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THE SQUID TODARODES SAGITTATUS (LAMARCK) DISTRIBUTION AND BIOLOGY IN NORTHERN WATERS AUGUST 1981-APRIL 1982

by

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ABSTRACT

Since 1977 the squid Todarodes sagittatus has invaded the Norwegian coast and adjacent areas every year. Materials for investigation were collected from August 1981 to April 1982. In coastal areas the mean dorsal mantle length (DML) of the femeales increased from 28 cm in August to 35-39 cm in November, and to 43 cm in March, while males measured averagely 31 cm in November. In oceanic and bank waters the mean DML's for males and females in August were 24 cm and 26 cm respectively, in March 32 cm and 39-40 cm.

Liver weight constituted 3-23% of total weight, in oceanic waters with mean of about 7% in August and 11% in March, in coastal areas 6-9% in August-November.

The most important food items were fish (redfish, blue whiting, pearlside), cephalopods, euphausiids and amphipods.

Males were usually scarce, 0-8.6% of the total number in fjord areas, 0-23% in open waters, but in March 1982 samples from the Viking bank had 80.8% males. In fjord areas nearly all males were immature in November, single larger animals maturing. In March most males in open waters were maturing or mature.

Of the females, a few were in stage 4 in November, the majority immature. In March most females in open waters were in stage 2, a few in stage 3 and 4.

Primary growth rings (GR) in the statoliths were counted and related to DML, and a functional GM-regression was fitted. In squid from the Hebrides-Faroe area in March-April 1981 the result was: DML=0.121GR + 1.850, r^2=0.686, n=38. In squid from the Norwegian Sea and the coast of Norway August-November 1981: DML=0.213GR - 31.020, r^2=0.185, n=416. In the latter case the regression is significant (F=94.1, $p<<0.01$), but only 18% of the total variance is explained by linear regression.

Most of the squid enters the area studied at an age of about 200 days. Local differences in available food may induce great variations in growth. Hatching periods indicated are: October-November, December-January, and March-May.

During August-November 1981, 3500 squid were tagged with anchor tags at 32 localities. Until June 10 1982, 26 tags have been recovered after maximum 66 days at or near the tagging locality. One squid was recovered after 154 days, 145 n. miles from hte tagging site.

In 1981 the Norwegian fishery yielded about 9000 m. tons of squid.

INTRODUCTION

During the second half of 1981 the European flying squid Todarodes sagittatus invaded the Norwegian Sea and adjacent areas for the 5th year in succession, in greater abundance than in 1980.

MATERIAL AND METHODS

Squid were collected during research cruises in the Norwegian Sea and Norwegian coastal waters from August 1981 to March 1982 and in the Hebrides-Viking Bank area in March-April 1982 (Fig. 1, Table 1). In coastal and bank areas, shoals of squid were located with SIMRAD echo sounders EK-38 and EK-120, TV/Gain 40 log R-20 dB, band width 3 kz, pulse length 0.6 ms and recorder gain 7.

In October-November squid were sampled in coastal and fjord areas, mostly with jigs, on the coastal banks also with pelagic and bottom trawls. If possible, samples of 50-100 squid were taken. At each station statoliths for age determination were removed from 5 males and 5 females. In oceanic areas, squid were taken as bycatch during trawling surveys for blue whiting, usually only a few per haul. Dorsal mantle length (DML) was measured to the nearest half cm below, in fresh squid during the cruise, in thawed squid from frozen samples in the laboratory. No correction was made for shrinking (WIBORG and GJØSÆTER 1981). Statoliths were prepared and growth rings counted as described in ROSENBERG, WIBORG and BECK (1980). Stomach contents were studied under a stereoscopic microscope.

Total weight and liver weight were determined to the nearest 5 g. Length of nidamental glands and testes were measured to the nearest mm, weights of gonads to the nearest g. Stages of maturity were determined after WIBORG and GJØSÆTER (1981). Squid for tagging were fished with jigs. As recommended by HURLEY and DAVE (1980), yellow spaghetti tags (anchor tags) were used, attached dorsally in the collar region of the mantle by the aid of a special gun. Damaged squid were discarded.

Table 1. Mantle lengths of T. sagittatus August 1981-April 1982. For localities, see Fig. 1. SD=standard deviation. n=number.

Area	Norwegian Sea		Fosnavåg	Fosnavåg	Grylle-fjord	North Norway 66°N-71°N		West Norway 62°N-66°N		Coastal banks 62°N-69°N		Station M	Norwegian Sea	Skogsvåg	Faroes-Viking Bank	
Date	Aug 1-31		Aug 12	Sept 9-11	Sept 1	Oct 14-31		Oct 31-Nov 11		Oct 25 Nov 11		Jan 31	Mar 8-19	Mar 22	Mar 21-Apr 2	
DML,cm	♂ n	♀ n	♀ n	♀ n	♀ n	♂ %	♀ %	♂ n	♀ %	♂ n	♀ n	♀ n	♀ n	♀ n	♂ n	♀ n
20		1														
1	1	1														
2	–	–		1												
3	3	–	1	1												
4	5	15	1	–												
5	4	8	14	1	6											
6	–	10	7	–	11	0.9									1	
7	1	5	13	1	10	4.4										
8		6	13	6	8	11.4	0.5									
9		3	18	8	4	17.5	3.6				1					
30		2	9	8	5	20.2	9.3		0.5	1	–				4	
1			8	11	5	24.6	16.6	1	5.2	1	1				6	1
2			–	9	3	14.9	20.2		8.1	–	1				4	1
3			–	1	2	4.4	16.9		7.1	1	2				3	
4			1	1	1	1.8	12.1		14.7	1	6				2	
5		1		3			8.9		15.6	–	3		2		1	1
6		1		1			6.7		16.6	1	2		1			
7							2.5		15.6		10	1	3			
8							1.4		6.6		9	–	1			1
9							0.4		5.2		4	2	–	1		
40							0.6		1.9		1	1	–	–		
1		1					0.3		1.9		2	1	1	–		
2									0.5		3		–	1		
3									–		3		2	1		
4									0.5		1		1	2		1
5											2		1	2		
6											2					
7											1					
8											1		1			
n	14	54	85	52	55	114	1622	1	211	5	55	5	13	7	21	5
DML,cm	24.25	26.61	28.08	30.40	28.35	30.42	32.99	30.0	35.66	33.10	38.49	39.50	40.08	43.50	31.74	36.00
SD	1.30	3.37	2.08	2.60	2.37	1.59	2.16		2.43	2.33	4.17	1.37	4.24	2.10	1.96	5.24
%♂	20.6					8.6		0.5		8.5					80.8	

Before tagging the squid at first were kept in tanks with running seawater, but as the animals attacked and damaged each other, this had to be abandoned. Finally, most squid were tagged and released immediately after capture. A few were measured. Only females were tagged, as males got the skin torn as soon as they were handled (WIBORG 1980). After tagging some squid did not dive immediately, but planed at the surface for some time. A few were caught by seagulls.

Size

Distribution of DML during the period investigated are shown in Table 1. In August-September 1981 female squid in the Norwegian Sea on an average measured 26 cm, in coastal areas, 28-30 cm. In October-November the mean length increased to 35.7 cm at the west coast of Norway, and to 33 cm north of 66°N. On the coastal banks, female squid taken in bottom trawl were still larger during this period, DML about 38 cm. During January-March 1982 females with mean lengths 40-43 cm were taken both in the Norwegian Sea and on the coastal banks. Males had mean lengths 2-5 cm below those of the females, in August-September about 24 cm, in March 31.7 cm. Maximum length recorded of males was 36.5 cm.

Liver percentage

Variations and mean percentages of weight of liver in relation to total weight for various localities are shown in Table 2.

The lowest average, 6.3% occurred at Gryllefjord in August, the highest figures, 10.4-11.8% were observed in the Norwegian Sea and Hebrides-Viking Bank area in January-March, but the variations were great, 2.9-22.8%.

Table 2. Weight of liver in % of total weight of T. sagittatus August 1981-March 1982. n=number, SD=standard variation.

Locality	Month	n	Variation	Mean	SD
Fosnavåg	Aug	53	5.3-13.4	8.5	2.06
Norwegian Sea	"	50	2.9-12.3	7.1	2.01
Gryllefjord	Sept	58	3.3-20.9	6.3	2.59
Coastal banks	Oct-Nov	40	4.0-19.1	9.3	2.96
Station M.	Jan	5	9.8-12.3	11.4	1.03
Norwegian Sea	March	10	3.8-16.1	10.4	4.20
Hebrides-Viking Bank	March	26	5.5-22.8	11.8	4.40

Stomach contents

The frequencies of various food organisms in the stomachs of T sagittatus from different localities, August 1981-March 1982 are shown in Table 3.

Empty stomachs have been excluded. The same species and organisms as found earlier (WIBORG and GJØSÆTER 1980) were identified, in roughly the same proportion, but at Fosnavåg, fish were of little importance in 1981, whereas krill dominated entirely. The opposite was the case in 1980. Of the fish species, redfish, pearlside and blue whiting dominated, in the order mentioned. In the Hebrides-Faroe Bank area, redfish was substituted by Norwegian pout. Other species were: Herring, capelin fry, pollock, silver smelt, small lumpsucker, sandeel, Benthosema glaciale and Paralepis krøyeri.

Table 3. Frequency in % of food organisms in stomach contents of T. sagittatus in various areas, August 1981-March 1982, n=number.

Locality	Month	Fish	Squid	Krill	Prawns	Amphipods Isopods	Cope-pods	Poly-chaetes	Chaeto-gnaths	n
Station M.	Jan	80.0	60.0	20.0	-	40.0	-	-	-	5
Hebrides-Viking Bank	March	88.4	17.8	39.3	-	-	-	-	-	28
Norwegian Sea	Aug	81.2	34.8	23.2	2.3	27.5	2.9	4.4	2.9	69
Fosnavåg	Aug	6.7	3.3	96.7	-	-	-	-	-	30
Skogsvåg	Aug	100.0	10.0	-	-	-	-	-	-	9
Gryllefjord	Sept	11.1	44.5	55.5	-	5.6	-	8.3	-	36
Norwegian coast, jigs	Oct-Nov	43.8	27.8	39.3	7.2	8.4	-	7.2	-	263
Norwegian coast, bottom trawl	"	88.0	24.4	24.4	4.9	4.9	-	2.5	-	41

Of squid remains T. sagittatus was found in Norwegian coastal areas, in oceanic waters Gonatus sp. dominated. Amphipods identified were Parathemisto sp.; Isopods: Idothea sp.; Prawns: Pasiphaea sp. Polychaetes: Nereis sp. Chaetognaths: Sagitta sp. Copepods: Pareuchaeta sp. It is emphasized that the observations are occasional. Repeated observations from the same locality during a longer period would undoubtedly show considerable variation in food items.

Sex ratio

In fjords and sheltered areas males were scarce, usually below 10%, in some samples entirely lacking. In open waters they were sometimes more frequent, in August in the Norwegian Sea about 20%, in October off Gryllefjord 28.6%, in March-April on the Viking Bank even 80%. Squids are known to form schools with

individuals of nearly the same size (MUUS 1959). As males of T. sagittatus are usually smaller than females, they may sometimes form separate schools.

According to LIPINSKI and WRZESINSKI (1982), males of Illex argentinus dominated in samples collected from the bottom trawl on the continental slopes while females predominated in samples from the jigging operations. One may assume that females have different feeding activity in comparison with males.

Maturation

T. sagittatus occurring in northern waters are mostly immature (WIBORG and GJØSÆTER 1981). Of 93 males taken at the Norwegian coast in October-November 1981, 91 were immature (stage 1), 2 mature (stage 3). Of 231 females in the same area, 230 were immature (stage 1), 1 in st. 4.

In March-April 1982 the males in the Hebrides-Viking Bank area were developed as follows: st. 1:1, st. 2:14, st. 3:6. Of 5 females 1 was in st. 1, 4 in st. 2.

In March 1982 some females from the Norwegian Sea were also in advanced stages: st. 1:1, st. 2:6, st. 3:1, st. 4:1. As found earlier (WIBORG and GJØSÆTER 1981) all squid in advanced stages of maturation were large, males with DML above 30 cm, females 35-40 cm or more, but some of the large females were also immature.

Age and growth

Growth rings in the statoliths were counted from 38 T. sagittatus taken in the Hebrides-Faroe area in March-April 1981 (see WIBORG and GJØSÆTER 1981, Fig. 1, No. 98-121). Following the recommendations of RICKER (1973) a functional GM-regression was fitted, and the result was

$$y=0.121x + 1.850$$

where y is dorsal mantle length in cm and x is number of rings counted (Fig. 2).

The coefficient of determination, r^2=0.686 and the 95% confidence limits of the regression coefficient: 0.101 and 0.146. Primary growth rings were also counted in 416 T. sagittatus taken in the Norwegian Sea and at the coast of Norway during August-November 1981. Fitting a functional regression to these data gave

$$y=0.213x - 31.020$$

with a coefficient of determination r^2=0.185 and 95% confidence limits of the regression coefficient 0.195 and 0.232 (Fig. 3). The regression is significant (F=94.1, $p<<0.01$) although only 18% of the total variance is explained by a linear regression.

The total sample was split in four subgroups and the following results were obtained:

Area	Sex	n	a	b	r^2	F_{slope}
Norwegian Sea	♀♀	149	0.13	- 8.32	0.008	1.15
" "	♂♂	8	0.05	10.00	0.364	3.44
Norwegian Coast	♀♀	210	0.20	-24.38	0.008	1.82
" "	♂♂	49	0.09	2.32	0.021	1.00

The slope a, and the elevation b, refer to a functional regression, while the statistical tests are based on predictive regression methods. The slope is not significantly different from 0 in these subsamples, and they are not significantly different from each other (F=0.09). The elevations are, however, significantly different (F=133.8).

ROSENBERG, WIBORG and BECK (1980) studying T. sagittatus from the Porcupine-Faroe area and off the coast of western Norway

during March-August 1980 found the regression $y=0.20x - 31.66$, with a coefficient of determination $r^2=0.75$.

It seems that T. sagittatus enters the Norwegian Sea and Norwegian coast at an age of 200 days or more, and that further growth depends greatly on the food available. This may lead to a great variation in growth as indicated by the statolith readings. This is also evident from recaptures of tagged squid, as will be mentioned later.

If we accept the counts of growth rings as age, the data may be used to determine the times and period of hatching (Table 4).

In the Norwegian Sea and adjacent areas, squid caught in August-September may have been hatched in October-November of the year before, those taken in October-November: in December-January, while squid caught during December-April were mainly hatched during March-May. T. sagittatus caught in the Hebrides-Faroe area during March-April 1981 were hatched during a very long period, January-September, most of them during May-August. The earlier theory of two periods of reproduction, one during spring and one during autumn-winter (ROSENBERG, WIBORG and BECK 1980) seems in the main to be confirmed, but variations in time may occur from one year to another. Squid hatched in November, and in December-January, may derive from different spawning areas.

Most of the squid taken are 8-10 months old. Older squid, 11-14 months, were taken in March in the Faroe-Porcupine area and in the Norwegian Sea. This may signify that T. sagittatus starts the spawning migration at an age of 10-11 months. The spawning areas are still unknown.

Table 4. Month of hatching of T. sagittatus taken in Norwegian and North Atlantic waters during 1978-1982.

Locality and date	Month of hatching and number of statoliths read.													
	A	S	O	N	D	J	F	M	A	M	J	J	A	S
DECEMBER														
Gryllefjord 5 Dec 1978							1	6	11					
Station M. 10 Dec 1980							1	4	2	3				
Total							2	10	13	3				
JANUARY														
Gryllefjord 17 Jan 1981					1	2	1	6	8	1	1			
Station M. 23 Jan 1981								3	5	10				
Station M. 31 Jan 1982								1	4					
Total					1	2	1	10	17	11	1			
MARCH-APRIL														
Hebrides-Faroes 19 March 4 Apr 1981						1	1	4	3	6	5	7	7	4
(Hebrides)-Viking Bank 21 Mar-2 Apr 1982								3	8	8	5			
Norwegian Sea 8-19 Mar 1982							1	1	4	3	3			
Skogsvåg 22 March 1982								2	3	2				
Total								10	18	19	13	7	7	4
AUGUST														
Tromsø 1 Sep 1981	1	4	1											
Norwegian Sea 1-22 Aug 1981	1	1	21	40	5									
Fosnavåg 12 Aug 1981			2	17	3									
Skogsvåg 20 Aug 1981			2	11	3									
Total	2	5	26	68	11									
SEPTEMBER														
Fosnavåg 22 Sep 1979				1	4	8								
Gryllefjord 1 Sep 1981			9	19	4									
Total			9	20	8	8								
OCTOBER-NOVEMBER														
Norwegian coast 14 Oct-21 Nov 1981			2	30	136	143	6							

Tagging

During the autumn of 1981 about 3500 T. sagittatus were tagged in 32 of the sampling localities (Fig. 1). In each place, 50-200 squid were tagged. Until June 10 1982, 27 tags had been returned, most of them from near or at the tagging locality, 2-66 days after tagging (Table 5).

Table 5. Recoveries of tagged T. sagittatus, 1981-1982. Localities, see Fig. 1. n=number

Tagging locality	Date	Tagged n	Recovered n	Place of recovery	Days in freedom
Skogsvåg	Aug 27	91	1	61°35'N 01°30'E	154
Fosnavåg	Sep 9-11	290	5	Fosnavåg	66
Stønesbotn	Oct 14	102	6	Stønesbotn	2-48
Øyfjord	Oct 21	173	7	Øyfjord	2-48
Kvæfjord	Oct 22	183	4	Kvæfjord	18-43
Eidsfjord	Oct 24	64	4	Eidsfjord, Gryllefjord	2-57

One squid was recaptured after 154 days, 145 n.miles from the tagging place. (Fig. 1).

At Fosnavåg, 5 squid recaptured after 66 days were reported to have had an average weight of 1.9 kg. If this holds true, they had more than doubled their weight in two months. As mentioned in the previous chapter such an intensive growth may obscure any correlation between age and length.

Experimental fishery

During commercial fishery with purse seine for pollock, mackerel and herring in Norwegian coastal waters and in the northern North Sea T. sagittatus has been caught occasionally, from a few kg to 50 m tons. During October-November 1981 experimental hauls were made with purse seine from a 70' fishing vessel. The squid were located with echo sounder and concentrated by means of lights mounted on a small anchored skiff. Squid were attracted, but not in sufficient quantities. Maximum catch was only 200 kg per haul.

On board a 93' prawn trawler, 5 jigging machines with double line drums were installed, the vessel fishing for 6 weeks during October-November 1981 in various fjords in northern Norway. Maximum catch was 3300 kg a day, whereas a commercial freeze trawler, equipped with 8 single drum jigging machines, caught 100 m tons of squid during one month in the same area, with maximum catch of 10-12 m tons a day.

A foreign trawler, being allowed to fish with trawl for squid in Norwegian bank waters during August-November 1981, caught negligible quantities, maximum 50-60 kg pr 2 hours haul. It may therefore be concluded that in coastal and bank waters jigging is the best fishing method for T. sagittatus.

In 1981 the Norwegian fishery for T. sagittatus yielded 9000 m tons.

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REFERENCES

HURLEY, G.V. and DAWE, E.G. 1980. Tagging studies on squid (Illex illecebrosus) in the New Foundland area. NAFO SCR Doc. 80/II/33:1-11.

LIPINSKI, M. and WRZESINSKI, O. 1982. Some observations on the behaviour of squid (Cephalopoda: Ommastrephidae) during jigging operations. International Squid Symposium Proceedings, August 9-12 1981. UNIPUB ISBN 0-89059-026-5. p.137-144.

MUUS, B.J. 1959. Skallus, søtænder, blæksprutter. Danm. Fauna 65: 1-239.

RICKER, W.E. 1973. Linear regressions in fishery research. J.Fish.Res. Bd Can. 30:409-434.

ROSENBERG, A.A., WIBORG, K.F. and BECK, I.M. 1981. Growth of Todarodes sagittatus (Lamarck) (Cephalopoda, Ommastrephidae) from the northeast Atlantic, based on counts of statolith growth rings. Sarsia, 66:53-57.

WIBORG, K.F. 1980. Akkar, Todarodes sagittatus (Lamarck). Innsig og forekomst ved norskekysten og tilstøtende havområder høsten 1979-våren 1980 (The squid Todarodes sagittatus (Lamarck). Immigration and occurrence at the Norwegian coast and adjacent ocean areas from the autum 1979 to the spring 1980). Fisken Hav., 1980 (3): 13-27.

WIBORG, K.F. and GJØSÆTER, J. 1981. The squid Todarodes sagittatus (Lamarck). Distribution and biology in northern waters, April 1980-April 1981. Coun. Meet. int. Coun. Explor. Sea 1981 (K:14): 1-18. 5 fig. (Mimeo).

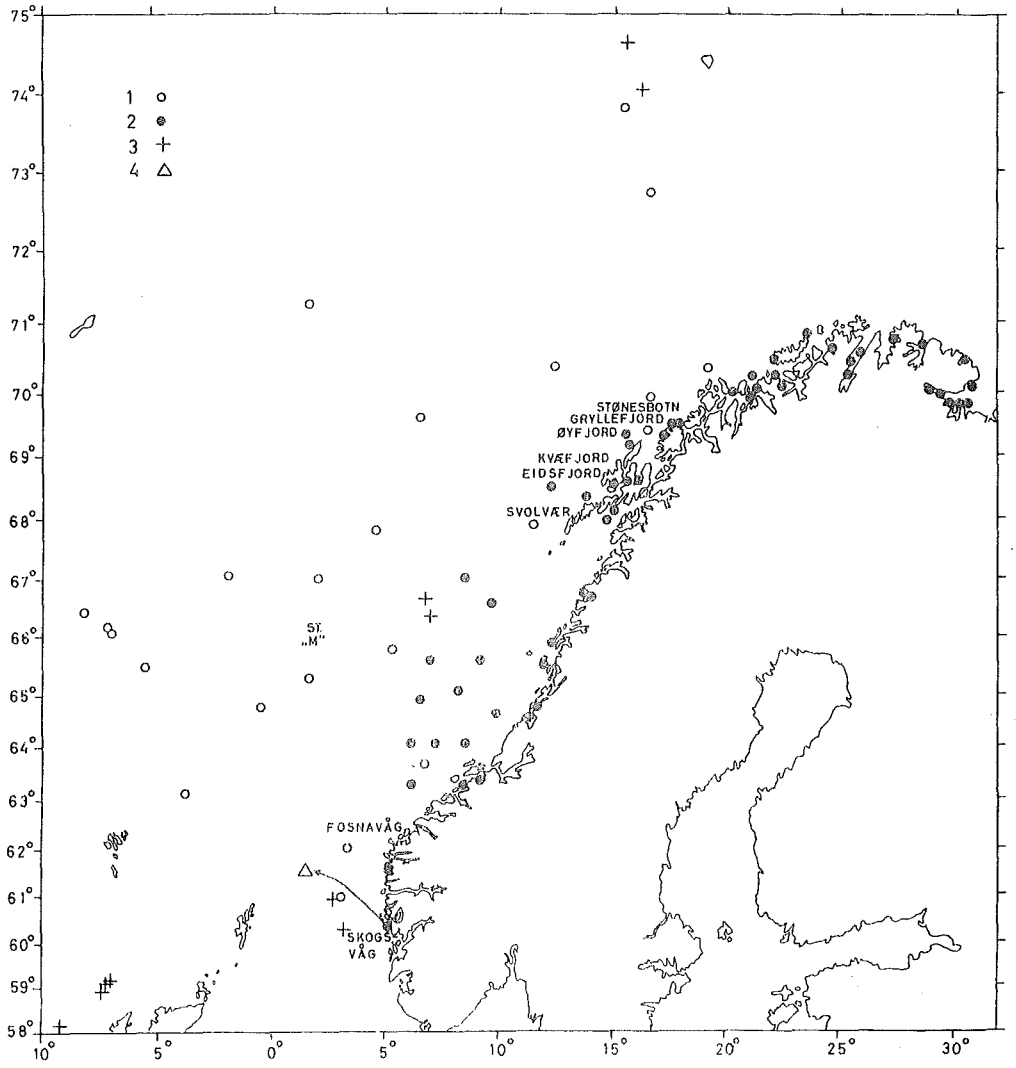

Fig. 1. Stations with catches of T. sagittatus in August-September 1981 (1), October-November 1981 (2) and March-April 1982 (3). Recapture of a tagged squid (4).

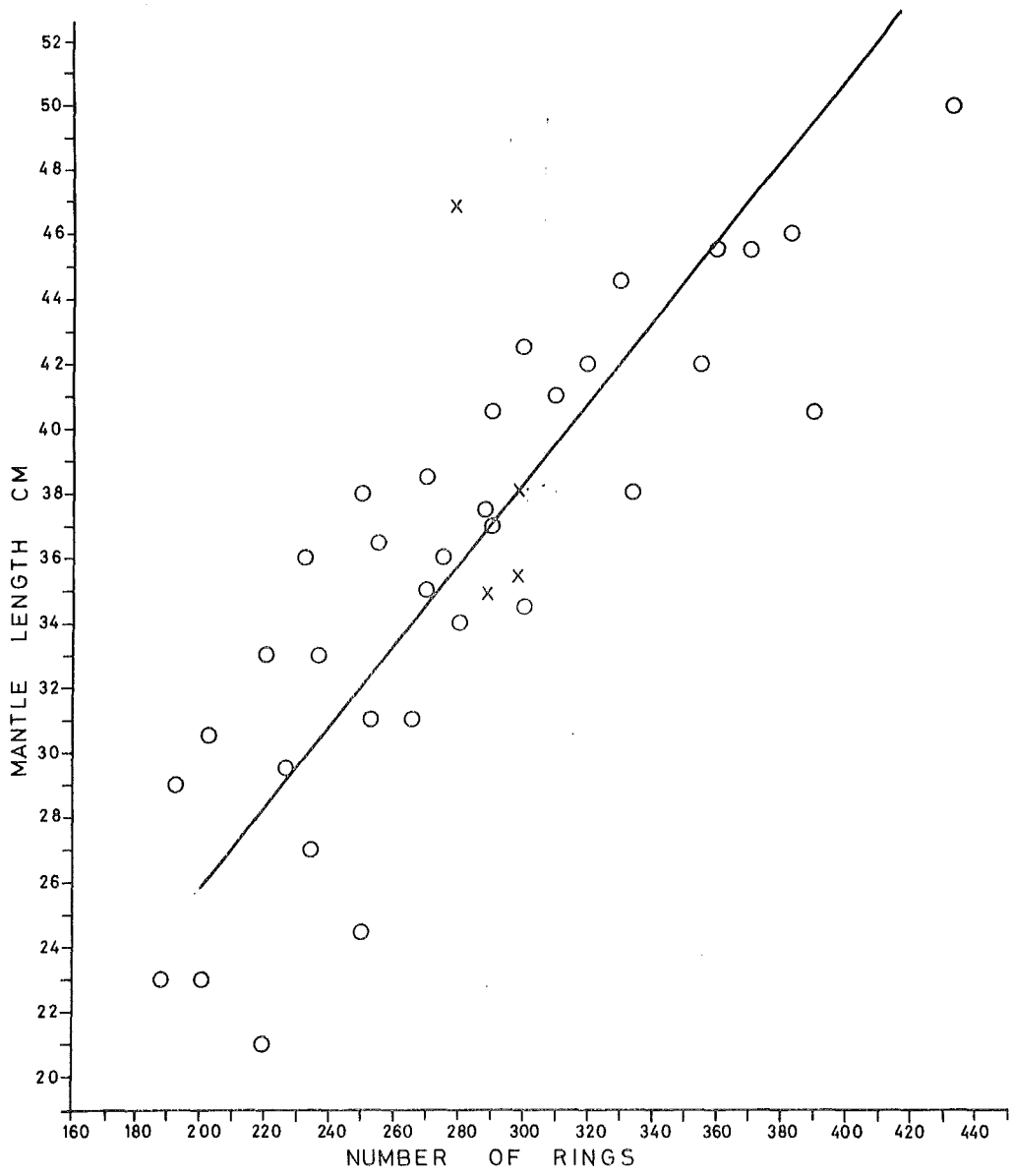

Fig. 2. Relationship between number of growth rings (GR) and dorsal mantle length (DML) of T. sagittatus from the Hebrides-west coast of Norway, March-April 1981. Circles: March 10-30, crosses: April 4. Regression line: DML=0.121GR + 1.850, r^2=0.69, n=38.

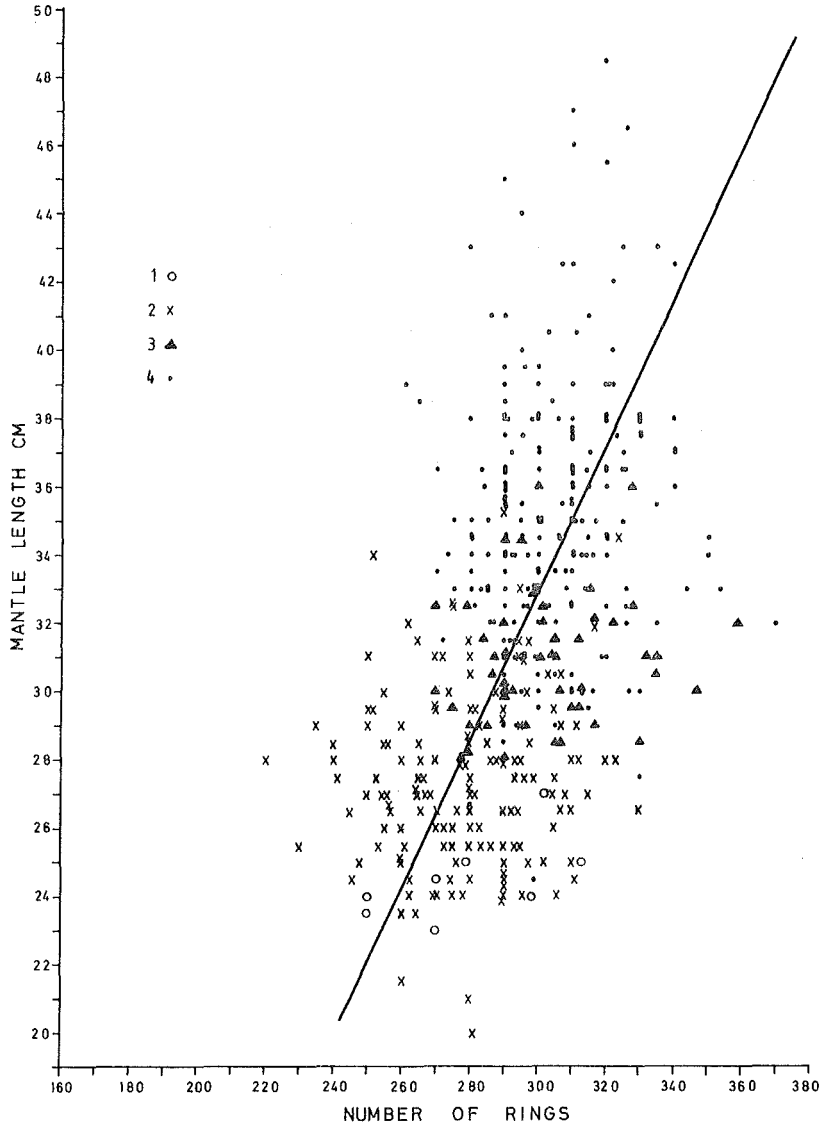

Fig. 3. Relationship between number of growth rings (GR) and mantle length (DML) of T. sagittatus from the Norwegian Sea and the coast of Norway, August-November 1981. 1) Norwegian Sea, August, ♂♂. 2) Norwegian Sea, August, ♀♀. 3) Coast of Norway, October-November 1981, ♂♂. 4) Coast of Norway, October-November 1981, ♀♀. Regression line: DML=0.213GR-31.020, r^2=0.185, n=416.