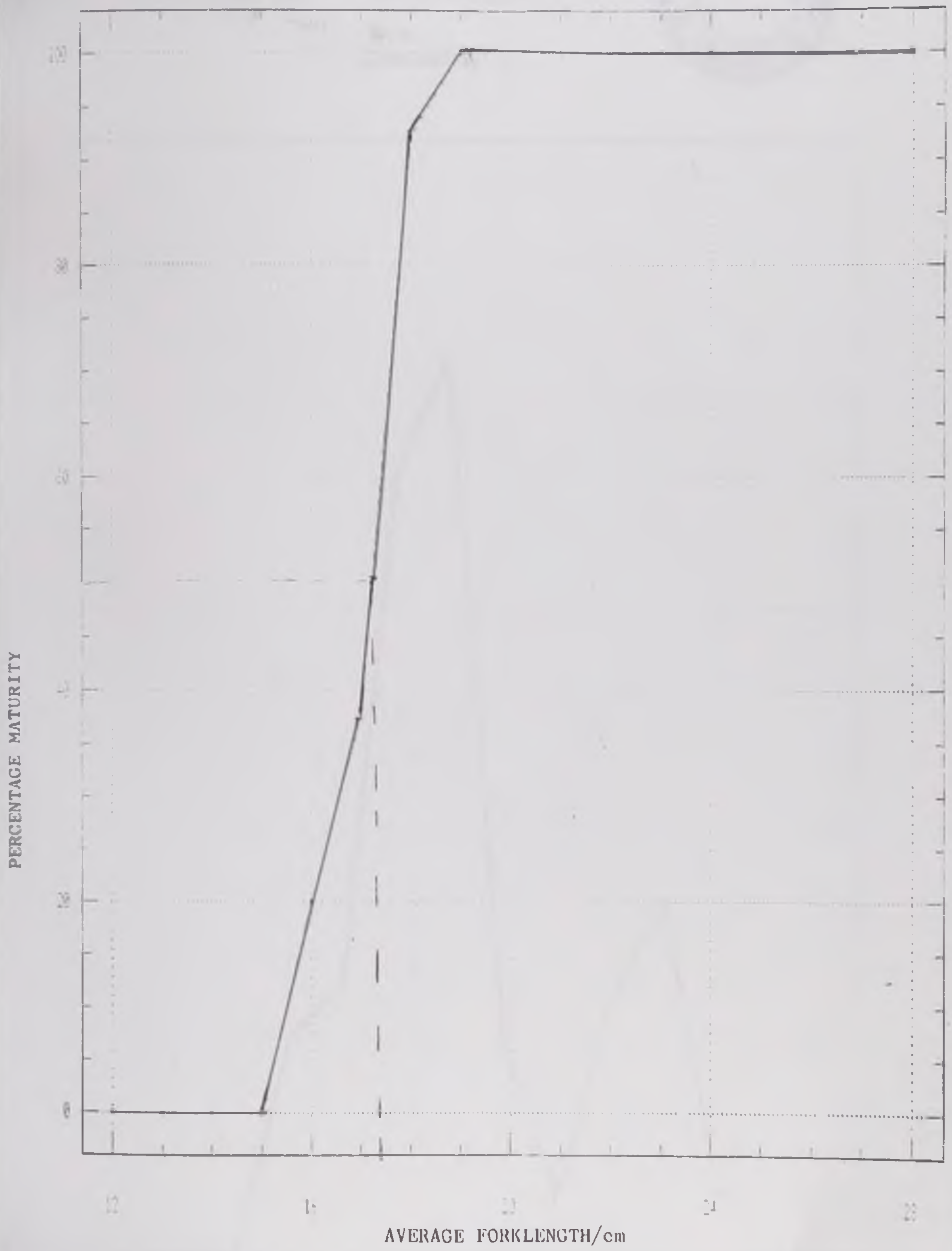


Fig. 36 Spawning seasonality of

S.caeruleostictus

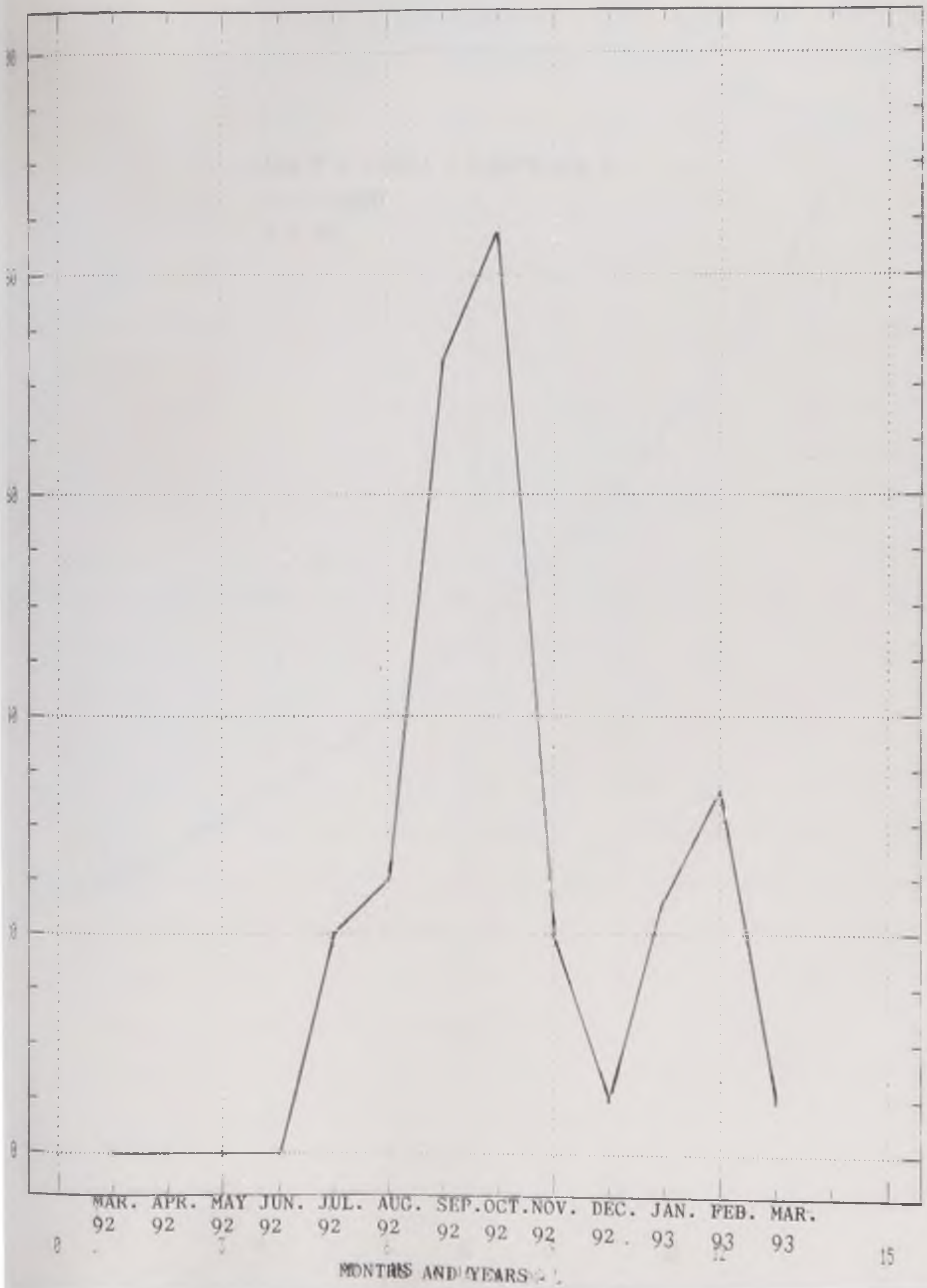
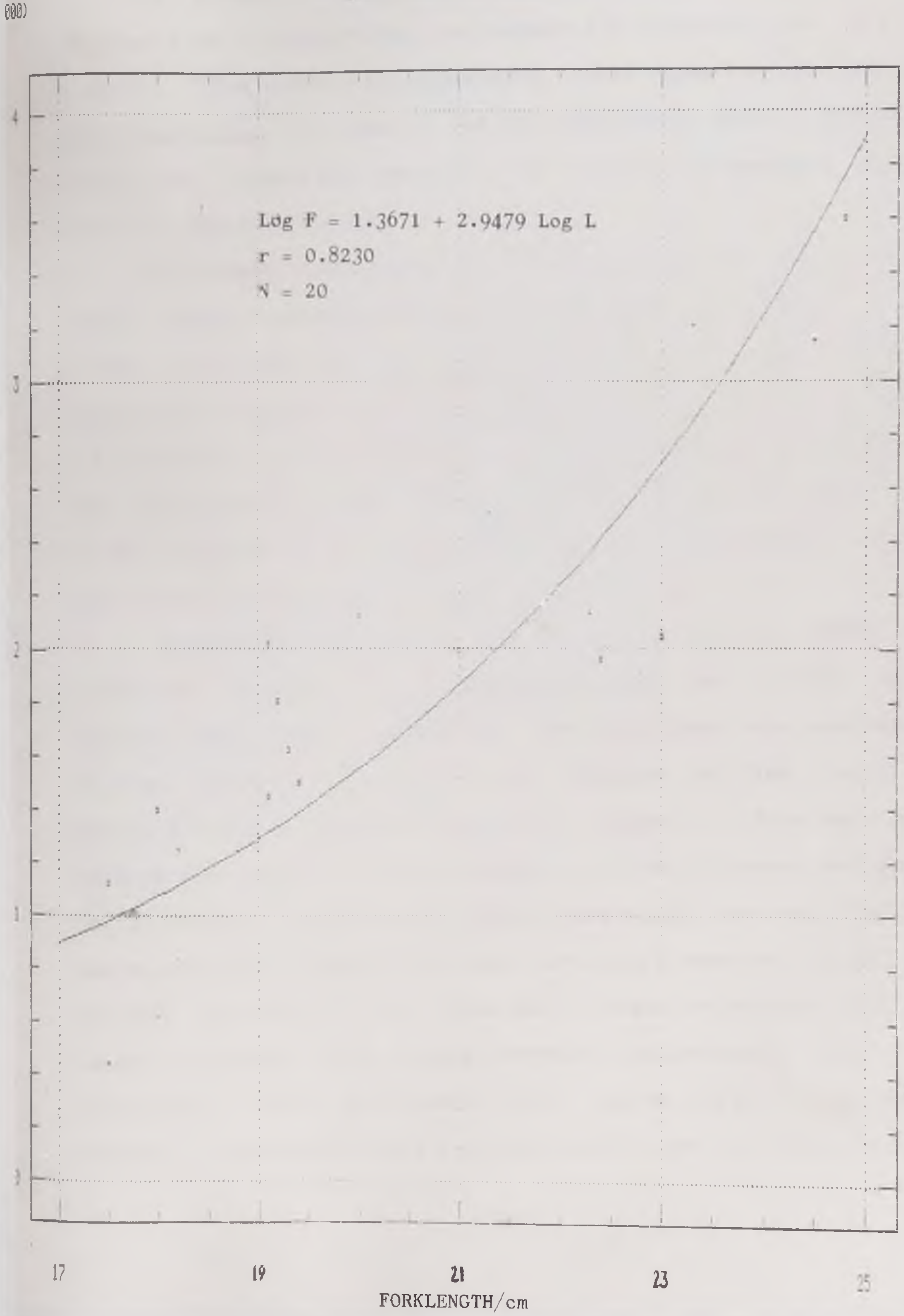


Fig. 37 Plot of the Fecundity-bodylength relationship for S.caeruleostictus



Log F = 1.3671 + 2.9479 Log L

r = 0.8230

N = 20

9. DISCUSSION

The present study shows that S. caeruleostictus is a coastal fish , inhabiting the waters off Ghana between 20 - 70 m depth. This confirms Longhurst's (1969) observation that S. caeruleostictus, belongs to the shallow-water sparid community which live above the base of the thermocline between the 15 and 70 m depth contours.

The skewed distributions (Fig.3) show that larger fish prefer deeper waters as shown by the shift from left to right of the modal lengths in strata A, B, and C. This is also indicated in Table 1. Few fish caught within the size range 6 - 8 cm might be attributable to incomplete recruitment since the calculated average length at first capture (Lc_{50}) was 10.747 cm which is a result of the 60 mm stretched mesh of the cod end of the trawl net.

According to Rijavec (1973) and Ofori-Adu (1989), the preferred habitat for S. caeruleostictus is a hard rocky bottom, where their preferred food organisms are available. This may account for the higher numbers of fish found in strata B and C than in stratum A (Table 1). This may also account for the low numbers caught in the Takoradi and Half-Assini sectors (Appendix 5) which have muddy bottoms. On this basis one would expect the Tema and Accra sectors to be the optimum habitat for this species in Ghanaian waters. Numbers caught in these sectors were however unexpectedly low. The reason for these low numbers could not be readily explained. However, temperature and salinity conditions in these sectors might be factors which determine abundance (Lowe-McConnell, 1987).

The calculated correlation coefficient, r, for the regression of the mean monthly bottom temperatures on catches (Table.2) was 0.3463, which was not statistically significant (P<0.05 ;11 d.f.). The poor correlation might be the result of the low number of observations (n=12). Snedecor and Cochran (1956), observe that small numbers of observations make r quite variable and unstable. Notwithstanding the low r value there appears to be a close relationship in the trend between the two. There appears to be a time lag of about a month between temperature change and corresponding effect on the catch which is most evident between October and November. From June to August, the fall in temperature and the decrease in catch corresponded to the upwelling period (Rijavec, 1980). July to September coincides with the coastal upwelling which was preceded by the breakdown of the thermocline and thus increase in nutrients (Houghton and Mensah, 1978). S. caerulostictus then migrates upwards and inshore to feed and spawn. Such an activity results in higher catches. It appears therefore that catches increase soon after the upwelling periods. October to December shows the decrease in temperature and a corresponding decrease in the catch. At this period there is a formation of the thermocline (Houghton and Mensah, 1978; Rijavec, 1980). The slight increase in temperature from January to March corresponds to the minor upwelling described by Rijavec, (1980). The corresponding increase in catches at this period may be the result of the same reasons mentioned earlier.

The most frequently used method of age determination is the interpretation and counting of growth zones or growth checks on the hard parts of fish like scales, otoliths, opercula and cleithra. These reflect various environmental or internal influences which occur annually in the temperate regions (Bilton, 1974; Simkiss, 1974). Unfortunately, in tropical regions like Ghana, the determination of age is often difficult because the growth zones or checks are not necessarily annual (Fagade, 1974). They may be associated with external factors such as dry season, changes in food supply, stock density (numbers of fish) and spawning (total or partial spawning). Rijavec (1973) and Domanevskaya (1987) studying the biology of _S._ _caerulostictus_ in the waters of Senegal and Ghana respectively, concluded that age determination from the scales of _S._ _caeruleostictus_ and other hard parts was impossible. In the present study, fish were aged by using the Bhattacharya method (Sparre et al., 1989). Table 15 compares the mean lengths from the Bhattacharya method with those from the growth model. It shows that the mean length of each cohort is quite close to the age assigned to it. Hence the ages assigned for each length-group appear reasonable.

The relationship between body-length and scale-length was defined by the rectilinear equation:

$$\text{Log } L = -3.88 + 3.63 \text{ Log } l.$$

The calculated coefficient of determination (r^2) which measured the goodness of fit of the regression line was 0.9814

($p > 0.05$). Consequently, body-length of *S. caeruleostictus* can be reliably predicted from scale-length with this equation with associated error of 0.05 %. The relationship of body-length to number of circuli was found to be exponential and defined by the equation : $C^n = 3.40\ L^{0.69}$; $r = 0.9897$; $p > 0.05$).

Thus the average number of circuli on a scale can be estimated from the fork length of the fish with this equation.

The calculated weight-length relationship was determined as:

$$\text{Log } W = -3.53 + 2.962 \text{ Log } L.$$

In this equation the calculated slope, b, is less than 3.0. This indicates that *S. caeruleostictus* grows allometrically (Bagenal and Tesch, 1978). Isometric growth depends on the level of feeding, which in turn depends on the utilization of food (Birkett, 1972). The weight-length relationships, for *S. caeruleostictus* determined by other authors were as follows:

$\text{Log } W = -1.155 + 2.70 \text{ Log } L$ (Delgaldo and Ariz, 1987) - Gabon waters.

$\text{Log } W = 0.508 + 2.96 \text{ Log } L$ (Domanevskaya, 1987) - Mauritanian waters.

$\text{Log } W = -1.612 + 2.86 \text{ Log } L$ (Rijavec, 1973) - Ghanaian waters.

The values of the slopes are quite close to each other in the different studies but there is a clear disparity in the values of the intercepts 'a' of each equation. Bagenal and Tesch (1978) ascribed such differences to sex ratios, maturity of fish, and seasons for the collections of each data.

The results of Fulton's condition factor CF (Fig.15), showed a fluctuation of the plumpness or well-being of S. caeruleostictus on a monthly basis. Examination of the gonads showed that from September-October when the fish were in advanced stages of development (stages V-VII) the condition factor increased. This phenomenum agrees with the observation of Birkett (1972) that increases in the condition factor are related to the higher developmental stages of the gonads.

There were two peaks of the condition factor : one in August and the other in January. These occurred before the two spawning seasons of S. caeruleostictus. The short decline from September to October and January occurred during the spawning season of S. caeruleostictus. This agrees with Birkett's (1972) observation that the condition factor increases with the accumulation of reserve material for sexual products, and decreases with the onset of the period of maximum spawning activity. Appendix 11 shows the mean monthly condition of S. caeruleostictus from Rijavec (1973). A comparison with the present study shows that there are similarities between the two studies.

Four methods of estimation of growth parameters were used. Comparison of results from these methods showed the relationships to be close. The estimate for L_∞ ranged from 44.08 - 45.82 cm , and for K, from 0.45 - 0.50. The calculated t_0 from the Von Bertalanffy plot was - 0.016 and from Pauly's empirical method, - 0.045. Notwithstanding these results the estimates of K and L_∞ from the ELEFAN I method were used for further calculations because it utilises a large number of samples as compared to the other methods. (Sparre and Venema, 1992). Table 12 gives the results of the present study and those of different authors. Rijavec's results were close to those of the present study and might indicate similar environmental influences. The growth performance index for the present study (Table 12) is similar to those of the other authors. Hence, despite the low R_n = 0.174, the estimates of K and L_{∞} of S. caeruleostictus for the present study appear reasonable.

Beverton and Holt (1959; cited by Sparre et al., (1989), observed that the ratio M/K (M-natural mortality. K-growth rate) is expected to be within the range of 1.5 to 2.5 for the tropics. The value of this parameter obtained in the present study was 1.78 which was lower than average (2) but within the range. This implies that the calculated value of M appears reasonable since higher or lower values of M would give M/K ratios outside the range.

Table 16 gives the results of mortality estimates from the catch curve of S. caeruleostictus in different waters compared with those of the present study. The Total Mortality (Z) of the Gabon waters is quite high as compared to those of Mauritania and Ghana. This is the result of the high Natural Mortality (M) and Fishing Mortality (F) values as compared to the corresponding lower values for of Mauritania and Ghana. However exploitation rate (E) = (F/Z) for Gabon is lower than the E for Mauritania and Ghana which are both higher than the optimum E which is given as 0.5 (Sparre et al., 1989). Hence for the present study the fishery of S. caeruleostictus may probably be over-exploited in Ghana. The values of M for the different waters are clearly different. Normally a high Growth rate (K) gives a higher M and vice versa. For both Ghanaian and Gabon waters, however, K is higher but M is lower than that of Gabon, with higher M value. The reason for this could not be readily found.

The computational details of the estimation of fishing mortalities (F) by the cohort analyses can be seen in appendix 15. The F at length array shows a steadily increasing F between 8 to 16 cm. This increase is probably a reflection of exploitation over this length range. For the larger specimens, the F at length array is irregular. This might be a result of periodical migration from the fishing grounds as observed by Vibhasiri (1988). The Z from the catch curve was estimated as 2.477/yr, with M as 0.856 and F as 1.621. The estimate of mean F from the cohort analysis was 1.093. as compared to F from the catch curve (1.621). The mean E = 0.561; from the cohort analysis as compared to E = 0.654 from the catch curve. Since both values were greater than E = 0.5 which is the proposed optimum in a fishery, one may say that the fishing pressure on the S. caeruleostictus stocks is past the optimum. The marked increase in F of fish from about 24 to 32 cm forklength also indicated an increase in their corresponding exploitation rates. This may mean that fish within this length range might be the most highly exploited in the fishery. The reason for this high exploitation may be that this length group are more easily retained by the trawl net.

The calculated average length at first capture (Lc_{50}) for S. caeruleostictus was 10.747 cm. From the gonadal studies, the average lengths at first maturity were 18.40 and 17.20 cm for males and females respectively. This means that the fish are caught before reaching sexual maturity. This will eventually result in a steady depletion of the fish to possible extinction.

The recruitment pattern of S. caerulostictus as shown in Fig. 24 suggests the occurrence of two recruitment pulses a year of unequal strength, the stronger in January and the weaker in September. These display two clear modes which may possibly correspond to two cohorts. The less pronounced mode in September probably represents the fish hatched during the minor spawning period between January and February. The more pronounced mode in January may represent fish hatched during the major spawning period between September and October. It is noted that the period between the estimated hatching period and recruitment is about 6 - 7 months. The estimated length for this period from both the Bhatthacharya analysis and Von Bertalanffy model is 9 to 11 cm. Since the Lc_{50} = 10.747 cm, fish at 6 - 7 months are likely to be caught. Precise estimates of absolute ages are needed for recruitment patterns to indicate the time of spawning when using the method (Samb, 1988; Moreau and Cuende, 1991).

The graphs of the Thompson and Bell analysis in Fig.25 clearly show that the present level of fishing effort for S. caeruleostictus (fishing effort (X) = 1.00), is well above that (X = 0.54) giving the maximum sustainable yield. A reduction in effort would give a higher yield as can be seen on the graph. However an increase in yield should not be considered in isolation but in conjunction with the catch per unit of effort (CPUE). A decrease in effort will always increase the CPUE, but the increase in yield should be significant to justify the increase in CPUE (Biradar, 1989). Although no explicit estimates of CPUE were made in the present study, the estimated mean biomass (Table 6) could be used as an index of CPUE . From the analysis, reduction in the effort to the left of the MSY (X <0.54) would be safe for the fishery.

The two plots of yield per recruit (Y/R)' involved two different mesh sizes, which were related to their Lc_{50}'s given as 10.747 cm for the present study and 14.0 cm, indicating an apparent increase in the mesh size. Fig.26 gives the E^{MSY} at the dome of the curve as 0.4784 for the Lc of 10.747 cm. Exploitation rate from the catch curve is given as 0.654. This position on the curve indicates that S. caeruleostictus is possibly being over-exploited. Fig.27 corresponding to the Lc_{50} of 14.0 cm was drawn in order to find out if an increase in mesh size would make the fishery safer at the present E of 0.654. The E^{MSY} for the curve has 0.5510 still less than the present E which again lies to the right of the dome, which is unsafe for the fishery. Hence from this result, an increase in the mesh size of the gear may not help in sustaining the fishery. Other factors of the fishery, such as the effort may have to be looked at closely to sustain the fishery.

Table 8 shows the food organisms identified from the stomachs of S. caeruleostictus. The presence of pelagic organisms like the amphipod Gammarus sp. in the diet suggest that S. caeruleostictus migrates vertically to feed on these organisms as observed in other fish. This confirms Marshall's (1960) observation that the daily climb towards the surface by a fish is feeding migration. In his study of the fish in Ghanaian waters, Rijavec (1973), discovered that S. caeruleostictus fed often on slow moving shelled benthic animals such as molluscs, crustaceans and ophiuroids, with fish being the main diet. Chakroun - Marzouk (1987), working on S. caeruleostictus in Tunisian waters also discovered that their food consisted of molluscs decapod crustaceans, echinoderms, polychaetes and fishes. The results of the present study differ from the above in that no species of the echinodermata were discovered in the fishes stomachs.

The results of the percentage occurrence method show that S. caeruleostictus feeds mostly on crustaceans. Fig.28 shows that more than 50% of the fish fed on crustaceans. It also shows that even though fish larvae and coelenterates were included in the diet, the crustaceans, molluscs and polychaetes dominate in that order.

In the numerical method, out of a total of 240 stomachs examined and 589 food items , only 3 (0.51 %) coelenterates and 20 (3.40 %) fish larvae were found as compared to 282 (47.88 %) crustaceans. Here again the crustaceans dominated the food organisms.

The points method shows that crustaceans constitute the most important source of food for the fish, since they dominate 6 out of the 8 sampling periods (Fig.30). Since the points method was based on size and degree of abundance of food items, in the stomachs it gives the best approximation of the relative value of food items in terms of biomass and energy (Windell and Bowen; 1978). Hence from Fig.30, crustacea, mollusca and polychaetes, may constitute the most important food items.

This distinct preference for crustaceans is however doubtful as a reflection of primary importance. This is due to the fact that even in advanced digestion stages, individual crustaceans, mostly decapods could still be found. This could perhaps be because the exoskeleton seems resistant to digestion (Foxton and Roe, 1974). Alternatively, the apparent selectivity for crustaceans and other food organisms in the order given by the three methods may be more of a reflection of the greater availability of the species during the period of investigation. This problem can only be resolved over a longer period of time with good quantitative evaluation of the relative abundance of the principal food organisms.

Feeding on fish larvae appears to be non-seasonal looking at the way they are distributed over the months. Coelenterates also appear to be non-seasonal (Figs.31 & 32). Their small numbers indicate that they are less likely to be encountered by the fish. Figs.31 and 32 show that polychaetes appear in the stomachs of the fish in March (1992). They show a seasonal change in importance as food for S. caeruleostictus. These changes suggest that polychaetes maybe readily available than other food items during these periods.

The predator size - prey size relationship from the data was significant ($r = 0.69$; d.f =18; $p < 0.05$). However this does not indicate that the species selects its prey fish at random or not.

Specimens within the length range (13 - 25 cm) studied showed no evident change of diet with increase in size.

The lengths at first maturity for male and female S. caeruleostictus were 18.40 cm. and 17.20 cm respectively. These were quite close to 20.98 cm and 19.58 cm for males and females respectively which Rijavec (1973) recorded in his study. From the dynamics study the Lc_{50} = 10.747 cm.

The results of the spawning seasonality give two peaks, a major one between September and October, and a minor one between January to February. These spawning seasons coincide with the major and minor upwelling seasons off the coast of Ghana between July and September and February and March respectively (Houghton and Mensah 1978; Rijavec, 1980).

There is an exponential relationship between the fork-length of S. caeruleostictus and its fecundity. Examination of the eggs in a given ripe ovary showed that they were of similar sizes (about 0.49 mm) in diameter at different sections of the ovary. This suggests that S. caeruleostictus may be a total spawner.

10. SUMMARY

1. *Sparus caeruleostictus* inhabits hard rocky and sandy bottoms between the 20 and 70 m depth contours on the continental shelf of Ghana. The larger *S. caeruleostictus* occur in deeper waters. The low frequencies of smaller fish of about 6 - 8 cm is due to incomplete recruitment since the average length at first capture is 10.747 cm based on the mesh size (60 mm) used. The most abundant catches of *S. caerulostictus* occurred in Stratum B (30-50 m) for the period under study.

2. There was a relation between the average monthly bottom temperatures and the monthly catches. Catches increased with the breakdown of the thermocline during upwelling and decreased with the return of thermal stability.

3. Six cohorts were present in the fishery, corresponding to ages of 0.5, 0.75, 1.0, 1.5, 2.0, and 2.5 years respectively. Longevity (t_{max}) is given by 3/K (Pauly, 1983). From the study, t_{max} = 3/0.48 about 6.2 years. The work of Rijavec (1973) shows that *S.caeruleostictus* in Ghanaian waters has a life span of about 6 - 7 years.

4. The relationship between body length and scale length is given by the rectilinear equation:

Log L = 3.88 + 3.63 Log l where L represent the fork length in cm and l, the scale length in mm. The body length - number of circuli relationship is given from the Log. transformed equation:

$$C_n = 2.511.9\ L^{0.69}$$

Growth for male and female *S. caeruleostictus* is allometric: The combined weight-length relationship is:

Log W = − 3.53 + 2.962 Log L where W represents body weight in grammes and L, the fork length in cm.

5. The growth parameters of *S. caeruleostictus* in Ghanaian waters were:

L_{∞} = 44.3 cm (ELEFAN)

K = 0.48 (ELEFAN)

t_0 = −0.045. (Pauly's (1984) empirical formula

From these the von Bertalanffy growth model is given as:

$$L(t) = 44.3\ [1 - \exp(-0.48(t + 0.045))]$$

The mortality rates of *S. caeruleostictus* in Ghanaian waters from the catch curve are:

Z = 2.477/yr.

M = 0.856/yr

F = 1.621/yr

The cohort analysis shows that fish between 24 to 32 cm were the most highly exploited.

6. Recruitment of *S. caeruleostictus* occurs all year round with two peaks in January and September as a result of the two spawning seasons which occur about 6-7 months before each recruitment. The predictive dynamics show that *S. caeruleostictus* may be over-exploited and hence the fishery is in danger. However, *S. caeruleostictus* is part of the multispecies fishery in Ghana and hence is not the only fish selected by the gear. Therefore, concluding that

S. caeruleostictus is over-exploited may not be correct. The conclusion can only be justified if data on the other demersal fish species caught in the gear are analyzed and similar results are obtained. Until this is achieved no concrete conclusion can be made.

7. S. caeruleostictus is a carnivore. The presence of the pelagic crustacean, Gammarus sp. in the diet suggests that S. caeruleostictus migrates vertically upward for feeding. The results from the three methods of stomach content analysis suggest that crustaceans are the most important food items for the species. Seasonal changes in food items were not clear except in the case of the polychaetes. Specimens studied showed no evident change of diet with increase in size.

8. There are two spawning seasons for S. caeruleostictus; major spawning between August and October, minor spawning between January and February. Males are sexually mature at a fork length of 18.40 cm whilst the females are sexually mature at 17.20 cm. During the spawning periods there is a noticeable increase in the condition factor K. This increase is an adaptation which ensures that there is enough reserve material for the development and formation of testes and ovaries. The relationship between the fork length and fecundity is exponential and the Log.tranformation is given by the equation:

$$\text{Log } F = 1.3671 + 2.9479 \text{ Log } L$$

where F represents the fecundity or number of eggs and L. the fork length in cm.

RECOMMENDATIONS

It is believed that implementation of the following will assist in the rational exploitation of the _Sparus caeruleostictus_ stocks in Ghanaian waters.

1. To maximise catches of _S.caeruleostictus_, it is advisable to trawl within stratum B (30-50 m). In order to prevent over fishing, a safe period for trawling should be between the two spawning seasons, namely between March and August and between November and January. This will prevent maximum capture of the adults which migrate inshore to feed and spawn during the spawning seasons. It will therefore ensure that each spawning period will be at its maximum.

2. The exploitation rate E (F/Z) = 0.654, for _S. caeruleostictus_ is high as shown by the yield per recruit analysis. The analysis further shows that increasing the mesh size of the gear will not bring the fishery to the desired MSY. Thompson and Bell analysis shows that the present level of effort (X = 1.00) will have to be reduced by 50 % to achieve the MSY (X = 0.54). Therefore the nature of the effort used in the fishery will have to be well defined and the necessary action taken. This involves the types and numbers of gear, the numbers and types of vessels and the numbers of hours spent fishing. Therefore there is the need for a further in depth study of the dynamics of this species in order to come out with concrete regulations on the exploitation of the species.

3. A detailed study of the environmental factors of the Keta, Tema, and Accra sectors should be undertaken in order to

discover the reason for the low catches in these areas.

4. Work should be done on the biology of S.caeruleostictus specifically on the hard parts to determine age in order to validate the results of the Bhattacharya method which only gives relative ages.

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MONTH AND YEAR	MEAN MONTHLY TEMPERATURE/°C	MONTHLY CATCH/TONNES
JUNE 1990	21.59	141.12
JULY 1990	18.46	141.02
AUG. 1990	17.20	118.49
SEPT. 1990	19.34	283.53
OCT. 1990	21.84	460.82
NOV. 1990	23.89	216.44
DEC. 1990	21.89	153.98
JAN. 1991	20.16	220.66
FEB. 1991	20.19	112.88
MAR. 1991	20.49	93.27
APR. 1991	20.42	110.56
MAY 1991	19.30	63.19

TABLE 2. Mean monthly bottom temperatures and catches from June 1990 to May 1991. (Source: F.R.U.B., Tema).

*MONTH	MEAN MODAL	LENGTHS (CM)		OF COHORTS		
	$\bar{L}_1$	$\bar{L}_2$	$\bar{L}_3$	$\bar{L}_4$	$\bar{L}_5$	$\bar{L}_6$
JUN'90	7.971	12.551	17.633	-	24.157	
JUL'90	7.881		18.471		27.500	
AUG'90	8.294		18.062	22.839	27.893	
SEP'90		12.705	18.032	22.145	27.858	
OCT'90		13.040	17.576	23.500		
NOV'90	-	14.157		21.880	27.690	
DEC'90	-	14.679	18.928	23.001		31.498
FEB'91		15.093	18.095	20.502		
MAR'91	10.000		16.611		24.000	
APR'91	10.792		-		-	
MAY'91	10.500		16.445			
Average	9.240	13.704	17.761	22.311	26.418	31.498

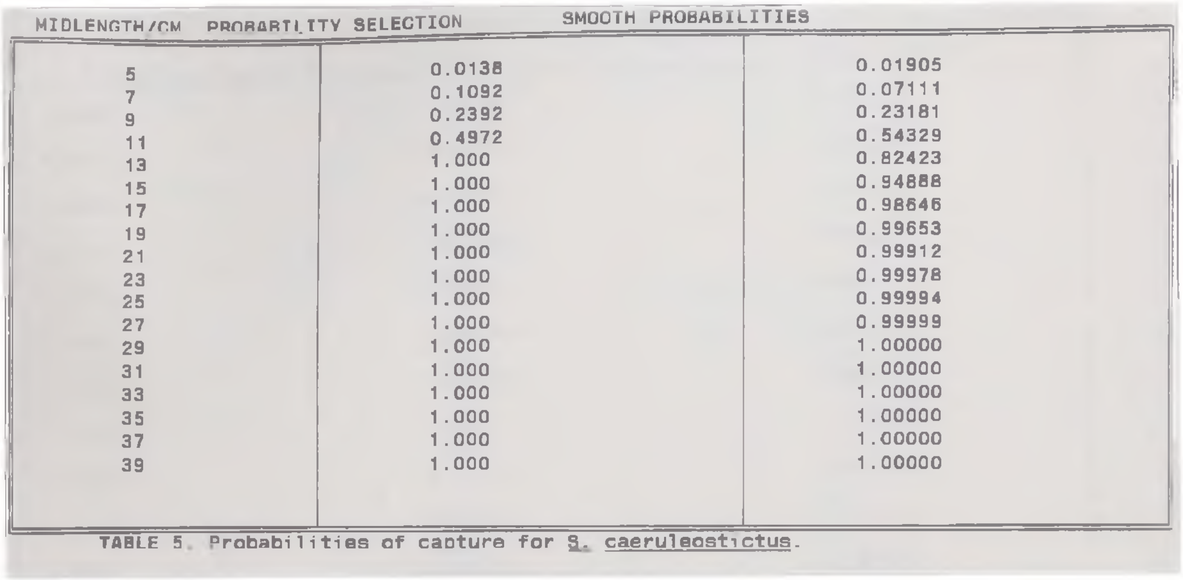
Table 3. Mean modal lengths of cohorts of S. caeruleostictus obtained from the Bhatthacharya analysis.

STRATUM	LENGTH RANGE/cm	MODAL LENGTH/cm	ABUNDANT LENGTH GROUPS	NUMBERS CAUGHT IN EACH STRATUM
A	5 - 32	10	6 - 14	914
B	7 - 39	14	9 - 27	960
C	8 - 36	17	15 - 26	941

TABLE 1. Length ranges, modal lengths, most abundant length groups and numbers caught for S. caeruleostictus in strata A,B, and C.

SPECIES	L_∞	K	ϕ'	AREA	SOURCE
S. caeruleostictus	44.30	0.48	2.97	GHANA	PRESENT STUDY
S. caeruleostictus	44.76	0.49	2.99	GHANA	RIJAVEC (1973)
S. caeruleostictus	70.00	0.15	2.87	MAURITANIA	FAO (1987)
S. caeruleostictus	55.20	0.29	2.95	SENEGAL	FAO (1987)

TABLE 4. Comparison of growth parameters, L_∞ and K of *S. caeruleostictus* with results from other authors.



MIDLENGTH/CM	PROBABILITY SELECTION	SMOOTH PROBABILITIES
5	0.0138	0.01905
7	0.1092	0.07111
9	0.2392	0.23181
11	0.4972	0.54329
13	1.000	0.82423
15	1.000	0.94888
17	1.000	0.98646
19	1.000	0.99653
21	1.000	0.99912
23	1.000	0.99978
25	1.000	0.99994
27	1.000	0.99999
29	1.000	1.00000
31	1.000	1.00000
33	1.000	1.00000
35	1.000	1.00000
37	1.000	1.00000
39	1.000	1.00000

TABLE 5. Probabilities of capture for S. *caeruleostictus*.

TABLE 6 SPARUS CAERULEOSTICTUS

X (effort level)	Yield	Mean Biomass
0.0000	0.00	24081.78
0.2000	3947.12	13583.81
0.4000	4976.96	8710.61
0.6000	5083.85	6128.12
0.8000	4889.49	4606.76
1.0000	4608.90	3629.28
1.2000	4319.25	2956.47
1.4000	4049.42	2468.37
1.6000	3801.24	2100.06
1.8000	3581.34	1813.86
2.000	3385.78	1586.46
2.2000	3211.86	1402.59
2.4000	3056.86	1251.81
2.6000	2918.29	1126.68
2.8000	2793.96	1021.77
3.0000	2681.99	933.01
3.2000	2580.76	857.30
3.4000	2488.90	792.22
3.6000	2405.23	735.89
3.8000	2328.76	686.81
4.0000	2258.62	643.78

TABLE 6. Results of the Thompson and Bell Analysis

Lc = 10.747 cm

E	Y' / R	E	Y' / R
0.05	.0056064	0.55	.0276103
0.10	.0106047	0.60	.0265610
0.15	.0149855	0.65	.0250375
0.20	.0187413	0.70	.0231049
0.25	.0218672	0.75	.0208448
0.30	.0243613	0.80	.0183572
0.35	.0262255	0.85	.0157612
0.40	.0274663	0.90	.0131940
0.45	.0280963	0.95	.0108053
0.50	.0281349	1.00	.0087423

LC = 14.619

E	Y' / R	E	Y'/ R
0.50	.005205	0.55	.0320904
0.10	.0105446	0.60	.0318489
0.15	.0150610	0.65	.0311305
0.20	.0190596	0.70	.0299723
0.25	.0225314	0.75	.0284234
0.30	.0254692	0.80	.0265473
0.35	.0278680	0.85	.0244237
0.40	.0297257	0.90	.0221497
0.45	.0310438	0.95	.0198390
0.50	.0318282	1.00	.0176184

TABLE 7 Results of the relative yield per recruit analysis.

1. BIVALVIA

   Pecten sp.

   Cardium sp.

2. FISH LARVAE

   MADE UP OF FISH BONES, SCALES AND JUVENILE WHOLE FISH

   IDENTIFICATION OF FISH WAS DIFFICULT

3. POLYCHAETES

   Nereis sp.

4. COELENTERATES

   Corals

5. CRUSTACEANS

   Decapods

   Stomatopods

   Amphipods: *Gammarus* sp.

TABLE 8. List of food organisms identified in stomachs of *S. caeruleostictus*.

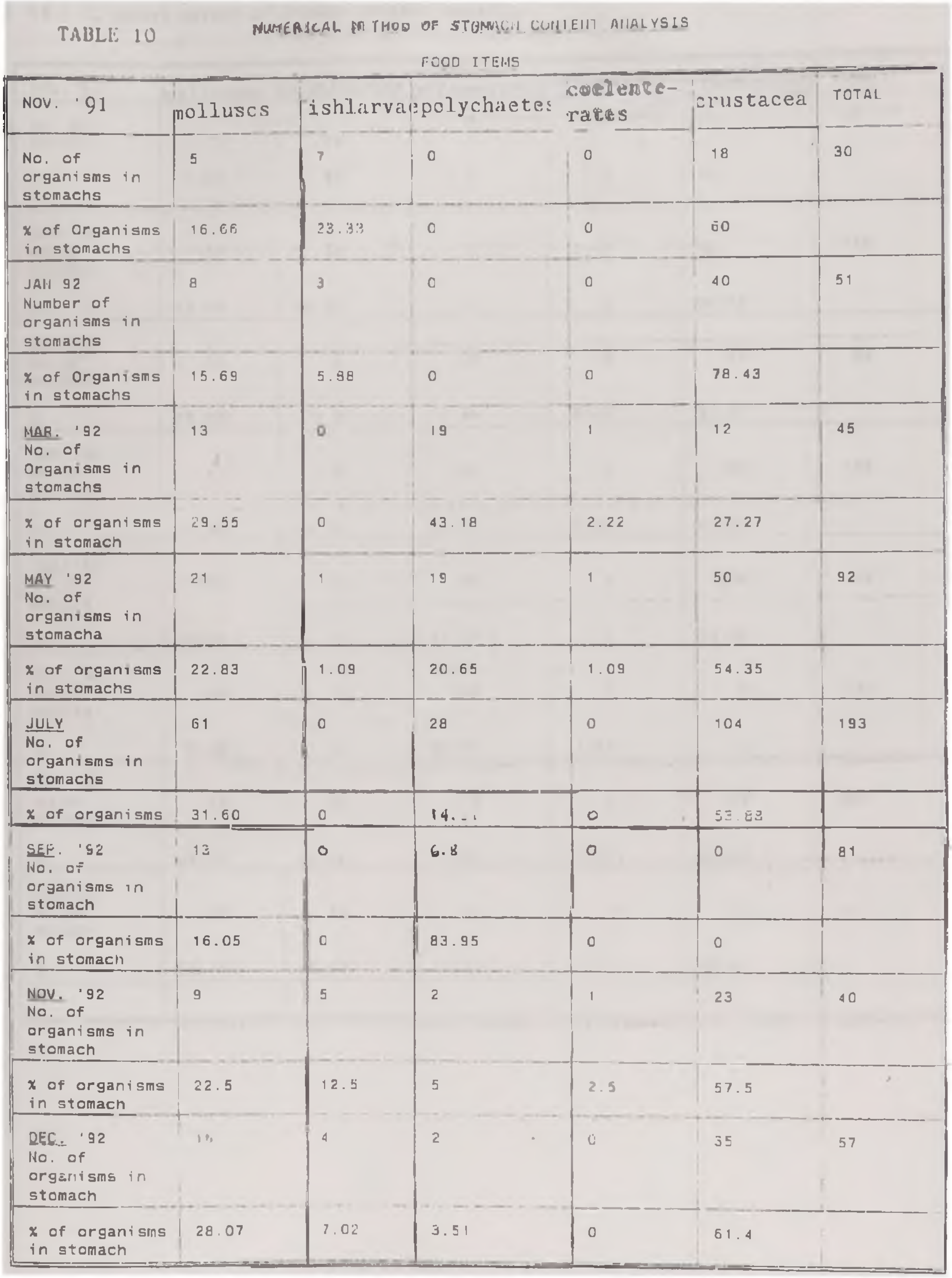


TABLE 10 NUMERICAL METHOD OF STOMACH CONTENT ANALYSIS

FOOD ITEMS

NOV. '91	molluscs	ishlarvae	polychaetes	coelenterates	crustacea	TOTAL
No. of organisms in stomachs	5	7	0	0	18	30
% of Organisms in stomachs	16.66	23.33	0	0	60	
JAN 92 Number of organisms in stomachs	8	3	0	0	40	51
% of Organisms in stomachs	15.69	5.88	0	0	78.43	
MAR. '92 No. of Organisms in stomachs	13	0	19	1	12	45
% of organisms in stomach	29.55	0	43.18	2.22	27.27	
MAY '92 No. of organisms in stomacha	21	1	19	1	50	92
% of organisms in stomachs	22.83	1.09	20.65	1.09	54.35	
JULY No. of organisms in stomachs	61	0	28	0	104	193
% of organisms	31.60	0	14.[illegible]	0	53.88	
SEP. '92 No. of organisms in stomach	13	0	6.8	0	0	81
% of organisms in stomach	16.05	0	83.95	0	0	
NOV. '92 No. of organisms in stomach	9	5	2	1	23	40
% of organisms in stomach	22.5	12.5	5	2.5	57.5	
DEC. '92 No. of organisms in stomach	16	4	2	0	35	57
% of organisms in stomach	28.07	7.02	3.51	0	61.4	

TABKE 11 . POINTS METHOD OF STOMACH CONTENT ANALYSIS

NOV. '91	molluscs	fishlarvae	polychaetes	coelenter-ates	crustacea	TOTAL
NO. OF POINTS	6	36	0	0	34	76
%	7.60	46	0	0	43	
JAN. '92 NO. OF POINTS	16	24	0	0	78	118
%	13.50	20.31	0	0	66.10	
MAR. 92 NO. OF POINTS	25	0	38	8	24	95
%	26.32	0	40	8.42	27.37	
MAY '92 NO. OF POINTS	42	8	38	4	100	192
%	21.88	4.17	19.79	2.08	52.08	
JULY '92 NO. OF POINTS	112	0	56	0	206	374
%	29.95	0	14.97	0	55.08	
SEP. '92 NO. OF POINTS	26	0	136	2	0	164
%	16.05	0	83.95	1.22	0	
NOV. '92 NO. OF POINTS	24	24	8	4	46	106
%	22.64	22.64	7.55	3.77	43.40	
DEC '92 NO. OF POINTS	32	16	6	0	70	124
%	25.81	12.90	4.84	0	56.45	

	PERCENTAGE OCCURENCE		POINTS METHOD		NUMERICAL METHOD	
FOOD ITEMS	FREQUE -NCY	%	FREQUE -NCY	%	FREQUE -NCY	%
MOLLUSCS	50	31.25	283	22.80	146	7.79
FISH LARVAE	19	11.88	108	8.70	20	3.39
POLYCHAETES	43	26.88	282	22.72	138	23.43
COELENTERATES	3	1.88	18	1.45	3	0.50
CRUSTACEANS	87	54.38	560	45.12	282	47.88

TABLE 12. Summary of food analysis in stomachs of *S. caeruleostictus*.

STAGE	STATE	DESCRIPTION
I	VIRGIN	Very small sexual organs, close under the ventral column Testis and ovary transparent, colourless Eggs invisible to the naked eye.
II	Maturing virgin and recovering spent	Testis and ovary translucent gray-red. Length half or slightly more than half the length of the ventral cavity. Single eggs can be seen with magnifying glass.
III	Developing	Testis and ovaries opaque reddish with blood capillaries. Occupy, about half of ventral cavity. Eggs visible to the eye as whitish granular.
IV	Developed	Testes reddish white. No milt drops appear under pressure. Ovary orange-reddish. Eggs clearly discernible opaque. Testis and ovary occupy about two-thirds of ventral cavity
V	Gravid	Sexual organs filling ventral cavity. Testis white, drops of milt full with pressure. Eggs completely round, some already translucent and ripe.
VI	Spawning	Roe and milt run with slight pressure. Most eggs translucent with few opaque eggs left in ovary.
VII	Spent	Not yet fully empty, no opaque eggs left in ovary
VIII	Resting	Testis and ovary empty red. A few eggs in the state of reabsorption.

TABLE 13: An eight point scale of gonad maturity adapted from Laevestu (1965).

FORKLENGTH/CM	FECUNDITY
23.3	214,000
18.2	84,000
17.5	45,204
19.3	162,322
21.3	250,612
24.5	316,200
19.1	202,421
19.2	140,000
18.0	62,300
18.0	145,116
19.1	320,245
23.3	360,128
24.8	196,405
22.4	212,400
20.0	200,000
21.0	112,000
17.5	124,000
18.2	150,000
19.4	205,144
23.0	195,400

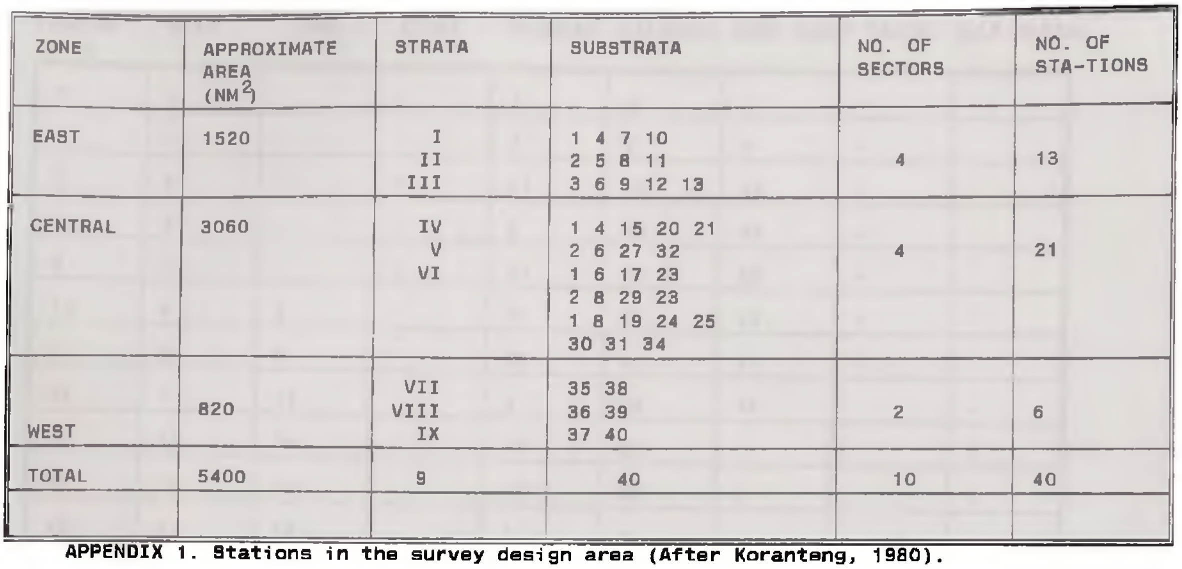
TABLE 14: Forklengths of gravid female S. caeruleostictus and their corresponding fecundities.

VON BERTALANFFY MODEL		BHATTACHARYA METHOD	
AGE/YR	FORKLENGTH/CM	COHORT	AVERAGE LENGTH/CM
0.50	10.19	1	9.240
0.75	14.05	2	13.704
1.00	17.47	3	17.761
1.50	23.20	4	22.311
2.00	27.70	5	26.418
2.50	31.24	6	31.498

TABLE 15. Comparison of mean lengths from the Bhattacharya analysis with mean lengths from the Von Bertalanffy Growth model.

COUNTRY	NATURAL MORTALITY (M)	FISHING MORTALITY (F)	TOTAL MORTALITY (Z)
MAURITANIA	0.24	0.80	1.04
GABON	2.82	2.50	5.32
GHANA	0.86	1.60	2.46

TABLE 16. Mortality estimates of _S_.<u>caeruleostictus</u> in different waters. (Source, FAO, 1987).



ZONE	APPROXIMATE AREA (NM^2)	STRATA	SUBSTRATA	NO. OF SECTORS	NO. OF STA-TIONS
EAST	1520	I II III	1 4 7 10 2 5 8 11 3 6 9 12 13	4	13
CENTRAL	3060	IV V VI	1 4 15 20 21 2 6 27 32 1 6 17 23 2 8 29 23 1 8 19 24 25 30 31 34	4	21
WEST	820	VII VIII IX	35 38 36 39 37 40	2	6
TOTAL	5400	9	40	10	40

APPENDIX 1. Stations in the survey design area (After Koranteng, 1980).

LENGTHS (CM)	FREQUENCIES							
	KETA	TEMA	ACCRA	WINNEBA	SALTPOND	CAPE COAST	TAKOR.	HALF ASSINI
5	0	–	–	1	4	–	–	
6	1	–	–	2	9	5	–	
7	8	–	4	21	13	19	–	
8	9	–	–	9	18	31	–	
9	10	–	–	41	23	20	–	
10	8	2	–	37	37	25	1	
11	4	6		29	22	17	–	
12	3	15		4	38	18		–
13	12	20		36	29	–		–
14	16	13		30	25	1		1
15	9	13		2	8	–		–
16	3	10		10	13	–		–
17	2	12		7	3	–		1
18	–	3		3	12			–
19	–	4		–	7			–
20	1	8		1	3			2
21	2	1		1	3			3
22	–	3		1	2			5
23	3	1		–	2			14
24	–	5		–	2			8
25	2	1		2	2			6
26	1	6		1	1			5
27		5		1	–			2
28	2	5		–	–			
29	5	5		2	–			
30	5	4		1				
31		2		2				
32		1		–				
33				–				
34				2				
35								
36								
37								
38								

APPENDIX. 2 Pooled length-frequency data for *S.caeruleostictus* in stratum A from June 1990 – May 1991.

LENGTHS (cm)	FREQUENCIES KETA	TEMA	ACCRA	WINNEBA	SALTPOND	CAPE-COAST
5		–	–	–	–	
6	–	–		–	–	
7	–	–	–	1	–	–
8	–	2	14	–	–	–
9	–	6	8	1	–	–
10	7	8	19	11	–	–
11	32	18	18	11	1	1
12	27	20	17	11	5	2
13	19	22	15	20	7	1
14	8	21	16	11	3	1
15	3	16	24	8	3	2
16	6	14	25	–	7	–
17	5	11	22	4	6	
18	5	8	29	6	9	–
19	4	12	11	3	9	–
20	4	6	18	4	9	–
21	–	–	13	11	4	3
22	4	6	8	1	4	3
23	4	5	9	–	5	–
24	5	4	6	5	5	1
25	3	5	6	1	1	1
26	4	6	10	11	1	1
27	10	9	8	4	–	2
28	9	5	6	1	1	1
29	8	3	–	5	–	–
30	2	3	–	–	–	–
31	2	1	–	–	–	–
32	1	3	–		–	–
33	–	2	–	–	–	–
34	–	1		–	–	–
35	–	–		–	–	–
36	–	–	–	–	–	–
37	–	–	–	–	–	–
38	–	–	–	–	–	–
39	–	–	–	–	–	–

Appendix 3 Pooled length-frequency data for S. caeruleostictus in stratum B from June 1990 - May 1991.

LENGTHS (cm)	FREQUENCIES KETA	TEMA	ACCRA	WINNEBA	SALT POND	CAPE COAST	TAKORADI
5	–	–	–	–	–	–	–
6	–	–	–	–	–	–	–
7	–	2	–	–	–	–	–
8	1	1	–	–	–	–	–
9	6	2	1	–	–	–	–
10	16	24	4	–	–	–	1
11	23	24	5	3	–	–	–
12	31	13	3	12	–	–	3
13	16	12	1	14	–	–	4
14	19	4	2	14	12	–	8
15	27	4	6	14	14	1	7
16	13	2	17	12	17	10	6
17	6	6	9	28	27	4	2
18	4	12	6	28	24	2	3
19	2	3	11	14	17	4	5
20	2	3	4	15	19	5	2
21	2	2	2	10	23	1	5
22	1	1	1	6	18	4	1
23	2	–	2	2	14	3	2
24	1	1	5	1	15	3	1
25	6	2	–	1	13	4	1
26	3	–	3	2	9	4	1
27	4	–	2	2	11	–	–
28	2	2	–	2	11	2	–
29	1	–	2	1	4	2	–
30	–	–	1	–	6	–	–
31	–	1	–	–	4	–	–
32	–	–	1	1	–	–	–
33	–	–	–	–	1	–	–
34	1	–	–	–	–	–	–
35	–	–	–	–	–	–	–
36	–	–	1	–	–	–	–
37	–	–	–	–	–	–	–

Appendix 4 Pooled length-frequency data for S. caeruleostictus in stratum C from June 1990 - May 1991.

LENGTHS	FREQUENCIES						
(cm)	KETA	TEMA	ACCRA	WINNEBA	SALT POND	CAPE COAST	TAKORADI
5	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-
7	-	2	-	-	-	-	-
8	1	1	-	-	-	-	-
9	6	2	1	-	-	-	-
10	16	24	4	-	-	-	1
11	23	24	5	3	-	-	-
12	31	13	.3	12	-	-	3
13	16	12	1	14	-		4
14	19	4	2	14	12	-	8
15	27	4	6	14	14	1	7
16	13	2	17	12	17	10	6
17	6	6	9	28	27	4	2
18	4	12	6	28	24	2	3
19	2	3	11	14	17	4	5
20	2	3	4	15	19	5	2
21	2	2	2	10	23	1	5
22	1	1	1	6	18	4	1
23	2	-	2	2	14	3	2
24	1	1	5	1	15	3	1
25	6	2	-	1	13	4	1
26	3		3	2	9	4	1
27	4	-	2	2	11	-	-
28	2	2	-	2	11	2	-
29	1	-	2	1	4	2	-
30	-	-	1	-	6	-	-
31	-	1	-	-	4	-	-
32	-	-	1	1	-	-	-
33	-	-	-		1		-
34	1	-	-	-	-	-	-
35	-	-	-	-	-	-	-
36	-	-	1	-		-	-
37	-	-	-	-	-	-	-

Appendix 4 Pooled length-frequency data for S. caeruleostictus in stratum C from June 1990 - May 1991.

LENGTHS	FREQUENCIES						
(cm)	KETA	TEMA	ACCRA	WINNEBA	SALT POND	CAPE COAST	TAKORADI
5	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-
7	-	2	-	-	-	-	-
8	1	1	-	-	-	-	-
9	6	2	1	-	-	-	-
10	16	24	4	-	-	-	1
11	23	24	5	3	-	-	-
12	31	13	3	12	-	-	3
13	16	12	1	14		-	4
14	19	4	2	14	12	-	8
15	27	4	6	14	14	1	7
16	13	2	17	12	17	10	6
17	6	6	9	28	27	4	2
18	4	12	6	28	24	2	3
19	2	3	11	14	17	4	5
20	2	3	4	15	19	5	2
21	2	2	2	10	23	1	5
22	1	1	1	6	18	4	1
23	2	-	2	2	14	3	2
24	1	1	5	1	15	3	1
25	6	2	-	1	13	4	1
26	3		3	2	9	4	1
27	4	-	2	2	11	-	
28	2	2	-	2	11	2	-
29	1	-	2	1	4	2	-
30	-	-	1	-	6	-	-
31	-	1	-	-	4	-	-
32	-	-	1	1	-	-	-
33	-	-	-		1		-
34	1	-	-	-	-	-	-
35	-	-	-	-	-	-	-
36	-	-	1	-	-	-	-
37	-	-	-	-	-	-	-

Appendix 4 Pooled length-frequency data for S. caeruleostictus in stratum C from June 1990 - May 1991.

FREQUENCIES

LENGTH (CM)	KETA	TEMA	ACCRA	WINNEBA	SALT-POND	CAPE-COAST	TAKO-RADI	HALF-ASSIN
5	-	-	-	1	4	0	-	-
6	1	-	-	2	9	5	-	-
7	8	2	5	1	13	20	-	-
8	10	10	14	21	18	34	-	-
9	16	8	9	10	23	20	-	-
10	31	34	23	52	37	25	2	-
11	59	48	23	51	23	18	-	-
12	61	48	20	52	44	20	3	-
13	47	54	16	38	40	1	4	-
14	43	39	18	61	40	1	8	-
15	39	33	30	52	25	3	7	-
16	22	26	42	14	37	10	6	-
17	13	29	31	42	36	4	2	-
18	9	23	35	41	45	3	3	1
19	6	19	22	20	33	4	5	-
20	7	29	22	19	31	5	2	-
21	4	3	15	15	29	1	5	1
22	5	10	9	8	24	7	1	-
23	9	6	11	3	21	3	2	1
24	6	10	11	6	22	4	1	2
25	11	8	6	2	16	5	1	3
26	8	12	13	15	11	5	1	5
27	14	14	10	7	11	2	-	14
28	13	12	6	4	12	3	-	8
29	14	8	2	6	5	2	-	6
30	7	7	1	2	6	-	-	5

Appendix 5 Pooled length-frequency data for *S. caeruleostictus* in sectors from June 1990 - May 1991.

LENGTH (CM)	KETA	TEMA	ACCRA	WINNEBA	SALT-POND	CAPE-COAST	TAKO-RADI	HALF-ASSIN
31	2	4	–	1	3	–	–	2
32	2	4	1	3	1	–	–	–
33	–	2	–	3	1	–	–	–
34	1	1	–	–	–	–	–	–
35	–	–	–	–	–	–	–	–
36	–	–	1	–	–	–	–	–
37	–	–	–	–	–	–	–	–
38	–	–	–	–	–	–	–	–
39	–	1	–	–	–	–	–	–

Appendix 5: (cont'd)

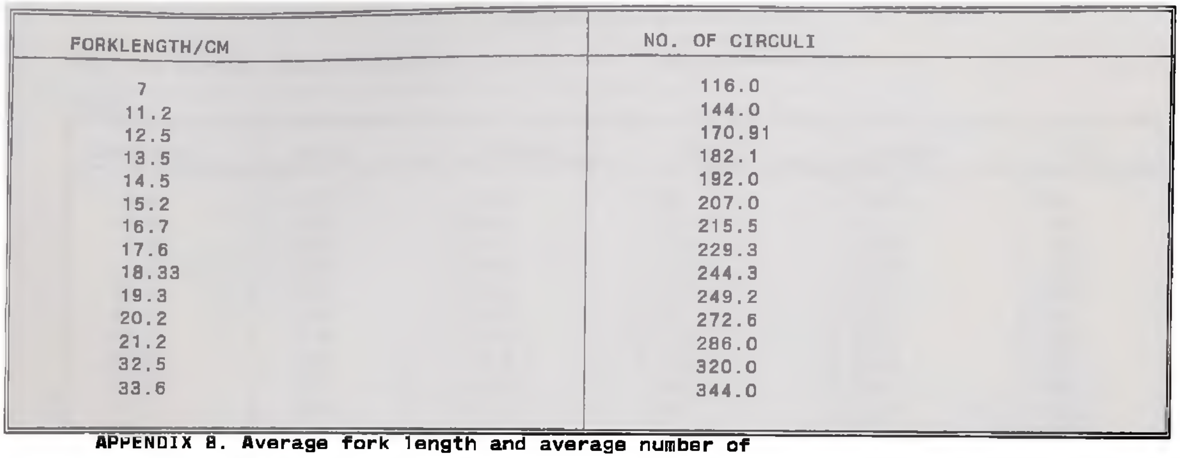
FREQUENCY

LENGH	JUNE	JULY	AUG.	SEPT	OCT.	NOV.	DEC.	FEB.	MAR.	APRIL	MAY
cm	1990	1990	1990	1990	1990	1990	1990	1991	1991	1991	1991
5	0	4	1	0	0	1	0	0	0	1	0
6	3	9	4	0	0	0	0	0	0	1	0
7	22	13	32	0	0	2	0	1	0	0	4
8	20	16	54	0	0	1	0	1	2	7	0
9	15	22	51	0	0	3	0	1	1	4	1
10	18	14	125	7	1	24	1	0	2	14	7
11	42	3	112	6	6	35	0	0	1	15	7
12	32	0	112	12	13	75	3	0	2	7	9
13	38	0	55	12	23	108	4	0	3	2	8
14	27	1	37	10	16	103	8	7	3	0	1
15	38	1	34	3	22	88	7	12	6	0	3
16	38	2	22	7	6	70	6	7	15	1	9
17	41	8	30	5	2	43	2	3	19	0	6
18	53	5	31	6	2	36	3	8	15	0	2
19	31	9	27	5	1	17	5	1	4	0	10
20	30	5	36	3	2	16	2	2	6	0	3
21	20	11	13	4	2	23	5	2	3	0	2
22	21	6	14	4	0	18	1	1	2	0	1
23	17	5	14	3	1	19	2	0	1	0	2
24	22	6	7	4	0	14	1	2	3	0	4
25	19	1	7	5	1	19	1	0	1	0	0
26	26	1	17	6	1	14	0	1	3	0	2
27	17	4	10	14	1	19	0	1	3	0	0
28	10	4	13	9	0	21	0	0	2	0	0
29	11	1	9	7	0	13	0	0	2	0	0
30	1	0	2	5	0	19	0	0	0	0	1
31	3	0	1	2	0	6	0	0	0	0	0
32	3	0	0	0	0	5	0	0	0	0	0
33	1	0	0	0	0	2	0	0	0	0	0
34	1	0	0	0	0	1	0	0	0	0	0
35	1	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	2	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0
39	0	0	0	0	0	1	0	0	0	0	0

APPENDIX 6. Pooled length-frequency data for *S. caeruleostictus* for the entire continental shelf (sectors and strata) from June 1990 - May 1991.

FORKLENGHTH/CM	**SCALE LENGTH/MM**
16.8	5
21.2	7.5
17.8	6.0
32.0	8.5
20.2	7.0
18.0	6.0
15.0	6.5
18.3	5.0
16.6	7.0
15.2	6.0
11.0	5.0
25.2	3.5
7.0	7.0
33.0	3.0
15.2	9.0
20.1	5.0
19.0	7.0
17.4	6.0
13.5	6
19.2	4.5
18.9	6.5
14.5	7.0
15.5	5.0
14.0	5.0
16.8	5.0
14.0	5.0

APPENDIX 7. Average fork length and average scale length for *S. caeruleostictus.*

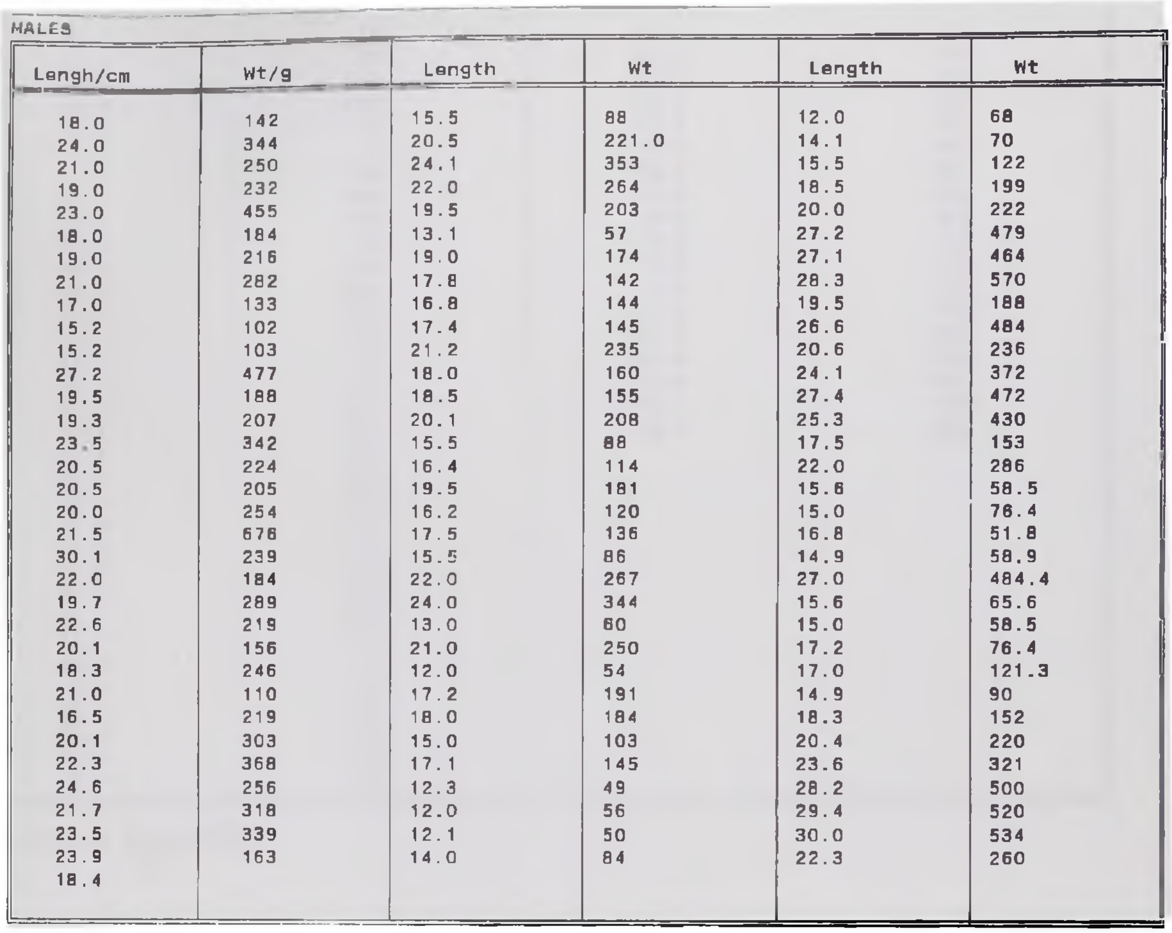


FORKLENGTH/CM	NO. OF CIRCULI
7	116.0
11.2	144.0
12.5	170.91
13.5	182.1
14.5	192.0
15.2	207.0
16.7	215.5
17.6	229.3
18.33	244.3
19.3	249.2
20.2	272.6
21.2	286.0
32.5	320.0
33.6	344.0

APPENDIX 8. Average fork length and average number of circuli for *S. caeruleostictus.*

Length Wt. Relationship

Species. Sparus Caeruleostictus



MALES

Lengh/cm	Wt/g	Length	Wt	Length	Wt
18.0	142	15.5	88	12.0	68
24.0	344	20.5	221.0	14.1	70
21.0	250	24.1	353	15.5	122
19.0	232	22.0	264	18.5	199
23.0	455	19.5	203	20.0	222
18.0	184	13.1	57	27.2	479
19.0	216	19.0	174	27.1	464
21.0	282	17.8	142	28.3	570
17.0	133	16.8	144	19.5	188
15.2	102	17.4	145	26.6	484
15.2	103	21.2	235	20.6	236
27.2	477	18.0	160	24.1	372
19.5	188	18.5	155	27.4	472
19.3	207	20.1	208	25.3	430
23.5	342	15.5	88	17.5	153
20.5	224	16.4	114	22.0	286
20.5	205	19.5	181	15.6	58.5
20.0	254	16.2	120	15.0	76.4
21.5	676	17.5	136	16.8	51.8
30.1	239	15.5	86	14.9	58.9
22.0	184	22.0	267	27.0	484.4
19.7	289	24.0	344	15.6	65.6
22.6	219	13.0	60	15.0	58.5
20.1	156	21.0	250	17.2	76.4
18.3	246	12.0	54	17.0	121.3
21.0	110	17.2	191	14.9	90
16.5	219	18.0	184	18.3	152
20.1	303	15.0	103	20.4	220
22.3	368	17.1	145	23.6	321
24.6	256	12.3	49	28.2	500
21.7	318	12.0	56	29.4	520
23.5	339	12.1	50	30.0	534
23.9	163	14.0	84	22.3	260
18.4					

Appendix 9 Weights and lengths for male S. caeruleostictus.

MALES CONTD.

Length	Wt	Length	Wt
27.4	476	14.2	72
14.3	77	15.2	74
16.1	110	11.3	48
22.0	264	16.3	144
13.0	80	12.4	58
15.2	74	19.7	184
16.3	140	18.4	163
17.0	188	23.2	300
18.2	184	13.1	60
12.0	55	16.5	113
19.2	236	15.0	72
23.0	313	17.8	156
24.0	344	17.0	150
19.3	235	24.1	350
14.0	70	20.0	208
20.0	219	20.0	201
21.2	234	19.1	105
23.4	320	16.2	140
27.2	470		
29.4	524		
32.0	531		
21.0	230		
16.2	130		
17.8	194		
19.2	231		
31.0	527		
22.1	271		
14.3	78		
15.6	86		
20.2	220		
13.4	60		
18.2	184		
13.0	59		

Appendix 9 (cont'd).

FEMALES

Length	Wt	Length	Wt	Length	Wt
22.1	267	16.6	125	14.1	78
21.0	276	18.3	154	19.1	214
17.1	191	15.0	82	19.2	216
17.0	145	17.3	139	21.3	282
19.0	214	15.9	100	17.2	133
15.5	122	17.5	132	26.4	454
18.5	199	18.0	136	26.3	503
20.0	222	14.0	80	22.0	273
26.3	502	17.5	130	21.2	264
22.0	272	15.0	82	19.3	207
21.3	266	14.5	79	18.0	154
27.1	464	18.9	167	23.5	340
28.2	569	19.2	171	22.5	310
18.0	152	13.5	66	26.5	479
22.5	310	18.5	162	24.0	370
19.3	187	18.1	150	23.5	378
23.0	304	15.9	106	23.7	356
24.9	400	16.0	90	15.0	55.7
20.4	210	18.5	163	15.4	95.5
17.9	139	19.0	182	17.0	60.2
12.1	43	21.6	246	28.0	472.2
21.5	243	18.5	110	22.1	231.8
18.0	148	15.5	88	19.0	187.0
18.7	176	14.0	66	18.5	147.4
17.0	121	20.0	234	22.0	218.2
14.0	64	18.0	142	18.5	150.5
15.6	107.5	19.0	170	21.6	242.0
18.3	155.5	15.0	102	19.0	214.0
12.9	54.5	19.1	232	18.5	149.0
18.5	160.0	23.2	216	16.0	95.5
14.7	82.5	15.1	108	15.5	84
15.2	98	21.0	276	17.5	132
15.2	92	23.4	455	16.2	120

Appendix 10 Weigths and lengths of female S. caeruleostictus

MONTHS	CONDITION FACTOR (K) PRESENT STUDY	RIJAVECS STUDY
MARCH	2.83	2.34
APRIL	2.81	2.33
MARCH	2.84	2.41
JUNE	2.85	2.39
JULY	2.80	2.31
AUGUST	2.97	2.48
SEPT	2.94	2.45
OCT	2.93	2.47
NOV.	2.95	2.42
DEC.	2.85	2.33
JAN	2.97	2.45
FEB.	2.82	2.34

APPENDIX 11. Mean monthly condition for the present study and Rijavec's (1973) study.

t/per year.	dt	L(t)/cm	dL(t)/cm	$\frac{dL(t)}{dt}$	L(t+)+L(0)/2 1 cm
0.5		9.240		17.042	13.501
1.0	0.5	17.761	8.521	9.100	20.036
1.5	0.5	22.311	4.550	8.214	24.365
2.0	0.5	26.418	4.107	10.160	28.958
2.5	0.5	31.498	5.08		

APPENDIX 12. Input data for the Gulland and Holt plot.

t/yr	L(T)/CM	-LN(1-L(T)/L_{∞}
0.5	9.240	0.225
1.0	17.761	0.490
1.5	22.311	0.667
2.0	26.418	0.859
2.5	31.498	1.163

APPENDIX 13 Input data for the von Bertalanffy plot

t/yr	L(t)/CM	L(t+dt)
0.5	9.240	17.761
1.0	17.761	22.311
1.5	22.311	26.418
2.0	26.418	31.498

APPENDIX 14 Input data for the Ford-Walford plot.

Interval	C	X*)	N	F/Z	F	Z
4.00- 6.00	14.500	1.0464	6689.66	0.0244	0.0214	0.8774
6.00- 8.00	133.000	1.0490	6095.30	0.1948	0.2071	1.0631
8.00- 10.00	255.000	1.0518	5412.55	0.3343	0.4299	1.2859
10.00-12.00	466.000	1.0550	4649.82	0.5098	0.8902	1.7462
12.00-14.00	492.000	1.0587	3735.71	0.5673	1.1225	1.9785
14.00-16.00	412.000	1.0628	2868.51	0.5750	1.1580	2.0140
16.00-18.00	331.000	1.0675	2151.96	0.5769	1.1673	2.0233
18.00-20.00	243.000	1.0731	1578.24	0.5598	1.0886	1.9446
20.00-22.00	171.500	1.0796	1144.16	0.5337	0.9797	1.8357
22.00-24.00	129.000	1.0874	822.82	0.5263	0.9512	1.8072
24.00-26.00	121.500	1.0969	576.78	0.5837	1.2001	2.0561
26.00-28.00	134.500	1.1087	368.61	0.7077	2.0724	2.9284
28.00-30.00	86.500	1.1238	178.56	0.7578	2.6783	3.5343
30.00-32.00	30.500	1.1438	64.41	0.7289	2.3020	3.1580
32.00-34.00	8.500	1.1714	22.57	0.6354	1.4915	2.3475
34.00-36.00	3.000	1.2123	9.19	0.5544	1.0649	1.9209
36.00-38.00	1.000	1.2787	3.78	0.4445	0.6850	1.5410
38.00- plus	1.000	0.0000	1.53	0.6540	1.6180	2.4740

*) X = ((L8-L(i))/(L8-L(i+1)))-(M/2K)

Interval	W +)	meanN *)	meanN*W	C*W
4.00- 6.00	0.0387	677.4041	26.2281	0.5614
6.00- 8.00	0.0995	642.5382	63.9317	13.2395
8.00-10.00	0.2049	593.1345	121.5479	52.2558
10.00-12.00	0.3671	523.4951	192.1522	171.0482
12.00-14.00	0.5980	438.3197	262.1299	294.2325
14.00-16.00	0.9099	355.7796	323.7112	374.8641
16.00-18.00	1.3145	283.5589	372.7343	435.0949
18.00-20.00	1.8238	223.2174	407.0985	443.1776
20.00-22.00	2.4496	175.0532	428.8026	420.0989
22.00-24.00	3.2036	136.1443	436.1520	414.8665
24.00-26.00	4.0976	101.2458	414.8691	497.8637
26.00-28.00	5.1434	64.8992	333.8015	691.7846
28.00-30.00	6.3525	32.2967	205.1639	549.4885
30.00-32.00	7.7365	13.2496	102.5060	235.9642
32.00-34.00	9.3072	5.6991	53.0420	79.1109
34.00-36.00	11.0759	2.8171	31.2015	33.2278
36.00-38.00	13.0544	1.4403	18.8018	13.0544
38.00 Plus	15.2249	0.6181	9.4098	15.2249
		Total	3803.2842	4735.1582

) meanN(i) = (N(i)-N(i+1))/Z(i) +) W(i) = a(L(i) b+L(i) b)/2

Mean F (L > 4) : .6502 (weighted by stock number)

Appendix 15 Computational details of the cohort analysis of *S. caeruleostictus*.

Forlkength/cm	Total length/cm
14.9	1.2
14.9	1.0
15.0	1.0
15.0	1.2
15.6	2.0
16.8	1.9
16.8	2.1
16.8	3.2
18.0	2.2
18.0	2.5
18.1	3.2
20.1	1.5
20.1	3.0
21.2	1.5
22.0	2.8
23.9	2.3
24.2	3.2
24.7	3.3
25.2	3.0
26.0	4.0

Appendix 16 Fork lengths of predator fish(S. caeruleostictus) with their corresponding total lengths of prey fish.

LENGTH GROUP (CM)	IMMATURE FISH	MATURE FISH	TOTAL NO. OF FISH	% OF MATURED FISH
11.5 - 12.5	5	0	5	0
12.5 - 13.5	15	0	15	0
13.5 - 14.5	15	0	15	0
14.5 - 15.5	33	0	33	0
15.5 - 16.5	12	3	15	20 ✓
16.5 - 17.5	32	19	51	37.25
17.5 - 18.5	4	48	52	92.30
18.5 19.5	0	25	25	100
19.5 - 20.5	0	4	4	100
20.5 21.5	0	10	10	100
21.5 - 22.5	0	12	12	100
22.5 23.5	0	6	6	100
23.5 24.5	0	11	11	100
24.5 - 25.5	0	2	2	100
25.5 26.5	0	16	16	100
26.5 - 27.5	0	0	0	100
27.5 28.5	0	3	3	100
28.5 29.5	0	0	0	100

APPENDIX 17 Fork lengths and corresponding percentage maturities for *S. caeruleostictus*.

LENGTH GROUP (CM)	IMMATURE FISH	MATURE FISH	TOTAL NO. OF FISH	% OF MATURED FISH
11.5 - 12.5	4	0	4	0
12.5 - 13.5	16	0	16	0
13.5 - 14.5	17	0	17	0
14.5 - 15.5	20	0	20	0
15.5 - 16.5	22	0	22	0
16.5 17.5	28	0	28	0
17.5 18.5	36	12	48	25
18.5 - 19.5	7	29	36	80
19.5 - 20.5	0	6	6	100
20.5 - 21.5	0	10	10	100
21.5 22.5	0	8	8	100
22.5 23.5	0	11	11	100
23.5 - 24.5	0	7	7	100
24.5 - 25.5	0	0	0	0
25.5 26.5	0	3	3	100
26.5 - 27.5	0	4	4	100
27.5 28.5	0	2	2	100
28.5 - 29.5	0	0	0	0

APPENDIX 18 Fork lengths and corresponding percentage maturities for *S. caeruleostictus*.

MONTHS AND YEAR	MATURED FISH	NUMBER SPAWNING	% OF FISH SPAWNING
MARCH 1992	11	0	0
APRIL 1992	14	0	0
MAY 1992	7	0	0
JUNE 1992	8	0	0
JULY 1992	5	1	20
AUGUST 1992	8	2	25
SEPTEMBER 1992	18	13	72
OCTOBER 1992	13	11	84
NOVEMBER 1992	20	4	20
DECEMBER 1992	17	1	5
JANUARY 1993	13	8	61
FEBRUARY 1993	12	4	33
MARCH 1993	22	2	9

Appendix 19 Percentage of gravid females of *S. caeruleostictus*.