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International Council for
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C.M. 1983 /K.7

Shellfish Committee

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THE SQUID TODARODES SAGITTATUS (LAMARCK)
DISTRIBUTION AND BIOLOGY IN NORTHERN WATERS
AUGUST 1982 - JUNE 1983

by

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ABSTRACT

In 1982 the squid Todarodes sagittatus invaded the Norwegian coast in somewhat less abundance than in 1981. Materials for investigation were collected from July 1982 to June 1983. In coastal areas of North Norway the mean dorsal mantle length (DML) of the females increased from about 28 cm in August to 35-36 cm in October-November. At the west coast the mean DML length increased from 27 cm to near 33 cm from September to December, 35-36 cm in January-February, and 40 cm in June. In July-September 1982 a few females, average DML 46-47 cm, were taken in fjords in North Norway. In March-April 1983 T. sagittatus in North Atlantic waters had a very extended length distribution, 21-47 cm, without any distinct maximum. Males measured on an average 1.5 - 4.0 cm below those of the females, but DML's up to 42 cm were observed. The percentage of males was always low in the jig samples, maximum 18.2%, while in trawl samples they were more frequent, up to 46%. Nearly all males taken during

August-February were immature. Males with DML 28 cm or more taken in the North Atlantic in April, were all mature or maturing.

Females with DML 42-51 cm taken in fjords of North Norway in July-September, were mostly in stages 3-4, one with eggs in the oviduct. In all areas investigated, smaller females taken during the period August-April were all in stage I, in June in stage 2.

Primary growth rings were counted in statoliths and assumed to represent daily growth. On a few occasions the number of days between successive samples also corresponded with the difference in the average number of growth rings. Squid taken in the area investigated during August-November seem to have been hatched mainly in November-January, those from December-February in March-April, those from June in July-August. The average age was 9-11 months. Some squid, taken in September, were nearly one year old.

Liver weight constituted 1-25% of total weight, the mean in coastal waters decreasing from 9.5% in November to 4.5% in February. The maximal liver weight, 10-12%, was observed in squid from the Faroes in August and in large females in Norwegian fjords in July-September.

Tagging experiments were unsuccessful. From about 800 squid tagged, only one tag was recovered near the tagging locality after about two months in liberty.

In 1982 the Norwegian fishery yielded about 17 000 m.tons of squid.

INTRODUCTION

During the second half of 1982 the European flying squid Todarodes sagittatus invaded the Norwegian Sea and adjacent areas in nearly the same abundance as in 1981.

MATERIALS AND METHODS

Squid were collected during research cruises in the Norwegian Sea and Norwegian coastal areas during August-November 1982 and in the Northeast Atlantic in March-April 1983 (Figs. 1,2). Samples of squid were also obtained from commercial catches from August 1982 till June 1983. Squid samples, taken at the Faroes in August 1982 were kindly placed at our disposal by Mr. Hjalti i Jakupsstovu, Torshavn.

Most of the squid was fished with jigs, some also with mid-water and bottom trawls during research cruises on the coastal banks and in the Northeast Atlantic, mainly as by-catch during surveys for blue whiting and 0-group fish.

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. In each sample statoliths were removed from 5-40 individuals and kept in 96% ethanol. Growth rings were later counted under a microscope with 250-400 x enlargement.

Stomach contents were studied under a stereoscopic microscope. Total weight and liver weight were determined to the nearest 5 g, weight of testes to the nearest g. Stages of maturity were determined after WIBORG and GJØSÆTER (1981).

About 800 squid were tagged as described in WIBORG et al. (1982).

RESULTS AND DISCUSSION

Size

Distributions of DML of squid in various areas during the period investigated are shown in Table 1. In July and September a few large females, DML 42-51 cm, were caught in fjords of North Norway. In August and September smaller females with mean DML about 26-28 cm were taken at the Faroes and in the Norwegian

Table 1. Mantle lengths of *T. sagittatus* July 1982 - June 1983. For localities see Figs 1-2. SD-standard deviation. N-number.

Area	Vågs- fjord		Grøt- sund		Sommar- øy		Telavåg		North Norway 67°N-71°N		West Norway 61°N-67°N		Coastal Banks		Vannylven		Blomvåg		Blomvåg		Vær- landet		Vær- landet		60°39'N 03°02'E		Porcu- pine B.		Hebrides- Porcupine B.		Blomvåg						
	Date	July 8	Sep.1	Aug.2-23		Aug. 27		Sept. 5		Oct. 13-26		Nov. 4-10		Oct.20- Nov.8		Nov. 6		Nov. 5		Dec. 5		Jan. 20		Feb. 17		Feb.3-8		Mar. 15-17		Apr.8-17		June 7					
DML cm	♀ n	♀ n	♂ %	♀ %	♂ n	♀ n	♂ n	♀ %	♂ n	♀ %	♂ n	♀ %	♂ n	♀ %	♂ n	♀ n	♂ n	♀ %	♂ n	♀ %	♂ n	♀ %	♂ n	♀ n	♂ n	♀ n	♂ n	♀ n	♂ n	♀ n	♂ n	♀ %					
17																																					
18																																					
19																																					
20				1.6	0.3																																
21					0.7																																
22					1.4	1																															
23				4.7	2.1				4.0																												
24				1.6	1.0	1			5.1																												
25				15.6	4.5		2	2	19.2				0.3																								
26				18.8	8.0		6		21.2		2	0.3								2																	
27				18.8	10.4	1	7		20.2			6	3.0	1		6																					
28				18.8	14.5	1	13		14.1	1		8	6.9	1		2	2																				
29				17.7	20.4	1	11		6.1			8	14.2		6.0	1	4																				
30				1.6	22.1		7		4.0	2	0.5	10	12.4		6.0	2																					
31				1.6	8.7		2		2.0	5	1.9	7	17.7	2	4.5	1	3																				
32					4.8				2.0	7	3.6	3	19.2	2	7.5		1																				
33					1.0				2.0	14	6.4	1	11.6		14.9																						
34										9	12.0	1	6.8	1	13.4	2																					
35											15.8	1	4.3		16.4																						
36											25.3		2.0		11.9	1																				2.9	
37											19.9		0.8		6.0																					11.4	
38											9.9		0.3		9.0																					15.7	
39											3.8		0.2		1.5																					17.1	
40																																					15.7
41																																					15.7
42																																					10.0
43																																					4.3
44																																					1.4
45																																					1.4
46																																					1
47																																					
48																																					
49																																					
50																																					
51																																					
n	7	26	64	289	5	48	2	99	38	747	47	605	7	67	10	15	1	92	9	79	2	60	9	59	5	3	5	65	77	1	70						
DML cm	47.2	46.4	27.0	28.6	26.4	27.9	25.5	27.1	32.7	35.9	29.7	31.4	30.6	34.6	28.1	30.9	31.0	32.4	28.8	32.8	34.0	36.4	31.2	35.8	29.8		24.2	29.0	31.9	34.4	40.1						
SD	2.4	2.0	1.9	2.3	2.8	3.3	-	2.0	1.4	1.9	2.0	2.2	2.5	2.9	1.3	2.3	-	2.0	2.5	2.4		2.3	1.6	2.6	2.8		2.0	4.9	5.9					2.2			
% ♂			18.2		9.4		2.0		4.8		7.2		9.5		40.0					10.2		3.2		13.2	(62.5)		-	46.1						1.4			

coastal waters. In October-November the mean length of females increased to 34.6-35.9 cm north of 66°N and 30.9-32.4 cm farther south. In January-February female squid on the west coast measured averagely 32.8-36.4 cm, in June 40.1 cm. The length distributions were as a rule unimodal, except at Værlandet, where peaks occurred at 33 cm and 38 cm. Males were averagely 1.5-4.0 cm smaller than the females. In the Hebrides-Rockall-Porcupine Bank area the size distribution in March-April 1983 was very irregular, 21-42 cm in males and 22-47 cm in females.

Sex ratio

In most of the samples, especially in those taken with jigs, males were scarce or absent. Maximum % of males in jig samples, 18.2%, occurred at the Faroes. In trawl samples males were usually more abundant, up to 40-46%. This is in agreement with earlier observations (WIBORG et al. 1982).

Maturation

Maturity stages were determined after WIBORG and GJØSÆTER (1981). In Norwegian coastal waters males of T. sagittatus with DML less than 30 cm taken during August 1982 - February 1983 were all immature. A few males with DML 30-34 cm caught in October-November 1982 had slightly increased gonads, but not sufficient to be characterized as maturing. A male with DML 34 cm, taken in June 1983, was mature (stage 3).

In the Hebrides-Rockall-Porcupine Bank males with DML 28 cm or more were all in stages 2-3 in April 1983.

Of the females, seven with DML 43.5-50 cm, taken in Vågsfjord on 8 July 1982 (Table 1) were maturing: stage 2: 1, stage 3: 4, stage 4: 2. The same were 12 females, DML 42-51 cm, from Grøtsundet 1 September 1982: Stage 1: 1, stage 3: 4, stage 4: 7. All other females taken between August 1982 and April 1983 were in stage 1 (immature). In June 1983 39 females, DML 36.0-46.0 cm, were in stage 2, average maturity index (MI) 139.1. (SD 17.5).

A female, DML 47 cm, taken at the Hebrides in April 1983, was in stage 4.

Stomach contents

The frequency of various groups of food organisms in the stomach of T. sagittatus from some localities during August 1982 - February 1983 is shown in Table 2. Empty stomachs were excluded (WIBORG et al. 1982). Fish were nearly always dominating.

Table 2. Frequency in % of food organisms in stomach contents of T. sagittatus in various areas August 1982 - June 1983. Selected samples.
n - number of stomachs examined. For localities, see Figs. 1 and 2.

Locality	Date	Fish	Squid	Krill	Prawns	Amphi- pods	Cope- pods	Poly- chaetes	Chaeto- gnaths Ptero- pods	Medu- sae	n
Faroes	Aug. 2	65.0	46.6	-	-	-	-	-	-	-	26
"	" 23	43.0	31.0		2.4	-	-	-	9.5P	54.8	42
Sommarøy	" 27	64.5	20.0	24.5	2.2	17.8	11.1	11.1	2.2C	-	44
66°-71°N	Oct.13-										
a. jigs	26	71.3	3.5	33.3	5.7	8.0	-	6.9	-	-	87
b. trawl		79.0	5.3	-	47.5	-	-	5.3	-	-	19
61°-66°N	Nov.5-9										
a. jigs		79.3	11.1	32.8	9.5	32.8	-	3.2	5.5P	12.7	63
b. trawl		69.5	5.5	19.5	5.6	19.5	-	-	-	8.3	36
Telavåg	Sept. 8	83.4	8.3	11.8	2.8	11.8	-	-	-	2.8	36
Blomvåg	Dec. 8	91.4	17.3	4.4	-	4.4	-	-	-	-	23
Værlandet	Feb. 17	48.1	18.5	7.4	63.0	-	-	3.7	-	-	27
Blomvåg	June 7	13.5	6.7	30.0	36.7	3.4	3.4	-	-	-	30

In Faroese waters sand eel and blue whiting were most usual, others were herring, and redfish also occurred.

In coastal waters of Norway north of 66°N, redfish and sand eel were most abundant in August. In October-November redfish, sand eel, herring and blue whiting with frequency in the order mentioned were found in squid from jig samples. In squid from trawl samples, red fish dominated, blue whiting was second. Norway pout, saithe and capelin were also present.

South of 66°N, pearlside were most frequent in squid taken with jigs. In samples from trawl, redfish was on the first place, with pearlside second, the latter indicating that some of the squid had been caught in mid-water. Other fishes were: blue whiting, saithe, Norway pout and silver smelt.

Frequent occurrence of squid in the stomachs, especially of pieces of arms and tentacles, may indirectly have been caused by the jig fishery. But in trawl-caught squid, the stomachs also contained remnants of T. sagittatus, Gonatus sp. and other squid species.

Krill were sometimes very abundant, indicating that this group may be an important food item.

Pelagic shrimps of the genus Pasiphaea were frequent in squid caught in trawl in North Norwegian waters, and in jig samples from the west coast.

Amphipods were mostly Parathemisto sp.

Pteropods, mainly Clio sp. occurred in stomachs of squid from the Faroes, and also from the west coast of Norway.

Medusae remains were frequent in squid from the Faroes, but could not be identified.

Daily rhytm in feeding

In order to study variations in feeding intensity during the day, the filling of the stomachs was subjectively divided into five degrees: empty, little, medium, full, distended, and related to various periods of the day. The squid analysed were taken in Norwegian coastal waters in October-November 1982 (Table 3).

Table 3. Diurnal rhythm in feeding of T. sagittatus in coastal areas of North Norway, October-November 1982. Distribution in %. Degree of stomach filling: 0-empty, 1-little, 2-medium, 3-full, 4-distended. n-number of stomachs examined.

Stomach filling	Hour	2200-0600	0800-1600	1700-2000
0		41.4	7.7	13.8
1		39.7	30.8	29.3
2		19.0	36.5	43.1
3		0	19.2	12.1
4		0	5.8	1.9
%		100.1	100.1	100.2
n		58	52	52

Most of empty stomachs were found during the night, very few during the day. Distended stomachs were only observed during the day and evening. The most intensive feeding evidently takes place during the day. More detailed sampling, preferably from the same locality, are needed to give information on the exact periods of feeding.

Liver percentage

Variations and mean percentage of weight of liver in relation to total weight are shown in Table 4. The range of variation was considerable in all localities, extremes 1.0% and 25.0%, mean values, 4.5 - 11.9%. At the west coast of Norway the average decreased from 9.5% to 4.5% during November-February.

Table 4. Weight of liver in % of total weight of T. sagittatus July 1982 - February 1983. For location see Figs 1-2.

Locality	Date	n	Variation	Mean %	SD
Vågsfjord	July 8	16	8.8 - 14.8	11.9	1.8
Grøtsund	Sept 1				
Faroës	Aug 2-8	101	8.0 - 15.3	10.1	1.8
"	" 21-23	184	4.1 - 14.6(25.0)	8.7	2.5
Sommarøy	" 27	35	5.5 - 12.5	8.9	1.9

Cont.

Table 4 Cont.

Locality	Date	n	Variation	Mean %	SD
Telavåg	Sept. 8	49	4.1 - 10.0	6.0	1.7
Blomvåg	Nov. 5	30	5.0 - 15.0	9.5	2.7
"	Dec. 8	29	1.0 - 14.8	6.8	3.6
Værlandet	Jan. 20	30	3.5 - 10.2	5.7	1.8
"	Feb. 17	29	3.5 - 6.0	4.5	0.8
Blomvåg	June 7	40	3.6 - 15.7	7.6	2.5

Age, and time of hatching

The growth rings in the statoliths have been supposed to represent daily growth (WIBORG and GJØSÆTER 1981, WIBORG *et al.* 1982). Growth rings were counted in a number of statoliths from each sample, varying from 5 to 71. In some cases more samples have been lumped (Table 5). A few large females, taken in coastal areas of North Norway in July and September, were nearly one year old. Squid, caught in August at the Faroes and at Sommarøy in North Norway, had ages of 6-10 months. The corresponding hatching period should be October-February, with maximum in December. Squid, caught north of 67°N in October, had also mainly been hatched in December.

The time interval between the samples of squid taken at the Faroes in August and those from North Norway in October is roughly 60 days, corresponding to the difference in average number of growth rings. The squid taken at Sommarøy in August also fit into the picture.

At the coast of Norway south of 67°N, conditions varied. Squid caught in September had nearly all been hatched in November-December, those from November samples mainly in January. Animals taken in December-February had mainly been hatched in February-April, while those caught at Blomvåg in June were mostly hatched in August.

Squid taken in the Northeast Atlantic area in March-April, had a peak of hatching in June.

Table 5. Months of hatching and average age of *T. sagittatus* taken in Norwegian and North Atlantic waters, July 1982 - June 1983. Figures in % or numbers. n-number of statoliths, SD-standard deviation. For location, see Figs 1-2.

Sample No.	Locality and date	Month of hatching										n	Average days	age SD			
		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July				Aug.	Sept.	Oct.
1	Vågsfjord July 8										<u>4</u>	<u>3</u>			7	345.0	18.5
2	Grøtsund September 1										<u>5</u>	<u>5</u>	1	1	12	357.2	26.2
3	Sommarøy August 27			39.7	<u>52.1</u>	8.3									48	266.8	16.6
4	Faroes August 2-23	2.1	29.2	<u>56.6</u>	11.4	2.1									288	251.4	16.5
5	Coast of Norway 67°-71°N October 13-26		19.8	<u>66.7</u>	13.5										141	311.0	15.8
6	Coast of Norway 61°-67°N November 1-8			33.5	<u>55.6</u>	11.1									171	301.3	16.1
7	Vannylven November 9			5	5	<u>10</u>									20	293.5	24.4
8	Telavåg September 5	2.1	<u>50.0</u>	43.7	2.1	2.1									48	282.1	19.6
9	Blomvåg November 8			3.8	<u>83.5</u>	13.3									30	291.3	12.2
10	Blomvåg December 5					6.9	<u>69.0</u>	24.1							29	263.0	13.5
11	Værlandet January 20				9.7	<u>61.4</u>	29.0								31	332.5	16.4
12	Værlandet February 17					13.8	<u>44.9</u>	38.0	3.4						29	328.9	20.7
13	Viking Bank 60°39'N, 03°02'E February 3-8						<u>4</u>	2							6	312.0	17.9
14	Porcupine Bank March 15								1	2	2				5	261.4	18.5
15	Hebrides-Rockall- Porcupine Bank April 8-26							5.6	29.6	<u>53.5</u>	11.3				71	311.3	18.3
16	Blomvåg June 7									10.0	20.0	70.0			40	306.0	21.8

In short, squid caught during the period August-February had evidently been hatched during winter (October-March), those taken during April-July belonged to a summer-spawning stock. Different stocks may be involved in the invasions to the coast of Norway.

It may be of interest to compare the supposed hatching periods of squid taken at the coast of Norway during October-November in 1981 and 1982 (Table 6).

Table 6. Months of hatching of T. sagittatus taken in Norwegian coastal waters during October-November 1981 and 1982. Percentage distribution. n-number.

Area	Year	Month of hatching					n
		Oct.	Nov.	Dec.	Jan.	Feb.	
67-71°N	1981	0.5	13.2	49.2	35.5	1.6	189
" "	1982	-	19.8	66.7	13.5	-	141
61-67°N	1981	-	3.8	35.1	58.0	3.1	131
" "	1982	-	-	33.5	55.6	11.1	171

The picture is very similar in the two years, squid caught in the northern areas being hatched mainly in December, those from the west coast with maximum of hatching in January.

The authors are still in doubt whether the number of growth rings represents the real age in days, especially in older squid. The maximum average age in the samples examined as a rule does not exceed 11 months. This may either mean that older squid emigrate as they get mature, or that the formation of growth rings may be delayed or even stop, perhaps due to lack of food. HURLEY et al. (1983) successfully put a time mark on the statoliths of Illex illecebrosus in captivity, feeding them with tetracycline and strontium, or exposing them to cold shocks. Similar experiments are planned for T. sagittatus.

Tagging

During the autumn of 1982, 822 T. sagittatus were tagged, 440 in fjords of Norway north of 70°N, and 382 south of 63°N. Until June 1983 only one tag had been returned, 44 days after tagging, 25 n.miles from the tagging locality in North Norway.

Experimental fishery

In April 1983, T. sagittatus were taken in pelagic and near-bottom hauls with a commercial blue whiting trawl, during a research cruise in the Hebrides-Rockall-Porcupine Bank area. Nearly all the squid were caught in the meshes of the wings of the trawl, and very few were found in the cod end. The sampling of the squid was very cumbersome and time-consuming. It was concluded that a pelagic trawl of the type used is not very well suited for catching flying squid. However, in April-May 1982, up to 4 tons of T. sagittatus per vessel per week were taken as bycatch in the Soviet fishery for blue whiting (WIBORG 1983).

T. sagittatus has occasionally been caught in drift nets for herring (WIBORG 1972). In 1978 drift nets were introduced in Japanese waters for fishing of pelagic squid (ANON 1982).

A few nets designed for fishing of squid were bought and tried during the late autumn of 1982 in Norwegian fjords. During the night, squid attracted by lights, assembled around the nets, but none were caught. It was assumed that the squid were too scattered, and weather conditions unfavourable. Sovietic experiments with drift nets were also unsuccessful (WIBORG 1983).

In 1982 the Norwegian fishery for T. sagittatus yielded 17 000 metric tons.

ACKNOWLEDGEMENT

We wish to thank Karsten Hansen and Berit Endresen for assistance during the cruises and for working with the material and drawing of the figures. Also many thanks to Gunvor Christensen for typing the manuscript.

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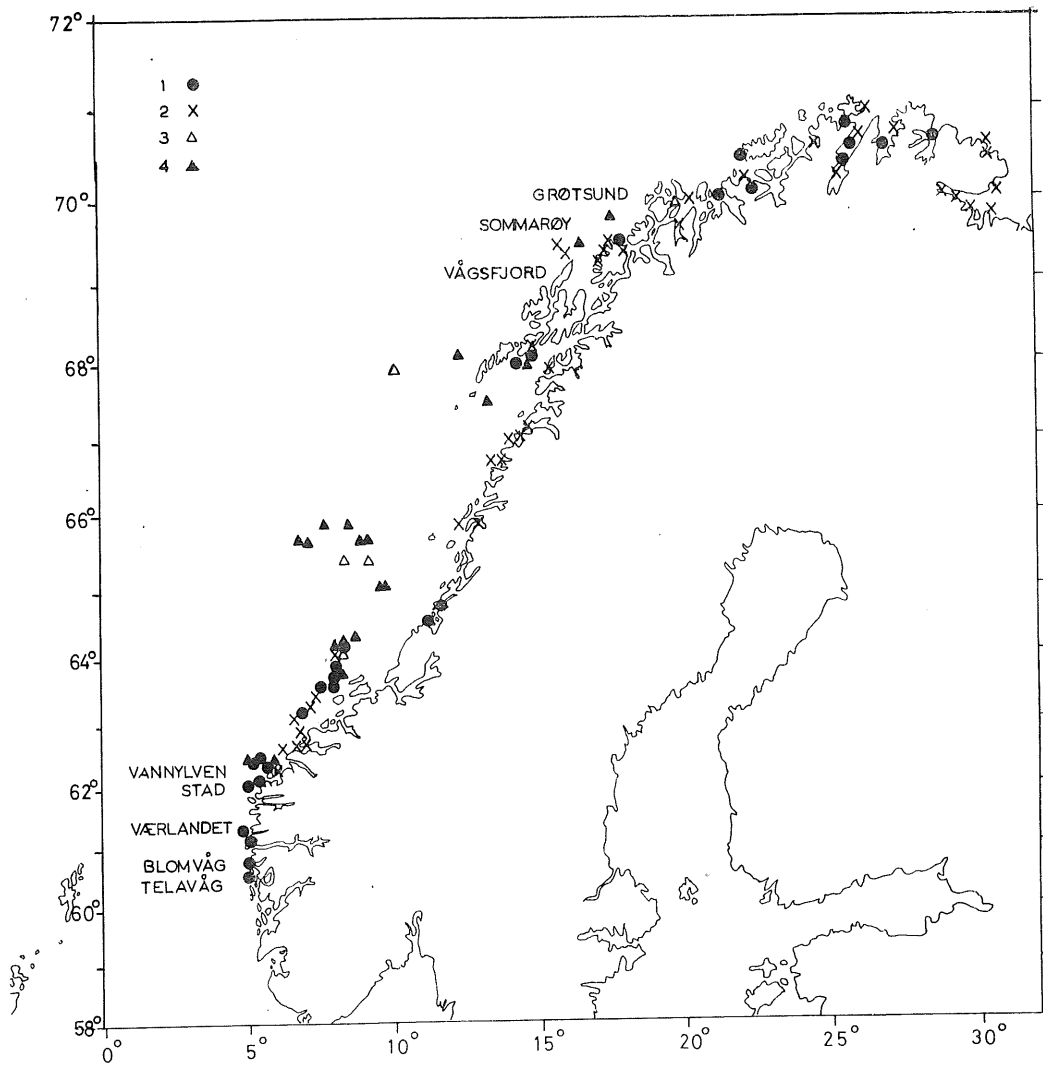


Fig. 1. Fishing for *T. sagittatus* July 1982 - February 1983. 1,2: jigging stations, 3-4: trawl stations, 1,4: with catch, 2,4: no catch.

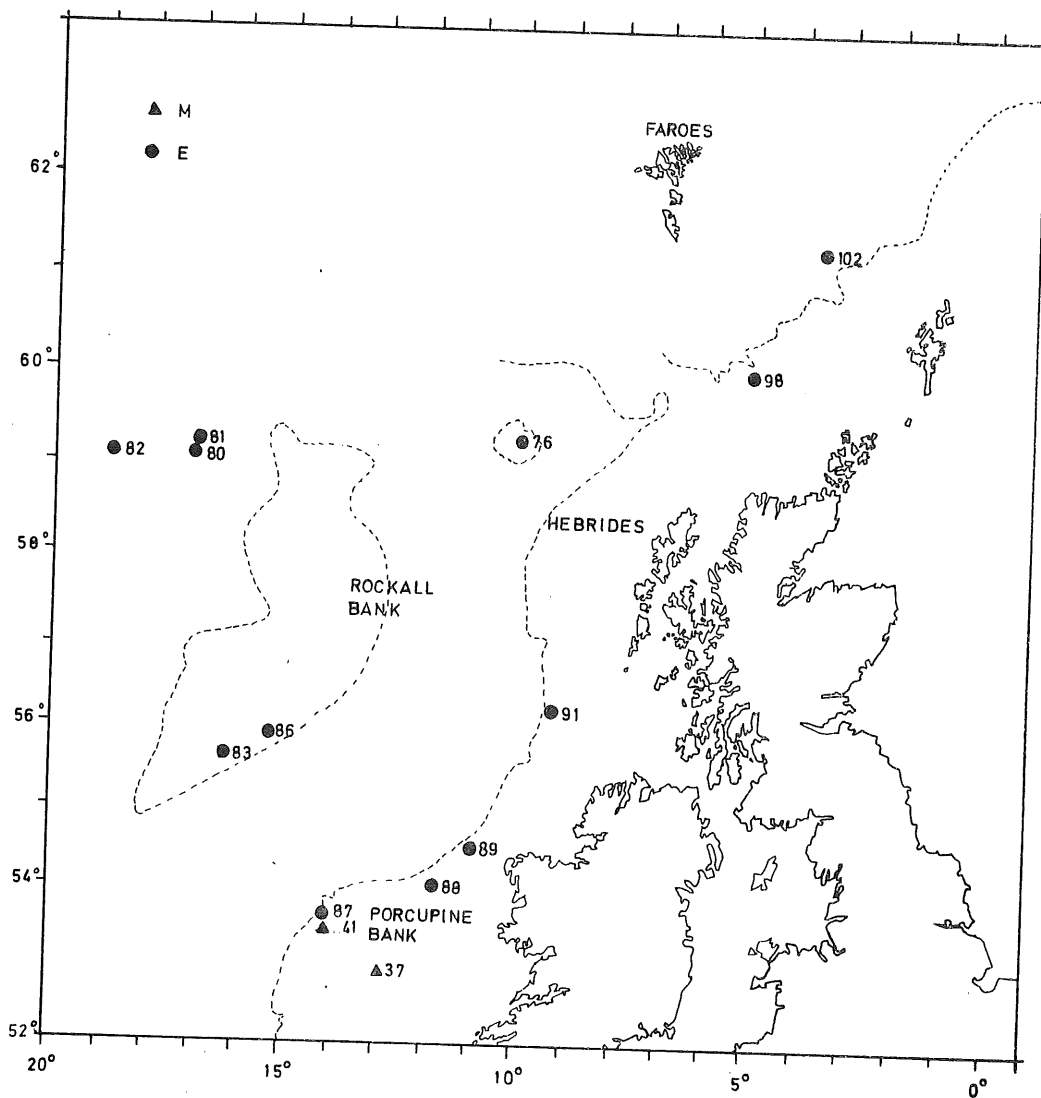


Fig. 2. Trawling stations with catches of *T. sagittatus*. M: March 1983, E: April 1983.

