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PRELIMINARY RESULTS OF NORWEGIAN INVESTIGATIONS ON THE GREATER SILVER SMELT, ARGENTINA SILUS (ASCANIUS)

by
Per-Otto Johansen and T. Monstad
Institute of Marine Research
P.O.Box 1870-72
5011 Bergen, Norway.

ABSTRACT

During the spring and autumn season of 1980 and 1981, the greater silver smelt, Argentina silus (ASCANIUS) were recorded over the Norwegian shelf between 62° and 70°N. The stock was more even distributed during autumn than during spring when it congregated in the deeper parts of the shelf for spawning.

Materials for greater silver smelt from Norwegian waters are compared with some samples collected at the British Isles and Faroes waters. The growth rate was higher and sexual maturity occurred earlier at the British Isles/Faroes than at Norway.

Spawning in Norwegian waters took place from March to August and the onset of spawning was earlier than at British Isles/ Faroes.

The materials from Norwegian waters showed highest total mortality for female. The mean length and proportion of males increased with increasing sampling depth. Length/weight relationship is given for four quarters of 1980. Fecundity were in average 6 000 and 24 500 eggs for specimens of 33 and 48 cm respectively.

INTRODUCTION

Greater silver smelt has been caught in Norway for years as bycatch from the mixed industrial fisheries. The commercial interests in this species have now increased, and from mid of the seventies a directed fishery for human consumation also started. It takes place in Skagerak and off Møre/Trøndelag in Mid-Norway. In the latter area the annual catches have increased from 250 t in 1977 to more than 9 000 t in 1981.

Norway started systematic investigation on A.silus only in 1980, and some preliminary results of the biological observations and distributions are presented in this paper.

MATERIAL AND METHODS

Acoustic surveys with research vessels have been conducted during spring -and autumn seasons. Integrator was connected to the echo sounder and the observations of greater silver smelt are presented as various hatching symbols representing ranges of echo-intensity in mm deflection per nautical mile. Fishing with pelagic and bottom trawl were done frequently for identification and sampling. The results of the trawl catches together with subjective judgement of the echo papers gave basis for sorting out the echo intensity of greater silver smelt from the rest of the recordings. Attempts were made to estimate the abundance acoustically. However, no density coeffisient has yet been established and besides, due to the mingling with other fish species and the bottom close distribution, too many errors were implified to give reliable estimates.

The samples of greater silver smelt from the British Isles/ Faroes area were in March 1981 caught near Shetland (ICES-area IVa west of the Greenwich meridian), at the Faroe (Vb) and west of Scotland (VIa).

In April 1980 samples were caught west of Scotland (VIa and VIb) and west of Ireland (VIIbc). The samples from the Norwegian coast were taken between 62° and 70°N from January 1980 to December 1981. They were collected both from commercial catches and from research vessels. The age was determined by reading the wintergrowth zones of the otoliths.

By the use of a method described by ALLEN (1966), were the parameters of a von Bertalanffy equation of the type $L_t=L_\infty (1 - e^{-k(t-to)})$, fitted to the observed data.

The total mortality was determined by a method described by RICKER (1975). The logarithm of N was plotted against the age groups. This method demands constant recruitment to fishery. WOOD & RAITT (1968) suggests small variation in yearclass strength of A.silus.

The maturity of gonads was categorized in eight stages. The first stage consisted of the sexually immature and the sixth stage of spawning specimens.

Non-linear functions of the type $Y= ax^b$ were fitted to the length/weight and length/fecundity data. The constants a and b were estimated by linear regression on logarithmic transformed data.

RESULTS AND DISCUSSION

Distribution

Greater silver smelt in Norwegian waters is distributed in connection with the shelf area along the whole coast from Skagerak to Finnmark. It may also extend a bit further north along the slope in the western Barents Sea.

Little is known about the migration pattern. The stock is mainly scattered near bottom at depths between 200 and 600 m. During spawning periods it congregates in deeper parts of the shelf or along the slope at depths around 400 m.

In 1980 the shelf area between 62° and 68°N was covered in April and again in November. The observations of greater silver smelt in April were patchy with highest concentrations on the middle of the shelf between 65° and 66°N. The temperature at bottom in the areas where greater silver smelt was caught, ranged from 5.4 to 7.6°C (WIBORG & THORSEN 1980).

The distribution and relative density during November 1980 are shown in Fig. 1, with corresponding bottom temperatures at Fig. 2. Scattered recordings were made over most of the area covered, with the highest concentrations at the outer parts of the shelf.

In 1981 the surveyed area was extended north to 70°N. During April/May relative weak recordings were also this time made over most of the shelf (Fig. 3). Some concentrations were located at the outer part, i.e. between 64° and 65°N, and others were found nearer to the coast. One patch of dense recordings was located off Lofoten at 68°N.

The temperatures at bottom or 500 m depth are shown in Fig. 4.

During October/November 1981 greater silver smelt was found in various densities continuously between 62° and 70°N (Fig. 5). Bottom temperatures are shown in Fig. 6. Areas with "medium" density were more extensive than during spring time the same year, but there was found no areas with high density.

Sex ratio

Table 1 shows the sex ratios of greater silver smelt from the Norwegian coast in four sampling intervals. The proportion of females was decreasing as the depth increased.

Total mortality

Catch curves of greater silver smelt from the coast of Norway, north of 62°N in 1980, are shown in Fig. 7. The age of full recruitment to fishery was 18 and 19 years for females and males respectively. The estimated total mortality was 0.35 for females and 0.25 for males. THORSEN (1979) estimated the total mortality within the same area. By using the same method, mortality rate was 0.19 in 1977 and 0.16 in 1978 for males and 0.31 in 1977 for females. Total landings have been relatively stable in the period 1972-1980 (Table 2), while fishing intensity north of 62°N have been increasing since 1977. Besides, the possibility of faults in age determination increases with increasing number of wintergrowth zones after sexual maturity.

The accuracy of the estimated total mortality is therefore still uncertain. However, there was observed a higher total mortality for females than males both in 1977 and 1980 at the coast of Norway.

Length -and age distributions

Length -and age distributions of greater silver smelt from the coast of Norway are shown in Fig. 8. Above 200 meters depth the mean length was 21.6 cm and most of the sampled fish were younger than 5 years. When depth increased, the mean lengths also increased. Thus were the number of older fish increasing with increasing depth. Below 400 meters, the mean length was 36.8 cm, and more than 10% of the samples were older than 20 years.

Length -and age distributions from the British Isles/Faroes are shown in Fig. 9. The samples A (Shetland and Faroes') and B (west of Scotland) are not showing increasing mean length with increasing depth. In these two samples the mean values of the length distributions are decreasing south- and westwards. The age distributions of A and B do not show any particular difference. The decreasing mean length and age distribution from

sample B to C (west of Scotland and Ireland) might be caused by both decreasing depth and more southern sampling.

The mean length increased and the proportion of females decreased with increasing depth at the coast of Norway. This agrees with the higher mortality rate of the females. CHRZAN & ZUKOWSKI (1966) found the same trend with regard to sex ratio and mean length on Browns Bank off Nova Scotia. They also found geographical variations in length distributions of the greater silver smelt.

The Norwegian greater silver smelt trawlers have been trawling at depths deeper than 400 meters. A.silus, in these catches, have mainly been sexually mature. However, the Norwegian industrial trawlers have mostly been trawling at depths shallower than 300 meters. Thus have the industrial trawlfishery to a large extent exploited the immature part of the stock.

Length growth

The length growth of greater silver smelt from the Norwegian coast and the British Isles/Faroes are shown in Fig. 10. In both areas the females increased faster in length than the males. Females and males from the Norwegian coast had significant different growth (5% level) from an age of 7-8 years. Females and males of age 11, 12 and 14 years from the British Isles/Faroes had significant different growth (5% level). As a consequence of the small samples from the British Isles, the high confidence limits hides any other possible differences.

BORODULINA (1968) observed also a faster growth of the females of A.silus at the coast of New Foundland, Nova Scotia, Iceland and Norway. KEYSLER (1968), however, did not find any difference in the growth of females and males in a sample from Greenland, Iceland, New Foundland and Norway.

A few earlier investigations on the growth of A.silus from the coast of Norway are published. According to KEYSLER (1968, Table 3:5) were the females 45 cm long at an age of 15 years.

BORDULINA (1964) found that females and males reached 44 cm and 42 cm respectively at an age of 15 years. Females, 15 years old were 42.8 cm according to WOOD & RAITT (1968). The material from all these works were collected at the Norwegian coast north of 67°N. This investigation, in which the material was mainly collected south of 67°N, gives 40 cm and 38 cm respectively for females and males 15 years of age.

Faster length growth of mature specimens off the coast of Iceland and Greenland than off the coast of Norway was observed by BORDULINA (1968), KEYSLER (1968) and WOOD & RAITT (1968). Temperature conditions seems to be important for growth, but other factors like food competition might also be of importance (BORDULINA, 1964).

The samples of A.silus from the British Isles/Faroes showed a faster growth than the sample from hte Norwegian coast. Table 3 shows the length growth parameters of the von Bertalanffy equations. The estimated maximum lengths were about 5 cm higher for both females and males in the samples from the British Isles/Faroes than in samples from the Norwegian coast.

WOOD & RAITT (1968, Table 3:16) found increasing mean lengths of A.silus from Porcupine Bank to the Faroes. Females 15 years of age increased in mean length from 39.8 cm to 44.5 cm northwards. The growth curves from the British Isles/Faroes (Fig. 10 were to a large extent based on data north and west of Scotland which gave females a mean length of 45 cm at 15 years of age. However, the decreasing mean length from A to B (Fig. 9) and the relative constant age distribution indicate a slower growth rate southwards.

Length/weight relationship

The parameters of the length/weight regressions of greater silver smelt from the Norwegian coast in 1980 are shown in Table 4. It showed allometric growth (b>3) in all four quarters of 1980. Females longer than 30-35 cm were in average heavier than males at the same length (Fig. 11). This is probably due

to the relatively heavier gonads of the females. During spawning the females were visibly thicker than the males.

Seasonal variations of the length/weight relationship of A.silus from the Norwegian coast in 1980 are shown in Fig. 12. Large females and males were relatively heavy in the second quarter of 1980. There was a decline in mean weight from the second to the third quarter of 1980. Females and males 50 cm long decreased 0.17 and 0.05 kg respectively. This is probably due to the spawning in spring. Females increased faster in mean weight than the males from the third to the fourth quarter of 1980.

Sexual maturity

Length growth of females of greater silver smelt was significantly faster than for males from an age of 7-8 years at the Norwegian coast (Fig. 10). The weight of females was increasing more than the weight of males from a length of 30-35 cm, that is 6-11 years (Fig. 11). Both these sexual differences indicate sexual maturity. Examination of the gonads gave onset of maturity from 5 to 11 years at the coast of Norway (Table 5). Fifty per cent were sexual mature at an age of about 6 years.

Sexual maturity from the British Isles/Faroes occurred mainly at an age of 3 to 9 years (Table 5). About fifty per cent in the samples were sexually mature at an age of 3-4 years. The onset of sexual maturity seems to be earlier at the British Isles/Faroes than at the coast of Norway. This corresponds with the results of WOOD & RAITT (1968) where A.silus was found to be sexually mature at an age of 2-9 years by the British Isles and 5-11 years by the Norwegian coast. A.silus seems to be one of the species of fish that mature later in life when living in cold waters (WOOD & RAITT, 1968).

Maturity distribution

Table 6 shows the maturity distribution of greater silver smelt at the coast of Norway 1981. In February was a large part of

the sampled fish in the stages maturing 1, 2 and 3. Most of the samples were mature or ripe in March. In the period April-June the spawning part was increasing. The period June-August shows a decreasing part of spawning A.silus and an increasing part of the stage maturing 1. Obviously a large part of A.silus at the Norwegian coast was spawning in the second and third quarters of 1981. KEYSLER (1968) suggested end of spawning in October in North Norway. WOOD & RAITT (1968) deduced spawning time of A.silus in North Norway from June to September.

In November some of the trawl hauls contained a large part of spawning adults. This is reflected in the increasing part of spawning fishes from October to November showed in Table 6.

Most of the specimens were in the maturing stage 1 in October and November. In December most were in the stage maturing 2. The gonads started developing towards a new ripening in December.

Most of the examined specimens from the British Isles/Faroes were in the stages maturing 2-3 in March 1981 and maturing 1-2 in April 1980 (Table 7). The gonads developed later in 1980 than in 1981. This difference might be caused by the difference in sampling areas at the British Isles in 1980 and 1981.

At the coast of Norway a large part of A.silus was mature or spawning in March and April 1981. It seems to spawn later at the British Isles/Faroes than at the coast of Norway. This corresponds with the results of WOOD & RAITT (1968). They concluded that the influence of temperature as a limiting factor in the onset of spawning, was not as important to A.silus as to most species.

Fecundity

Fecundity is shown as a non-linear function of the length of females in Fig. 13. The calculated parameters from a sample of 42 females were: a= 0.0104 and b= 3.7897. The sample was collected April/May 1981 at the coast of Norway between 64° and

65°N. The examined specimen were all in the stages maturing 3 or mature.

Females 33 cm long contained in average 6 000 eggs, while females 48 cm long contained 24 500 eggs in average.

KEYSLER (1968) examined 19 gonads of A.silus from the North Atlantic. The estimated parameters were a= 1.106 and b= 2.5826. BORODULINA (1968) examined 50 females from North Norway and found 12 000-14 000 eggs and 36 000-28 000 eggs in females respectively 36-38 cm and 46-48 cm. WOOD & RAITT (1968) sampled 28 females from North Norway. Females 34-40 cm and 48-51 cm contained respectively 6 000-11 000 and 16 000-26 000 eggs.

The relatively low fecundity of A.silus are due to the large size of the eggs by spawning. The eggdiameter of a spawning specimen was measured to 3.0-3.5 mm.

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WIBORG, Kr. Fr. og THORSEN, T. 1980. Intern toktrapport "Michael Sars" 8-19 april 1980 (Cruise report "Michael Sars" 8-19 April 1980) Fiskeridirektoratets Havforskningsinstitutt, Bergen, 4 pp 6 Figs. 1 Table (Mimeo).

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Table 1. Sex ratios of A.silus in four depth intervals from the Norwegian coast 1980.

Depth interval(m)	Number of females	Number of males	Total number	Per cent females
100 - 199	118	60	178	66.3
200 - 299	278	252	530	52.5
300 - 399	509	564	1073	47.4
400 - 500	384	441	825	46.5
Sum	1289	1317	2606	

Table 2. Landings (t) of A.silus from the coast of Norway 1972-1980.

	1972	1973	1974	1975	1976	1977	1978	1979	1980
Landings from north of 62°N	4400	2700	2700	2400	3100	3200	6800	4500	7000
Landings from south of 62°N	9400	4700	7800	5600	10700	2300	4100	4400	5300
Total landings	13800	7400	10500	8000	13800	5500	10900	8900	12300

Table 3. Growth parameters of A.silus from the coast of Norway and the British Isles.

	Sex	L_∞ (cm)	K	to (year)	yearclasses (year)	N	Year of collection
Norwegian coast north of 62°N	♀♀	43.72	0.1474	-1.74	1 - 20	1010	1980
	♂♂	39.74	0.1581	-2.01	1 - 20	1910	
British Isles from 53°N to 63°N	♀♀	49.72	0.1132	-3.71	3 - 16	185	1980 and 1981
	♂♂	44.39	0.1420	-3.24	3 - 16	286	

Table 4. Parameters of the length/weight relationship of A.silus from the Norwegian coast 1980. a & b are constants in the function $W=a \cdot L^b$. N are the number of measured fishes. Correlations of the logaritm-transformed linear regressions were never less than 0.98.

	1. quarter			2. quarter			3. quarter			4. quarter			1. - 4. quarter		
	a	b	N	a	b	N	a	b	N	a	b	N	a	b	N
♂♂	0.0009	3.6150	226	0.0020	3.3869	322	0.0014	3.4639	199	0.0028	3.2865	745	0.0044	3.1665	1827
♀♀	0.0021	3.3775	110	0.0014	3.5069	119	0.0017	3.4201	48	0.0012	3.5410	386	0.0017	3.4401	844
♂&♀	0.0010	3.5732	342	0.0017	3.4336	468	0.0017	3.4186	247	0.0015	3.4696	1132	0.0027	3.3087	2707

Table 5. Sexual maturity of A.silus by the coast of Norway and the British Isles by examining gonads.

	Age(years)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	>20	SUM
I	numbers examined	27	32	140	55	49	35	98	89	74	83	57	37	22	24	37	29	29	20	25	23	70	1055
	per cent sexual mature	0	0	0	0	26	51	82	90	97	98	98	100	96	100	100	100	100	100	100	100	100	-
II	numbers examined	0	0	7	29	30	12	9	26	42	68	57	79	56	29	16	9	7	2	2	0	0	480
	per cent sexual mature	-	-	14	62	90	92	89	92	98	99	100	99	100	97	100	100	100	100	100	-	-	-

I : Norwegian coast, ICES area IIa, east of Greenwich, April 1981
Depth: 142 - 465 meters

II : British Isles, ICES area IVa west of Greenwich, Vb_1, VIa, VIb and VIIbc, April 1980 and March 1981. Depth: 160 - 515 meters.

Table 6. Maturity condition of A.silus 1981 at the coast of Norway (ICES-area IIa, east of Greenwich). Per cent distribution of each stage with respect to month. Sexually immatures are excluded.

	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Maturing 1	31.5	3.3	18.9	5.6	2.8		31.1		59.9	49.1	30.0
Maturing 2	17.1	6.7	8.7	6.1	3.5		5.0		20.7	13.0	39.4
Maturing 3	18.0	11.7	15.8	9.1	2.1		3.6		7.6	5.3	1.3
Mature	21.6	45.0	13.1	15.5	22.8		4.1		1.3	4.1	1.1
Spawning	3.6	26.7	29.8	40.2	54.5		41.0		1.3	5.1	0.0
Spent 1	1.8	1.7	6.6	16.4	13.8		9.5		2.5	8.0	8.0
Spent 2	6.3	5.0	7.1	7.2	0.7		5.9		6.6	15.4	20.1
Numbers examined	111	60	1784	824	145		222		604	1205	616

Table 7. Maturity condition of A.silus off the British Isles/Faroes April 1980 and March 1981. Per cent distribution of each stage with respect to month. Sexually immatures are excluded.

	March 1981	April 1980
Maturing 1	18.1	38.5
Maturing 2	33.7	43.4
Maturing 3	31.9	5.7
Mature	4.7	4.1
Spawning	1.5	2.5
Spent 1	9.2	5.7
Spent 2	1.0	0.0
Numbers examined	404	131

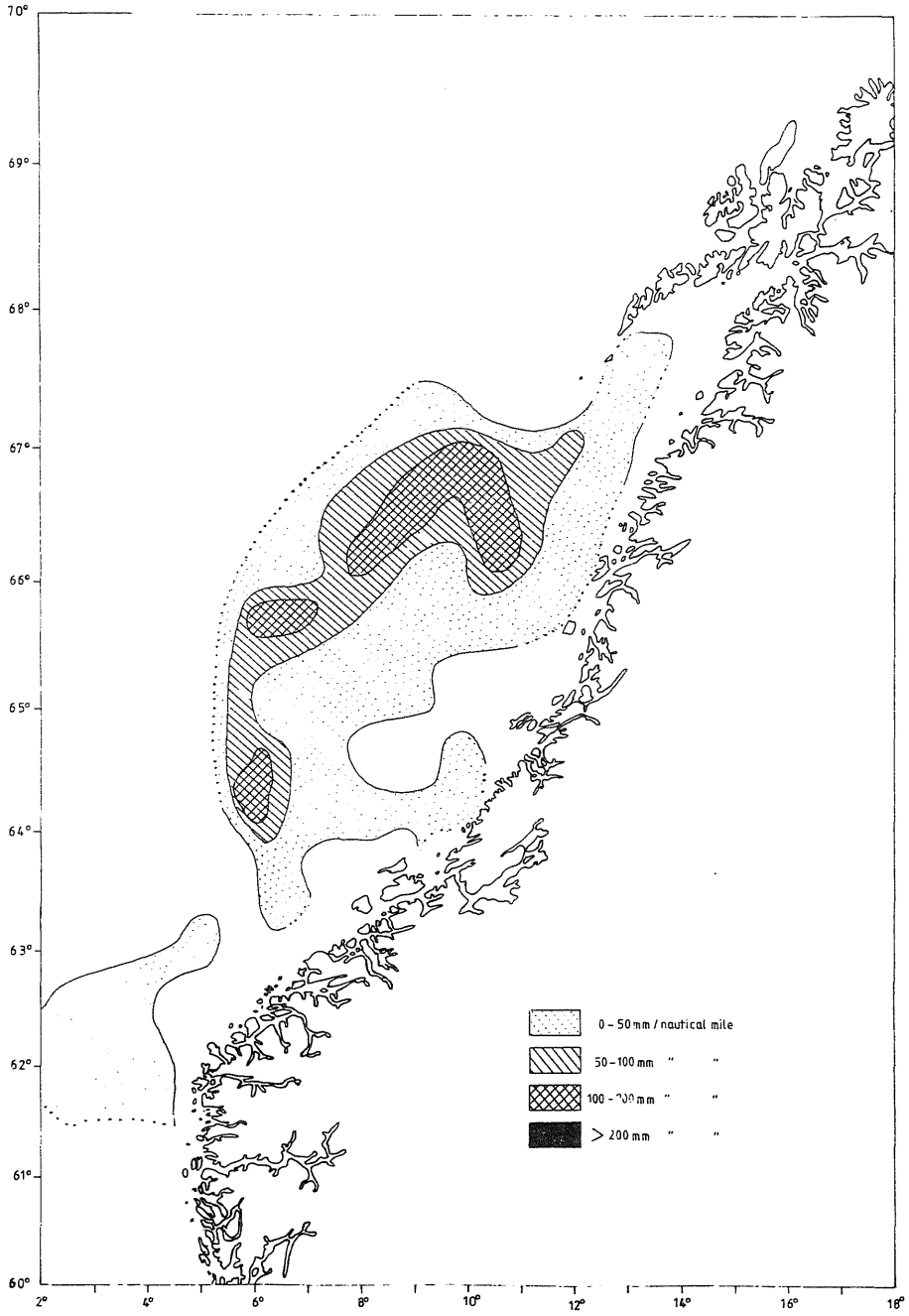


Fig. 1. Distribution and relative densities of Argentina silus, November 1980.

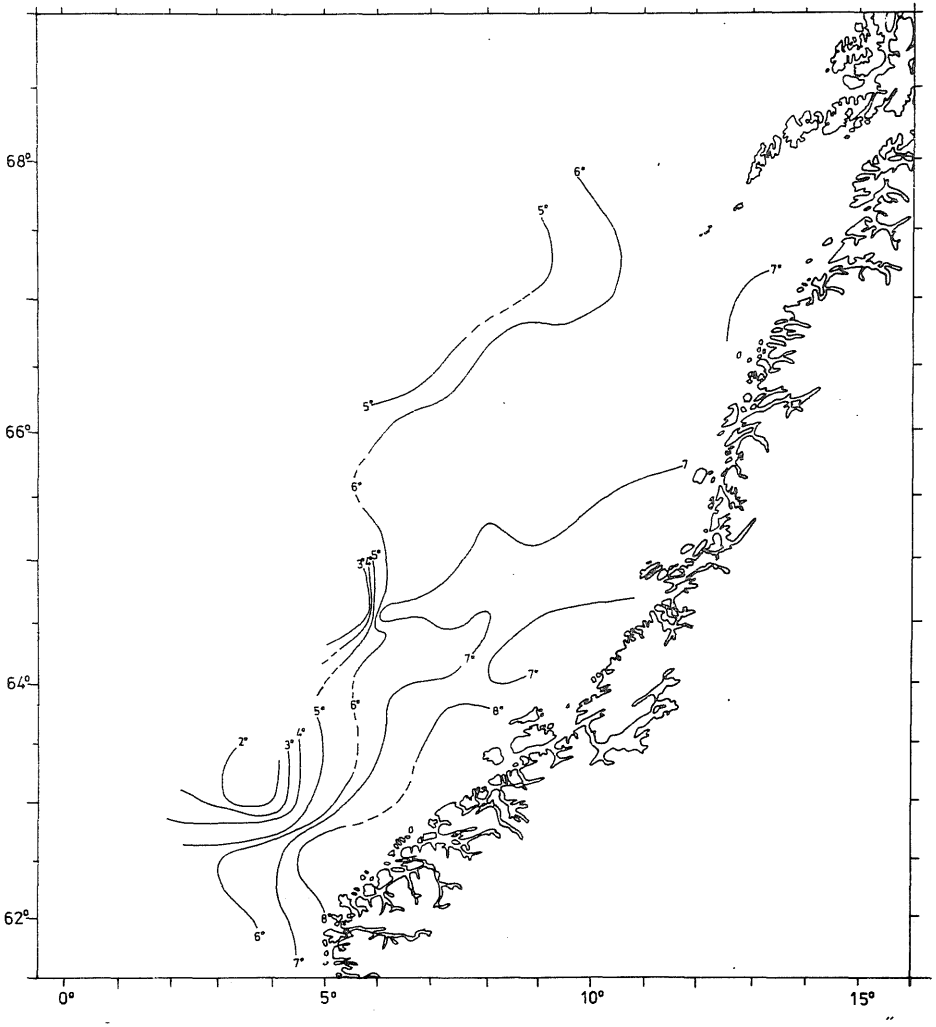


Fig. 2. Temperature, t°C, at 500 m or bottom, November 1980.

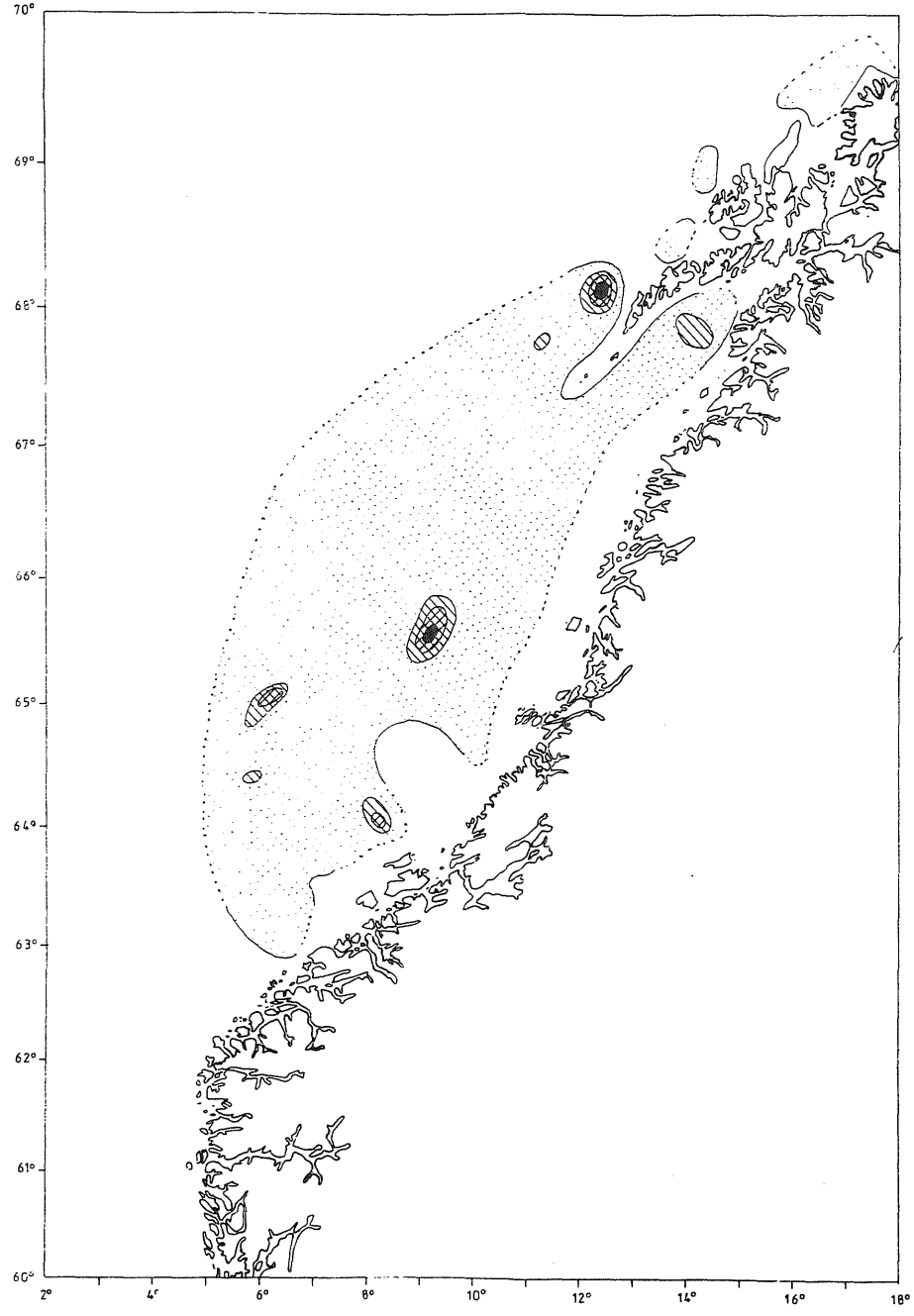


Fig. 3. Distribution and relative densities of A. silus, April/May 1981. Symbols as in Fig. 1.

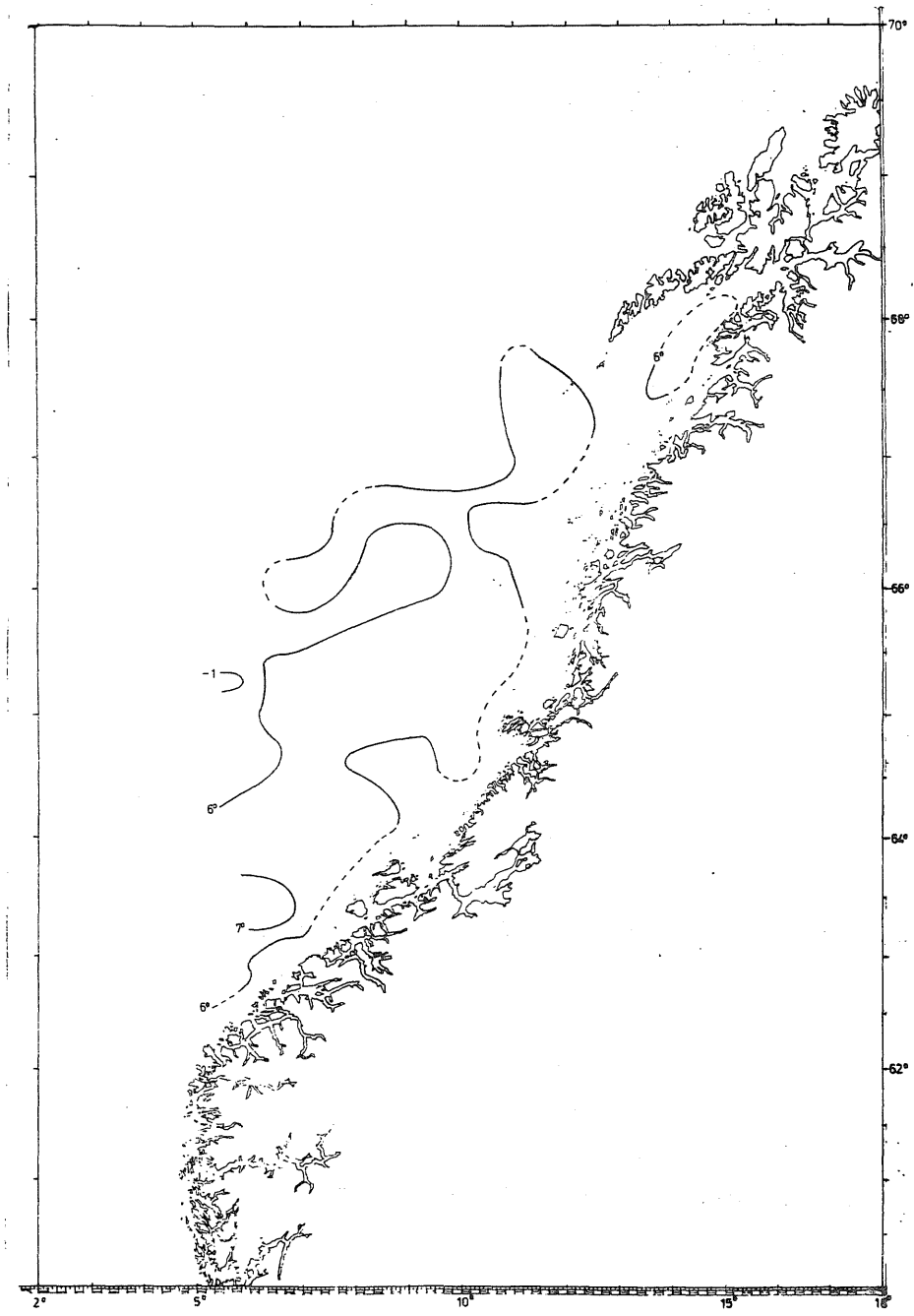


Fig. 4. Temperature, t°C, at 500 m or bottom, April/May 1981.

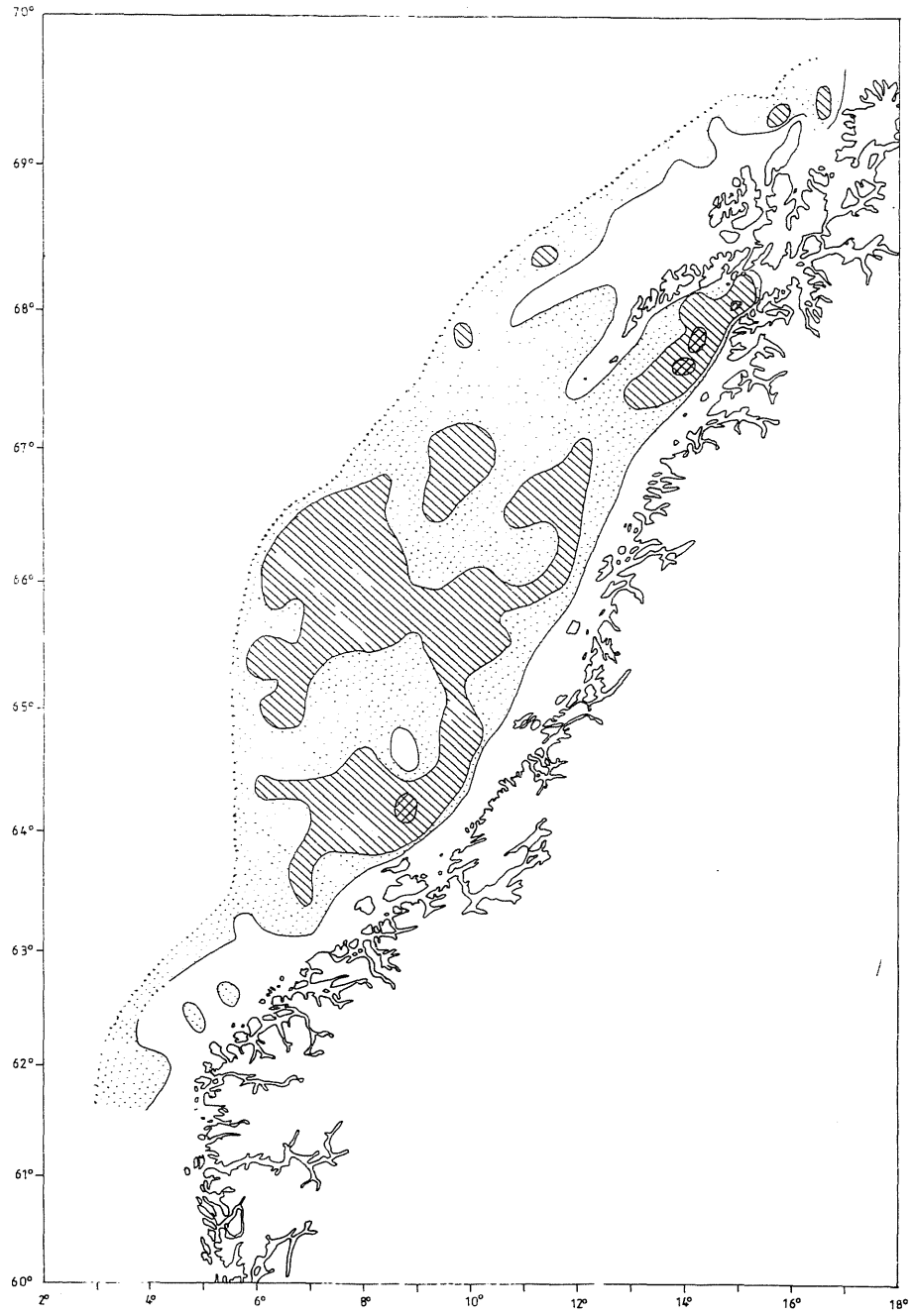


Fig. 5. Distribution and relative densities of A. silus, October/November 1981. Symbols as in Fig. 1.

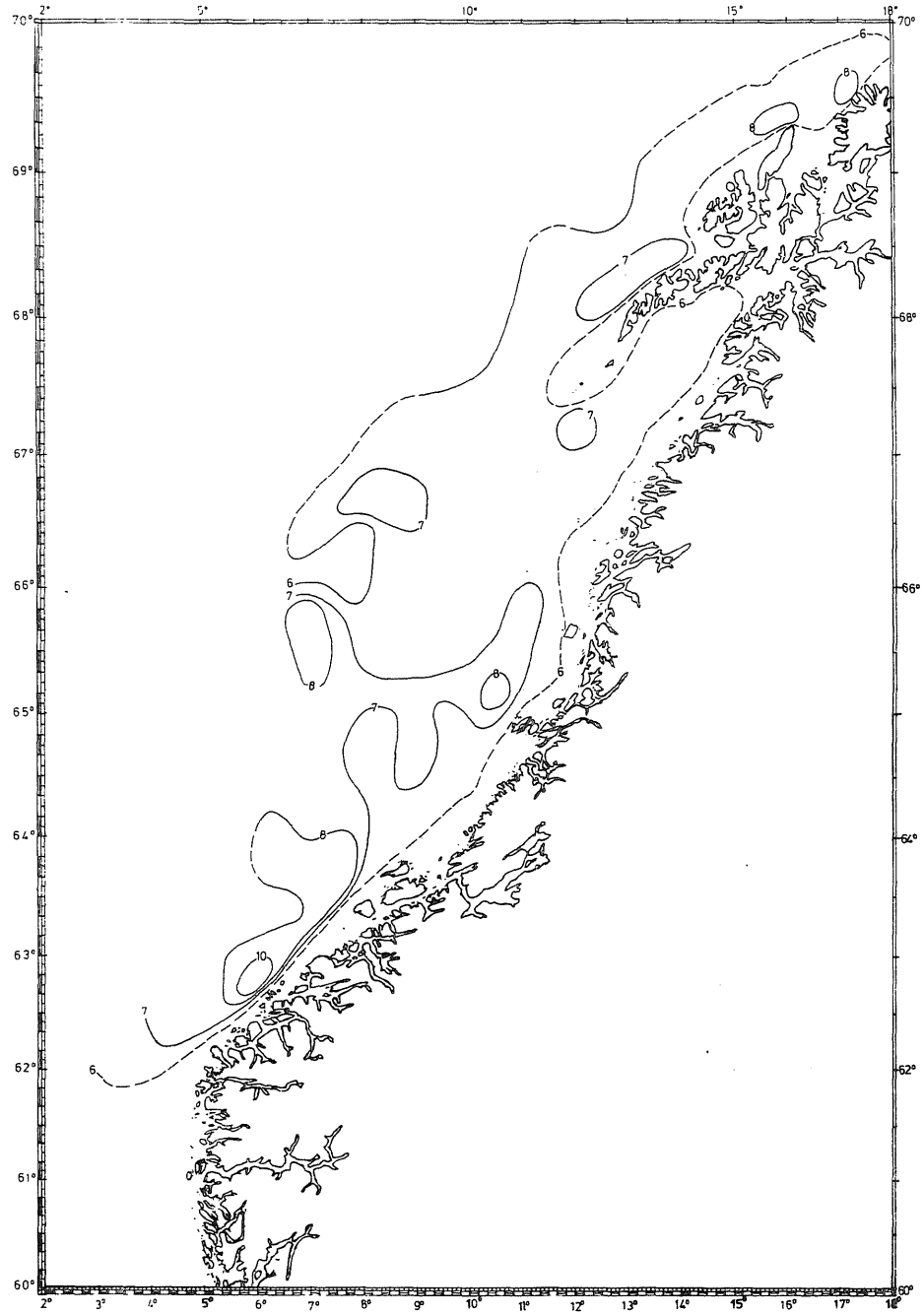


Fig. 6. Temperature, t°C, at 400 m or bottom, October/November 19[illegible].

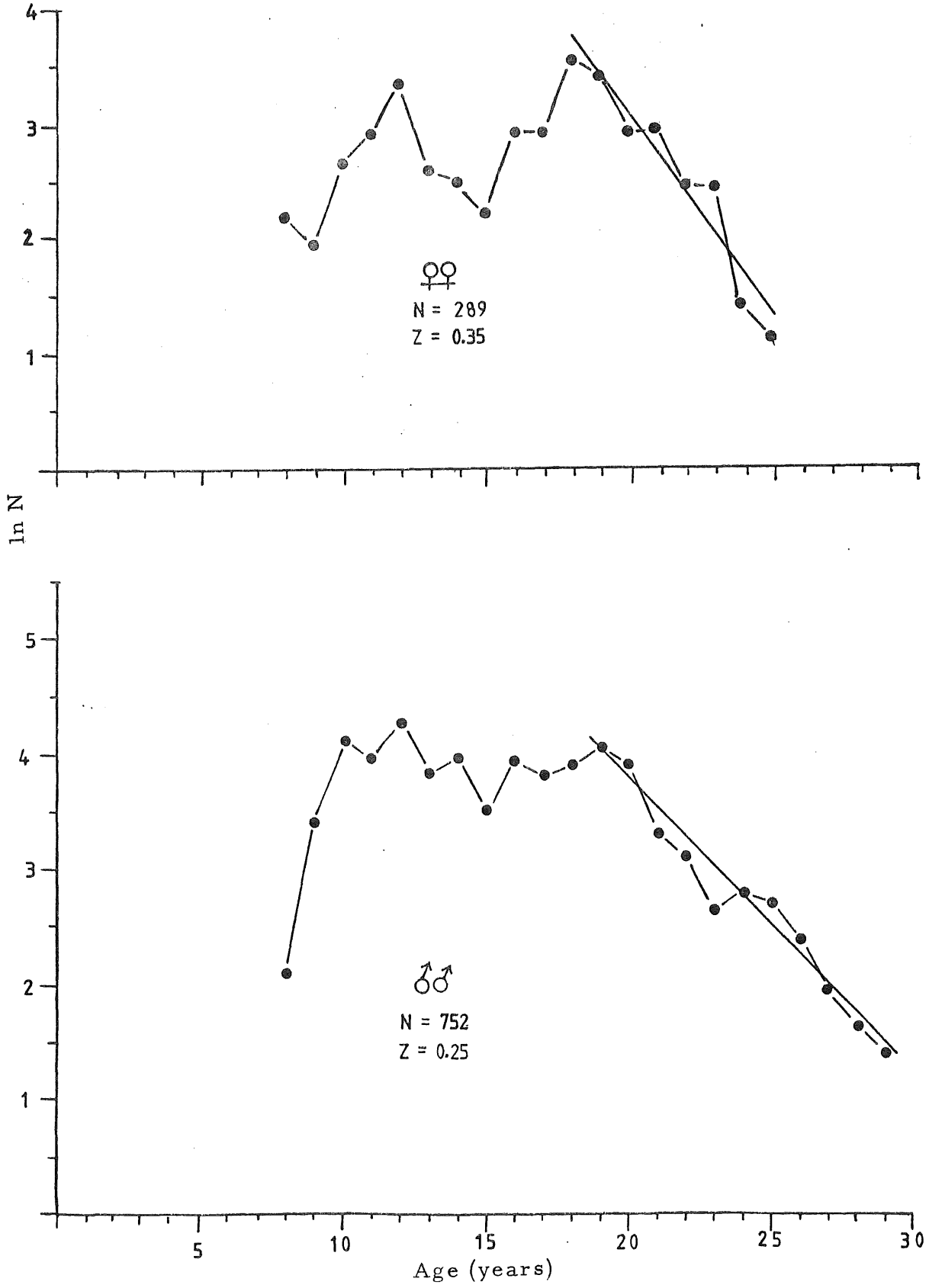


Fig. 7. Catch curves of A. silus from the Norwegian coast north of 62°N in 1980.

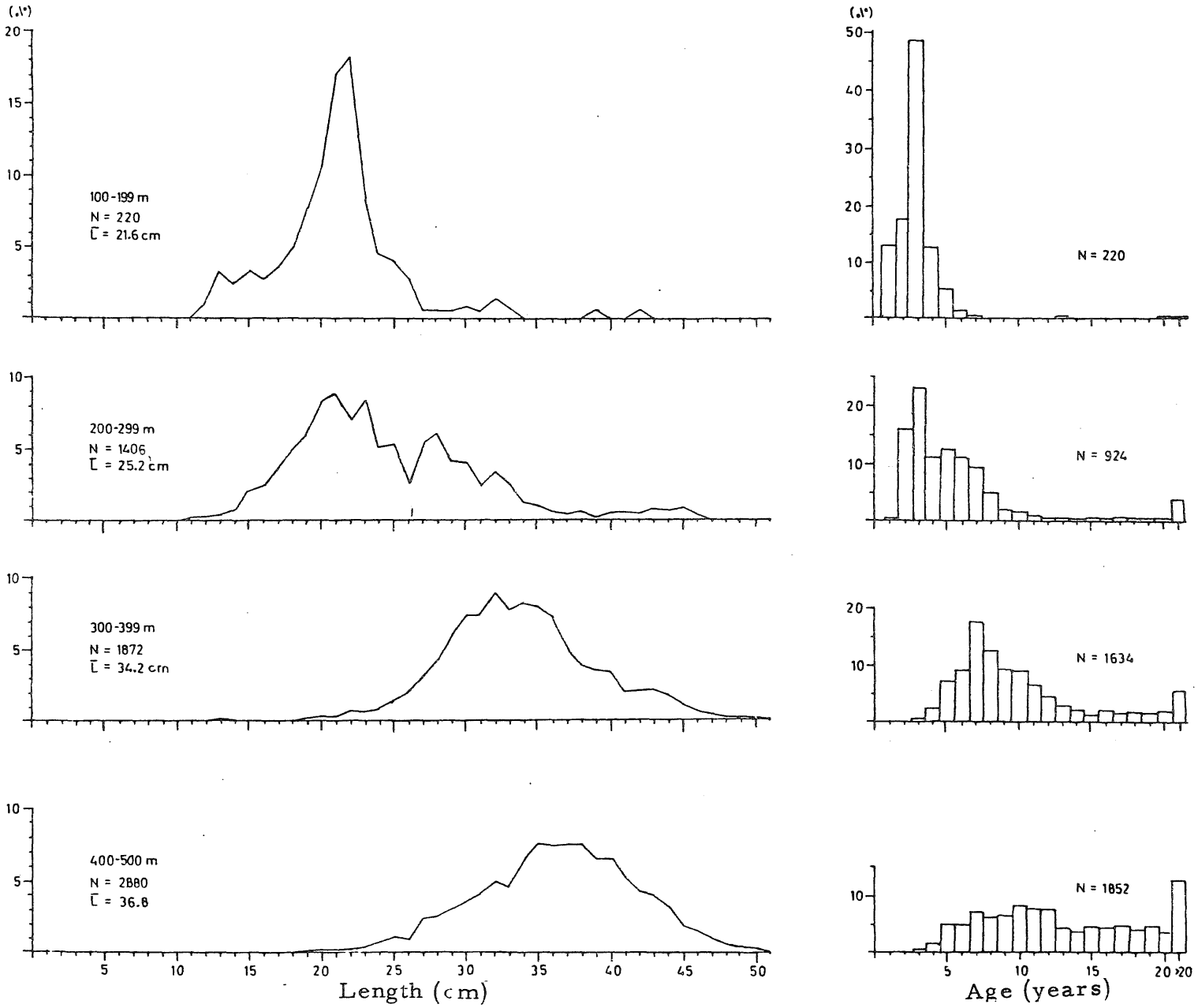


Fig. 8. Lengthdistribution and agedistribution of A. silus from the coast of Norway 1980. The samples from Norwegian research vessels were categorized in four depth intervals.

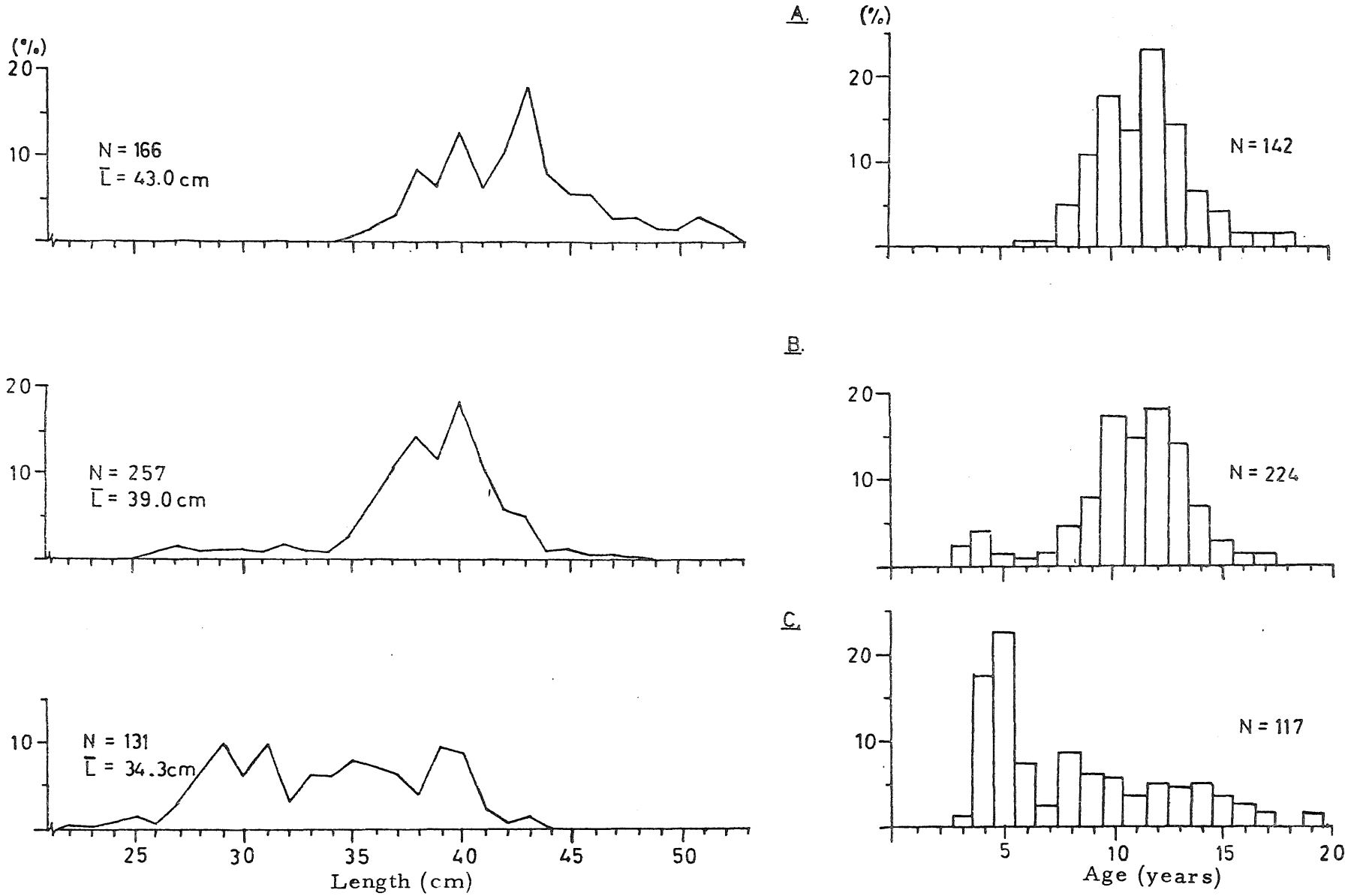
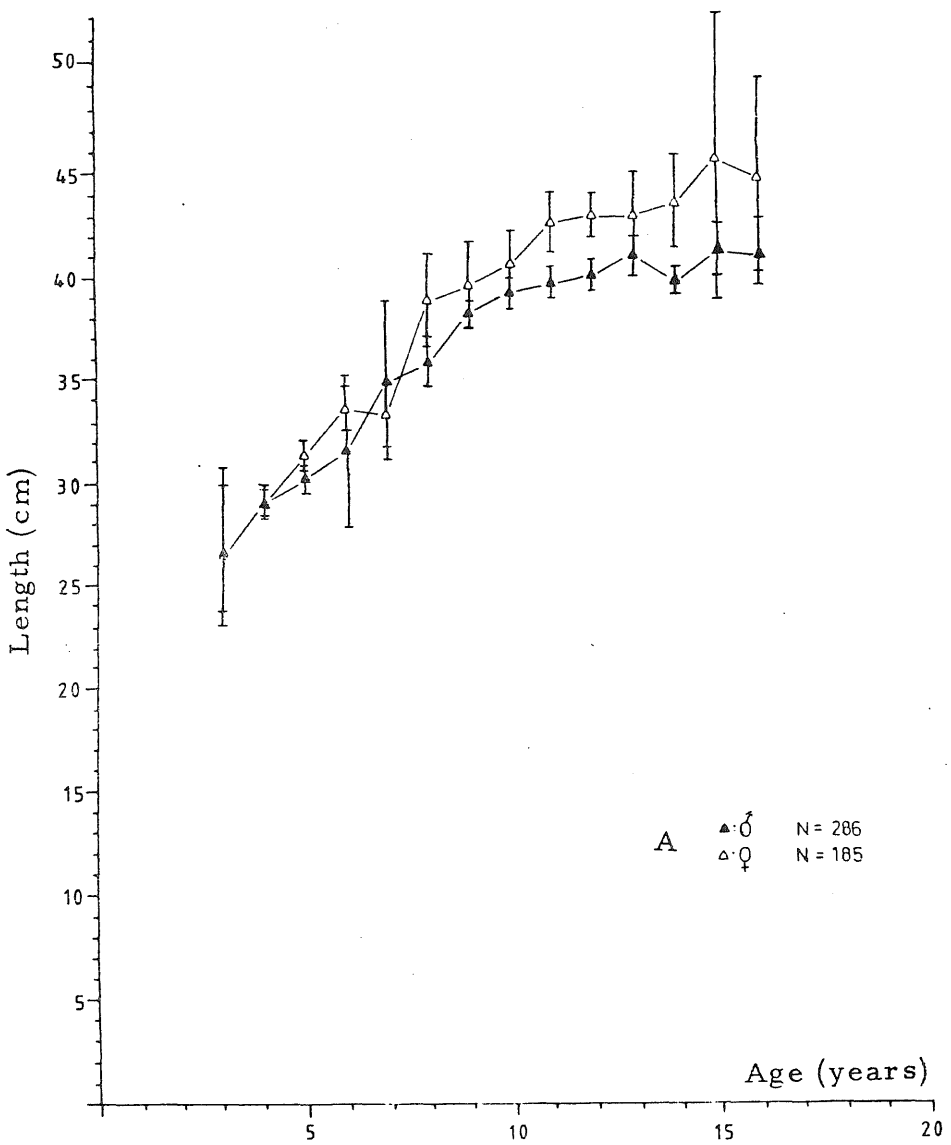


Fig. 9. Lengthdistribution and agedistribution of A. silus from the Brichish Isles april 1980 and march 1981.

A : ICES - areas IVa west of Greenwich and Vb_1. Depth : 255 - 500 meters. March 1981.

B : ICES - area VIa. Depth : 400 - 515 meters. March 1981.

C : ICES - areas VIa, VIb and VIIbc. Depth : 160 - 400 meters. April 1980.



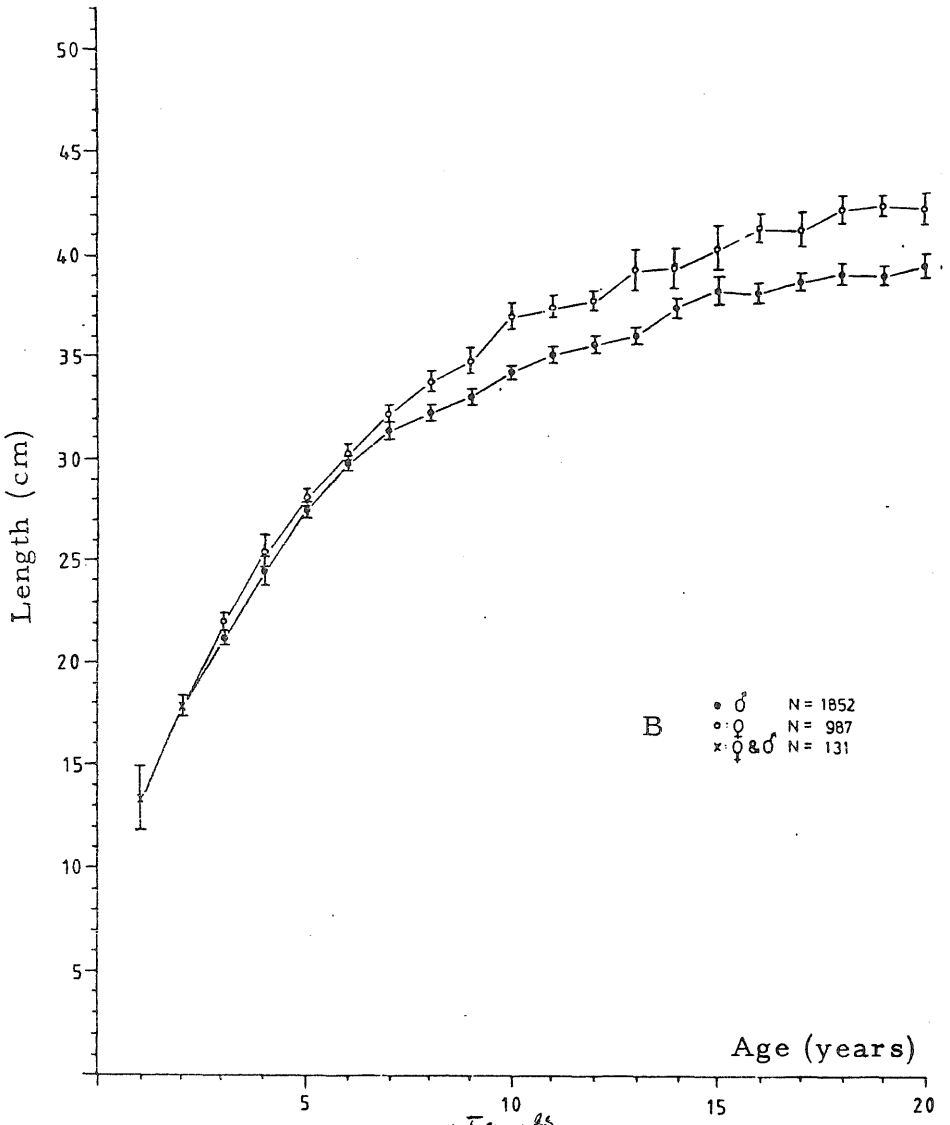


Fig. 10. Growth of A. silus by the Norwegian coast and British Isles. The meanlengths are drawn with 95 per cent confidence limits.

A British Isles, ICES - areas IVa west of Greenwich, Vb_1, VIa, VIb and VIIbc. Material from april 1980 and march 1981.

B Norwegian coast, ICES - area IIa east of Greenwich. Material from 1980.

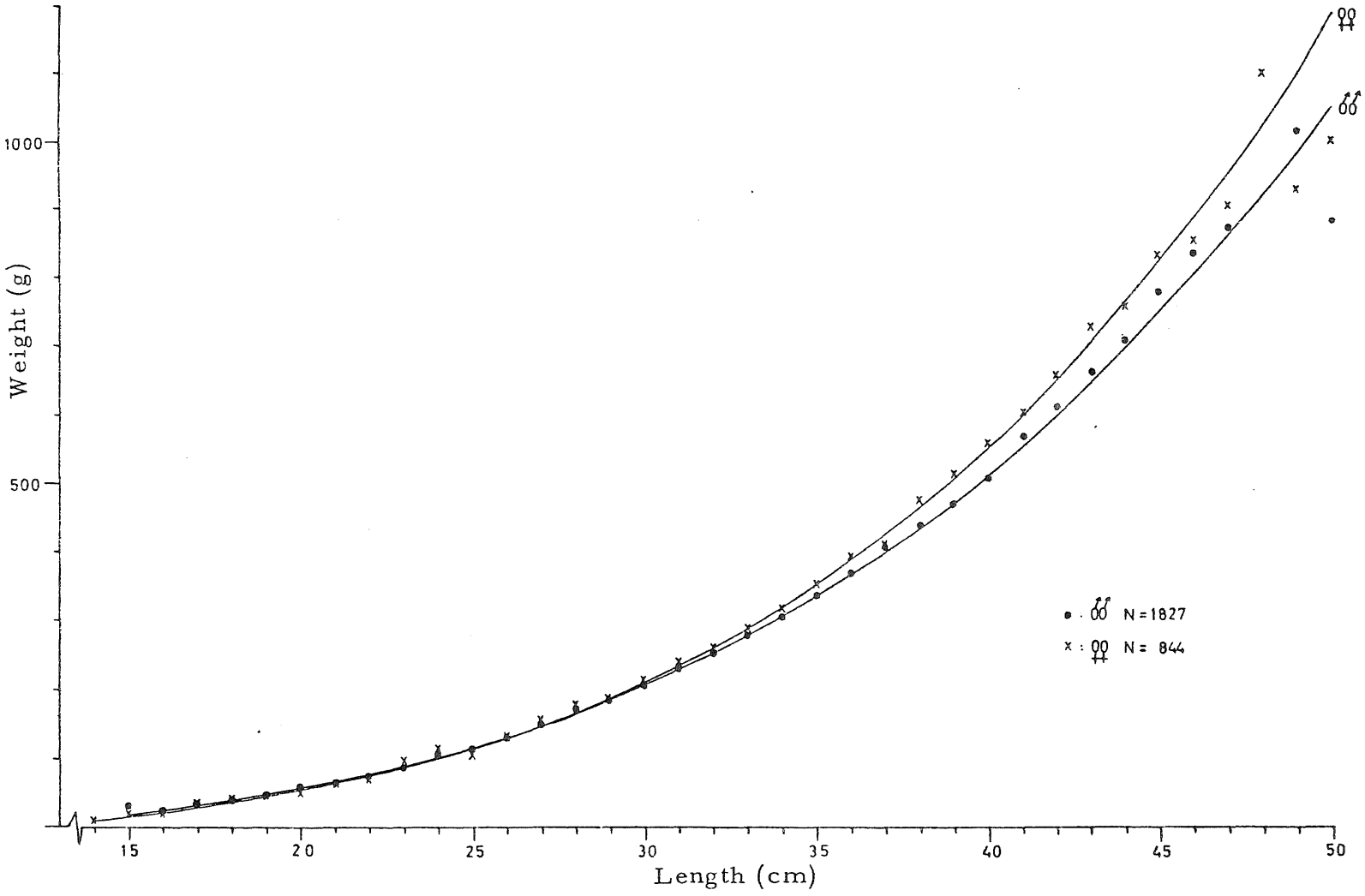


Fig. 11. Length/weight relationship of A. silus from the Norwegian coast from all four quarters of 1980.
The meanweights of females and males are plotted for each lengthgroup.

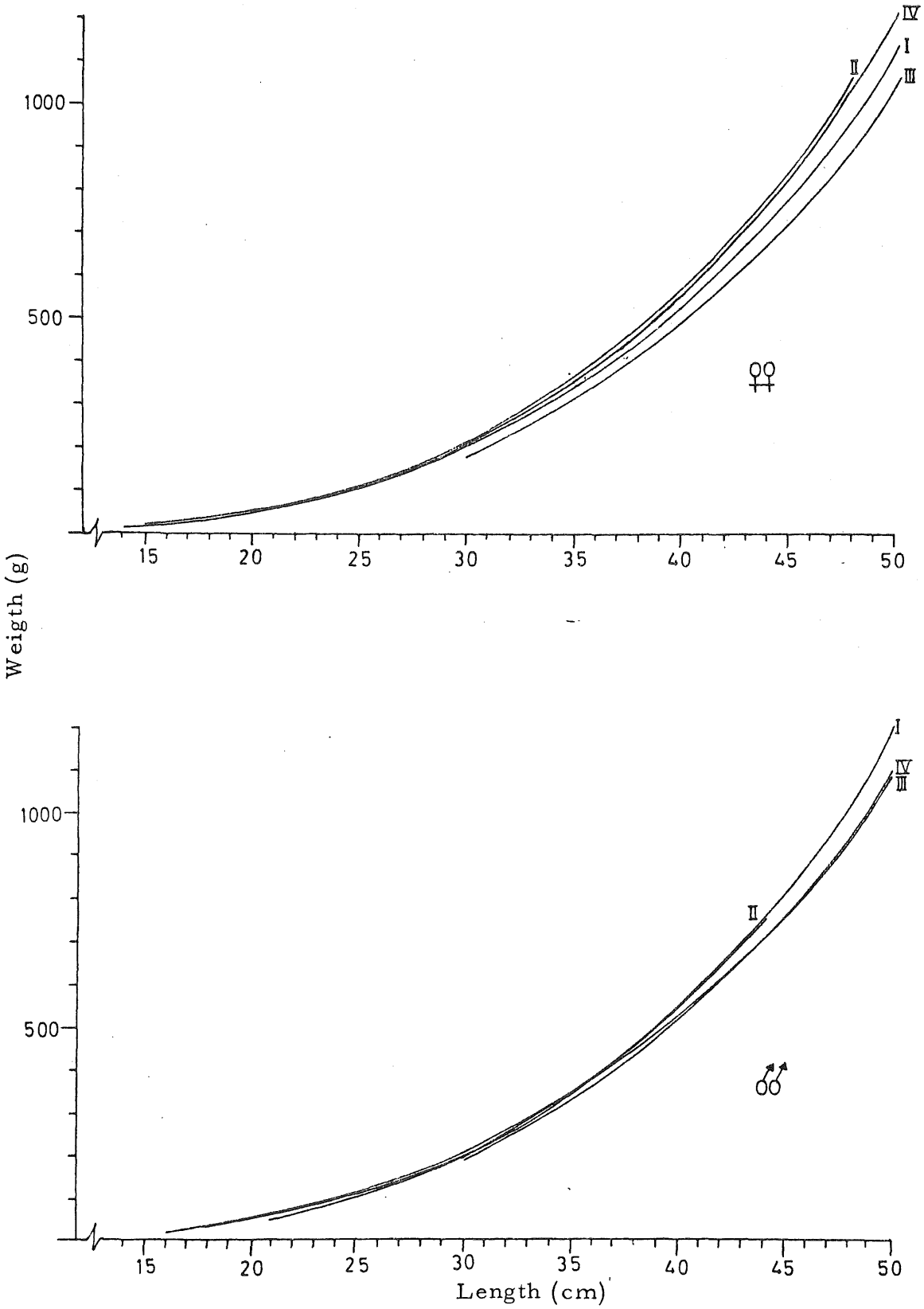


Fig. 12. Seasonal length/weight relationship of A. silus from the coast of Norway 1980. The 1., 2., 3. and 4. quarters of 1980 are named respectivly I, II, III and IV.

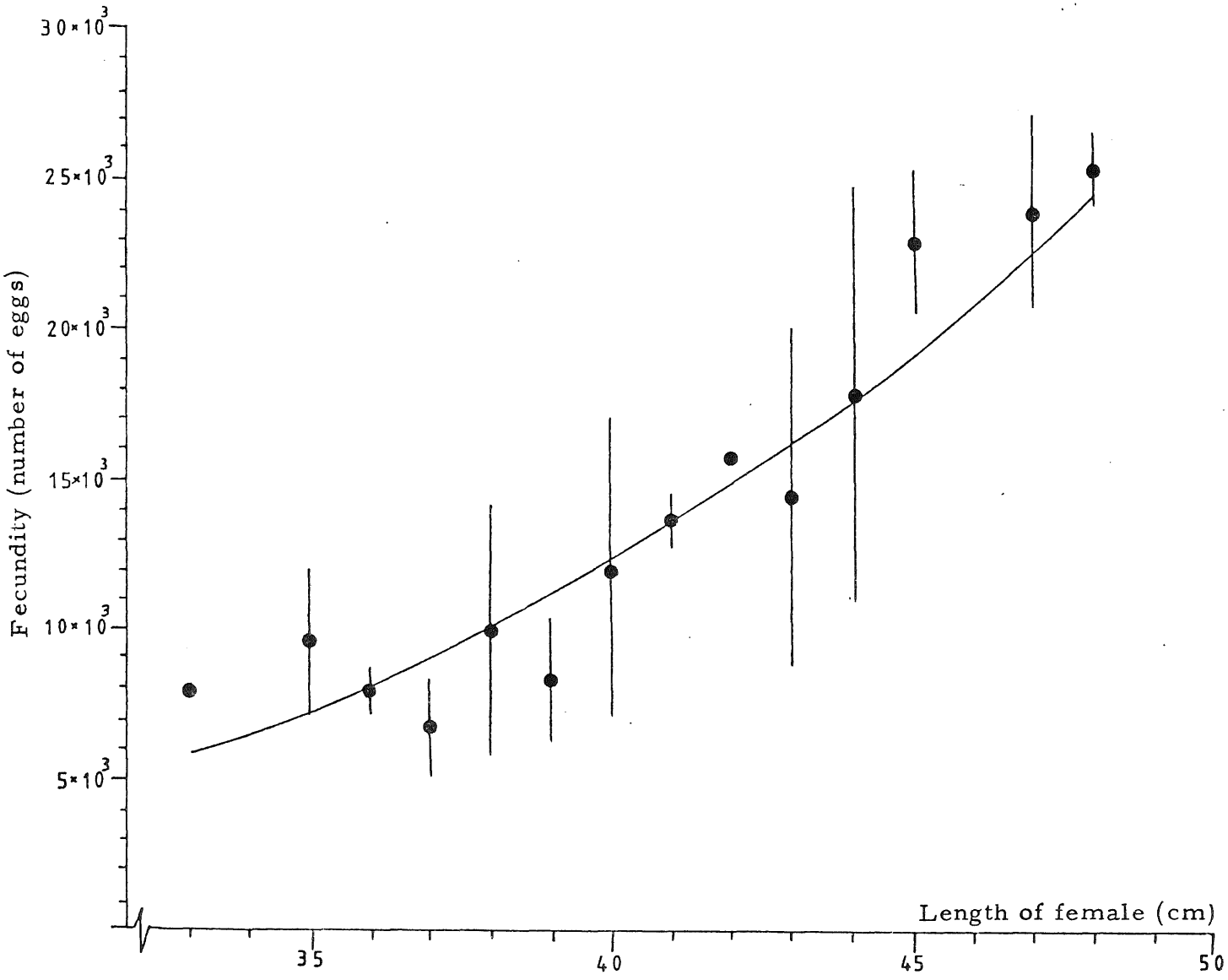


Fig. 13. Fecundity of A. silus from the Norwegian coast. The mean fecundity of each lengthgroup is plotted with standard deviation.