INTERNATIONAL COUNCIL FOR
THE EXPLORATION OF THE SEA

CM 1998/O: 47
Deep water Fish and Fisheries (O)

BIOLOGY OF BLACK ANGLERFISH (*Lophius budegassa*) IN THE BAY OF BISCAY WATERS, DURING 1996-1997

by

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ABSTRACT

A total of 1140 Black Anglerfish were analysed from monthly samples taken in the Bay of Biscay on board of commercial vessels and at the main fishing ports of the Basque Country during 1996-1997. The specimina length range was between 14.5-85.5 cm of total length.

The total length (cm)-total weight (g) relationship was described by the multiplicative function: $Wt = 0.015\ L^{3.004}$, $r = 0.9936$. Other relationships (total length–commercial gutted, –scientific gutted, –tail weight) were also obtained.The conversion factor for the commercial gutted (i.e. with liver) to total weight relationship was 1.21, and for the tail to total weight relationship was 2.54.

The reproductive period in the Bay of Biscay observed, by macroscopic and histological studies, extends from April to July with a peak in May-July. The L_{50} was calculated at 34.5 cm in length for males, at 64.5 cm for females and at 49.0 cm for both sexes. The A_{50} was calculated at 6,0 years in age for males, at 10.4 years for females and at 9.0 years for both sexes. Sex ratio in fish below 65 cm in length did not appear to depart from 1:1; above this length females predominated.

For growth studies, 2006 specimina were aged by illicia reading. Fish between 1-18 years old were found. Annual age-length keys were established. The annual parameters of the von Bertalanffy growth equation were for both sexes: $L_\infty = 100$, $t_0 = 1.4581$, $K = 0.1102$, for Males: $L_\infty = 100$, $t_0 = 1.1015$, $K = 0.1001$ and for Females: $L_\infty = 100$, $t_0 = 1.4772$, $K = 0.1113$.

Key-words: *Lophius budegassa*, biology, growth, reproduction, illicia, age, Bay of Biscay.

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INTRODUCTION

Black Anglerfish (*Lophius budegassa* (Spinola 1807)) is a lophiiform fish distributed from Barents Sea to Gulf of Guinea and Mediterranean Sea at depths ranging from 50 to more than 800 meters. Multispecific fisheries catch this species in ICES Sub-areas VI to IX. France, Spain, United Kingdom and Ireland take the major proportion of these catches.

Two ICES Working Groups on the Assessment (Southern Shelf Demersal Stocks, SSDSWG and Northern Shelf Demersal Stocks, NSDSWG) are involved in the monitoring and assessment of this species. Three stocks have been recognised for assessment and management purposes: Anglerfish in Sub-area VI (little abundant), Anglerfish in Divisions VIIb-k and VIIIa,b,d and Anglerfish in Divisions VIIIc and IXa. The catches (landings and discards) from the three anglerfish stocks amounted in 1996 for *ca.* 350 t, 7,271 t and 1,629 t respectively (ICES CM, 1998a,b).

In the Bay of Biscay (Div. VIIIa,b,d) anglerfish catches are usually comprised by two species: Black Anglerfish (*L. budegassa*) and White Anglerfish (*L. piscatorius*, L. 1758). In this sea area 1.650 t of Black Anglerfish were caught in 1996. Mean annual landings in the Basque Country ports from the Bay of Biscay in the last three years period [1994-1995-1996] were around 390 t and most of them were obtained by "baka"- and "bou"-trawlers.

There is a rather scarce number of studies about the biology, ecology, and growth of anglerfish in the Northeast Atlantic in spite of its economical importance. The existent information is referred mainly to its morphologic description, systematic, taxonomy and geographical distribution (Lozano, 1960; Whitehead et al., 1986; Smith et al., 1986; Moyle et al., 1988; Sánchez et al., 1991). There are also some studies about age and growth (Dupouy, 1986; Peronnet et al., 1991), feeding (Pereda et al., 1990), genetic relations between both anglerfish species (Crozier, 1988). However no studies have been found about reproductive and other biological aspects of this species in the Bay of Biscay.

In this work the results of a biological study on growth and reproduction of Black Anglerfish, *L. budegassa*, carried out during 1996-1997 in the Bay of Biscay (Div. VIIIa,b,d) are presented.

MATERIALS AND METHODS

During 1996-1997, an intensive-sampling program was carried out to obtain representative number of *Lophius budegassa* to advance in the biology knowledge of the species. The sampling and the posterior analysis of the biological data were founded by E.U. under the Study Contract DGXIV: Biological Studies of Demersal Fish (BIOSDEF) and by Basque Country Government (Department of Industry, Agriculture and Fisheries). Biological samples were collected from Spanish landings at the main fishing ports of the Basque Country and on board of commercial vessels which operate in Northeast Atlantic waters (ICES Div. VIIIa,b,d). For the purpose of this study, all the investigations are based on the compiled analysis of samples of the two years as only one synthetic "biological year".

To study the relationship between length (in cm) and weight (in g), the aim of the sampling was to weigh –at least for the commercial gutted weight- 10 fish by length classes of 2 cm, by quarter. The length considered was the total length. Weighting was carried out on board using a precision balance specially designed for measuring on unstable sea conditions. "Total weight (Wt)", "commercial gutted weight (Wg)" (i.e. with liver), "scientific gutted weight (Ws)" (i.e. full gutted and without liver) and "tail weight (Wb)" (i.e. full gutted and without head) and total length relationships were described by multiplicative functions using Statgraphics Plus 3.0 program. Different conversion factors –i.e. for commercial gutted weight (Wg) to total weight (Wt), scientific gutted weight (Ws) to total weight, and tail weight (Wb) to total weight relationships- were also calculated by forcing the linear relationships through the co-ordinates origin. At the end of the study, a total number of 1138 Black Anglerfish were measured and weighted ("commercial gutted weight (Wg)").

A total of 2006 sectioned illicia of *L. budegassa* were prepared and read for determining the fish age. Once the illicium was removed from the fish at sea or in the fishing port, it was stored in a little paper envelope with the basic data relating to the exemplar examined. Before mounting and cut in the laboratory, illicia were peeled to make reading easier. They were embedded in black plastic plates and sectioned at *ca.* 500 μm to a distance of 5 mm of the illicia basis. After this, they were mounted in slices covered with a layer of non-plastic resin (Eukit), without a coverslip on surface. Readings were made with a binocular microscope under transmitted light at usually 100 x magnifications.

The criteria used for ring interpretation were the same as the one used in the "Workshop on Anglerfish Growth" hold at Lorient (France) in June of 1997. Well-defined opaque (because of transmitted light) rings, corresponding to periods of low growth, were counted as annual rings.

Annual Age-Length Keys (ALK) were built. Mean length and weight at age were also calculated. Growth parameters were estimated from the mean length at age for the study period. FISHPARM program (Prager *et al.*, 1987) was used for those purposes. The model chosen to estimate growth was the von Bertalanffy (1938) growth equation: $L_t = L_\infty\ (1 - e^{-K(t-to)})$. For each sex, the largest lengths found during the three years period were assigned to L_∞.

Monthly evolution of the condition factor (CF) was calculated as the relationship between the total or gutted weight and length. The monthly evolution of the gonosomatic index (GSI) was calculated as the relationship between gonad weight and total or gutted weight.

Spawning season was estimated by means of the study of the percentages of maturity stages assigned *de visu* and histologically to the specimina. Maturity ogives (*de visu* and by histology or microscopy) by length and age were calculated by means of the percentage of mature males, females and both sexes combined during the spawning period of the study (1996-1997).

The histological characterisation of the maturity cycle stages for *L. budegassa* males and females was also attempted in the present work. The gonads (ovaries and testes) were collected on board of commercial boats immediately after the fish catch. The aim of the sampling was to obtain the gonads of a maximum of 5 fish by 2 cm length classes, sex and month, all along a "biological year" in the period 1996-1997, both for macroscopical and histological studies. The gonads were fixed in a 4% formaldehyde buffered solution, at once after the fish were caught. Later in the laboratory the samples were embedded in glycol methacrylate resin, sectioned at 2-3 μm, stained with Harris haematoxylin and 1% aquose yellowish eosin and mounted in slices with a coverslip on surface. For the histological study, a sub-sampling squeme of all the gonads collected was established: a maximum of 10 females and 5 males were chosen randomly by month and by length range. For this purpose 6 length ranges of 10 cm were established (i.e. [30-39], [40-49], [50-59], [60-69], [70-79] and ≥80 cm). For upper ranges (i.e. for biggest fish) in few months it was possible to accomplish the "maximum desideratum". At the end of the study a total of 86 histological samples of male and 357 samples of female Black Anglerfish were prepared, examined and described. The reading of the histological samples were made by means a binocular microscope under transmitted light at different magnifications.

RESULTS

1. Sampling level

The *L. budegassa* biological data were obtained by a routinely sampling on the main ports of the Basque Country (Ondarroa and Pasajes) or mainly on board of commercial vessels. The sampling period started in April 1996 and finished in May 1997. The sampling level for the different biological purposes, grouped by quarters and for the total sampling period, is shown in Table 1.1. The length ranges of the specimina obtained are presented in Table 1.2.

Table 1.1. Sampling level of *L. budegassa* carried out during the period [1996-1997] in Div. VIIIa,b,d.

YEAR	Quarter	ICES Division	Illicia	Length/ Commercial Gutted Weight (Wg)	Length/ Total Weight (Wt)	Length/ Scientific Gutted Weight (Ws)	Gonads
1996	3	VIIIa,b,d	342	158	153	-	287
1996	4	VIIIa,b,d	648	210	82	81	395
1997	1	VIIIa,b,d	386	341	166	74	216
1997	2	VIIIa,b,d	630	431	189	89	293
TOTAL	ALL	VIIIa,b,d	2006	1140	590	243	1191

Table 1.2. Length range (cm) of *L. budegassa* collected during the period in Div. VIIIa,b,d.

YEAR	Quarter	ICES Division	Illicia	L/W (Wg)	L/W (Wt)	L/W (Ws)	Gonads
1996-97	ALL	VIIIa,b,d	14.5-94.5	14.5-85.5	14.5-84.5	14.5-85.5	17.5-84.5

2. Length and Weight relationships

2.1. Annual Length and Weight relationships

The total length and weights relationships for the total year and by sexes are shown in Table 2.1.1, 2.1.2, 2.1.3 and 2.1.4. Statistical differences were checked at 95% confident level. Length ranges used for comparison were the same for each sex (* denotes that were found statistical differences at 95% confidence level).

Table 2.1.1. Total Length-Total Weight (Wt) relationship

	Function	N	R	Length range (cm)	Weight range (g)
Males *	$Wt=0.016\ L^{2.965}$	203	0.9935	15.5-74.5	53.5-5696.5
Females *	$Wt=0.014\ L^{3.016}$	324	0.9913	14.5-84.5	40.5-10430.5
Sexes combined	$Wt=0.015\ L^{3.004}$	590	0.9936	14.5-84.5	40.5-10430.5

Table 2.1.2. Total Length-Commercial Gutted Weight (Wg) relationship

	Function	N	R	Length range (cm)	Weight-range (g)
Males *	$Wg=0.013\ L^{2.995}$	268	0.9914	14.5-84.5	37.5-8990.5
Females *	$Wg=0.015\ L^{2.967}$	458	0.9932	14.5-79.5	36.5-8730.5
Sexes combined	$Wg=0.015\ L^{2.963}$	1138	0.9956	14.5-85.5	36.5-8990.5

Table 2.1.3. Total Length-Gutted Weight (Ws) relationship.

	Function	N	R	Length range (cm)	Weight range (g)
Males *	$Ws=0.011\ L^{3.045}$	104	0.9922	15.5-74.5	44.5-4750.5
Females *	$Ws=0.014\ L^{2.957}$	106	0.9967	15.5-84.5	36.5-8990.5
Sexes combined	$Ws=0.013\ L^{2.989}$	243	0.9958	14.5-85.5	37.5-8990.5

Table 2.1.4. Total Length-Tail Weight (Wb) relationship.

	Function	N	R	Length range (cm)	Weight range (g)
Males *	$Wb=0.0024\ L^{3.229}$	85	0.9892	15.5-45.5	17.5-524.5
Females *	$Wb=0.0040\ L^{3.0723}$	68	0.9950	14.5-79.5	13.5-2480.5
Sexes combined	$Wb=0.0035\ L^{3.1206}$	184	0.9931	14.5-79.5	13.5-2480.5

2.2. Total and Gutted Weight and Tail Weight relationship.

The annual relationship between Total Weight (Wt) and Commercial Gutted Weight (Wg), Scientific Gutted Weight (Ws) and Tail Weight (Wb) for males, females and both sexes combined are presented in the following Tables 2.2.1, 2.2.2, 2.2.3 and 2.2.4. The slopes and intercepts of these linear regressions were statistically compared at a 95 % confident level to determine whether there were differences between males and females in weight growth (* denotes that were found statistical differences at 95% confidence level).

Table 2.2.1. Total Weight (Wt)-Commercial Gutted Weight (Wg) relationship

	Function	N	R	Wt range (g)	Wg-range (g)
Males *	Wt=9.279 + 0.862 Wg	203	0.9929	53.5-5696.5	45.5-4750.5
Females *	Wt=90.70 + 0.819 Wg	324	0.9858	40.5-10430.5	37.5-8990.5
Sexes combined	Wt=52.80 + 0.828 Wg	590	0.9901	40.5-10430.5	37.5-8990.5

Table 2.2.2. Total Weight (Wt)- Scientific Gutted Weight (Ws) relationship

	Function	N	R	Wt range (g)	Ws-range (g)
Males	Wt=11.417 + 0.827 Ws	104	0.9957	53.5-3574.5	44.0-2722.0
Females	Wt=31.519 + 0.778 Ws	107	0.9916	40.5-10430.5	36.3-8730.0
Sexes combined	Wt=27.319 + 0.794 Ws	244	0.9931	40.5-10430.5	36.3-8730.5

Table 2.2.3. Commercial Gutted Weight (Wg)-Scientific Gutted Weight (Ws) relationship

	Function	N	R	Wg range (g)	Ws-range (g)
Males *	Wg=1.1003 + 0.970 Ws	104	0.9999	45.5-2752.5	44.0-2722.0
Females *	Wg=5.6279 + 0.961 Ws	107	0.9995	37.5-8990.5	36.3-8730.0
Sexes combined	Wg=4.2708 + 0.962 Ws	244	0.9996	37.5-8990.5	36.3-8730.0

Table 2.2.4. Total Weight (Wt)-Tail Weight (Wb) relationship

	Function	N	r	Wt range (g)	Wb-range (g)
Males	Wt=-16.627 + 0.441 Wb	84	0.9912	53.5-1396.5	17.4-3124.0
Females	Wt=-7.484 + 0.392 Wb	67	0.9969	40.5-6465.5	13.0-2480.0
Sexes combined	Wt=-4.699 + 0.393 Wb	183	0.9967	40.5-6465.5	13.0-3124.0

3. Conversion Factor

Conversion factors between weights were calculated for all the year by sexes (Table 3.1, 3.2, 3.3 and 3.4).

Table 3.1. Conversion Factor for Commercial Gutted Weight (Wg) to Total Weight (Wt) by sex.

	Conversion Factor Function	S.E.	N	r	Length-range (cm)
Males	Wt=1.16058 Wg.	0.00729	203	0.9929	15.5-74.5
Females	Wt=1.22072 Wg	0.00778	324	0.9986	14.5-84.5
Sexes combined	Wt=1.20755 Wg	0.00484	590	0.9901	14.5-84.5

Table 3.2. Conversion Factor for Scientific Gutted Weight (Ws) to Total Weight (Wt) by sex.

	Conversion Factor Function	S.E.	N	r	Length-range (cm)
Males	Wt=1.20905Ws	0.00763	104	0.9957	15.5-61.5
Females	Wt=1.28528Ws	0.00993	107	0.9916	17.5-79.5
Sexes combined	Wt=1.27801Ws	0.00595	244	0.9931	14.5-79.5

Table 3.3. Conversion Factor for Commercial Gutted Weight (Wg) to Scientific Gutted Weight (Ws) by sex.

	Conversion Factor Function	S.E.	N	r	Length-range (cm)
Males	Ws=0.97126Wg	0.00086	104	0.9996	15.5-61.5
Females	Ws=0.96231Wg	0.00157	107	0.9999	14.5-79.5
Sexes combined	Ws=0.96324Wg	0.00101	1244	0.9995	14.5-79.5

Table 3.4. Conversion Factor for Tail Weight (Wb) to Total Weight (Wt) by sex

	Conversion Factor Function	S.E.	N	r	Length-range (cm)
Males	Wt=2.26767Wb	0.00645	84	0.9912	15.5-45.5
Females	Wt=2.54892Wb	0.00376	67	0.9969	14.5-79.5
Sexes combined	Wt=2.54293Wb	0.00236	183	0.9967	14.5-79.5

4. Growth at Age

The age determination of *L. budegassa* was made by means of illicia readings. As explained before, illicia were obtained in routine sampling carried out at sea on board of commercial ships and at the main fishing ports of the Basque Country. The way of preparing and reading the illicia was similar to the recommended at the "Workshop on Anglerfish Growth" hold at Lorient (France) in 1997 (Anon, 1997).

4.1. Age-Length keys

From the age reading results, Semestral Age-Length Keys for sexes combined and Annual Age-Length Keys for males and females were built. In this paper, a synoptical annual Age Length Key (ALK) for *L. budegassa* in ICES Divisions VIIIa,b,d, during the biological year 1996-1997 is presented (Table 4.1.1.). In this Table the original ages read and lengths are presented.

Table 4.1.1. Annual Age Length Key for Black Anglerfish (Div. VIIIa,b,d) in the study period [1996-1997]

Length (cm)	Age (years) 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total (n)	Length (cm)
14			3																	3	14
15			3																	3	15
16				4																4	16
17			2	8																10	17
18				16																16	18
19				1	3															4	19
20				13	4															17	20
21				4	8															12	21
22				7	1															8	22
23				1	8															9	23
24				2	8															10	24
25					12	1														13	25
26					12	4														16	26
27					9	7														16	27
28					7	1														8	28
29					3	13														16	29
30					2	15	1													18	30
31						1	2													3	31
32						1	5													6	32
33						7	3													10	33
34						5	8													13	34
35						1	1													2	35
36						2	14	1												17	36
37							14	3												17	37
38							14	4												18	38
39							14	3												17	39
40							5	14												19	40
41							9	2												11	41
42							2	18	1											21	42
43							3	2	5											10	43
44								12	4											16	44
45								15	11											26	45
46								9	25											34	46
47								8	26	1										35	47
48							2	5	23	4										34	48
49								2	23	3										28	49
50									18	9										27	50
51									15	13										28	51
52									7	22										29	52
53									5	22										27	53
54									2	2	2									6	54
55										15	4									19	55
56										17	9									26	56
57										16	1									17	57
58										16	11									27	58
59										5	18	1								24	59
60										1	23	3								27	60
61											11	8								19	61
62											16	8								24	62
63											8	8	1							17	63
64											8	1								9	64
65											3	16								19	65
66											2	22	4							28	66
67												9	8							17	67
68												14	5	1						20	68
69												8	13	3						24	69
70													11	11		1				23	70
71													7	9						16	71
72													5	12	2	1				20	72
73													4	8	6	1				19	73
74													1	1	1					3	74
75														2	8	2				12	75
76														2	14	4				20	76
77															8	2				10	77
78															4	5	1			10	78
79															5	3	1	1		10	79
80																4	1			5	80
81																1				1	81
82																	1	2		3	82
83																1				1	83
84																2	1	3		6	84
85																1	1			2	85
86																					86
87																					87
88																					88
89																					89
90																					90
91																					91
92																		1		1	92
93																					93
94																					94
95																					95
96																					96
97																			1	1	97
98																					98
99																					99
100																					100
Total (n)			8	56	77	58	97	98	165	146	116	98	59	49	48	28	6	7	1	1117	Total (n)
Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total (n)	Age

4.2. Mean Length at Age and Mean Weight at Age

For the study period, Mean Length and Weight at Age were calculated using the Age Length Keys and the new Total Length-Total Weight relationships obtained (Table 4.2.1.).

Table 4.2.1. Mean Length at Age and Mean Weight at Age for the 1996-1997 period.

Males				Females				Sexes combined			
Age	N	Mean W (g)	Mean L (cm)	Age	N	Mean W (g)	Mean L (cm)	Age	N	Mean W (g)	Mean L (cm)
0				**0**				**0**			
1				**1**				**1**			
2				**2**				**2**	8	51.88	15.63
3	12	112.19	20.50	**3**	9	109.95	19.94	**3**	65	107.28	19.68
4	20	206.80	24.75	**4**	15	212.99	24.43	**4**	86	222.65	24.91
5	32	390.39	30.47	**5**	25	432.06	31.02	**5**	85	412.71	30.65
6	34	762.59	37.89	**6**	43	800.07	37.92	**6**	106	782.45	37.77
7	57	1159.19	43.43	**7**	42	1211.19	43.76	**7**	134	1178.64	43.36
8	77	1598.61	48.31	**8**	56	1684.58	48.80	**8**	165	1657.35	48.58
9	52	2155.99	53.23	**9**	78	2408.63	54.95	**9**	164	2353.88	54.53
10	11	2847.03	58.32	**10**	78	3203.67	60.41	**10**	125	3202.73	60.40
11	6	3726.56	63.5	**11**	75	4137.91	65.78	**11**	107	4105.99	65.60
12	3	5297.88	71.5	**12**	42	5031.58	70.19	**12**	59	4962.02	69.87
13				**13**	40	5566.85	72.60	**13**	58	5534.98	72.46
14				**14**	41	6462.35	76.28	**14**	57	6416.06	76.09
15+				**15+**	28	8094.82	82.1	**15+**	42	7969.14	85.98

On an annual basis, mean length at age obtained for males was similar to that for females until age 9. Females older than 9 years appear consistently larger than males. Females reach older ages. Thus, in general younger fish were similar in length but from age 9 to older ages, females appeared bigger than males in all cases.

It has to be pointed out that only the synthetic tables are showed. However, when ages were not grouped in a 15+ age class, the illicia readings resulted in highest ages of 17 years old for females and 12 years old for males. One unsexed individual of 97 cm in length was aged 18 years old.

4.3. Growth parameters

The von Bertalanffy Growth equation were estimated by means the FISHPARM program (Prager et al., 1987) applying the Mean Length values at Age calculated from the annual ALK for the 1996-1997 study period (Table 4.3.1). The observed Mean Length at Age for males, females and sexes combined and the expected values obtained by the von Bertalanffy growth function are presented in Figure 4.3.1.

Table 4.3.1. Growth parameters of Black Anglerfish in the Bay of Biscay for the study period [1996-97] with restricted L_∞

	Males	Females	Sexes combined	Period
L_∞	100	100	100	Annual
K	0.1001	0.1113	0.1102	Annual
t_0	1.1015	1.4772	1.4581	Annual
r^2	0.9909	0.9954	0.9988	

5. Condition Factor

The condition Factor (CF) was calculated as : $CF_t = W_t / L^3 * 100$ and $CF_g = W_g / L^3 * 100$.

Where W_t = Total weight (g.), W_g = Commercial Gutted weight (g.), L = Total Length (cm)

In this section, the values of the monthly evolution of the condition factor calculated using the Total and Commercial Gutted Weight (i.e. with liver) are shown (Figure 5.1). For this purpose, different length rages of males and females were used. In the Figure 4.1 only the results on CF study for eventual "mature" fish are presented (males >36 cm. and females >65 cm.).

It must be pointed out that because of the scarcity of the sampling on higher lengths in some months, the number of samples was greatly reduced. Thus, for CF_t during February, June and August it was not possible to obtain males greater than 36 cm and so values were estimated by means an average of the values of the two contiguous months. Females greater than 65 cm were absent during February, June, August, October and December, thus CF_t for those months were also averaged.

Males reached their highest CF_t in winter (maximum value in January) decreasing to a minimum in May. After this, there was a slight increasing trend until July. The males CF_t slightly and slowly decreased for the rest of the summer and autumn. Females reached their best condition later in the year (March). From March to May the CF_t decreased rapidly and increased again during the summer months. For the rest of the year steadily decreased.

In the same months, that for CF_t, for the CF_g study the values are averaged. The followed the same trend during the year.

Males were at their highest condition in winter (maximum value in March) and sharply decreased in May. For the rest of the 2nd and 3rd quarter the CF_g continually September and then markedly decreased in October. The CF_g obtained for females increased from January to March reaching a maximum. After this month there is a sharply decreased in May. The female CF_g recovers until September and then steadily decreases towards the end of the year.

6. Reproduction

6.1. Sex ratio

For the analysis of the sex ratio, only individuals sexed *de visu* were considered. That specimina whose sex was uncertain were not considered. A total number of 1498 fish were sexed (545 males and 953 females). The annual sex ratio of the study period is shown in Figure 6.1.1.

During the year, rather similar proportions of both sexes were observed until 55 cm and only slight departures of the 1:1 sex ratio were detected. However, from 55 cm towards larger sizes females were dominant and males disappeared when 75 cm of length were reached.

6.2. Gonadosomatic index

The Gonosomatic index (GSI) was calculated in two ways: $GSI_t = W_{gon}/W_t * 100$ and $GSI_g = W_{gon}/W_g * 100$

Where W_t = Total weight (g), W_g = Commercial Gutted weight (g) W_{gon} = Gonad weight (g)

Monthly evolution of the GSI_t and GSI_g for males and females are shown in Figure 6.2.1. and 6.2.2.

Two ranges of males and females were selected to carry out this study: males smaller and greater than 36 cm length and females smaller and greater than 65 cm length (i.e. presumably "juvenile" and "adult" fish respectively). But, as for the analysis of the CF monthly evolution, there were sampled neither males ≥36 cm in February, June and August nor females ≥65 cm in February, June, August, October and December to obtain values for the GSI_t or GSI_g study during those months. Thus, the values for these months were estimated averaging the values of the two contiguous months.

The monthly evolution of the GSI_t for "adult" males presented maxima values in May and minima values in July (Figure 6.2.1). The GSI_t values for males increased from January to May and decreased from May to July. As for males, the GSI_t for "adult" females followed the same trend: low values during the 1st quarter and an increase until a maximum in July. For the rest of the 3rd quarter the values decreased sharply to a minimum in September and they continued to a rather low level in the 4th quarter but with a slight increase. The maxima values appeared to coincide with the spawning season and the minima values with the resting season (post-spawning). The GSI_t for "juvenile" are always smaller than the GSI_t for "adult" fish, as it was expected.

The monthly evolution of the GSI_g presented in males and females a very similar pattern to the observed for GSI_t (Figure 6.2.2.). As for GSI_t, the GSI_g for "juvenile" are always smaller than the GSI_g for "adult" fish

6.3. Macroscopic and microscopic maturity stages

Five stages of gonad maturation were established for anglerfish. The description of these stages in relation to the relative size and weight and to the external appearance and colour of the gonads is presented in Table 6.3.1. However, it is well known that the use of macroscopical (*de visu*) keys to classified maturity stages is open to a great amount of subjectivism. Also, to discriminate between two continuous stages presents a repeated problem. Thus, histological studies were carried out to solve these difficulties. Five histological maturity stages of the gonads were established by AZTI in relation to those given for the macroscopic analysis (Table 6.3.2). The results of both methods are presented and compared. Only individuals assumed to be "adult" were chosen for both studies. Thus, males greater and equal than 36 cm and females greater and equal than 65 cm were studied. To put in perspective the results obtained, it is necessary to keep in mind that in relation to the macroscopical study it was possible to analyse a rather relevant number (*ca.* 20 or more fish) for males and females in all months excepting February and October. But for the histological study the number of fish analysed was smaller.

Table 6.3.1. Maturity stages assigned *de visu* for *L. budegassa*

Maturity stage (*de visu*)	Males	Females
I Immature or Virgin	Tube-shaped testicles, pink or transparent, cover a small proportion of the visceral cavity. Sperm not visible	Band-shaped ovaries, very transparent and without visible oocytes
II Maturing	Testicles cover a great proportion of the visceral cavity, pearl-coloured, some sperm in the lumen.	Ovaries cover a great proportion of the visceral cavity, with creamy colour. The band is longer and has visible oocytes.
III Mature or Prespawning	Pearl-coloured testicles and with the lumen full of sperm.	Orange-coloured oocytes with accentuated vascularization and the presence of some hyaline eggs (hydrated)
IV Spawning	Sperm is easily freed by applying pressure to the abdomen.	An enormous gelatinous yellow mass wraps the hyaline oocytes.
V Post-spawning	Testicles appear red and stained. There is no sperm, or a little residual.	Soft or retracted ovaries, possible residual oocytes, reabsorbed.

Table 6.3.2. Maturity stages assigned by means of histology for *L. budegassa* (AZTI maturity stages).

Maturity stage (by histology)	Males	Females
I Immature or Virgin	Spermatogonia and Spermatocyte present, Spermatozoids absent.	Only Oogonia, Chromatin nucleolus stage.
II Maturing	Spermatogonia and Spermatocyte present, few Spermatozoids.	Oogonia, Chromatin nucleolus stage, Perinucleolus stage, early vitellogenesis.
III Mature or Pre-spawning	Spermatozoids predominant, Spermatogonia and Spermatocyte present only in the testis cortex.	Vitellogenesis, early nucleus migration and mucus layer present.
IV Spawning	Spermatozoids predominant.	Migratory nucleus stage and Oocyte hydration. Unable to see Oogonia and the other immature stages. Great mucus layer.
V Post-spawning	Empty seminiferal ducts, residual Spermatozoids and few Spermatogonia.	Post-ovulatory follicles and follicular atresias. Oogonia and Chromatin nucleolus stage.

The results of both methods are presented and compared. Only individuals assumed to be "adult" were chosen for both studies. Thus, males greater and equal than 36 cm and females greater and equal than 65 cm were studied. To put in perspective the results obtained, it is necessary to keep in mind that the number of fish analysed histologicaly was smaller.

The proportions of the Maturity Stages, based on the macroscopic studies, for males ≥36 cm length and for females ≥65 cm, are presented in Figure 6.3.1.

Immature males (stage I) were not found during January, (February), June, July and (October). The highest proportions of immature males occurred during April (38%). Maturing males (stage II) did not appear in (February), May, July and (October). The higher number of occurrences of maturing males occurred in August and September (around 50%). Mature or pre-spawning males (stage III) appeared all around the year, at very higher and variable frequencies but always in proportions higher than 40%, with the maxima values in March, July, October (only 1 male sampled) and November. Spawning males (stage IV) were found mainly in late spring -May and June-, but also in winter -January and March . Post-spawning males (stage V) appeared in late spring and early summer in very low frequencies reaching a maximum in May.

Immature females (stage I) appeared in all months, excepting February and October (but in these months the sampling coverage was very limited. The frequency of maturing females (stage II) was very high during the whole year, expect in February that they were absent of the sampling. Females mature or ready to spawn (stage III) were found during all the year except in September (and in February and October, but in these two months the sampling was very scarce). For the rest of the year, they reached their higher frequencies during January and May. Females in spawning condition (stage IV) were found at their highest proportion in June-July (in February (100%) only 1 female was sampled). Post-spawning females (stage V) were found at the end of spring and all long the summer.

The maturity stages assigned by histological process were also analysed for the same range of fish (Figure 6.3.2.). In this case, immature males (stage I) appeared only in January, June, August and September; in the 4th quarter they were no present in the sampling. Immature females appeared all along the year - excepting February and October (where sampling null or very limited)- in variable proportions reaching a maximum values in January, March and November.

The proportion of maturing males (stage II) was at it highest in January and August decreasing for the rest of the year where they appeared scattered in low (In November and December only 1 fish was analysed in each of these months). Half of the females appeared maturing from August to January reaching their higher values in December, but from March till July the proportions were decreasing. Thus, for males and females the higher frequencies of maturing individuals appeared in the second part of the year and in January; during the rest of the year the frequencies were maintained rather lower.

Mature or pre-spawning fish (stage III) appeared in higher frequencies in March, April and May, males reaching a maximum in April and females in April and May. Then, in June-July mature females were at decreasing and low frequencies, disappeared in August and started to appear again in November and December. Mature males appeared in relative high frequencies only until September, but in the 4th quarter the males sampled were very few.

Spawning females (stage IV) were found during the 2nd and 3rd quarters from May to August, reaching a maximum frequency in June; for the rest of the year they were absent of the sampling. Spawning males were observed from January to July, but not from August to December, although the males sampled were very scarce. In general, we can say that spawning males appeared earlier in the year than females, both sexes coincided in spawning condition from May to July, and, practically from August to the end of the year no spawning fish were recorded.

Post-spawning females (stage V) started to appear in increasing proportions in May reaching a maximum in July, and for the rest of the year they steadily decreased. The first post-spawning males appeared in June and they were detected until August. Later they were no more recorded, but in the 4th quarter the males sampled were very few.

6.4. Spawning period

For this analysis, fish were considered "mature" when they were found in whatever of the III, IV or V established stages. Moreover, the peak spawning season should be considered that part of the year in which the highest frequencies of mature fish –above all in spawning stage- and the highest values of Gonosomatic Index (GSI) for both sexes approximately at the same time take place.

Based in the macroscopical studies on Maturity Stages, the annual pattern of occurrences of "mature" individuals appears not to be different in main lines for females and males (Figure 6.4.1). Mature males occurred practically along the whole year. There were at their higher values during January, March, May and July. Their maximum frequencies varied from around 94 % in January, 75% and more in March and May and 100% in July. (The maximum value (100%) observed in October corresponded to only 1 fish). The minimum proportion of mature males (25%) occurred in September. From here to the end of the year frequency of mature males increased. The higher proportions of mature females coincided in some way with those of males. From March to July mature females were at increasing frequencies ranging from 19% in March to 74% in July. (The maximum value (100%) observed in February corresponded to only 1 female). As for males, the occurrences decreased sharply in late summer and in early autumn reaching a minimum in October when no mature females were recorded. During November and December mature females as mature males started to appear in increasing but low proportions.

When the same study was carried out by means of histology, "mature" males and females appeared at the same time of the year in different proportions. It has to be pointed out that no histological sampling of mature fish was available for males in February and October (and only 1 specimen per month in November and December) and that no females were sampled in February. High proportions of mature males occurred from March to July, being reached the maxima values in May and July (100%). After July they decreased to a rather constant minimum (around 50%) that appeared in August, September and January. For the rest of the months no fish or only 1 fish per month was analysed. Mature females appeared all around the year but in very different proportions. The highest and rather similar frequencies (about 68%) were reached in May, June and July. As for males, mature females decreased rapidly from July towards the end of the year. Usually from August to December and January less than 20% females were mature. Frequencies increased again in January when half of the females sampled were mature. From March onwards the proportion of mature female started again to increase.

According to the results of both the histological and the *de visu* maturity stages study as well as the analysis of the GSI monthly evolution, the peak spawning period for Black Anglerfish appeared, in a first approximation, to take place, in the Bay of Biscay (Div. VIIIa,b,d), in the first part of the year, more precisely between May and June-July. However more detailed studies and a more intensive sampling all along the year mainly for adult females have to be carried out to determine with more precision the occurrences of pre-spawning and spawning females in order to concrete with more certainty when the peak spawning season occur.

6.5. First maturity by length and age: Maturity ogives

6.5.1. First maturity by length

For the 1996-1997 study period, the beginning of the reproduction in males and females was calculated macroscopically and by means of histology. Firstly, the percentages of mature specimina were calculated for [1996-1997] based on the stages assigned *de visu* and thus length-maturity keys were obtained. In the same way length-maturity keys were calculated based on the maturity stages assigned by histology. For this purpose, all data from January to July were selected.

The stage "I" and "II" were considered as " immature" fish. The fish that presented other stages ("III", "IV" and "V") were considered as "mature" fish. The length at which 50 % of the males and females became mature (L_{50}) was estimated by a linear regression of the logarithm data transformation of the percentages of mature fish. The function used for this purpose was: Logit = 0.5 * Ln (P/(1/(1-P))

In Table 6.5.1.1. the results of the calculations of the L_{50} by means of macroscopical observations are presented by sexes for the period [1996-1997]. In Figure 6.5.1.1. the observed percentages of mature fish obtained by means of macroscopical data and the logistic function adjusted to this values are also presented.

Table 6.5.1.1. Estimation of the Maturity Ogive parameters (L_{25}, L_{50} and L_{75}) for the study period by macroscopy.

[1996-1997]	L25	L50	L75	Period
Male	31.50	36.05	48.14	January-July
Female	62.22	65.36	73.79	January-July
Sexes combined	35.67	48.61	83.24	January-July

The results of the histological study of the L_{50} are presented in Table 6.5.1.2. by sexes and for the study period [1996-1997]. In Figure 6.5.1.2. the observed percentages of mature specimina obtained by means of histology and the logistic function adjusted to this values are presented.

Table 6.5.1.2. Estimation of the Maturity Ogive parameters (L_{25}, L_{50} and L_{75}) for the 96-97 period by means of histology.

[1996-1997]	L25	L50	L75	Period
Male	30.63	34.53	44.98	January-July
Female	60.26	64.49	75.82	January-July
Sexes combined	37.85	49.02	78.96	January-July

Males appeared to mature at a smaller size than females. The small difference in the sizes may be due in part to the accuracy of the two methods employed (*de visu* and microscopy). But the big difference observed in the first maturity size between sexes is probably due to a real biological fact. By other hand, it appeared that histology is a more accurate method to assign the maturity stages and so the first length of maturity.

6.5.2. First maturity by age

The age at which reproduction begins in males and females was also calculated macroscopically and by histology for the 1996-1997 period with the same method that in First maturity at Length. The results of the calculations by means of macroscopy of the A_{50} are presented by sexes for 1996-1997 in Table 6.5.2.1.and Table 6.5.2.2. shows the results of the histological analysis for the study period. In Figure 6.5.2.1.and 6.5.2.2. the observed percentages of mature fish obtained by means of macroscopical and histological data, respectively, and the logistic function adjusted to these values are also presented.

Table 6.5.2.1. Estimation of the Maturity Ogives parameters (A_{25}, A_{50} and A_{75}) for the study period [1996-1997] by macroscopy.

[1996-1997]	A_{25}	A_{50}	A_{75}	Period
Male	4.05	5.24	6.44	January-July
Female	10.02	11.18	12.34	January-July
Sexes combined	5.37	7.02	8.67	January-July

Table 6.5.2.2. Estimation of the Maturity Ogives parameters (A_{25}, A_{50} and A_{75}) for the [1996-1997] period by means of histology.

[1996-1997]	A_{25}	A_{50}	A_{75}	Period
Male	5.95	6.00	6.05	January-July
Female	9.62	10.35	11.08	January-July
Sexes combined	7.04	9.06	7.04	January-July

When the results obtained by macroscopic and microscopic methods are compared, no great differences appeared in the estimations of males and females Maturity Ogive parameters. Based on the knowledge of the species it appears that the ogive calculated for males should be closer to the reality of the species than the one calculated for females. This may be due to the scarcity of specimina with both age and maturity stage assigned

DISCUSSION

1. Growth in weight at length. The growth in weight related to the total length of Black Anglerfish appeared to be different for males and females. Only it was not detected different relationships between males and females when the scientific gutted weights were compared annually. Because of the significant number of samples and length ranges used, it appears to be a different weight growth pattern for males and females during the whole year.

2. Mean lengths at age. Mean lengths at age of males were similar for males and females until age 9 when females started to be much larger than males. Based on the microscopy method males mature at smaller sizes than females and also at younger ages. Difference in length between sexes appears to take place in fish older than 9 years when sexual maturity takes place for males and much later for females It appears that when the reproduction occurs the pattern of growth of females and males starts to change.

3. Growth parameters. The growth pattern observed in males and females appears to fit adequately to the von Bertalanffy growth equation. Females reached older ages and greater lengths than males. The estimate of the instantaneous growth rate (*K*) was higher in females than in males, when it was assumed that both sexes reach the same maximum length. However, based in what it was observed, the values of the maximum lengths were registered in females. Thus, females are expected to grow longer and faster than males.

4. Condition factor. For females (≥65 cm) and males (≥36 cm), the optimal condition of the individuals occurs during winter and early spring and started to decrease in May recovering again by the end of July. As it was expected, this pattern is the opposite to the one presented by the Gonadosomatic Index. The highest values for the condition of the gonads (GSI) were registered from April to July. These opposite trends indicate when it is expected to find the maturing time of this species. In this case it was established to occur from January to July.

5. Sex ratio. When all samples were together considered, in an annual basis, males appeared in a rather similar abundance to females in length classes until 55-60 cm while females started to be dominant in bigger lengths. The intensity of the sampling as well as the presence of all length classes in the sampling leaded to think that these departures are real differences in the growth pattern of this species and not only due to a different catchability of sexes.

6. Maturity evolution. The maturity stages assigned *de visu* resulted in short and discrete post spawning periods and in very high frequencies of maturing specimina. The presence of maturing fish along almost the whole year appeared to be a problem of macroscopical differentiation between this stage and the post spawning stage. Thus, some of the maturing fish that by eye were distributed along the year in very high frequencies, using histology were considered as mature and post-spawners already recovering from the spawn.

The emergency of maturing females during the 2nd and 3rd quarters of the year, while in the macroscopic analysis were in very low proportions, was due to the facility to identify by means of histology oocytes with migrated nucleus, oocytes hydrating and atretic oocytes. The macroscopic method resulted very useful to identify the spawning individuals because this stage is the easiest to identify and so spawning period of the year can be easily assigned. However, macroscopy appeared to overestimate the presence of maturing individuals along the year. Thus, microscopical methods appeared as the most accurate to clearly distinct between the different maturity stages. Thus, these were constricted to a concrete time of the year and in sequential proportions.

Data on maturing and spawning maturity stages are in very close agreement with the peaks observed for the GSI_t and GSI_g evolution. Both series of data confirm that the reproductive activity for these species in the Bay of Biscay (Div. VIIIa,b,d) takes place from January to July –but the peak spawning season might be from May to July- and that after that the reproductive activity keeps going.

7. First maturity at length and at age. Based on both macroscopic and microscopic studies, males mature at smaller sizes than females and also at younger ages. There was a difference of 6 years in sexual maturation at age (A_{50}) between the two sexes. Males mature at around 5 years, females at around 11 years and both sexes combined at *ca.*7 years (according to the macroscopic method). Likely the age and length at first maturity calculated for females have been greatly overestimated.

Comparing these results to those used by the SSDS Working Group (ICES CM, 1998), Black Anglerfish appeared to mature at older ages (and lengths) that it has been considering until now.

MATURITY AT AGE (%)	AGE (years) 0	1	2	3	4	5	6	7	8	9	10+
SSDS WG (1998)	0	0	0	30	75	100					
Present study [1996-1997]	0	2	3	7	12	21	34	50	66	79	88

ACKNOWLEDGEMENTS

The work was founded by E. U. (Study Contract DGXIV Ref N°.: 95/038), Basque Country Government (Industry, Agriculture & Fisheries Department) and partly supported by a grant to I. Quincoces from Education and Culture Ministry. The authors thank to the staff of AZTI their technical support and to Shipowners and Fishermen form Ondarroa and Pasajes the facilities for sampling on board.

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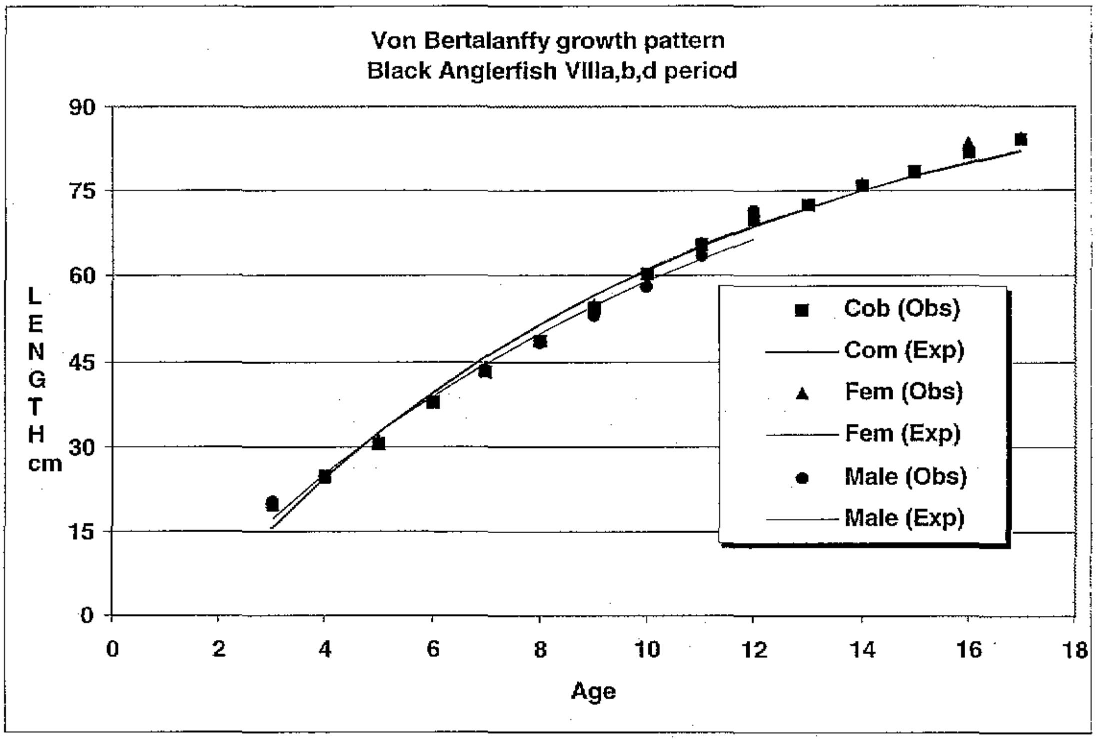


Figure 4.3.1. Von Bertalanffy growth pattern for Black Anglerfish (Div. VIIIa,b,d) in the study period [1996-1997]

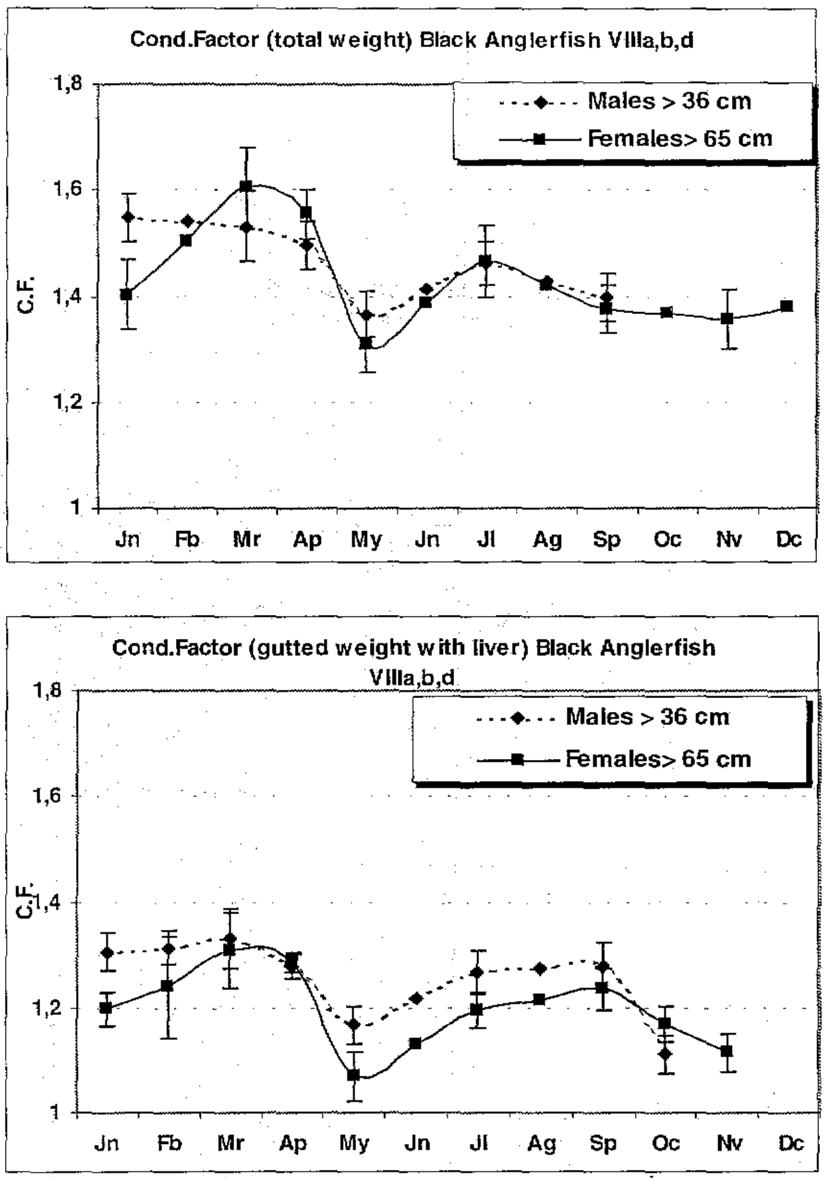


Figure 5.1. Condition factor monthly evolution calculated using: (above) the Total and (below) the Commercial Gutted Weight (i.e. with liver) for Black Anglerfish (Div. VIIIa,b,d) in the study period [1996-1997]

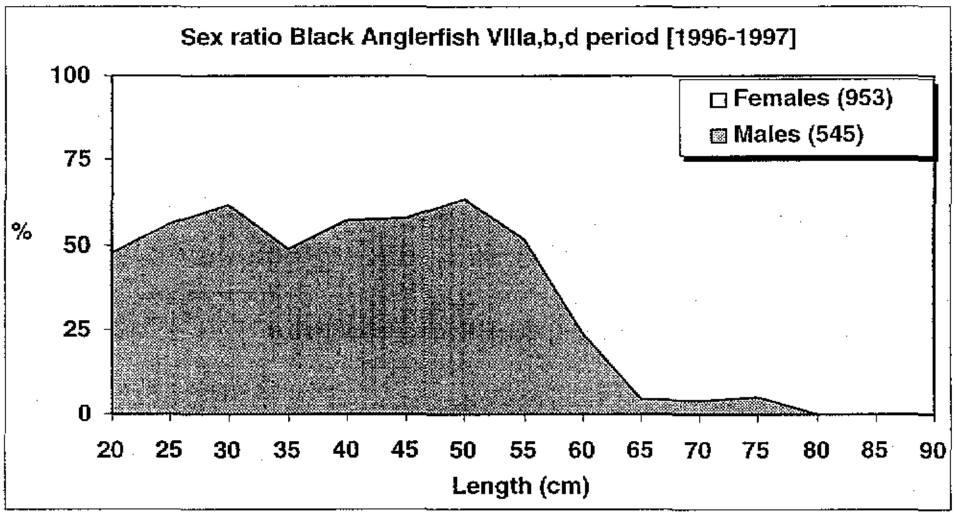
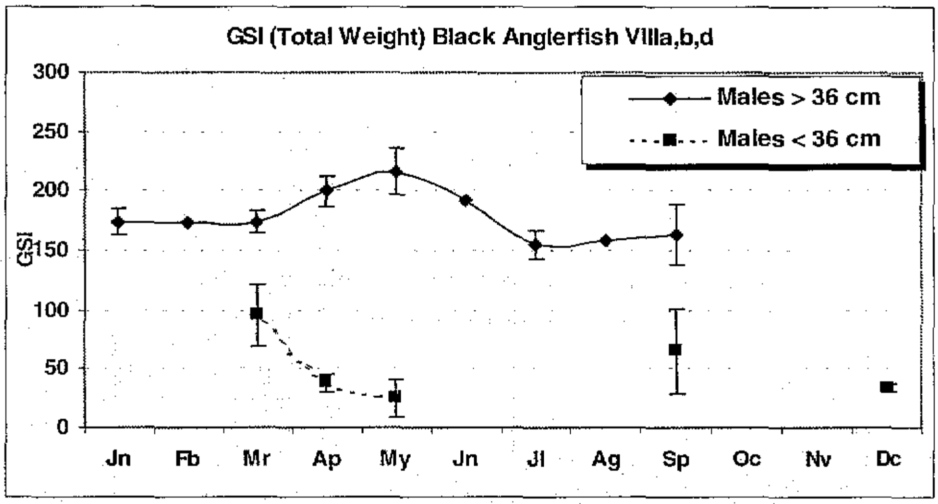


Figure 6.1.1. Sex ratio for Black Anglerfish (Div. VIIIa,b,d) in the study period [1996-1997]



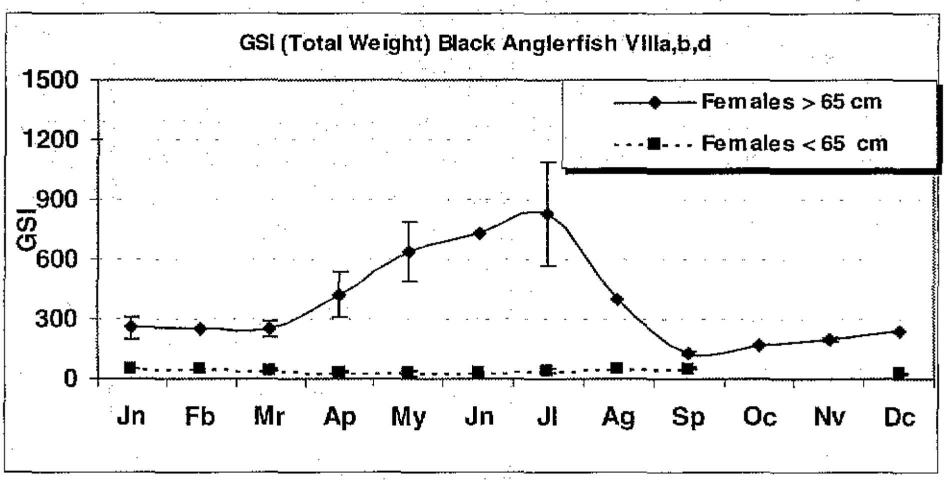
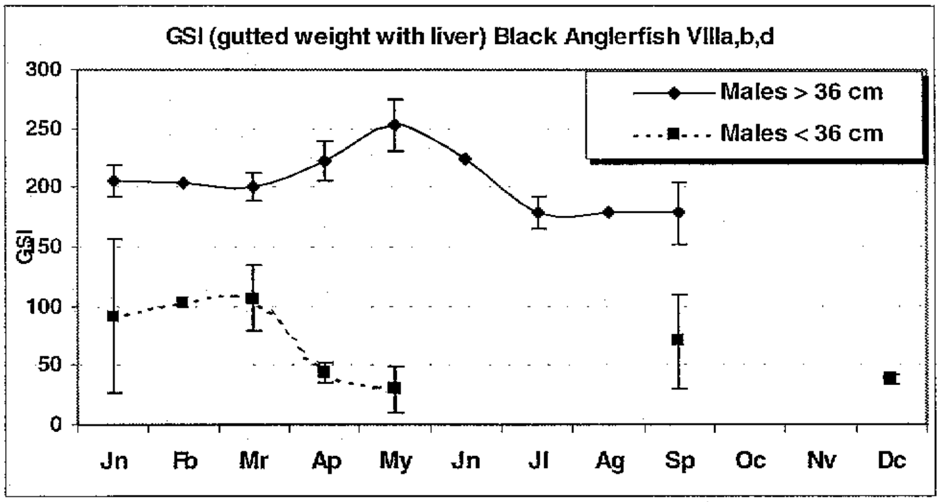


Figure 6.2.1. Gonadosomatic Index monthly evolution calculated for (above) Males and (below) Females using the Total Weight for Black Anglerfish (Div. VIII a,b,d) in the study period [1996-1997]



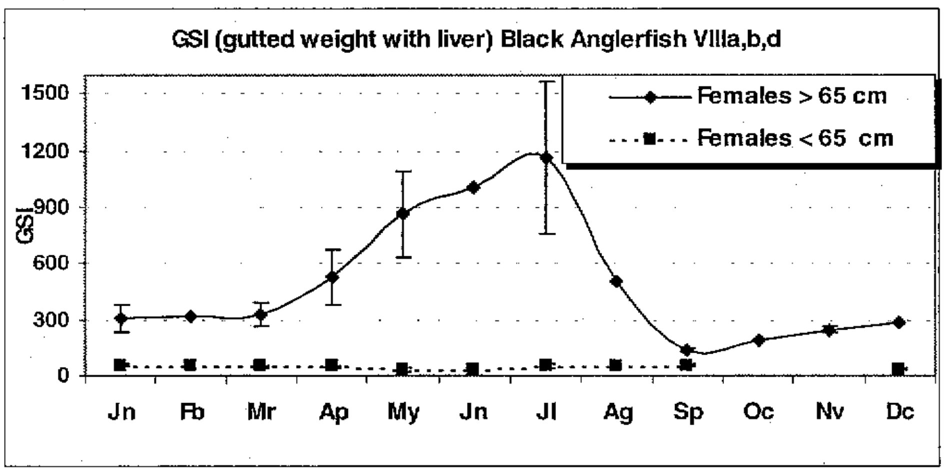


Figure 6.2.2. Gonadosomatic Index monthly evolution calculated for (above) Males and (below) Females using the Commercial Gutted Weight (i.e. with liver) for Black Anglerfish (Div. VIIIa,b,d) in the study period [1996-1997]

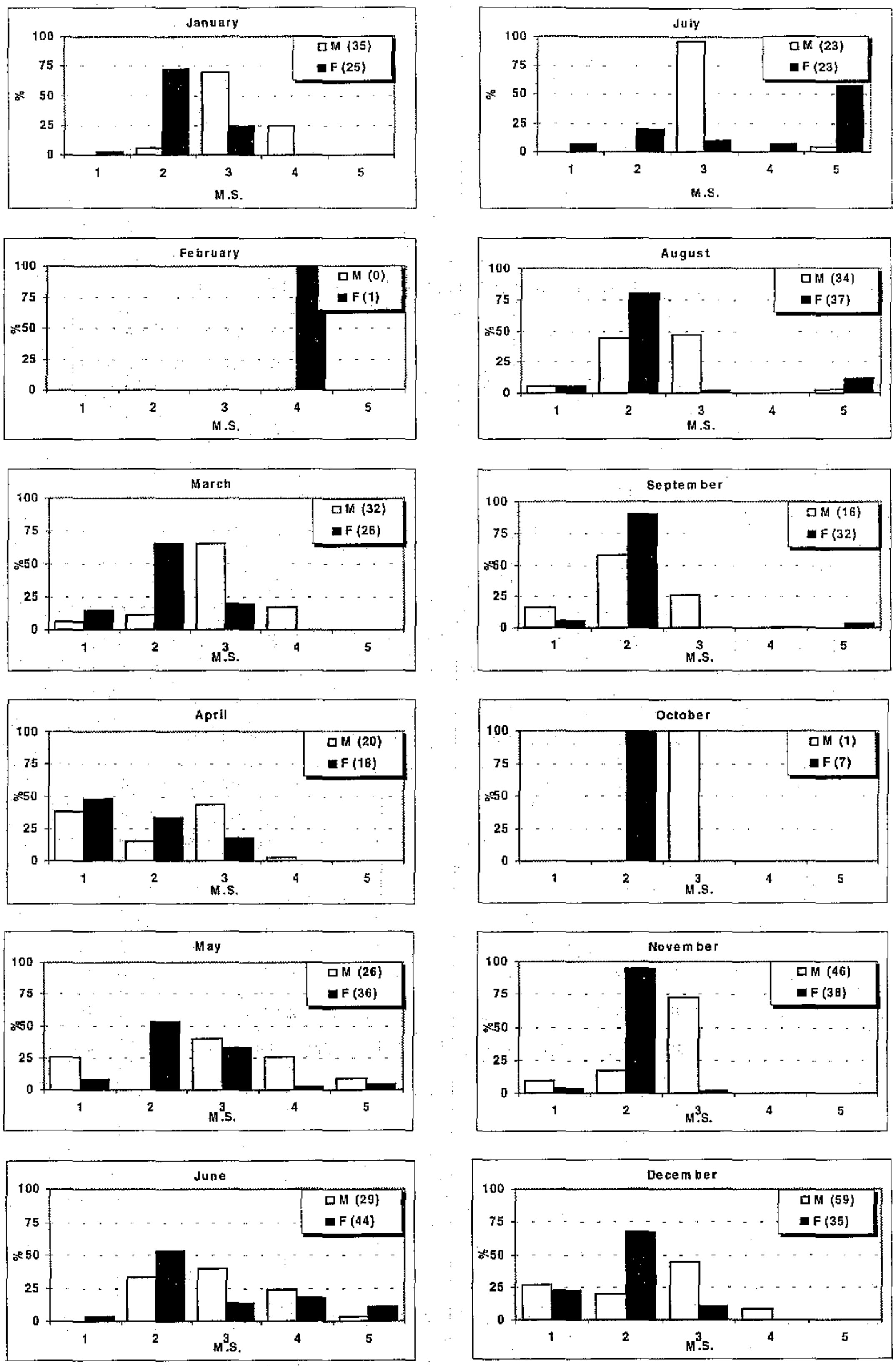


Figure 6.3.1. Maturity stages assigned *de visu* for male (≥ 36 cm length) and female (≥ 65 cm length) Black Anglerfish (Div. VIIIa,b,d) in the study period [1996-1997]. Maturity stages: 1) Immature, 2) Maturing, 3) Mature or Pre-spawning, 4) Spawning, 5) Post-spawning

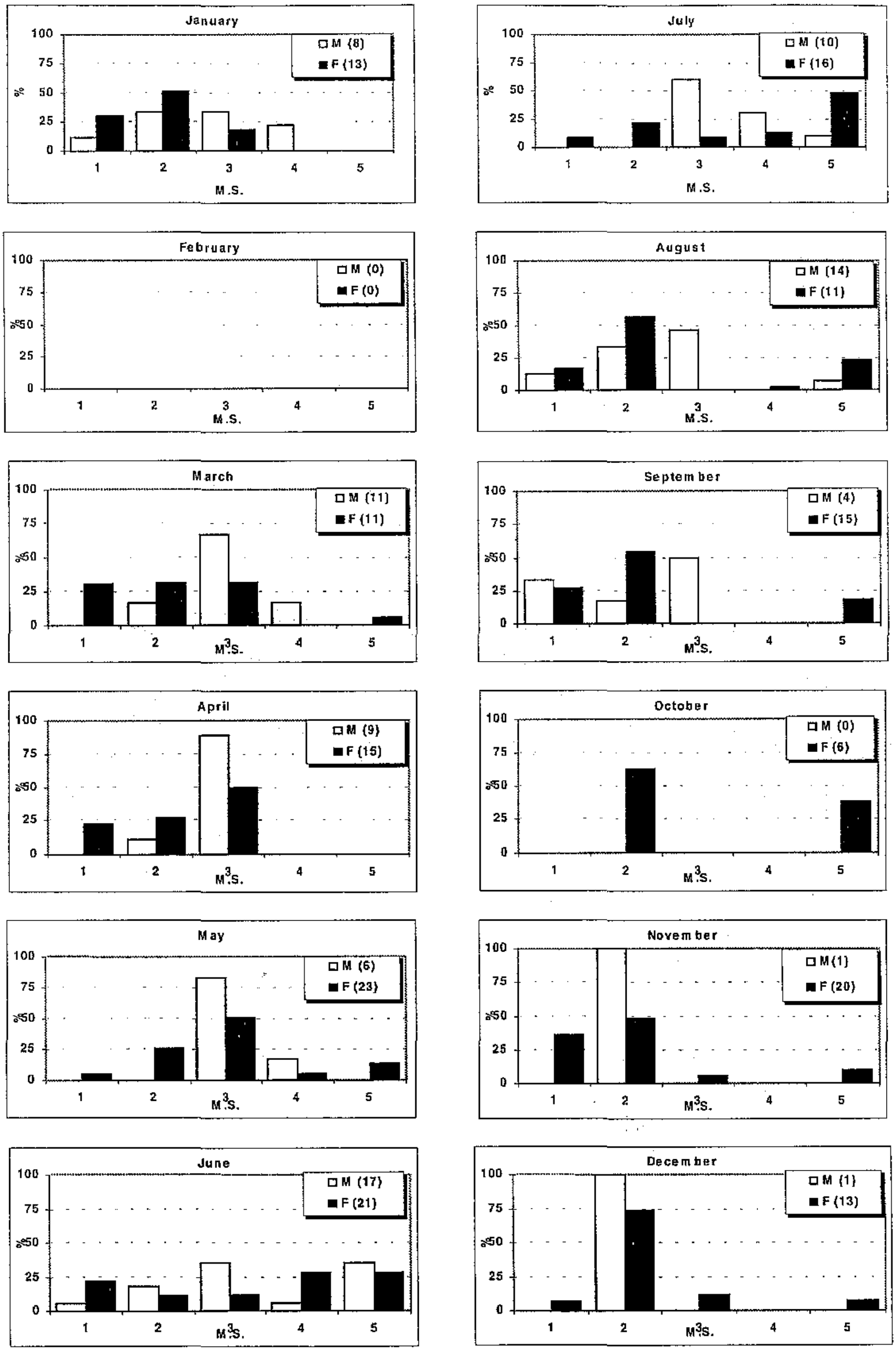
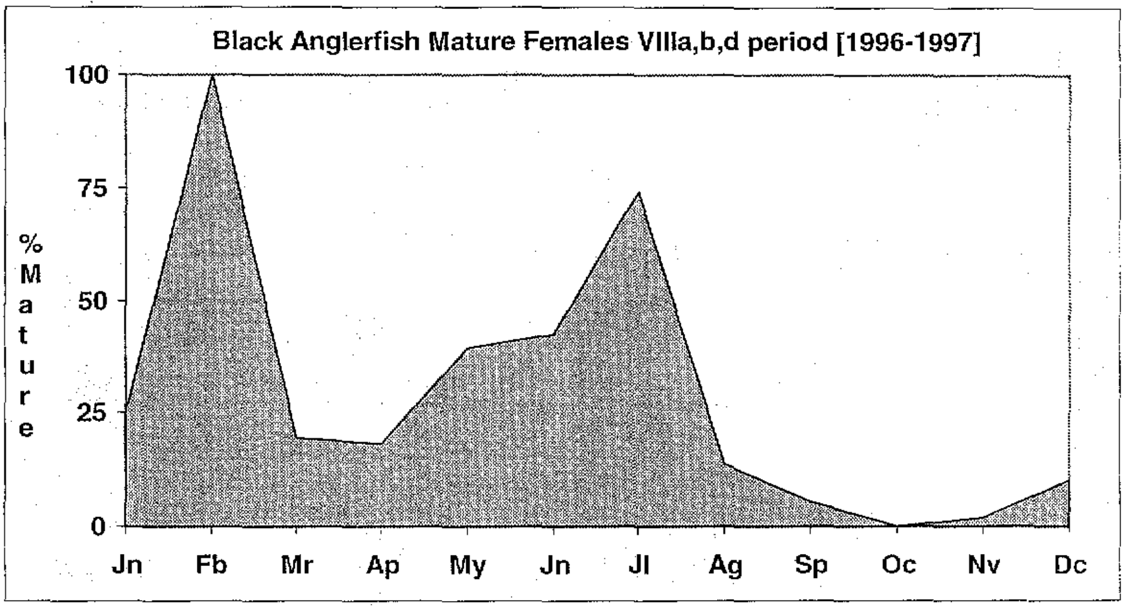


Figure 6.3.2. Maturity stages assigned by means of histology for male (≥ 36 cm length) and female (≥ 65 cm length) Black Anglerfish (Div. VIIIa,b,d) in the study period [1996-1997]. Maturity stages: 1) Immature, 2) Maturing, 3) Mature or Pre-spawning, 4) Spawning, 5) Post-spawning



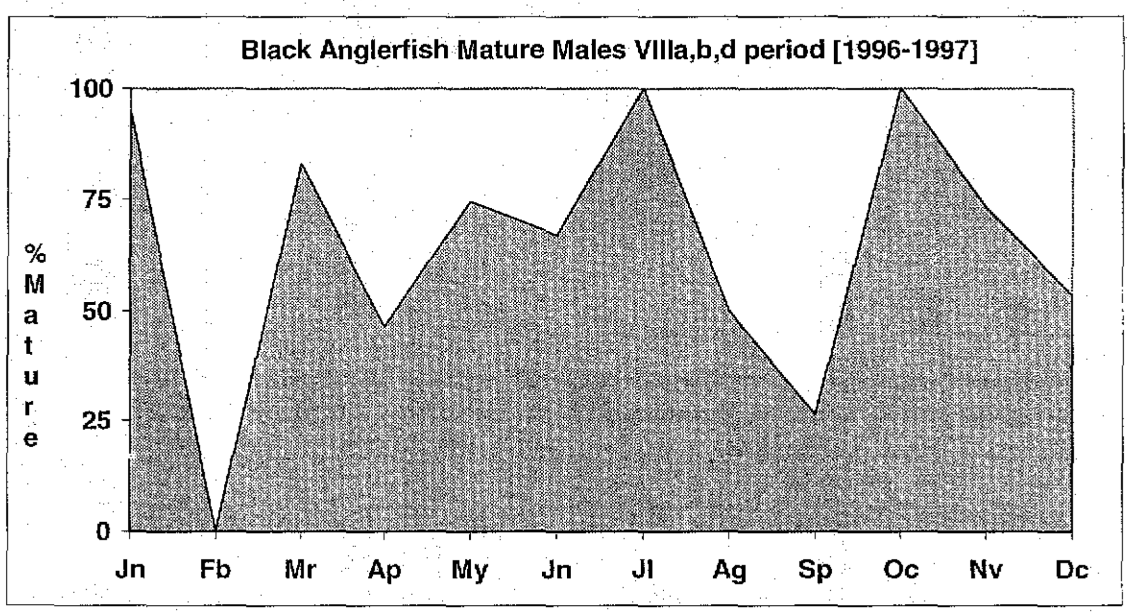
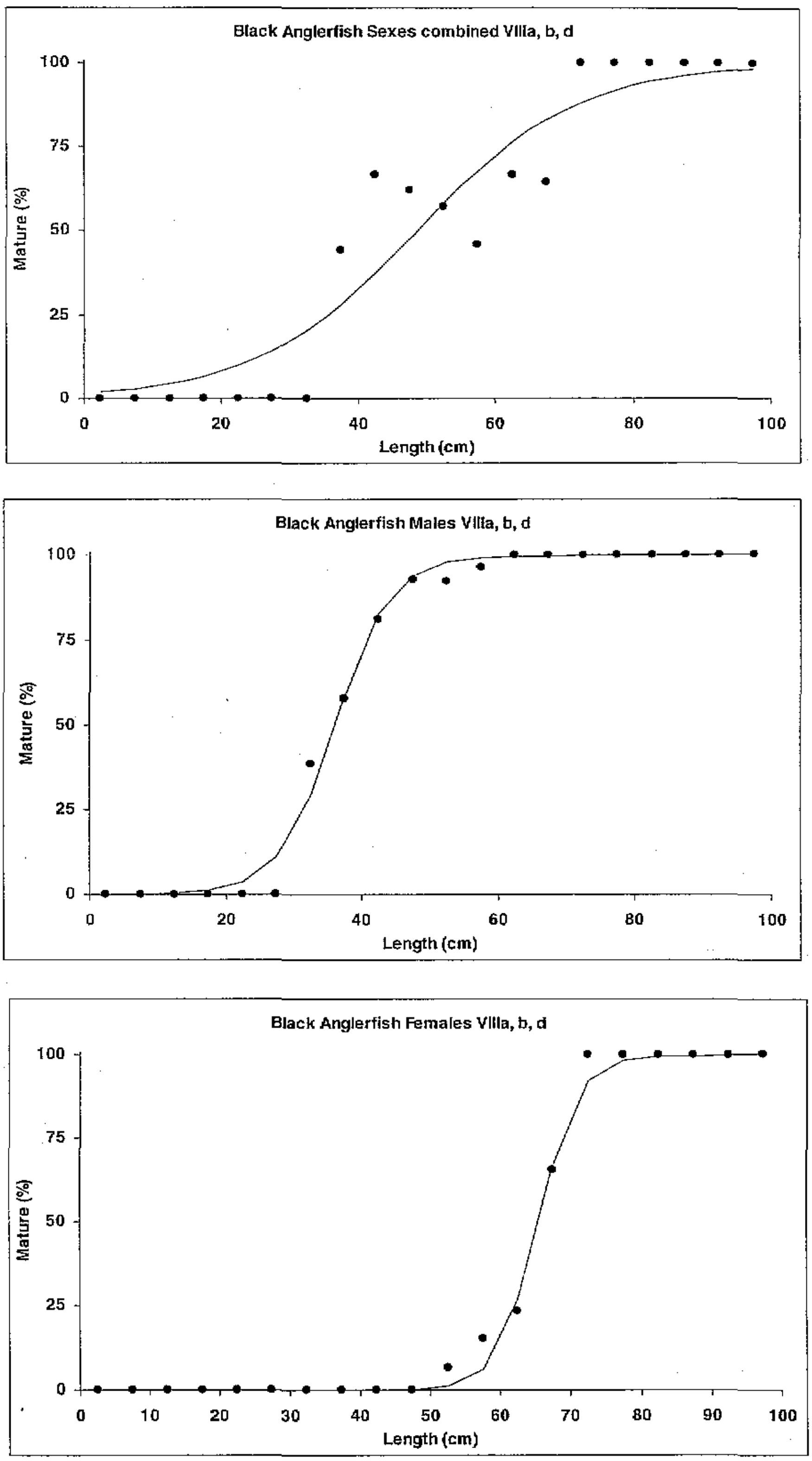


Figure 6.4.1. Percentage of "mature" (based on macroscopical observations) Black Anglerfish (Div. VIIIa,b,d) in the period [1996-1997]. Above: Females (≥ 65 cm length). Below: Males (≥ 36 cm length). "Mature" fish are considered fish in Mature and Pre-spawning, Spawning and Post-spawning stages (see text).



Macroscopic Study
Sexes combined

L50 = 48.61
L75 = 83.24
L25 = 35.67

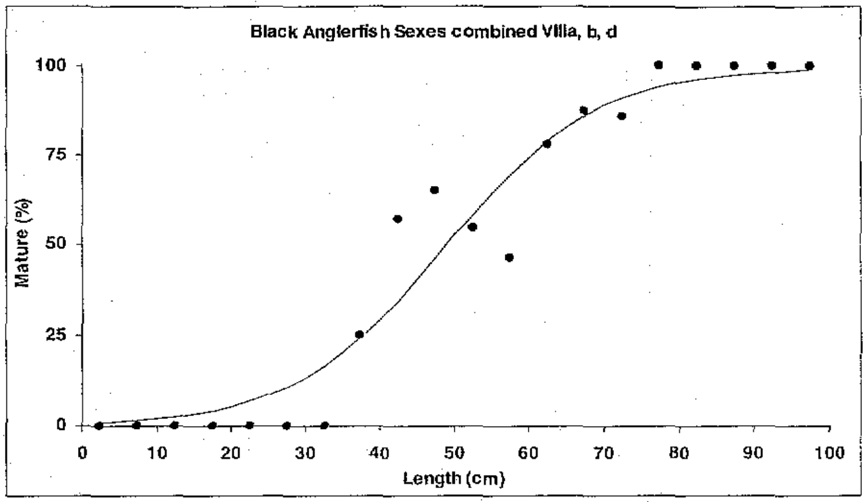
Macroscopic Study
Males

L50 = 36.05
L75 = 48.14
L25 = 31.5

Macroscopic Study
Females

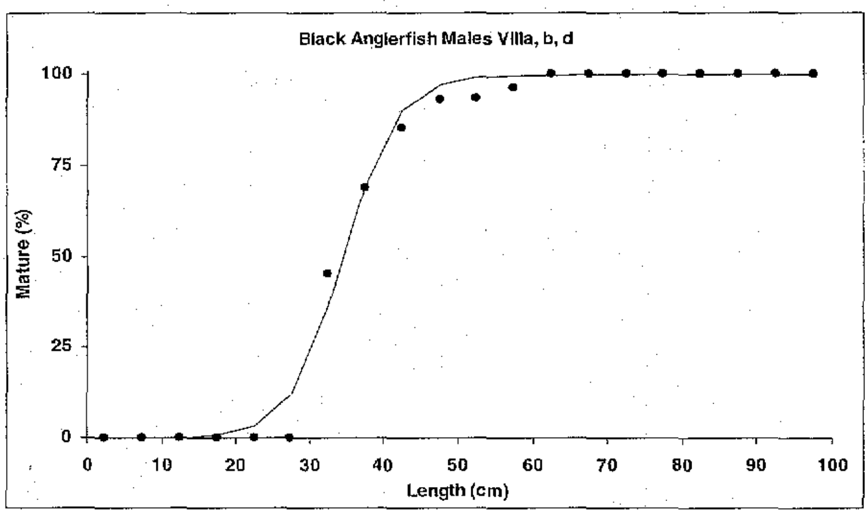
L50 = 65.36
L75 = 73.79
L25 = 62.22

Figure 6.5.1.1. Maturity ogives by length (based on macroscopical observations) for Black Anglerfish (Div. VIIIa,b,d) in the study period [1996-1997]



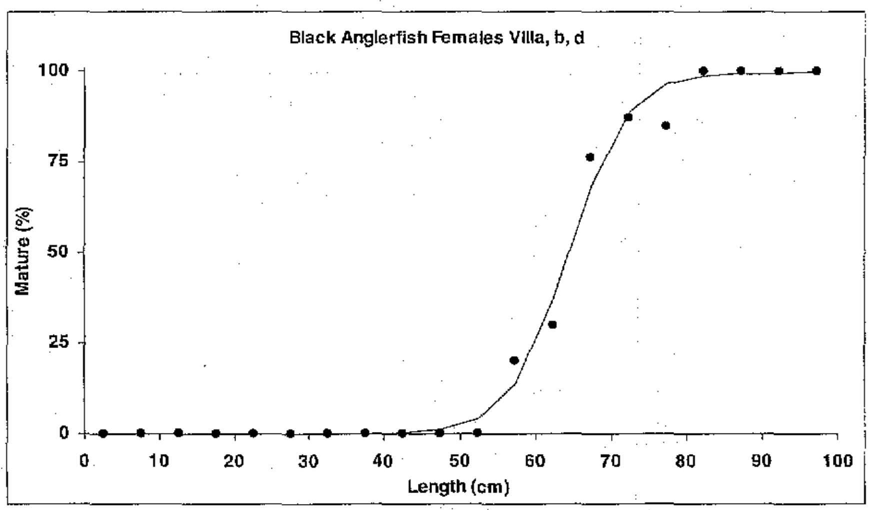
Microscopic Study
Sexes combined

L50 = 49.02
L75 = 78.96
L25 = 37.85



Microscopic Study
Males

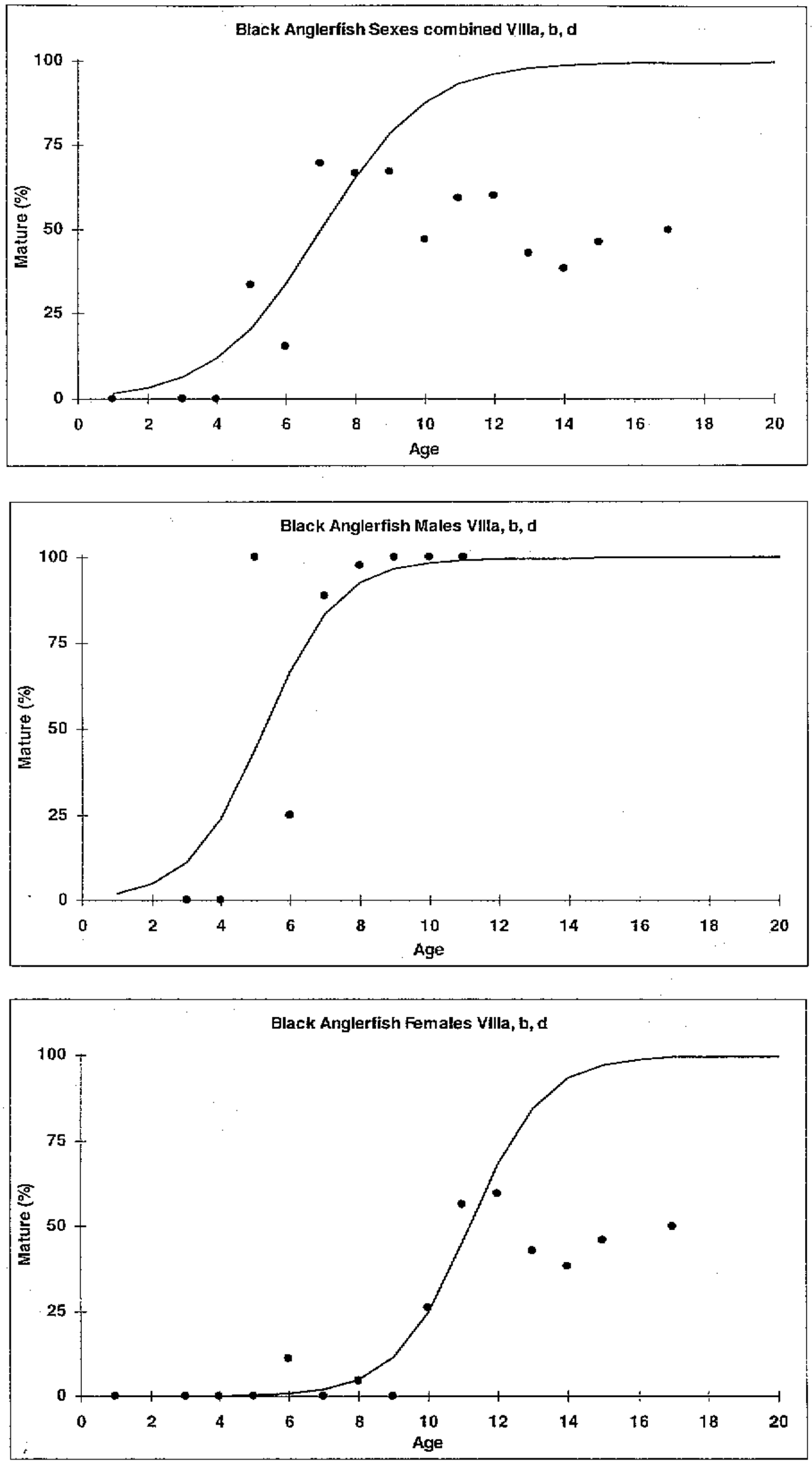
L50 = 34.53
L75 = 44.98
L25 = 30.63



Microscopic Study
Females

L50 = 64.49
L75 = 75.82
L25 = 60.26

Figure 6.5.1.2. Maturity ogives by length (based on histological observations) for Black Anglerfish (Div. VIIIa,b,d) in the study period [1996-1997].



Macroscopic Study
Sexes combined

A 50 = 7.02
A 75 = 8.67
A 25 = 5.37

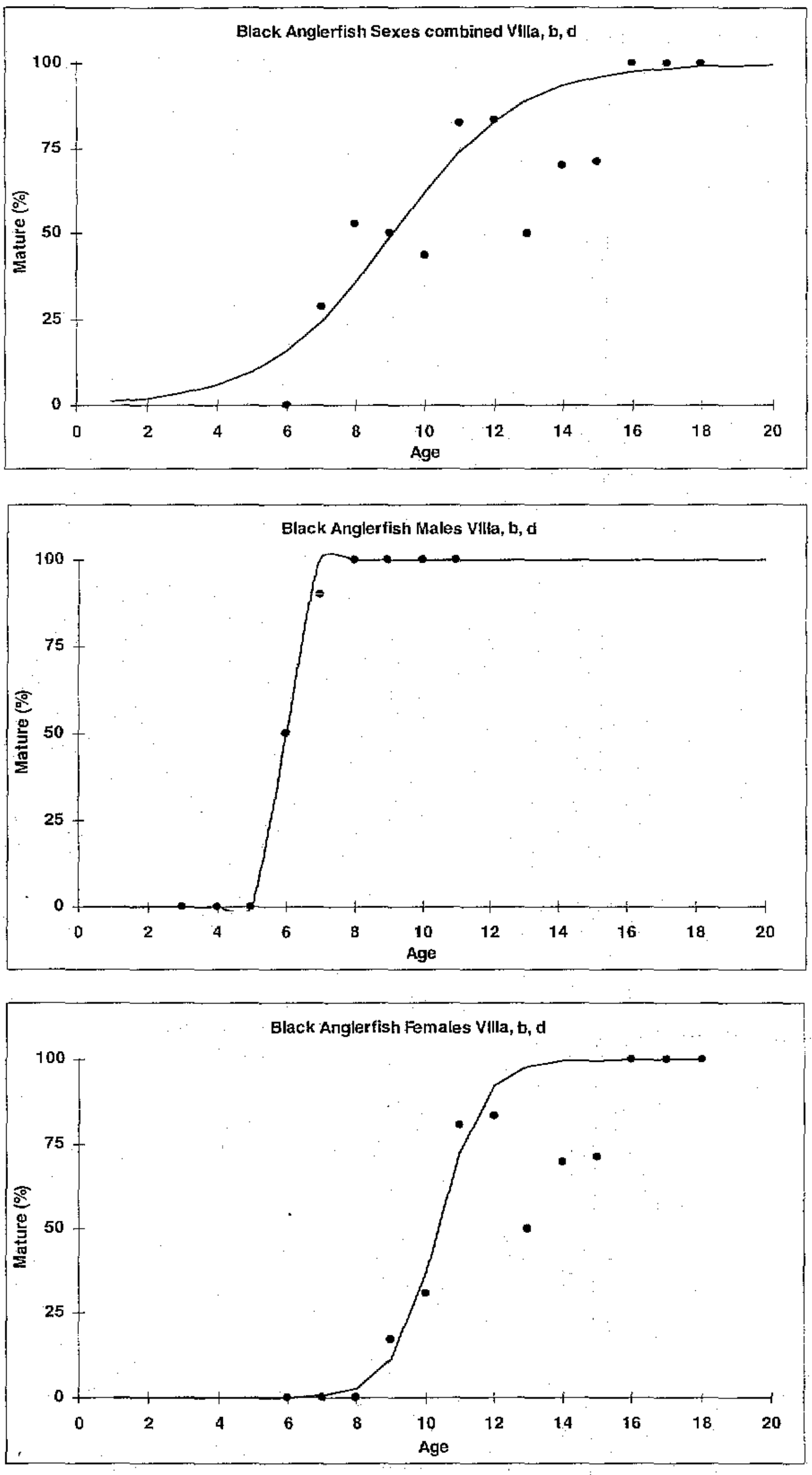
Macroscopic Study
Males

A 50 = 5.24
A 75 = 6.44
A 25 = 4.05

Macroscopic Study
Females

A 50 = 11.18
A 75 = 12.34
A 25 = 10.02

Figure 6.5.2.1. Maturity ogives by age (based on macroscopical observations) for Black Anglerfish (Div. VIIIa,b,d) in the study period [1996-1997]



Microscopic Study
Sexes combined

A50 = 9.06
A75 = 11.09
A25 = 7.04

Microscopic Study
Males

A50 = 6.00
A75 = 6.05
A25 = 5.95

Microscopic Study
Females

A50 = 10.35
A75 = 11.08
A25 = 9.62

Figure 6.5.2.2. Maturity ogives by age (based on histological analysis) for Black Anglerfish (Div. VIIIa,b,d) in the study period [1996-1997]