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THE SQUID TODARODES SAGITTATUS (LAMARCK). DISTRIBUTION AND BIOLOGY IN NORTHERN WATERS, APRIL 1980 - APRIL 1981.

by

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ABSTRACT

During the summer and autumn of 1980 the squid Todarodes sagittatus invaded the Norwegian Sea and adjacent areas in great quantities. The invasion may partly be connected with an increased influx of Atlantic water, as indicated by considerable numbers of salps. Materials for investigation were collected from April 1980 to April 1981 in northeast Atlantic waters, the North Sea, the Norwegian Sea, and in the coastal waters of Norway. The mean dorsal mantle length (DML) increased from 16-18 cm for both sexes in April 1980 to 31-32 cm (males) and to 35-38 cm (females) in December, and further to 33 cm and 40 cm respectively in March 1981. Weight-length relations were calculated for various size groups. Growth curves were fitted to the length-frequency data, applying the von Bertalanffy equation $L_t=L_\infty(1-e^{-K(t-t_o)})$. The liver weight varied from 4% to 17% of the total weight, average figures from 6.7% to 10.9%. Males constituted from 0% to 10% of the samples in coastal

areas, in open waters, 20-28%. Food consisted mainly of fish, followed by cephalopods, euphausids and amphipods. In coastal areas T. sagittatus is supposed to eat a lot of 0-group fish. Age readings of daily rings in the statoliths indicate a life cycle of 1-1½ years. Most of the squid investigated were 6-11 months old. Behaviour of squid was studied using echo sounders and underwater TV cameras. The Norwegian squid fishery yielded 2.500 metric tons in 1980.

INTRODUCTION

The European flying squid, Todarodes sagittatus, invades the North-east Atlantic and the Norwegian Sea and adjacent areas more or less regularly. During the years 1949-1971 it came to Norwegian coastal waters nearly every year, but failed to occur during 1972-1976. Since 1977 it has arrived every autumn, in increasing abundance up to 1980. The biology and fishery of this squid in northern waters have been studied (WIBORG 1972, 1978 , 1979, 1980, 1981, HAUGEN and WIBORG 1979, ROSENBERG, WIBORG and BECH 1981). This report deals with the invasion of T. sagittatus in 1980.

MATERIALS AND METHODS

Squid were collected during research cruises in the North-east Atlantic waters in April-May 1980 and in March-April 1981, in the North Sea in July 1980, and in the Norwegian Sea and coastal waters of Norway from August 1980 to March 1981 (Figs. 1, 2).

Dorsal mantle length (DML) was measured to the nearest half cm below in fresh squid during the cruises and in frozen squid after thawing in the laboratory. Total weight and liver weight were determined to the nearest 5 g. The lengths of nidamental glands and testes were measured to the nearest mm, weights of gonads to the nearest g. Sex and stage of maturity were determined visually, size of oocytes with an eye-piece micrometer

under a stereoscopic microscope. Stomach contents were also studied under a microscope. Recordings of shoals or swarms of squid were made with SIMRAD echo sounders EK-38 and EK-120, TV/Gain 40 log R/-20dB, band width 3 kHz, pulse length 0.6 ms and recorder gain 7.

RESULTS

Size

Earlier length measurements of T. sagittatus indicated some shrinking after freezing and thawing (WIBORG 1980). In order to study this problem more closely, one hundred squid (DML 29.0 - 41.5 cm) were measured fresh, then frozen, kept at -35°C for one month, thawed, and measured again, each time to the nearest half cm below. The results were as follows:

Decrease in DML, cm	N	Increase in DML, cm	N	No change in DML	N
0.5	35	0.5	7		48
1.0	8	1.0	1		
1.5	1	-	-		

The mean DML of the squid measured fresh was 34.36 ± 3.04 cm, after freezing and thawing 34.14 ± 3.00 cm. The difference is only 0.6%. Corrections for freezing and thawing should therefore not be necessary. AMARATUNGA (1980) came to the same conclusion for the squid Illex illecebrosus.

Changes in DML during the period investigated are given in Table 1.

In April 1980 different length groups could be distinguished at the Porcupine Bank, males and females with mean DML of about 18 cm and 16 cm respectively, and others of larger squid, males 29-38 cm (mean 31.90 cm) and females 29-53 cm (mean 35.20 cm). In the Faroes-Hebrides area, the smaller squid were scarce or missing, while larger squid were more abundant. From July 1980

Table 1. Mantle lengths of T. sagittatus April 1980 - April 1981. For localities see Figs. 1, 2.

Area	Porcupine Bank		Faroes Hebrides		North Sea (N)		Station M		Fosnavåg		Skogsvåg	Norwegian Sea		Svolvær, Eidsfjord, Grylleфj.		North Norway 66°-71°N		Coastal banks 62°-66°N		Vingen		Station M		Eidsfjord Kvalsund		Grylle-fjord	Station N		Faroes-Hebrides		Skogsvåg
Date	Apr.24-28		Apr.12-May 7		July 25-28		Aug. 10		Aug.13-15		Aug.27	Aug.15-27		Aug.28-30		Oct.14-31		Nov. 4-11		Nov. 13		Dec. 10		Dec.5-12		Jan.15	Jan.23		Mar.10-Apr.5		Mar.31
DML,cm	♂ n	♀ n	♂ n	♀ n	♂ n	♀ n	♂ n	♀ n	♂ n	♀ n	♀ n	♂ n	♀ n	♂ n	♀ %	♂ %	♀ %	♂ n	♀ %	♂ n	♀ %	♂ n	♀ n	♂ n	♀ %	♀ n	♂ n	♀ n	♂ n	♀ n	♀ n
15		1																													15
6	1	3																													6
7	2	1																													7
8	2	1																													8
9																															9
20					2	2				1																					20
1			1		1	3				2																		1			1
2	1					2	2			2								+													2
3						1	2	2		10																		1	1		3
4			1		1	5	2	2		14				1	0,4			+											1		4
5					1		2	7		17				1	9,5			+						1							5
6			2	2			2	6		15	1				9,5			1											1		6
7								2		9	1	1			21,6	1,8													1		7
8				1				6	1	13	8		1		17,3	15,8	0,2											1	1		8
9	4	2	1	1			1	4		10	17		4		13,4	31,6	1,6					1		1					2		9
30	2	2						5		4	16		2	1	13,0	19,3	5,5	4	4,9			1		1		1		2			30
1		4		1				4		5	10		3	1	8,3	7,0	9,1	1	4,9	2				3	2,3	1		2	2		1
2		2		2							4		1		3,9	3,5	15,5	2	7,3	2	0,9	1		3	9,2	4		3			2
3	2	3	1					1			5		1		1,2	7,0	12,7	1	8,5		3,8			4	21,6	6	1	1	2	2		3
4		5		2							1				0,8	3,5	14,4	1	12,2		6,6		2	1	19,2	8	1		4	2		4
5		2	3	3									1		0,8	5,3	13,3		8,5	1	24,5				14,6	7			3	4		5
6		-	1	6												5,3	9,3	2	12,2		17,9				6,9	11			1	5		6
7	1	2	4	2													7,4		11,0		20,8		1		9,2	5	1	1	2	5		7
8	1	1	1	3													4,1		11,0		17,0		4		4,6	5	1	3	2	6	1	8
9		1	1	3													3,9		6,1		8,5		2		8,5	3		2		10		9
40		1		3													2,7		6,1						1,5	2			2	14		40
1				5													0,3		3,7				2		2,3	4		2		9		1
2				3													+		1,2							2		3		12		2
3				3																			1			2		3		8	2	3
4		1		1																						2		1		17	2	4
5				2															1,2											5		5
6				1																										1		6
7		1		2																										5		7
8																			1,2													8
9																																9
50																														1		50
1																																
2																																
3		1																														
n	(6)	10 (6)	28	16	46	5	13	11	39	1	102	63	1	13	4	254	57	1201	12	82+	5	106	3	12	14	130	63	4	16	26	115	5
$\overline{DML}$, cm	31,9	35,2	33,1	38,4	22,4	22,6	24,8	27,7	(28,0)	26,3	30,1	(27,5)	30,8	27,1	28,5	30,6	34,1	32,2	36,1	32,6	36,5	30,7	38,5	31,5	35,1	36.6	35.9	40.3	33.4	40.1	42.50
SD	3,5	5,5	5,6	5,2	2,2	1,5	2,0	2,5		2,4	1,6		1,9	3,4	2,1	2,3	2,6	2,6	3,2	1,8	1,6	1,6	2,5	2,2	2,3	3.2	2.3	3.0	4.6	5.0	2.3
% ♂	26,4	-	25,8		27,8		22,0		0,9			7,2		1,6		4,3		12,8		4,7		20,0		9,7		-	20.0		18.4		-
$\overline{DML}$, cm	(18,2)	(16,7)																													
SD	(2,1)	(0,9)																													

to the beginning of April 1981 the average size of males and females increased steadily. At the end of July females measured on average 22 cm, at the end of August 28-30 cm, in December 36-38 cm, in March 1981 40 cm. Local variations in DML observed in the fjords of North Norway in October may indicate differences in feeding conditions.

The mean DMLs of females T. sagittatus in coastal and bank areas of North Norway in October 1980 and 1981 were very close, 34.06 ± 2.61 cm, and 33.00 ± 2.40 cm, respectively (WIBORG 1980).

The size variations of the males largely followed the same pattern as that of the females, the mean DML always being 3-6 cm below.

A computer program based on a method described by ALLEN (1966) was worked out for fitting the length-frequency data in Table 1 to the Bertalanffy equation $L_t=L_\infty(1-e^{-K(t-t_o)})$. Of the samples from the Porcupine bank in April 1980 only squid with DML below 22 cm were used for the calculations. Growth curves are shown in Fig. 3, and growth curve parameters in Table 2.

Table 2. Growth curve parameters for T. sagittatus for the period April 1980 - March 1981.

	♂	♀
L_∞, cm	39.2	45.8
t_o (year)	0.00	0.03
K (year)	1.80	1.70

The parameters seem to be quite similar to the maximum sizes observed. AMARATUNGA (1980) obtained similar K values for Illex illecebrosus.

Weight-Length relations

The constants a and b in the weight-length equation:

$W = a(DML)^b$ were calculated separately for different size-groups of males and females in the material from 1980. The following values were found:

♂, DML 16.0 - 38.5 cm(n=50): a= 0.0240, b= 2.9534, r^2= 0.9576

♀, DML 14.5 - 51.0 cm(n=467): a= 0.0171, b= 3.0448, r^2= 0.9622

♂, DML 16.0 - 29.5 cm(n=32): a= 0.0580, b= 2.6756, r^2= 0.9146

♂, DML 30.0 - 38.5 cm(n=18): a= 0.0090, b= 3.2369, r^2= 0.7995

♀, DML 14.5 - 29.5 cm(n=193): a= 0.0343, b= 2.8301, r^2= 0.8776

♀, DML 30.0 - 51.0 cm(n=274): a= 0.0118, b= 3.1483, r^2= 0.9143

The equations indicate changes in the relation for DML below and above 30 cm, (Fig. 4). Below 30 cm (A) the constant b is less for males than for females and the curves converge at DML 30 cm. Above 30 cm males are heavier than females at the same DML. In T. pacificus males are also heavier than females at the same DML (MURATA 1978).

Liver percentage

The liver or digestive gland also serves as a food reserve, containing up to 50% fatty acids (WIBORG 1978). Variations and mean percentages are given in Table 3. Low values were observed in squid from the Porcupine Bank and from St. M in the Norwegian Sea, higher percentages were noted along the Norwegian coast, in the North Sea and in the northern Norwegian Sea. The range of variation was considerable in all localities, from below 4% to above 17%.

Sex ratio

Males were always scarce, in coastal and fjord areas comprising usually 10% or less of the samples (Table 1). In open waters

they were more numerous, on the coastal banks 12.8%, at St. M, 20%, in the North Sea and on the Faroe Banks, about 25-28%.

ZUEV, NESIS and NIGMATULLIN (1976) infer that most males of T. sagittatus remain in the spawning areas and do not take part in the feeding migrations northwards. The males are smaller than the females, and as they have a skin which is easily scarred (WIBORG 1980), they may be exposed to agression, especially in confined areas, e.g. fjords. Cannibalism has also been observed in Illex illecebrosus in Canadian waters (O'DOR, DURWARD, VESSEY and AMARATUNGA 1980).

Table 3. Weight of liver in % of total weight of T. sagittatus, April - December 1980. (For location, see Figs. 1, 2)

Locality	Month	N	Variation	Mean	SD
Porcupine Bank	April	24	4.4-12.3	6.67	1.92
Faroes-Hebrides	April-May	37	4.9-14.8	8.78	2.41
North Sea	August	17	6.2-11.3	9.51	1.57
St. "M"	August	50	4.7-11.6	6.98	1.68
Fosnavåg	August	50	4.2-13.1	9.24	1.97
Norwegian Sea	August	14	6.1-16.3	10.89	3.00
Stønesbotn	October	100	4.9-17.2	9.46	2.69
St. "M"	December	15	3.7-10.5	6.87	2.58

Table 4. Weights of testes in percent of total weight, and occurrence of spermatophores in male T. sagittatus with DML 30.0 cm or above in the Faroe-Porcupine bank area April 12 - May 5 1980 and March 10 - April 5 1981.

Year	DLM, cm Variation	Mean	N	Weight of testes in % of total weight Variation	Mean	SD	Spermato-phores
1980	31.5-34.0	32.8	2	1.4	1.4		No
	33.0-38.0	35.4	8	1.4-2.4	1.80	0.33	Yes
1981	30.5-35.5	32.7	8	1.0-2.5	1.65	0.45	No
	32.0-40.0	35.6	10	1.4-2.6	1.93	0.39	Yes

Maturation

In northern waters T. sagittatus caught during summer and autumn are mainly immature. In males with DML above 30 cm the testes increase in size from December-January. In January-February 1980, a male with DML 33.0 cm at St. M had a testis weighing 10.9 g, 0.74% of the total weight, four males, 35.5-38.5 cm, had testes 12.8-19.8 g, averaging 1.55% of the total weights. In January 1981 four males, DML 33.0-38.5 cm had testes averaging 1.52% of the total weight, the largest male with spermatophores developed. In the Faroe-Porcupine Bank area, males with DML 30.0 cm or larger in April-May 1980 and March-April 1981 had testes constituting 1.0-2.9% of the total weight, some also with spermatophores (Table 4). The largest males were most advanced in development, and more males had spermatophores in 1980 than in 1981, which indicates that a peak of mating may occur in May.

AMARATUNGA and DURWARD (1979) established maturity indices for Illex illecebrosus. These may be adapted to T. sagittatus.

For males there are four stages: 1. immature, 2. maturing, 3. mature, 4. spent.

In Table 4 the stage without spermatophores may correspond to stage 2, spermatophores present - stage 3.

For females, AMARATUNGA and DURWARD (1979) based a maturity index of five stages on the relationship: length of the nidamental glands (NGL) to the (dorsal) mantle length (DML). MANGOLD-WIRZ (1963) classified the female T. sagittatus in the Mediterranean according to egg (oocyte) size into four stages. Immature, with very small eggs, up to 0.6 mm in diameter (I), with small eggs 0.7-2.4 mm (II), with middle-sized eggs 1.3-1.8 mm (III) and with large eggs 1.9-2.4 mm (IV). These criteria have been used together with the modified index of AMARATUNGA and DURWARD (1979) as shown in Table 5.

Table 5. Characteristics of the maturity stages in female T. sagittatus adapted from AMARATUNGA and DURWARD (1979) and MANGOLD-WIRZ (1963). NGL-nidamental gland length, DML-dorsal mantle length.

Maturity stage (MS)	Range of NGL, mm	Maturity index (MI) range of NGL/DML x 1000	Oocyte (egg) diameter (ED), mm
1	10-40	100 and below	up to 0.6
2	40-90	101-200	up to 0.6
3	80-110	201-300	0.7-1.2
4	100-130	301-400	1.3-1.8
5	190-	401-	1.9-2.4

As few females have been found in an advanced stage of maturity, the criteria for MS stages 4 and 5 must be taken with reservation. The numbers of females T. sagittatus in various stages of maturity in the Faroes-Porcupine Bank area in the spring of 1980 and 1981 are shown below.

Maturity stage	April-May 1980	March-April 1981
1	24	10
2	22	88
3	1	3
4-5	2	0

The characteristics of the two females in stages 4-5 were as follows:

No.	DML cm	Total weight g	Ovarium weight g	NGL mm	NGL weight g	Eggs in oviduct, g	Oocyte diameter, mm
1	53	3815	95	212	173	0	1.5-2.0
2	44	2175	55	-	276	107	1.5-1.7

In No. 2, the number of oocytes in the oviduct was estimated to 84 500. MANGOLD-WIRZ (1963) calculated the number of eggs in mature females with DML 36-37 cm to be 12 000 - 15 000, which is considerably lower, but the number may possibly be reduced during the final stages of maturation.

Five females of T. sagittatus caught off the west coast of Norway in May 1978 with DML 40.0, 41.0, 41.0, 45.0 and 46.5 cm, had MI: 225, 170, 317, 245, 129, corresponding to maturity stages (MS) 2-4. The female with MI 317 had oocytes measuring 1.2-1.5 mm.

From the data presented, it is very difficult to estimate the time these females would spawn, but it might occur during June-July. CLARKE (1966) reports a female caught in March to be in spawning condition. It had a DML of 45 cm and NGL of 194 mm, giving an MI of 431 .

Stomach contents

The frequency of various food organisms in the stomachs of *T. sagittatus* from different localities in 1980-1981 is shown in Table 6. Empty stomachs have been excluded.

Table 6. Frequency in % of food organisms in stomach contents of *T. sagittatus* in various areas, April - December 1980. n-number.

Locality	Month	Fish	Squid	Krill	Prawns	*Parathemisto* sp.	Polychaetes	Chaetognaths	Indet.	n
Porcupine Bank	Apr.	100	14.3	0	0	0	0	0	0	14
Faroes-Hebrides	Apr.-May	73.0	16.2	24.3	8.1	0	0	0	10.8	37
North Sea	Jul.-Aug.	100	6.7	0	0	0	0	0	0	15
St. "M"	Aug.	67.5	28.2	10.9	21.7	58.8	0	0	48.0	46
Fosnavåg	Aug.	78.0	11.1	14.8	7.4	0	0	0	0	27
Skogsvåg	Aug.	95.0	5.5	0	0	2.7	0	0	0	37
Norwegian Sea	Aug.	44.5	11.1	11.1	0	44.5	0	44.5	22.2	9
Stønesbotn	Oct.	13.5	76.7	6.7	10.0	0	10.0	0	10.0	30
North Norway	Oct.	35.2	32.5	58.5	2.7	2.7	8.1	2.7	0	37
St. "M"	Dec.	60.0	26.6	86.7	6.7	20.0	0	0	6.7[x)]	15

x) *Pareuchaeta* sp.

Fish dominated the food in most areas. Squid ranged second or third. Krill occurred regularly, occasionally dominating. Amphipods were frequent a few times.

The species of fish identified were as follows:

The Faroes-Porcupine Bank area: Blue whiting, pearlside, Notoscopelus kröyeri, Paralepis kröyeri, silver smelt.

North Sea: whiting, gadoids.

Norwegian Sea: redfish, blue whiting, pearlside,

Coast of Norway: redfish, herring, sprat, silver smelt, whiting, pollock.

Most fish remains were from small fish, maximum 20-30 cm long. In Norwegian fjords, however, squid have been observed to attack shoals of larger herring, and they also feed on fish caught in nets or on longlines.

Of squid remains, T. sagittatus was most common in fjords and coastal areas, Gonatus fabricii in the Norwegian Sea and North Atlantic. A high percentage of squid may sometimes be caused by the squid fishery, as squid captured on hooks are attacked, and torn-off tentacles are eaten by other squid.

Amphipods identified were Parathemisto abyssorum and P. gaudichaudi; Prawns: Pasiphaea sp.; polychaetes: Nereis sp (pelagica); copepods: Pareuchaeta sp. In the fjords, pieces of the seaweed Ascophyllum and of polystyrene were found in the stomachs.

The large numbers of squid present in Norwegian coastal areas during the autumn and winter of 1980-1981 may have had a serious effect on the 0-groups of fish, especially herring. A survey in November-December 1980 with acoustic equipment revealed that north of 62°N 0-group herring were far less abundant than in the year before, in spite of a relatively successful spawning and hatching (I. Røttingen, pers. comm.).

Age

Age determinations, based on counts of growth rings in the statoliths as suggested by LIPINSKI (1978), have continued since 1979 (WIBORG 1979, 1980, ROSENBERG, WIBORG and BECH 1981). Earlier hypoteses of age and time of spawning were largely confirmed. Two main periods of spawning/hatching seem to occur, September-November, and April-June (ROSENBERG et al. 1981), but according to ZUEV et al. (1976) reproduction may go on from January to late in summer. This is also evident from age determinations in squid caught at St. M in December 1980 and in the Faroes-Hebrides area in March 1981.

As only a few statoliths from each size- group were read, the results below are given with reservation.

Month of hatching	Number of squid	
	St. M	Faroes-Hebrides
December	1	
January		1
February	1	1
March	4	6
April	2	23
May	3	62
June		9
July		12
August		6
September		5

These samples contained squid mainly hatched in March-July.

Maximum age estimated hitherto, 432 days, was found in a squid with DML 50 cm. A similar age, 421 days, was observed in a squid with DML 51 cm (ROSENBERG et al. 1981). As a rule, there is quite good correlation between DML and age, but individuals of the same age may vary considerably in length, e.g. DML 22.5 cm, 320 daily rings, DML 31.0 cm, 316 rings (A. Rosenberg,

pers. comm.). Feeding conditions may influence the growth in DML very much, (O'DOR, DURWARD and VESSEY 1979) causing differences in mean length within short distances, as mentioned earlier.

Behaviour

In coastal and bank areas T. sagittatus during the autumn usually keep to 80-200 m depths or close to the bottom during both day and night. From a moving vessel echo traces appear either as dots or vertical or oblique feather-like stripes, extending vertically from 20-40 m to 100 m (Fig. 5). When jigging starts, the squid quickly move upwards, some following the jiggers right to the surface, the main shoal halting 10-20 m under the vessel (Fig. 5). The recordings and behaviour are similar to those reported for the Pacific squid T. sloani pacificus (SHIBATA and FLORES 1972).

During the night, strong lights seem to attract T. sagittatus, but the fishery may be as efficient with the ship's lights only. However, systematic studies on this have not been carried out. The fishery is usually as efficient during the day as during the night.

In October 1979 underwater observations were made during the night, using baits of fish and squid suspended in a frame in front of a TV camera combined with a variable light source. The squid did not react adversely to moderate light, but readily attacked the bait, sometimes two and three simultaneously. Squid were observed clinging to the bait for more than half an hour, devouring large pieces. These observations confirm reports that squid attack and eat fish caught in nets or on longlines.

Conditions for invasion

As already mentioned, T. sagittatus may not invade Norwegian coastal and bank waters every year. The last and longest

absence, 1972-1976, largely coincided with the minimum in stock size and spawning of the Atlanto-scandian herring, but this may merely be a coincidence. Other causes, such as size of the stock of squid and environmental conditions, may have greater effects. During most of the years with invasion of squid, salps (Salpa fusiformis) have been observed in Norwegian coastal and offshore waters in smaller or greater quantities (WIBORG 1972, 1978, 1981). In 1980, salps were abundant in Norwegian coastal waters in August, and large quantities were taken in pelagic trawl hauls by research vessels in October. Salps are considered as indicators of influx of water of Atlantic origin, but when introduced under favourable sea temperatures they may also reproduce in northern waters (BRATTSTRØM 1972).

Fishery

The Norwegian fishery for squid is mainly carried out by jigging, either by hand or with automatic jigging machines of Japanese or Scandinavian design, and with various types of jiggers (HAUGEN and WIBORG 1979). With two machines, up to 2000 kg of squid may easily be caught during one day. Using a purse seine 2-3000 kg squid have occasionally been caught in a haul together with pollock, but fishing with purse seine and light has not been successful, mainly because the squid are too swift in their movements.

In 1980 the Norwegian squid fishery was limited to 2500 metric tons, of which more than half was used as bait. With increased effort, more than ten times as much might have been taken.

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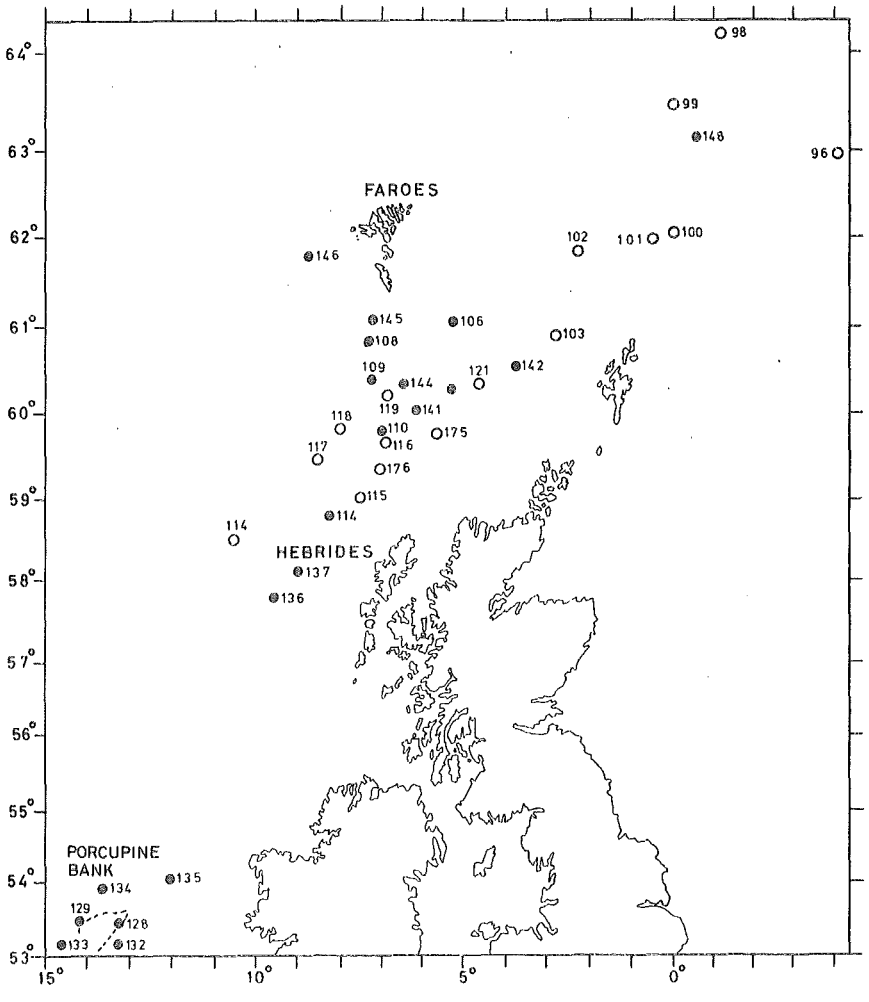

Fig. 1. Stations with catches of T. sagittatus in bottom and pelagic trawls with R/V "G.O. Sars" in April-May 1980 (filled circles) and with R/V "Michael Sars" in March-April 1981 (open circles).

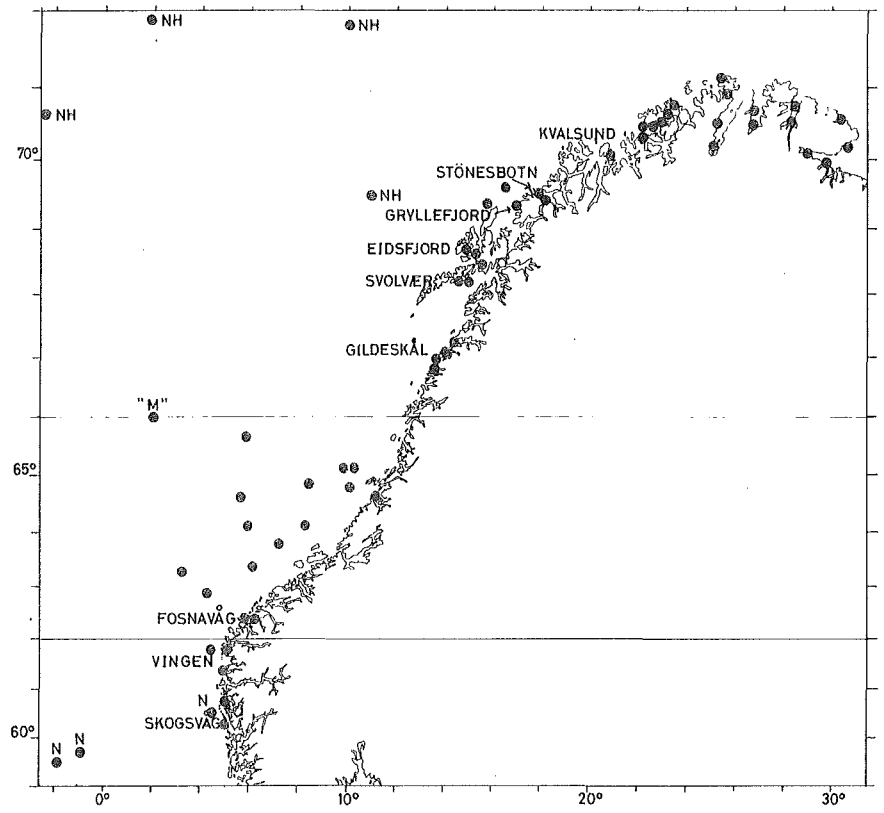

Fig. 2. Stations with catches of T. sagittatus in 1980 during cruises with R/V "G.O. Sars" in August in the North Sea (N), in August in the Norwegian Sea (NH) and with the R/V "Michael Sars" in October-November in Norwegian waters (names and circles). "M" - weathership station.

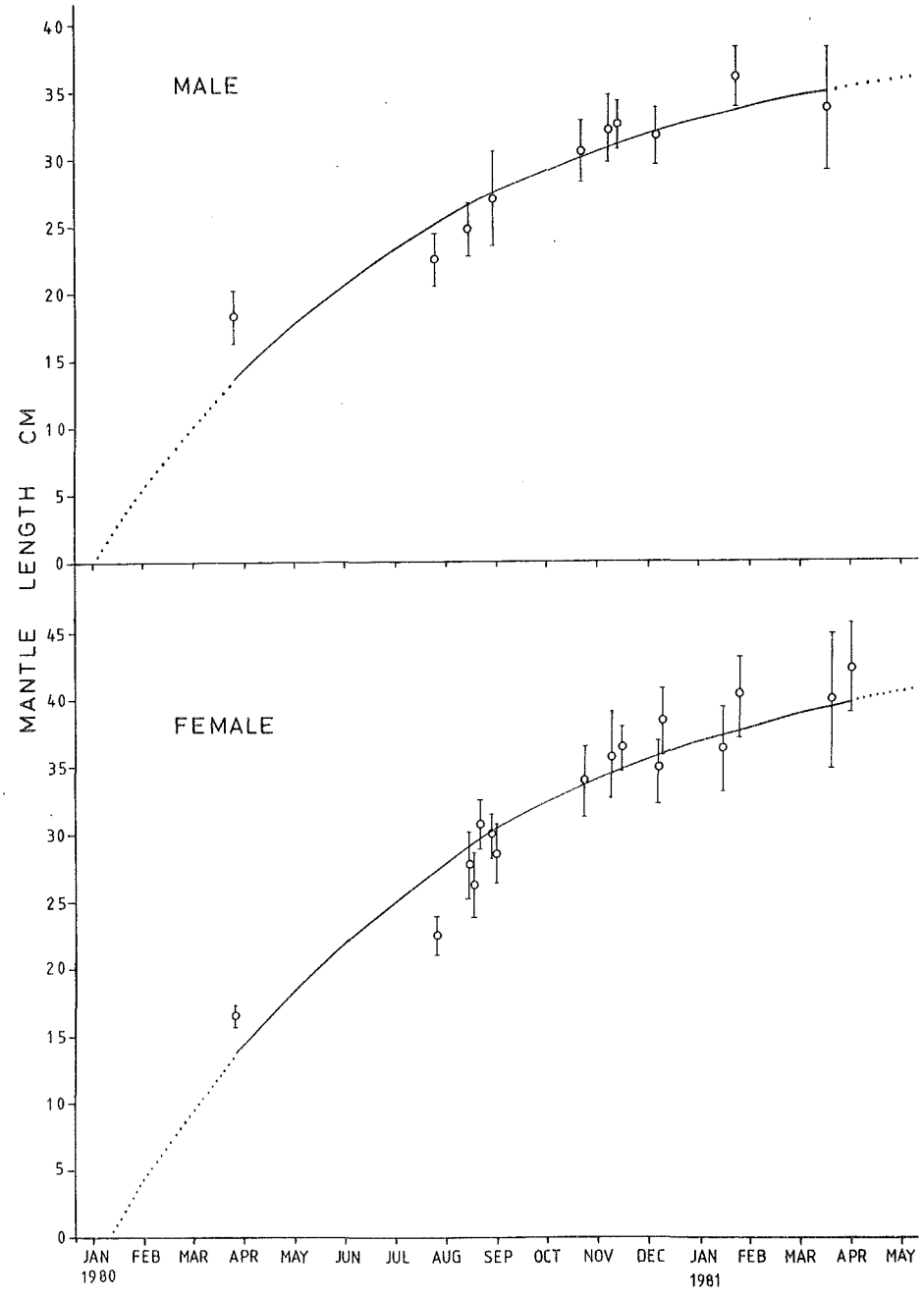

Fig. 3. Growth curves fitted with von Bertalanffy equation $L_t = L_\infty (1 - e^{-K(t-t_o)})$ to length-frequency data of T. sagittatus from April 1980 to March 1981. Males: 144, females: 2220.

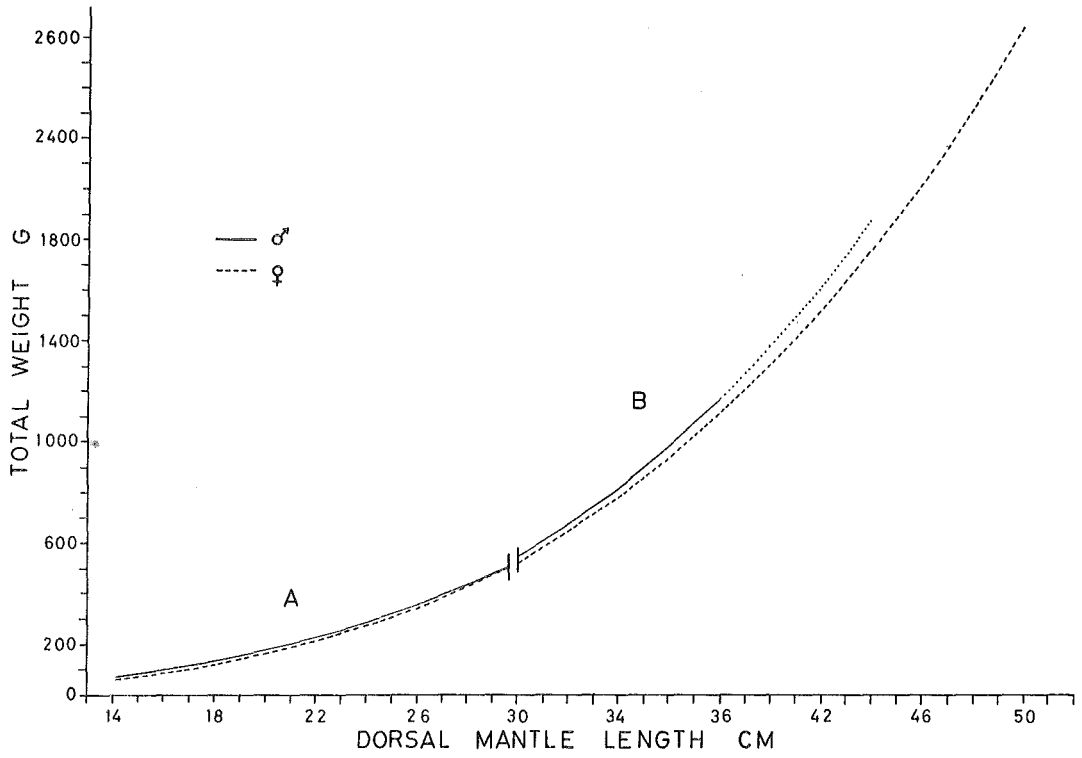

Fig. 4. Length-weight relationships for T. sagittatus in northern waters during 1980. A, males: $W = 0.0580L^{2.6756}$, females: $W = 0.0343L^{2.8301}$. B, males: $W = 0.0090L^{3.2369}$, females: $W = 0.0118L^{3.1483}$. Further data in the text.

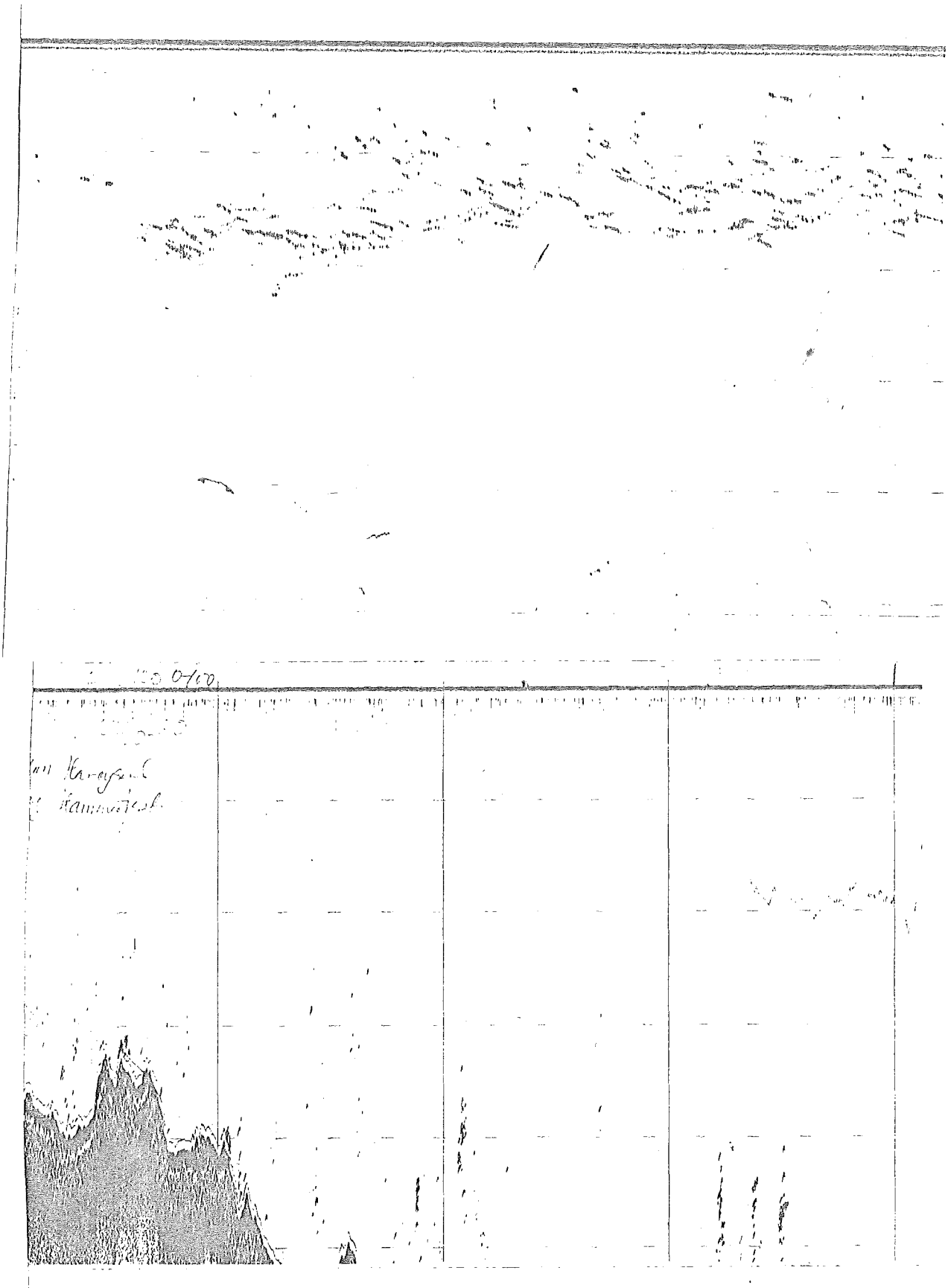

Fig. 5. Echo traces of T. sagittatus. Above, vessel stationary after jigging in Glåmfjord, North Norway, October 30, 1980, about 2000 hr. EK-38, 0-100 m. Below, vessel running, north of Hammerfest, North Norway, October 22, 1980, about 0900 hr. EK-120, 0-100 m.