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CATCH, SIZE DISTRIBUTION, AGE AND SOME POPULATION PARAMETERS OF SWORDFISH, *XIPHIAS GLADIUS* L., IN THE GREEK SEAS.

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ABSTRACT

Greek swordfish, *Xiphias gladius* L., landings are estimated at 1530 MT in 1986 and 1179 MT in 1987. The bulk of the catches is made up of young specimens. The catch-at-length and the catch-at-age indicate that most of the individuals were up to three years of age and belonged to the length classes between 46 and 143 cm. Estimates of age were made from counts of growth bands on anal spine sections. The estimated von Bertalanffy growth parameters were:

for males Loo=203.2; k=0.21; to= -2.0
for females Loo=236.5; k=0.17; to= -2.1
for both sexes Loo=243.8; k=0.14; to= -2.6.

Theoretical growth in weight was obtained by converting length to weight. Females grow faster after the second year of age and reach a larger size than males.
Total mortality rates computed by two methods were higher in 1986 (Z=0.464 and Z=0.443, 1986; Z=0.309 and Z=0.305, 1987).

INTRODUCTION

In the years 1986 and 1987 a survey was carried out in the Greek seas on the fishery of large pelagic species (*Xiphias gladius* L., *Thunnus thynnus* L., *Thunnus alalunga* Bonn.), financed by the European Community Commission with the basic aim of obtaining an estimate of the fishery in Greece in terms of total production and of C.P.U.E. (De Metrio et.al., 1988).

In the present work swordfish data and biological material collected on that occasion, at the various fishing ports, are used. The aim is to provide information on the catch, size distribution, growth and mortality of swordfish exploited in the Greek Seas which could be useful for a future stock assessment of this species in the Mediterranean Sea.

MATERIALS AND METHODS

Data on the number of swordfish fishing fleets, on the number of boats in each fleet and of the total catch of each boat was collected, by means of inspections, interviews and direct surveys for the whole of Greece, in 1986 and 1987.

In two pilot ports(Kalimnos in Dodecanese and Chania on the island of Crete) in 1986 and in three (Kalimnos, Chania and Kithnos in the Cyclades Islands) in 1987, permanent observers collected additional data on: number of fishing days, number of hooks, number and weight of fish caught per day. Measurments of lower jaw fork length (LJFL) and the weight (free of all abdominal organs, fins and sword) were taken. Anal fins were collected from 270 swordfish of which the LJFL, the weight, the sex and the date of capture were recorded.

Using the data collected, the total swordfish catch in weight and in number of fish for the whole of Greece was calculated, both for 1986 and 1987.

As it was seen that the length frequencies of the catch of the varius fleets showed differences due to the dimensions of the boats and the fishing areas in which they operated, it was decided to group all the Greek fleets by area and assimilate the catch of each area to that of the pilot port.

Therefore in the first year of research Greece was divided into two large areas: Dodecanese, in which size samples from Kalimnos were used to size the catches and the rest of Greece (Ionian Islands, Crete, Peloponnese etc.), in which the size samples from Chania were used to size the catches.

In the second year of the research, a more accurate analysis of the Greek fishing situation and of the length frequencies, suggested the necessity to establish a third pilot port in the Cyclades Islands. For this the port of Kithnos was chosen. The size samples of Kithnos were used to size the catch of the Cyclades Islands.

Raising the monthly size frequency samples to the corresponding catch in number of fish, it was possible to calculate the catch-at-length per month and per whole fishing season for each pilot port and area. The raising factors were estimated by dividing the catch in number by the total number of fish in the size frequencies used. Grouping the results of the individual areas it was possible to estimate the catch-at-length for Greece. The frequencies were calculated in number of swordfish by 5 cm intervals of LJFL.

The age of the swordfish was estimated (MEGALOFONOU and DE METRIO, 1989) using sections of the spines of the anal fins. The relationship between lower jaw fork length and spine radius was determined with regression analysis. Back calculations of the length at estimated age was obtained using the equation (TESCH, 1971; RICHER,1975):

$$Ln - c = (Sn/S) \cdot (L - c)$$

where L = LJFL at the time of capture

Ln = LJFL when band n was formed

c = a correction factor (intercept on length axis from regression of length on spine radius)

Sn = distance from spine focus to the edge of band n

S = radius of the spine.

Mean back-calculated lengths at estimated ages were calculated. Estimates of theoretical growth in length were obtained by fitting the mean back-calculated lengths at estimated ages to the von Bertalanffy growth equation (SPARRE,1987). Theoretical growth in weight was obtained by converting length to weight using the length-weigth relationships established in the present work and that of De Metrio and Megalofonou (1987).

The catch-at-age was calculated from the total swordfish catch-at-size (in number of fish by 2 cm intervals of LJFL) using the mean lengths at ages from the growth equation developed for the two sexes together. Lower and upper limits of LJFL at each age were established and used to assign fish to an age class.

Two methods were taken into consideration for the calculation of total mortality rates (Z): 1) length converted catch curve analysis 2) Beverton and Holt equation (SPARRE, 1987).

RESULTS

A - Total Catch and Length Distribution

In 1986 the total swordfish catch in Greece was estimated at 1530 tons of which 712 tons were caught in the Dodecanese area (pilot port Kalimnos) and 818 tons in the rest of Greece (pilot port Chania).

At Kalimnos 4343 individual fish were weighed out of 8805 caught, and their average weight was 32.6 kg.

At Chania 756 individuals were weighed out of 996 caught and their average weight was found to be 23.1 kg.

Assimilating the catch of the two areas with that of the respective pilot ports, the following results were obtained,

Dodecanese : 712 MT / 32.6 kg = 21840 individuals

Rest of Greece : 818 MT / 23.1 kg = 35411 individuals

Therefore, in 1986, the total number of individual fish caught was presumably 57251.

In 1987 the total estimated catch was 1179 tons, of which 540 were caught in Dodecanese, 35 tons in the area of the Cyclades Islands (pilot port Kithnos) and 604 in the rest of Greece.

The individuals weighed in the pilot ports were:

Kalimnos: 6209 individuals (100% of the catch) with an average weight of 35.1 kgs;

Chania : 998 individuals (100% of the catch) with an average weight of 18 kgs;

Kithnos : 361 individuals, out of 451 caught, with an average weight of 10.8 kgs

The catch of the different areas was assimilated with that of the pilot ports and it was found that:

Dodecanese : 540 MT / 35.1 kg = 15384 individuals

Cyclades Islands: 35 MT / 10.8 kg = 3241 individuals

Rest of Greece : 604 MT / 18.0 kg = 33553 individuals

from which it can be deduced that the total number of individuals caught in 1987 was probably 52178.

The distribution of the total swordfish catch in Greece, according to length, is shown in Table I for 1986 and in Table II for 1987. The percentage frequencies are shown respectively in Figure 1 and Figure 2.

B - Length-Weight Relationships, Age and Growth

Swordfish length (LJFL) ranged from 71.5 to 207 cm while weight was from 3 to 104 kg. Of the 241 specimens which were used in the analysis 129 were males and 108 were females. The length-weight relationships (Figure 3) are found to be:

for males $W = 7.416 \times 10^{-6} \times LJFL^{3.07}$ (r=0.97)

for females $W = 3.968 \times 10^{-6} \times LJFL^{3.19}$ (r=0.98)

for both $W = 5.371 \times 10^{-6} \times LJFL^{3.14}$ (r=0.97)

The regression analysis carried out between the radius of the spine and the LJFL showed a significant linear correlation for both sexes:

males $LJFL = 70.0 + 19.69 \times S$ (r=0.91)

females $LJFL = 71.1 + 19.20 \times S$ (r=0.93)

As no significant difference was observed between the two sexes, the relationship was calculated together for males and females (figure 4):

$LJFL = 71.07 + 19.22 \times S$ (r=0.92)

which was used for the back calculation analysis.

Age estimates ranged from 0+ to 9+ years. The oldest fish found was a nine year old female with a LJFL of 207 cms; the oldest male was 8 years old. The relationship between the estimated age and the LJFL is shown in figure 5. Mean back calculated lengths at estimated ages and the lengths at age predicted by the model of von Bertalanffy, are shown in Table III while the von Bertalanffy growth parameters and the confidence limits are illustrated in Table IV. Von Bertalanffy's equations for the theoretical growth in length are:

for the male $l_t = 203.23\ [\ 1 - \exp\ (-\ 0.21)\ (t+2.04)\ ]$

for the female $l_t = 236.49\ [\ 1 - \exp\ (-\ 0.17)\ (t+2.10)\ ]$

both $l_t = 243.77\ [\ 1 - \exp\ (-\ 0.14)\ (t+2.60)\ ]$

Theoretical growth in weight (Table V), was obtained by converting LJFL to weight using the equations established from the regression analysis. Von Bertalanffy's equations are:

for the male $W_t = 90.4\ [\ 1 - \exp\ (-\ 0.21)\ (t+2.04)\ ]^{3.07}$

for the female $W_t = 153.0\ [\ 1 - \exp\ (-\ 0.17)\ (t+2.10)\ ]^{3.19}$

both $W_t = 168.0\ [\ 1 - \exp\ (-\ 0.14)\ (t+2.60)\ ]^{3.14}$

Theoretical growth in weight for the two sexes together was also obtained using the equation of De Metrio and Megalofonou (1987) (Table V). Estimated W_∞ values are: 112 kg for males, 180.8 kg for females and 199 kg for the sexes combined.

C - Catch-at-age

Because sex ratio samples were only available for one area, the growth curve obtained from the sexes combined was selected as the most appropriate for the purpose of aging the catch at size (Table VI). Most of the swordfish catch consists of young individuals for both 1986 and 1987. About 50% of the landing comprises fish one and two years old.

D - Mortality

The estimates of total mortality rates (Z) carried out according to the Beverton and Holt equation are:

1986: $Z = 0.464$ $l' = 132.5$ cms $l = 156.7$ cms

1987: $Z = 0.309$ $l' = 97.5$ cms $l = 141.8$ cms

where l'= length of smallest fish fully represented in the sample and l = average length of all fish above l'.

Calculation of the mortality rates through the analysis of length-converted catch curves in 1986 showed
Z = 0.443; st.dev. 0.042; confidence limits from 0.352 to 0.534. The first length class used for the analysis was that with LJFL between 130 and 135 cm while the last one was between 205 and 210 cm; r= -0.94.

In 1987 Z = 0.305 was found with a standard deviation of 0.301 and confidence limits from 0.239 to 0.370.
First class used: 95 - 100 cms; last class: 205 -210 cms; r= -0.90. The length-converted catch curves for 1986 and 1987 are shown in Figures 6 and 7 respectively.

CONCLUSIONS

Although swordfish fishery is a relatively recent activity in Greece, it has evolved rapidly in the brief period of twenty years and still shows a tendency to expand. Today, with an annual production of about 1.500 tons, Greece has established itself decisively as the second most important country in the Mediterranean for swordfish fishery (DE METRIO et al.,1988).

The characteristics of the catch reveals that, also in this country, the majority of fish caught are from the first age groups, with groups 1 and 2 being the most frequent. This situation now seems a general characteristic in all parts of the Mediterranean. In fact, the sizes, found in both years, do not seem different from those reported, for the same period, by us and other authors for the Central and Western Mediterranean (DE METRIO and MEGALOFONOU,1987; DE METRIO et al.,1988; MARANO et al.,1987; REY et al.,1987).

The results of the age estimates suggest a maximum lifespan of at least 8 years for males and of at least 9 years for females. Therefore the swordfish can be considered a large moderately longlife pelagic fish. However, the maximum lifespan of the species in this area could be higher in that individuals were caught which are larger than those examined for this work. In fact, the largest individual caught in the Aegean in the years 1986-87 had an LJFL of 221 cms, while the largest individual caught in the Gulf of Taranto in the four years 1985-88 had an LJFL of 230 cms.

Estimates of population parameters indicated that females reach a larger asymtotic size than males. Considering the fact that also in areas like the Atlantic, where the greatest dimensions for the swordfish have been recorded, few males exceed an LJFL of 200 cms (BECKETT,1974), the estimate of a Loo of 203.4 cms for males seems acceptable. In fact among all the males examined in the Aegean during the two years considered, none exceeded 200 cms. The estimate of a Loo of 236.5 also seems acceptable for the female considering the maximum dimensions of the animals recorded in the Aegean and in the Ionian Sea (DE METRIO et al.,1986, 1988; DE METRIO and MEGALOFONOU, 1987) in the Adriatic (MARANO et al.,1987)

and other areas of the Western Mediterranean (REY et al.,1987). Anyway this is much smaller than those found in the Atlantic (Loo = 340 cm BERKELEY and HOUDE,1983; Loo = 266.7 cm RADTKE and HURLEY,1983). A lack of large females in the sample from the Mediterranean may have had an effect on the resulting von Bertalanffy parameter of Loo.

The growth rate in the two sexes appears different as had already been shown in previous studies (GUITART-MANDAY,1964; BECKETT,1974; BERKELEY and HOUDE, 1983; WILSON and DEAN,1983; RADTKE and HURLEY,1983). It seems that the females, after the second year of life, grow more quickly than the males. In any case the differences in the growth rates found in this work are less than those observed in the Atlantic by other authors (Table VII). The results reported here are much closer to those of BERKELEY and HOUDE (1983) than they are to those of WILSON and DEAN (1983) and to those of RADTKE and HURLEY (1983).

The differences observed previously, relative to the values of Loo and to k, although they cannot be completely explained, can however be related to various factors: different techniques used, different dimension range of the sample, the existence of different populations, different environmental conditions.

Results of the length frequency modal analysis (DE METRIO and MEGALOFONOU,1987) have been used to examine the validity of age estimates made on swordfish using anal spine sections. It was observed that length at ages one and two derived from spine sections agreed well with the results of length frequency modal analysis. In fact, modal analysis suggested that the swordfish with a length (LJFL) between 95 and 100 cm captured during July are one year old and those with a length between 120 and 125 cm are two years old. Our results indicated that swordfish of one year old are

97 cm in LJFL as regards males and 98.3 cm as regards females while swordfish of two years old are 117.4 and 120.4 respectivelly. It is obvious, that length frequency modal analysis validate the method for the first age groups but cannot be used for the older age groups. Considering that most of the catch consists of young individuals, the validity of the two first groups is very important, especially for the purpose of aging the catch at size. However a complete validation of the method is necessary. Examination of the hard parts of the swordfish marked and treated with tetracycline could be a good solution in the future for the validation problems.

As the complex rearrangement of the data does not permit the drawing of definite conclusions on the mortality of swordfish in the Mediterranean, it does however seem that the different values of the mortality rates found in the two years studied, could be attributed to the fact that recruiting is widely represented in the catch and its contribution is quantitatively subject to annual variations dependent on the success of the reproductive process and the survival of the larvae and juveniles. Initially a doubt had emerged that the difference could be due to the incidence, in 1987, of catch by the Kithnos fleet. For this reason the mortality rate for that year was recalculated excluding the Kithnos catch. The difference between the two calculations was not significant (0.305 with Kithnos; 0.295 without Kithnos).

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Table I - Swordfish catch-at-length. Greece 1986.

LJFL	1 - 6	7	8	9	10	11	12	Total
45		0	0	165	0	0	0	234
50		0	0	82	987	0	0	1405
55		0	0	91	63	0	0	240
60		181	0	9	501	0	0	1168
65		0	0	0	147	0	0	298
70		121	0	0	273	0	0	694
75		181	312	0	42	0	0	740
80		228	312	82	42	0	0	931
85		501	156	82	0	0	0	1051
90		726	346	197	164	0	0	1994
95		894	881	228	0	0	0	2851
100		865	1294	296	0	0	0	3583
105		634	536	260	21	0	0	2076
110		918	993	324	42	0	0	3548
115		1406	546	200	42	0	0	3474
120	N O	1662	1082	273	42	0	0	4723
125		1720	1405	163	0	0	0	5076
130	D A T A	1143	714	283	0	0	0	3392
135		747	948	160	0	0	0	2784
140		354	703	86	168	0	0	2185
145		579	480	36	63	0	0	1844
150		582	948	50	84	0	0	2556
155		275	346	18	42	0	0	1038
160		535	167	82	21	0	0	1366
165		640	413	23	21	0	0	1643
170		373	759	27	21	0	0	1864
175		427	346	32	0	0	0	1183
180		529	257	18	0	0	0	1178
185		199	190	9	0	0	0	620
190		199	312	14	0	0	0	751
195		32	0	5	0	0	0	72
200		215	0	14	0	0	0	359
205		60	156	9	0	0	0	298
210		0	0	0	0	0	0	0
215		16	0	0	0	0	0	32
220		0	0	0	0	0	0	0
	19600	16942	14602	3318	2786	0	0	57251

Table II - Swordfish catch-at-length. Greece 1987.

LJFL	1 - 2	3*	4*	5	6	7	8	9**	10-12	Total
45		0	0	0	0	0	0	0	0	0
50		0	0	0	0	0	0	0	0	0
55		168	0	0	45	0	0	0	0	228
60		101	0	0	45	0	19	0	0	179
65		0	235	9	223	0	0	0	0	503
70		0	101	280	113	392	42	0	0	1013
75		34	403	254	222	406	127	0	0	1615
80		0	101	156	311	428	932	146	0	2276
85		0	24	94	170	850	1059	0	0	2437
90		0	34	110	81	1833	1407	146	0	4000
95		34	0	0	0	922	1049	365	0	2576
100		34	0	76	12	379	1191	959	0	2889
105		36	34	46	31	195	508	468	0	1424
110		34	101	247	227	332	376	473	0	1947
115		0	34	338	194	302	166	142	0	1341
120	N O	0	0	396	311	497	431	215	0	2040
125		34	0	271	355	335	696	177	0	2041
130	D A T A	0	0	328	341	394	549	508	0	2404
135		0	0	494	626	680	1055	250	0	3448
140		0	0	319	204	549	638	484	0	2428
145		0	0	389	148	267	384	177	0	1550
150		0	0	354	192	489	347	755	0	2345
155		0	0	155	322	542	703	230	0	2167
160		0	0	329	203	885	406	474	0	2534
165		0	0	243	237	239	382	288	0	1556
170		0	0	158	218	233	229	302	0	1258
175		0	0	365	166	506	304	264	0	1786
180		0	0	195	255	230	187	317	0	1311
185		0	0	265	200	312	102	88	0	1080
190		0	0	97	37	63	132	93	0	473
195		0	0	124	0	138	57	88	0	452
200		0	0	103	55	52	42	146	0	443
205		0	0	82	74	13	85	0	0	284
210		0	0	24	0	0	42	0	0	75
215		0	0	0	0	56	0	0	0	62
220		0	0	12	0	0	0	0	0	14
	- -	473	1067	6313	5618	12519	13647	7555	0	52179

* - The catch of Kalimnos is not included
** - The catch of Kithnos is not included

TABLE III - Mean back-calculated lengths at age and predicted by the von Bertalanffy model for swordfish

Age	LJFL Back calculated			LJFL von Bertalanffy		
	Males	Females	Both	Males	Females	Both
1	96.4	97.8	97.0	97.0	98.3	99.0
2	117.9	120.2	118.9	117.4	120.4	118.3
3	134.7	140.1	137.4	133.9	138.8	135.0
4	148.0	155.0	151.7	147.3	154.3	149.5
5	158.2	167.8	163.3	158.0	167.3	162.0
6	165.0	174.9	170.1	166.7	178.3	172.9
7	171.6	188.6	177.2	173.8	187.6	182.3
8	182.0	195.1	188.6	179.4	195.4	190.5
9	-	202.8	202.8	-	202.0	197.6

TABLE IV - Estimates of growth parameters, standard deviation and confidence limits derived from the von Bertalanffy growth equation

		Estimate	std.dev.	confidence limits
Males	Loo	203.23	6.53	186.44 - 220.02
	k	0.21	0.02	0.15 - 0.28
	to	-2.04	0.28	-2.75 - -1.32
Females	Loo	236.49	6.72	220.00 - 252.97
	k	0.17	0.01	0.13 - 0.21
	to	-2.10	0.21	-2.62 - -1.58
Both	Loo	243.77	21.50	191.09 - 296.44
	k	0.14	0.03	0.05 - 0.23
	to	-2.60	0.61	-4.15 - -1.14

Table V. Estimated weights at age. * Weights calculated from the equation of De Metrio and Megalofonou (1987)

Age	Eviscerated weight (kg)			
	Males	Females	Both Sexes	
1	9.3	9.3	9.9	11.5 *
2	16.8	17.6	17.3	20.3
3	25.1	27.6	26.3	30.7
4	33.6	38.7	36.2	42.4
5	41.7	50.2	46.6	54.7
6	49.2	61.5	57.1	67.2
7	55.9	72.3	67.4	79.4
8	61.6	82.3	77.4	91.3
9		91.5	86.9	102.5

TABELLA VI Swordfish catch-at-age in the Greek Seas. Age 9+ refers to fish that were 9 or more years old

Age	1986 No	1986 %	1987 No	1987 %
1	17197	30.0%	19142	36.7%
2	15658	27.3%	6370	12.2%
3	9034	15.8%	8559	16.4%
4	5475	9.6%	5261	10.1%
5	3258	5.7%	5139	9.9%
6	3039	5.3%	2993	5.7%
7	1996	3.5%	2514	4.8%
8	835	1.5%	944	1.8%
9 +	759	1.3%	1255	2.4%
TOTALE	57.251	100%	52.177	100%

TABLEA VII - Length at age estimates of swordfish from different studies. M=male, F=female.

Age	Berkeley and Houde, 1983 M	Berkeley and Houde, 1983 F	Wilson and Dean, 1983 M	Wilson and Dean, 1983 F	Radke and Hurley,1983 M	Radke and Hurley,1983 F	Megalofonou and De Metrio M	Megalofonou and De Metrio F
1	97.2	98.0	116.9	122.9	84	73	97.0	98.3
2	118.5	119.9	123.3	130.6	98	85	117.4	120.4
3	136.0	139.7	130.2	138.8	110	114	133.9	138.8
4	150.4	157.8	137.4	147.5	122	131	147.3	154.3
5	162.3	174.3	145.0	156.8	133	147	158.0	167.3
6	172.0	189.3	153.0	166.6	143	160	166.7	178.3
7	180.0	202.9	161.5	177.1	153	172	173.8	187.6
8	186.6	215.3	170.4	188.2	161	183	179.4	195.4

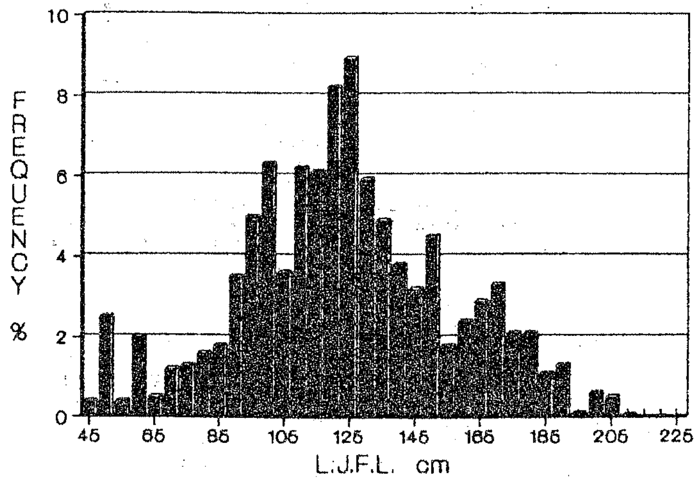

Fig.1 Length frequency distribution 1986

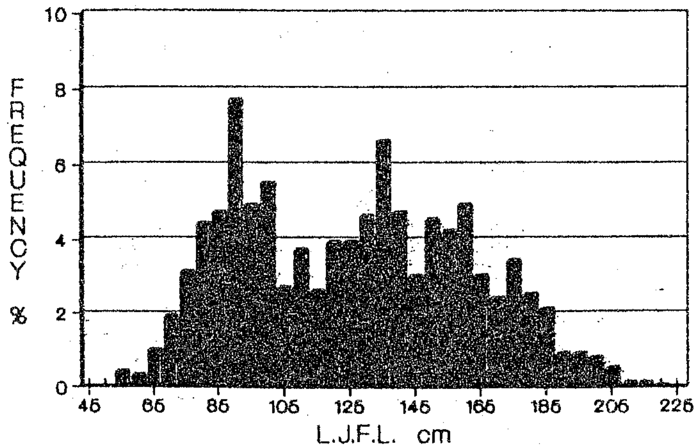

Fig.2 Length frequency distribution 1987

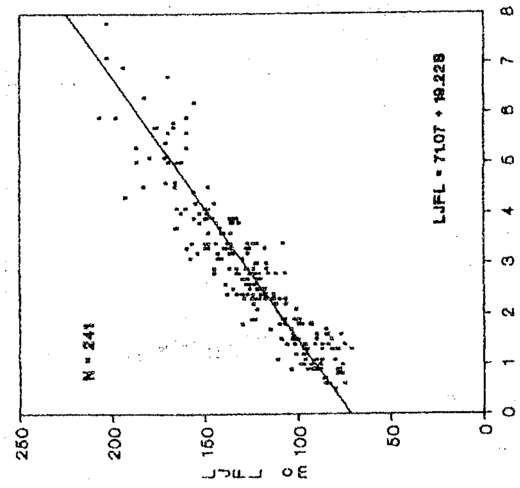

Fig. 4 Spine radius-length relationship for the sexes combined

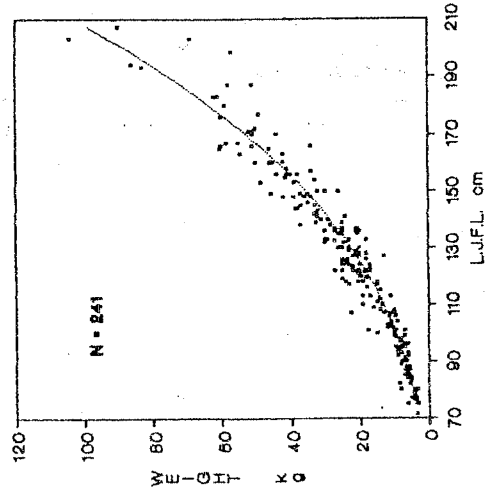

Fig. 3 Length-weight relationship for the sexes combined

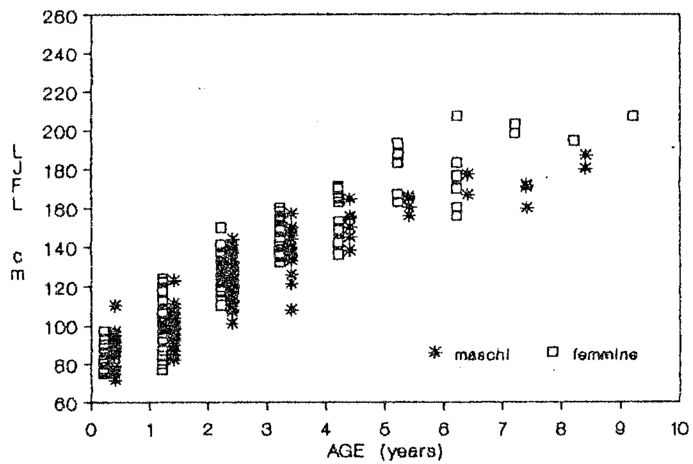

Fig.5 Lengths at estimated age

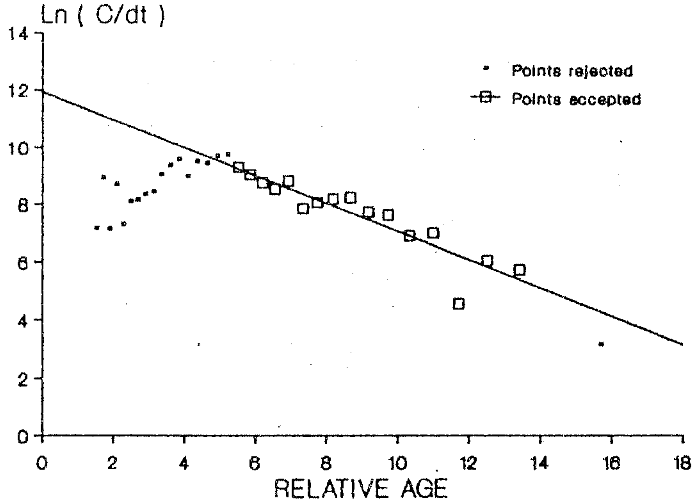

Fig.6 Length converted catch curve 1986

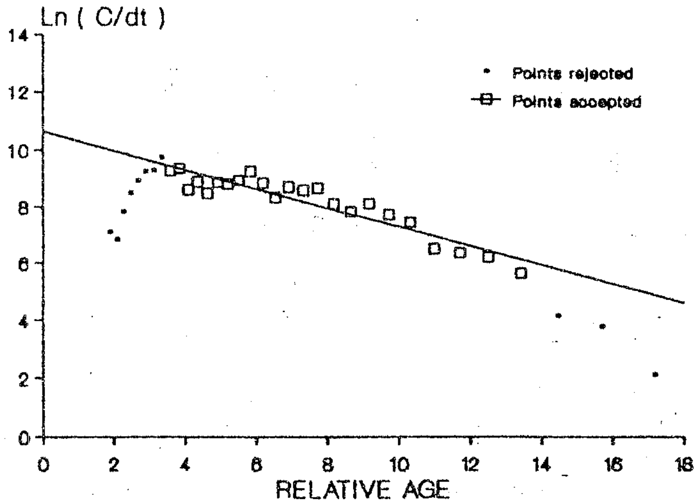

Fig.7 Length converted catch curve 1987