International Council for the
Exploration of the Sea

C.M. 1994/G:26
Demersalfish Committee

STUDY ON THE GROWTH OF BLACK MONKFISH (*Lophius budegassa*, Spinola) AND WHITE ANGLERFISH (*L. piscatorius*, L.) OF ICES STOCK IN DIVISION VIIIc+IXa

by

Rafael Duarte*
Manuela Azevedo*
Pilar Pereda**

*Instituto Português de Investigação Marítima
Avenida de Brasília, 1400 Lisboa
PORTUGAL

**Instituto Español de Oceanografía
Apdo 240, 39080 Santander
ESPAÑA

ABSTRACT

Black monkfish growth parameters of ICES stock in Division VIIIc+IXa were obtained by sex and for combined sexes, based on age reading performed on 336 *illicia*. Black monkfish were caught along the Portuguese coast, between 1989 and 1993. A brief description of the preparation and observation of the sections is presented. The age of the fish was considered at the 1st January and back-calculation procedures were applied to infer the fish length at that time. The growth parameters were estimated fitting the von Bertalanffy growth model by non-linear methods. The results show different growth pattern by sex, attaining females higher body lengths. The growth parameters were estimated for combined sexes based on the overall sample, which sex-ratio of 1:1.3 (females *vs* males) is considered to be representative of that of the exploited population. The results were as follows: L=101.69 cm, k=0.08 year^{-1} and t_0=-0.2 year. It is considered that these results may contribute to improve the assessment of this stock.

White monkfish growth parameters of the same stock as previous species were calculated for sexes combined, based on age reading of 244 illicia. Fish were caught in 1990 and 1993 in VIIIc and IXa ICES Divisions, which length were included beetween 12 and 99 cm. The results were as follows: $L\infty =$ 121.54 cm, $K = 0.102$ $t_o =$ 0.032 .

It is considered that these results may contribute to improve the assessment of these stocks.

Introduction

In spite of both species of monkfish (*Lophius budegassa) and (L. piscatorius)* have an important economical value in the Portuguese and Spanish fisheries both in trawl and artisanal in VIIIc and IXa ICES Divisions , their biology is poorly known.
Black monkfish and white monk fish are landed jointly. Mean catch was near 5000 tonnes of white monkfish and 2500 tonnes of black monkfish from the southern stock that include the ICES Divisions VIIIc and IXa.
In general white angler fish is more abundant, although in the Division IXa both species are caught in similar quantities.

Growth of this species has been studied in other areas (Fulton 1902, Guillou 1978, Tximenidis et Ondrias 1890, Dupouy et Kergoat 1985, 1986) but we have no knowledge of growth studies of specimens caught in the so called southern stock.

The monkfish stocks in ICES Division VIIIc+IXa are annually assessed within the ICES working Group for the Assessment of Southern Shelf Demersal Stocks. Azevedo (1992) provided, for the first time, growth parameters for the stock of *L. budegassa* obtained for combined sexes using Shepherd´s Robust Length Composition Analysis, SRLCA (Shepherd, 1987) and, for L. piscatorius growth parameters were provided to the 1993 Working Group which estimation was based on the mean length at age observed in direct readings (Pereda com. pers.). During the 1993 WG meeting, an attempt was made to assess these stocks using analytical stock assessment methods (Annon, 1994).

Black monkfish *(L. budegassa)*

Material

The analyzed *illicia* were collected on board several bottom trawl research surveys carried out by the Portuguese Institute for Marine Research (IPIMAR). During October/90, October/91, July/92, June/93 and November/93 the sampled area was the entire Portuguese coast, while in June/89, July/89, February/92, April/93, and December/93 only the southwest and south zone of the Portuguese coast (south of Lisbon) was sampled.

A total of 391 black monkfish *illicia* were retrieved, being also registered the individual length, weight and sex. These specimen were mainly caught in the area south of Lisbon.

Methods

Preparation and observation of the sections

All the pre-reading can be divided in three phases: setting the plates, blade sectioning and the preparation of readings. These phases are very important in order to assure the clearness of growth rings observation. For the setting of the plates, the *illicia* should first be defrosted. Through previous practice it is shown that the annual rings are best distinguished 0.5 cm above the base of the *illicium* (Figure 1). Therefore it is only necessary to put on the plate the part between 0.5 cm above the base till the half point of the *illicium*.

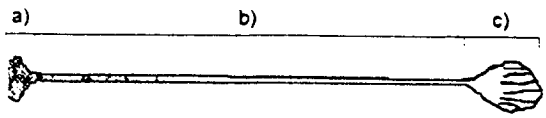

Figure 1: *Illicium* of *L.budegassa*: a) Peduncle or base, b) Stem, c) Cutaneous bulb.

All the black monkfish *illicia* were mounted on plates consisting of a mixture of four components which were resine, a black colour dye, hardener and a catalyser. A 0.5 mm section thickness was realized with a diamond blade to have an optimal observation of the rings. To improve the observation of the rings a mixture of glycerin and alcohol 70% covering the section was adopted.

Readings were performed with an optical microscopy using a magnification between 100 and 120 times and a microcomputer-based system that films and displays on a screen the image amplified by the microscope. This system was used to measure the *illicium* and the annual rings (*annuli*) radius. A total of 336 black monkfish were finally aged, consisting of 144 females, ranging from 19.4cm to 65.5cm and 192 males, their length ranging from 19.5cm to 56.0cm. This sample represents a sex ratio of 1:1.3 (females *vs* males).

Treatment of the results

Main difficulties in age reading appear for the youngest and the oldest ages. In order to verify if the *annuli* determination for the young black monkfish was not biased, an analyse of variance (ANOVA) was performed to test the significance of the differences of the measurements corresponding to the 1st, 2nd, 3rd and 4th rings observed between younger, where 4 rings were observed and older individuals, where 8 rings could be observed. Differences between sexes were also tested. The statistical requirements of normality, homocedasticity and uncorrelated means and standard deviations where verified.

To determine the period of the year when the deposition of the *annuli* occurs we analyzed, by quarter, the evolution of the distance between the last *annuli* and the border of the *illicium*. This distance was computed by subtracting from the total radius the last *annuli* radius. When a new *annuli* is being deposited this distance should reach it's annual maximum and after that it should reach it's annual minimum.

The age of the fish was attributed according to the number of annual rings present on the section. Since the black monkfish were caught at different seasons and the age was considered at the 1st January than the growth between the 1st January and the date of capture corresponds to a certain time interval that is not accounted for in terms of time by the determination of the annual rings. This error can be passed by back-calculating the total length correspondent to the growth just till the time of formation of the last *annuli* (Weatherley & Gill, 1987). To do this an initial regression of the radius of the *illicia* with the total body length or vice versa is made (Francis, 1990). This author refers that the relation between body length and the radius of the analyzed structure is a central part of the back-calculation procedure and also that there are always two functions that can be obtained by the regression of the body length (C) on the structures radius (I) and of I on C. The author mentions further that this question is sometimes ignored in favour of the C on I regression with the false argument that only this type of regression permits to calculate body length from structure radius. In this paper, both regressions were performed.

The von Bertalanffy growth model was fitted to estimate the growth parameters. This fit can be performed using linear and non-linear methods. The non-linear methods are almost in all cases the most accurate and precise (Vaughan *et.al.*,1982) and therefore, the iterative non-linear method of Quasi-Newton was used.

Results

Differences between older and younger individuals and sexes

Table 1 presents the mean *annuli* radius (micron) and their standard deviation for *annuli* 1 to 4 in younger monkfish (4 *annuli*) and for *annuli* 1 to 8 in older monkfish (8 *annuli*) by sex.

Table 1 - Black monkfish mean *annuli* radius (micron) and standard deviation by sex (F-female, M-male) observed for individuals with 4 and 8 *annuli*.

N° of *annuli*	Sex		*annuli* 1st	2nd	3rd	4th	5th	6th	7th	8th
4	F	Number	10	10	10	10				
		Mean	31.18	58.76	86.59	111.35				
		St. dev.	4.70	12.87	16.43	20.18				
8	F	Number	5	5	5	5	5	5	5	5
		Mean	32.23	59.62	94.59	122.67	150.75	185.05	221.69	254.17
		St. dev.	3.48	6.47	10.47	17.50	19.52	26.13	36.86	38.98
4	M	Number	10	10	10	10				
		Mean	31.75	54.00	81.63	109.82				
		St. dev.	4.48	11.61	12.46	12.72				
8	M	Number	10	10	10	10	10	10	10	10
		Mean	30.58	54.24	83.05	109.43	137.14	167.57	197.05	228.31
		St. dev.	5.33	7.49	10.77	11.35	10.45	12.07	15.51	13.16

Table 2 presents the p-values corresponding to the ANOVA tests performed on main effects *annuli* and sex at the 5% significance level. It is therefore concluded that there are no significant differences between *annuli*, these results suggesting that the younger black monkfish *annuli* observations were unbiased. On the other hand, there are also no significant differences between sexes.

Table 2 - P-values of the tests performed by *annuli* and sex.

Effect	*annuli* 1st	2nd	3rd	4th	5th	6th	7th	8th
4 and 8 *annuli*	0.97	0.88	0.32	0.33	—	—	—	—
Sex	0.76	0.18	0.08	0.19	0.35	0.24	0.20	0.17

Time of the year of deposition of the annuli

The mean (micron) and standard deviation of the differences between the last *annuli* and the *illicium* border is presented in Table 3, by quarter. These results point out higher mean differences during the 1st and 4th quarter of the year, which contrasts with the lower means observed during the 2nd and 3rd quarter and suggesting two distinct growth periods.

Table 3 - Quarterly mean (micron) and standard deviation of the differences between the last *annuli* and the *illicium* border observed in the aged black monkfish.

	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
Nb.	8	206	88	34
Mean	18.10	13.90	11.42	17.81
St. dev.	8.10	6.34	5.79	7.35

Planned comparison tests were performed in order to statistically validate the empirical results referred regarding the two growth periods. The resulting p-value was 0.0001, which is much lower than the 5% significance level adopted and therefore, the null hypothesis of no differences between the two groups (1st and 4th quarter against 2nd and 3rd quarter) was rejected.

Back-calculation of the total length

Figures 2 and 3 present the relation between the radius of the *illicia* (I) and the total length of the fish (C), by sex. The visual analyses of both graphs suggests that these relations are linear but, retrograding C in I or vice versa, with linear and non-linear expressions it is shown that the regression that best explains this relation is non-linear and is obtained retrograding I on C, using the following equation: $I = a + b * C^V$. For the females this expression explains 90.9% of the total variance, with a regression constant of 0.95 while for males these values where respectively 81.7% and 0.90. The equation parameters obtained by sex are presented in Table 4, and these where used to back-calculate the body lengths following the four stages implicit in the Structure Proportional Hypotheses (SPH) method (Francis, 1990).

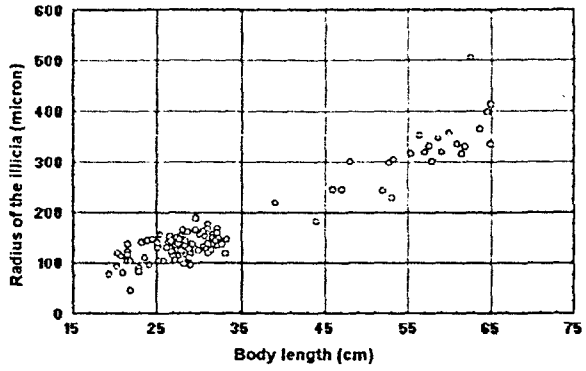

Figure 2: Relation between the body length (C) and the radius of the *Illicium* (I) for females.

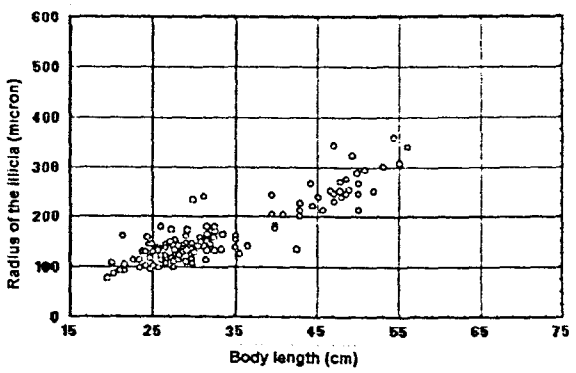

Figure 3: Relation between the body length (C) and the radius of the *Illicium* (I) for males.

Table 4 - Parameters values obtained using the regression of I on C with the expression: $I = a + b * C^v$, for black monkfish females and males.

	Females	Males
a	61.04	77.72
b	0.15	0.03
v	1.84	2.22

Estimation of the growth parameters

The back-calculated lengths at the 1st January where used to estimate the growth parameters by sex and for both sexes, according to the von Bertalanffy growth model (Table 5). To estimate the parameters for the combined sexes the growth model was applied to the overall sample since the sex-ratio of this sample was considered to be representative of the sex-ratio of the exploited population (1:1.3 according to Azevedo, *pers.comm.*). Since the minimum observed length of the black monkfish analyzed in this study was 19.4cm, corresponding to 2 years old individuals, the parameter **to** was subsequently modified to adjust the first age length. The resulting growth curves by sex are presented in Figures 4 to 5.

Table 5 - Black monkfish growth parameters by sex and for sexes combined.

	Females	Males	Females + Males
L_{oo} (cm)	105.91	81.66	101.69
K ($year^{-1}$)	0.08	0.11	0.08
t_o (year)	-0.20	-0.10	-0.20

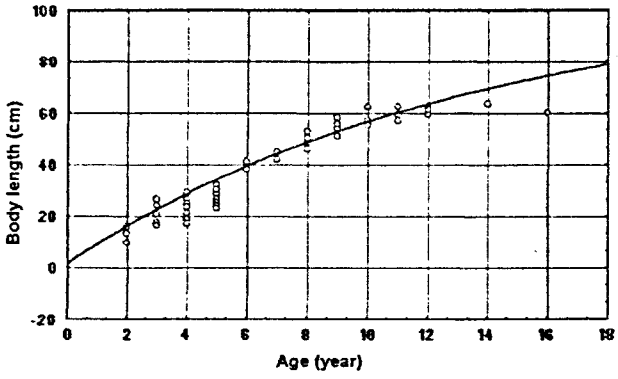

Figure 4: Von Bertalanffy growth curve for females.

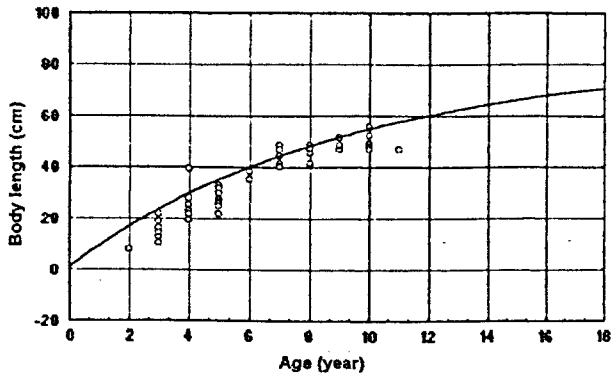

Figure 5: Von Bertalanffy growth curve for males.

Conclusions

Black monkfish presents two distinct periods of growth: one in spring and summer with a lower distance between the last *annuli* and the border of the *illicium* and the other in autumn and winter where the highest distance appears. The observed increase in this distance, from the summer period to the winter, is a consequence of the black monkfish growth that happens during the 2nd and 3rd quarters of the year. The observed decrease from the winter period to the summer is a consequence of the deposition of a new *annuli* during the winter period of low growth.

The relation between the body length and the radius of the *illicia* is non-linear, being a SPH (Francis, 1990) that shows that the radius of the *illicia* is a consequence of the body length (Sokal, 1981).

The estimated growth parameters by sex indicate that females attain higher lengths than males (L_∞=**105.91**cm for females and L_∞=**81.66**cm for males), presenting initially a slower growth. This feature is also observed for black monkfish stock in ICES Division VIIb,k+VIIIa,b where the range of the growth parameters, estimated by Dupouy *et. al.* (1986) also based on age reading, are as follows: L_∞: 105-111 cm, k: 0.07-0.08 year^{-1} and t_0: 0.50-0.70 year for females and L_∞: 76-85 cm, k: 0.10-0.11 year^{-1} and t_0: 0.56-0.80 year for males. The maximum black monkfish length observed between 1988 and 1993 in Portuguese waters was around 98cm, being this specimen a female.

White monkfish *(L. piscatorius)*

Material

The illicia were collected in the market of Santander along the year 1990 and 1993. The white monkfish were caught in The Cantabrian Sea, VIIIc ICES Division.

Length composition were from the catch made during several bottom trawl surveys carried out by the "Instituto Español de Oceanografía" from 1983 until 1993. All the surveys were carried out in autumn in the Cantabrian Sea and Galician coast.

Methods

The methodology was based on the described by Dupouy and Kergoat (1986) modificated and adapted to the means of our laboratory.

The *illicia* were cut completed with the help of a scissors and kept into an envelope individually. For each *illicia* name of the specie, length, sex, date, area, etc were recorded.

In the laboratory the each piece was skinned and the 2 cm part near the base was stocked. The pieces were mounted in resin black coloured into small moulds made of cardboard. Once the moulds were dried and were cut in slices of 0.5 mm approximately. Each slice was cut in duplicate. Slices were preserved into a solution of alcohol (70%) with glycerine and water in the same proportion. This conservation liquid clarified the cuts for the identification of growth rings.

The lecture was made with a binocular microscope using a magnification of 50 and trasmited or reflected light. A video monitor was adopted to the microscope which easy the lecture of the rings.

The interpretation of the rings was made following the criteria adopted during the French-Spanish Work Shop of ageing of monk and megrim Annon 1991.

Length distribution of the white monkfish caught during annual bottom trawl surveys carried out by the Spanish Institute of Oceanography in autumn (September-October) from 1982 to 1993 (exception 1987), employing a standardized stratified random sampling design (Pereiro et al 1991) were plotted and split into theoretical components, when possible, using Harding method (Harding 1949 in Pereiro 1982).

Results

Results of direct lectures of the *illicia* cuts for the first ages were as follows:

AGE	MEAN OBSERVED LENGTH	Nº OF SAMPLES
1.5	17.5	20
2.5	30.1	64
3.5	36.5	27
4.5	42.9	10
5.5	50.0	5
6.5	58.0	16
7.5	64.6	14

From this lectures the following growth parameters were stimated:

$$L_{inf} = 137cm \qquad K = 0.09 \qquad t_o = 0.19$$

L_{inf} value seemed excessively high if we take into account the biggest lengths observed both in the catches of the commercial fisheries and in those of the bottom trawl surveys, between 1988 and 1993 the maximum length landed was not superior of 127 cm.

When we fixed the value of L_{inf} previosly the new growth parameters resulted more robust.

$$L_{inf} = 121.54\ cm \qquad K = 0.102 \qquad t_o = 0.03$$

Last growth parameters are considered as preliminary if we take into account the reduced number of *ilicia* observed in comparison with the wide range of length that this species presents.

The Spanish Institute of Oceanography carry out bottom trawl surveys annually, length distribution of white monkfish caught during this surveys from year 1982 to 1993 (except 1987 when the survey did not take place an 1991 due to the reduced number of white monkfish caught) are represented in figures and .

This source of information is also limited because of the scarce number of specimens witch length over 40 cm and cast light on the first ages growth only. On the other hand the number of white anglerfish vary enormously from year to year, taking place a considerable reduction of the catches of this species along the series.

Two modes can be identified in the length distribution, the first nearby 17 cm, (between 15 cm and 21 cm), and the second around 30 cm (between 28 cm and 33 cm). In the table below are the recognized modes of the distribution represented in the aforementioned figures and the mean length and standard deviations of the respective distributions.

	1982	1983	1984	1985	1986	1988	1989	1990	1992	1993
1st Mean length	17	20	15	16	18	17	17	16	17.5	16
Standard deviation	2.5	3.5	3	3	4	1	2.5	1	4	2.5
1st Mode	17	19	15	16	18	17	16	17	21	17
2nd Mean length	31	32	33		27	30		32		
Standard deviation	3	6.5	3.5		5	4		6.5		
2nd Mode	29	30	31		28	30		33		

Mean length and modal length resamble to the mean length obteined fron the direct lectures.

Conclusions

Black monkfish presents two distinct periods of growth: one in spring and summer with a lower distance between the last *annuli* and the border of the *illicium* and the other in autumn and winter where the highest distance appears. The observed increase in this distance, from the summer period to the winter, is a consequence of the black monkfish growth that happens during the 2nd and 3rd quarters of the year. The observed decrease from the winter period to the summer is a consequence of the deposition of a new *annuli* during the winter period of low growth.

The relation between the body length and the radius of the *illicia* is non-linear, being a SPH (Francis, 1990) that shows that the radius of the *illicia* is a consequence of the body length (Sokal, 1981).

The estimated growth parameters by sex indicate that females attain higher lengths than males (L=105.91cm for females and L=81.66cm for males), presenting initially a slower growth. This feature is also observed for black monkfish stock in ICES Division VIIb,k+VIIIa,b where the range of the growth parameters, estimated by Dupouy *et. al.* (1986) also based on age reading, are as follows: L: 105-111 cm, k: 0.07-0.08 year^{-1} and t_o: 0.50-0.70 year for females and L: 76-85 cm, k: 0.10-0.11 year^{-1} and t_o: 0.56-0.80 year for males. The maximum black monkfish length observed between 1988 and 1993 in Portuguese waters was around 98cm, being this specimen a female.

The following parameters were obtained for combined sexes: L= 101.69 cm, k=0.08 year^{-1} and t_o=-0.2 year. Validation of age assessment is an essential and routine part of every study that

involves the extraction of age data from calcified structures of fish (Weatherley & Gill, 1987). By comparing these values with the parameters obtained by Azevedo (1992) for this stock (L=96 cm, K=0.06 year^{-1}, t_o=-0.2 year) it is seen that small differences occur. These were obtained using a length-frequency data analysis method (SRLCA) and although this method is accurate within certain constraints (Basson *et. al.*, 1988) it is considered that the results can be usefull to test the accuracy of the age determination.

Finally, it is suggested that the growth parameters presented in this study should be used in the black monkfish stock assessment

Growth parameters were obtained for white monkfish: L_{inf}= 121.54 cm, k= 0.102, t_o= 0.03.

A tentative of validation for the first two ages showed that directs lectures made on *illicia* cuts are in agrement with the age groups identified in the length frequency distribution from bottom trawl surveys.

We are conscious of the preliminarily of the results, however we suggest, as for the previous species, that the growth parameters presented in this study should be used for the assessment of the stock of white monk fish from the VIIIc and IXa ICES Divisions.

References

Azevedo, M.,1992. Update of monkfish Portuguese catch statistics. I.C.E.S. Working Paper to the 1992 Meeting of the ICES WG on the Assessment of the Southern Shelf Demersal Stocks, 14pp.

Basson, M.; Rosenberg, A. A. & Beddington J. R., 1988. The accuracy and reliability of two new methods for estimating growth parameters from length-frequancy data. *J. Cons. int. Expl. Mer*, 44: 277-285.

Bertalanffy, L. Von., 1938. A quantitative theory of organic growth (inquiries on growth laws II). *Hum. Biol.*, 10: 181-213.

Dupouy, H. et Kergoat B., 1985. Données sur la croissance de la baudroie blanche (lophius piscatori) des côtes françaises de l´Atlantique (Division CIEM VII et VIII).- I.C.E.S. Com C.M. 1985/G: 36: 22p.

Dupouy, H.; Pajot, R. & Kergoat, B., 1986. Etude de la croissance des baudroies, *Lophius piscatorius* et *L. budegassa*, de L´Atlantique Nord-Est obtenue à partir de l´illicium. *Rev. Trav. Inst. Pêches marit.*, 48: 107-131.

ICES, 1994. Report of the Working Group on the Assessment of Southern Shelf Demersal Stocks. Copenhagen, 6-15 September 1993. **C.M.1994/Assess:3**

Francis, R.I.C.C., 1990. Back-calculation of fish length: a critical review. *J. Fish Biol.* 36, 883-902.

Fulton, W.T., 1902. The distribution growth and food of the angler (*Lophius piscatorius* L.). *Rep. Fish. Bd. Scotland*, 21, Part III: 186-199, 1 tabl.

Guillou , A. 1978 Premieres observations sur la biologie des baudroies (*Lophius piscatorius* et *L. budegassa* Spinola) dans le golfe de Gascogne. *Rev. Trav. Inst. Peches marit.*, 42 (1 a 2).

Pereiro, J.A. 1982. Modelos al uso en dinámica de poblaciones marinas sometidas a explotación. Inf. Téc. Inst. Esp. Oceanog. nº 1 .

Pereiro, F.J., F. Sánchez and J. Fontela. 1991. Hake recruitment in the Southern stock (ICES Divisions VIIIc and IXa). Demersal fish Committee C.M. 1991/G:52.

Shepherd, J. G., 1987. A weakly parametric method for the analysis of length composition data. *In* Length-based methods in fisheries research. Ed. by D. Pauly and G. P. Morgan. ICLARM Conf. Proc., 13, Manila.

Sokal, R.R. & F.J. Rohlf, 1981. *Biometry. The Principles and Practice of Statistics in Biological Research.* San Francisco, Freeman and Company (2nd ed.).

Tsimenidis, N. CH. & J. CH. Ondrias, 1980. Growth stidies on anglerfish *Lophius piscatorius* L. 1758 and *Lophius budegassa* Spinola, 1807 in Greek waters. Thalassographica, volume 3, nº 2.

Vaughan, D.S. & P. Kanciruk, 1982. An empirical comparison of estimation procedures for the von Bertalanffy growth equation. *J. Cons. int. Explor. Mer*, 40:211-219.

Weatherley, A. H. & Gill, H.S., 1987. *The biology of fish growth.* Academic Press, N.Y.

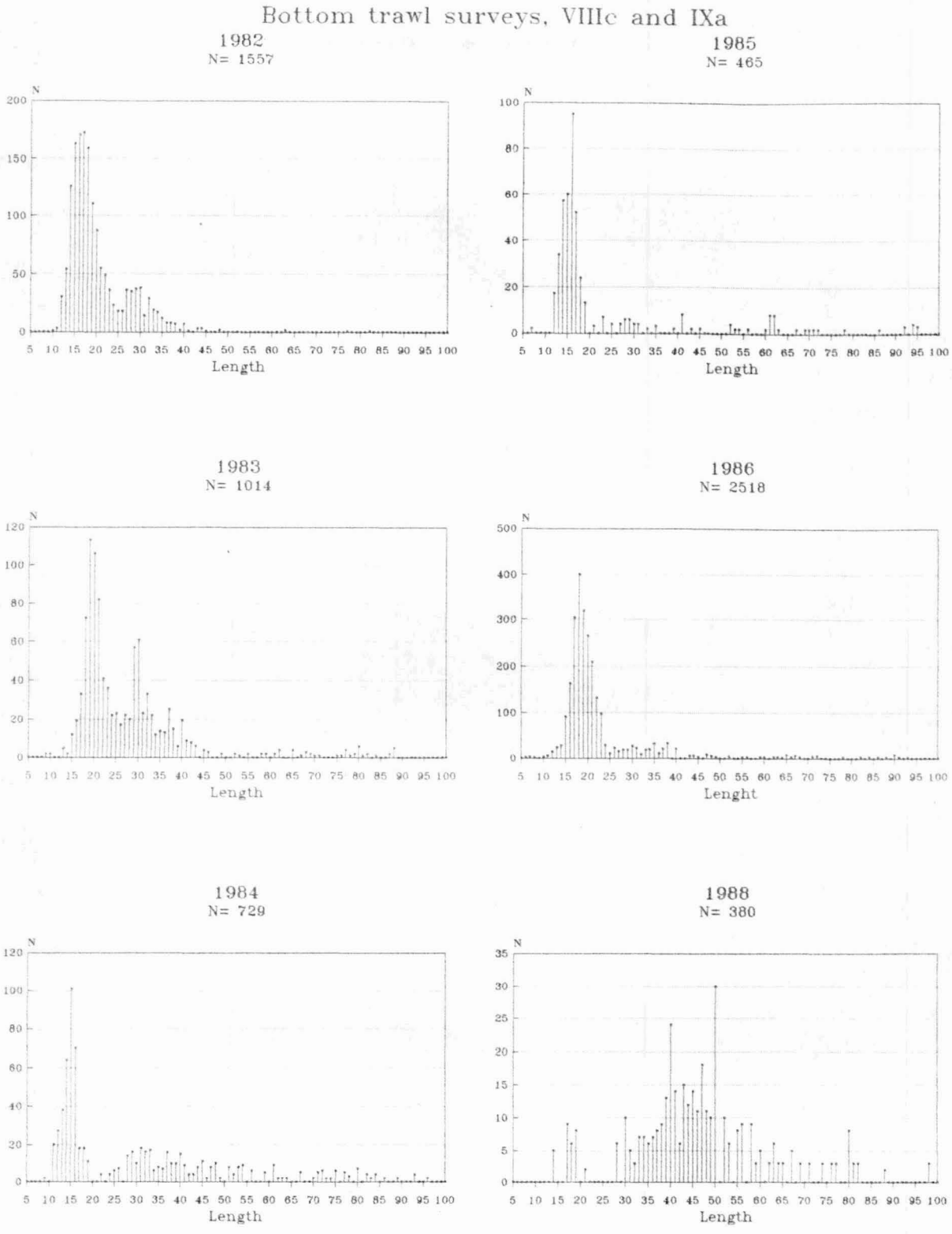

Fig. 6 Length distributions of white monk fish.

Bottom trawl surveys, VIIIc and IXa

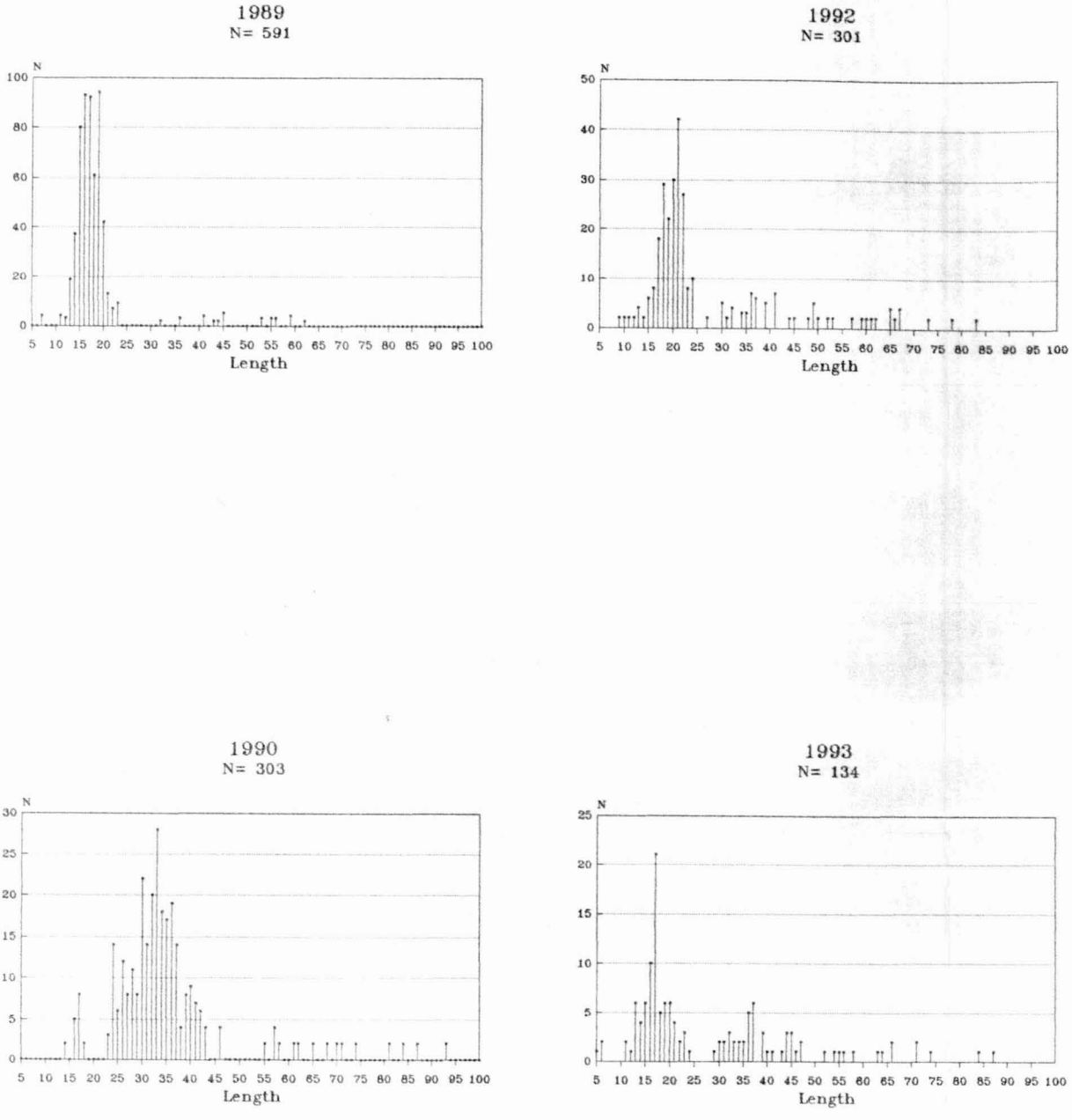

Fig. 7 Length distributions of white monk fish.