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THE SQUID GONATUS FABRICII (LICHTENSTEIN) INVESTIGATIONS IN THE NORWEGIAN SEA AND WESTERN BARENTS SEA 1978-1981

by

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ABSTRACT

Gonatus fabricii is widely distributed in the arctic and sub-arctic waters of the north Atlantic Ocean. During summer and autumn juveniles are numerous in the surface layers of the Norwegian Sea. The adults live mainly below 300-500 m. G. fabricii is important as food for whales, seals and pelagic fish, and may be a potential fishery resource.

Materials were collected with pelagic trawls during June - September 1978 - 1981, and from stomach contents of whales and seals caught at Jan Mayen and east of Iceland in earlier years.

Dorsal mantle length (DML) in juveniles were 10-80 mm, in June-July with peaks at 20-24 mm and 55-59 mm, in September at 30-40 mm. The relation between DML and rostral length of the beak was calculated. Age and growth was estimated from counts of

growth rings in the statoliths. In the juveniles there is a linear relation between DML and number of growth rings, with correlation coefficient r, varying from 0.44 to 0.89.

The eggs are supposed to be hatched on the bottom at 300 m depth or more, with an incubation period of 70-100 days. A corresponding number of growth rings may be formed during this period. Hatching goes on during most of the year, with maximum in February - April. Growth of the juveniles is slow, about 0.2 mm a day. When the squid leave the surface layers, their growth rate increases considerably. The maximum age at a DML of 200-250 mm probably does not exceed one year.

The food of juveniles consists of amphipods, copepods, chaetognaths and euphausiids. Larger animals also take young fish and squid. The distribution and spawning areas of G. fabricii are related to the current system of the Norwegian Sea.

INTRODUCTION

Gonatus fabricii is a pelagic squid of the suborder Teuthoidea. It is widely distributed in the arctic and subarctic waters of the North Atlantic Ocean, including the Norwegian and Western Barents Seas, the Greenland Sea, and the areas off West Greenland, Labrador and New Foundland (KRISTENSEN 1981). Earlier records from the continental slope west of Scotland to the Bay of Biscay referred to as G. fabricii are probably G. steenstrupii Kristensen, those from the Pacific Ocean, other species of Gonatus (KRISTENSEN 1981).

During spring, summer and autumn larvae and juveniles of G. fabricii are abundant in the surface layers of the northeastern Norwegian Sea (NESIS 1965, WIBORG 1979, 1980, 1982). G. fabricii is important as food for the beaked whale, Hyperoodon ampullatus (MURRAY and HJORT 1912, HJORT and RUUD 1929, BENJAMINSEN and CHRISTENSEN 1979), hooded seals (WIBORG 1979), herring (NESIS 1965) and salmon (P. Hansen, pers. comm.). Juvenile G. fabricii, drifting ashore on beaches along the coast of Finmark, North

Norway during the autumn, are collected for bait (T. Robertsen, pers. comm.).

The present paper are based on earlier reports (WIBORG 1979, 1980, 1982) supplemented with a study on age and growth.

MATERIALS AND METHODS

G. fabricii (hereafter gonatus) were mainly collected in the Norwegian Sea and adjacent areas during surveys for postlarval and 0-group fish during late summer and autumn in the years 1978-1981, some also during other cruises, e.g. in the Norwegian Sea in April-June 1958 (WIBORG 1960). At 66°00'N, 02°00'E, the weathership station M, plankton hauls were taken regularly during 1949-1977. Some of the hauls contained larvae of gonatus (Table 1).

Table 1. Larvae of G. fabricii from plankton net hauls at St. M, 66°00'N, 02°00'E 1953-1966, by the month.

Month	Year	Depth, m	Number	Mantle length, mm
January	1966	0	2	6.5, 8.5
February	1956	0	1	10.0
"	"	400-0	1	?
March	1958	0	1	10.0
April	1954	600-100	1	6.6
"	1961	0	6	8.5,9.9,10.0,10.5,18.0
May	1961	600-100	1	8.0
June	1960	100-0	1	22.0
"	1960	25-0	1	10.0
"	1960	600-100	1	8.0
July	1960	0	several	?
December	1953	0	1	7.3

Larger individuals and beaks of gonatus have been identified in stomach contents of hooded seals caught near Jan Mayen, and in stomachs of beaked whales caught off East Iceland and Labrador (BENJAMINSEN and CHRISTENSEN 1979). A few larger gonatus were taken in deeper pelagic and bottom trawl hauls off the Norwegian continental slope in September 1980 and July 1981, and near Jan

Mayen in February 1980 (Table 2). A large number of juvenile gonatus were measured fresh during the cruises, others deep-frozen and studied in the laboratory after thawing. Materials from stomach contents and plankton hauls were preserved in 4% formalin.

The dorsal mantle length (DML) was measured to the nearest mm, in gonatus larger than 15 cm to the nearest cm. Beaks in stomach contents from whales and seals were identified by comparison with beaks from whole individuals and after CLARKE (1962). The length of rostrum in the lower beaks (RL after CLARKE 1962) was measured to the nearest 0.1 mm and the correlation between RL and DML calculated.

Stomach contents were studied under a binocular microscope. Statoliths were removed from a number of gonatus and kept in 96% ethanol. Later they were prepared as described in ROSENBERG, WIBORG and BECK (1980) and growth rings counted under a microscope with 1000 x magnification.

RESULTS AND DISCUSSION

Distribution

Fig. 1 shows the distribution of gonatus in the Norwegian Sea and adjacent areas, based mainly on observations from June - September in 1978-1981, and supplemented with data from other months and years. In July 1980, up to 8000 gonatus per haul were taken west of Jan Mayen, and more than 500 gonatus were frequently taken off northwestern Norway during June-August of the various years. At St.M, 66°N, 02°E, single gonatus larvae have been taken in surface and vertical plankton hauls each month between December and July. In the Barents Sea, juvenile gonatus were taken eastwards to 35°E, northwards to east of Hopen Island. The largest concentrations are usually met with outside the 1000 m contour line. Large and adult gonatus have only been taken at 300 m or deeper either in bottom or pelagic trawl hauls, or in stomach contents from beaked whales and hooded seals.

Size distribution

Gonatus taken with trawl in the upper 50 m have usually mantle lengths of 10-60 mm, a few up to 80-100 mm. In plankton hauls the larvae had mantle lengths 6.5 - 22 mm.

Size distributions from the Norwegian Sea in June-September 1980 and 1981 are shown in Fig. 2.

At the end of June 1980 there were two peaks in DML off northern Norway, at 20-24 mm and 55-59 mm, while in July 1981 only the smaller gonatus were taken. In August-September the mean size had a peak at 30-40 mm, but with a great range in variation. In the central Norwegian Sea small gonatus were present in August 1980. West of Jan Mayen the size distribution in July 1980 (Fig. 2.1) had the same range as the right side of the figure off northern Norway one month earlier (Fig. 2.2).

Larger gonatus with mantle lengths 60-280 mm have been found in stomach contents of beaked whales and hooded seals (WIBORG 1979). As most of the stomach contents were beaks of gonatus, the correlation between the rostral length and DML was calculated (WIBORG 1979). The equation for the linear regression is:

$$DML(mm) = 41.3\ RL(mm) - 38.6$$
$$r = 0.96$$

The size distribution of gonatus in stomach contents of beaked whales caught at Labrador in May-June 1971 (BENJAMINSEN and CHRISTENSEN 1979) was calculated from 133 beaks taken at random. Using the equation, the distribution of mantle lengths were as follows:

DML, cm	6-9	10-12	13-17	18-25	26-28	larger
Per cent	2.2	11.8	23.4	34.8	26.5	1.5

Most of these had mantle lengths above 18 cm, and were probably mature.

Some data on larger gonatus taken in trawl hauls at 400-550 m or in bottom trawl near Jan Mayen, are given in Table 2.

Table 2. G. fabricii caught in bottom trawl at Jan Mayen 20-21 February 1980, 140-425 m (No. 10 and 12), in pelagic trawl 16 July 1981, 550 m, position 73°48'N, 13°24'E (No. 6) and in pelagic trawl 25 September 1980, 400 m, position 74°30'N, 08°54'E (the remainder). +) minimum figures for damaged gonatus.

No	DML	Sex	Total Weight	Weight of liver	% of liver	Length of testes/ nidamental glands
	mm		g	g		mm
1	50	-	5			
2	75	-	15			
3	83	-	17			
4	94+	♂	-	-		18
5	95	♂	24	3	12,5	16
6	126	♀	39	-	-	8
7	155	♂	94	15	16,0	40
8	175	♀	75+	-	-	12
9	190	♂	89	13	14,6	35
10	205+	♀	188+	54	28,7	20
11	205+	♀	330+	23	7,0	40
12	210	♂	154	34	22,0	-
13	215+	♀	280+	20	7,2	45
14	250+	♀	415+	32	7,7	45

Age and growth

Age and growth of squid were previously mainly estimated from analyses of modal length frequencies. MUUS (1962) supposed that gonatus with DML 8-20 cm were 2 years old, 24 cm - 3 years. CLARKE (1962) thought that the development to adult G. fabricii might be accomplished within one year, while ZUEV and NESIS (1971) assumed individuals with DML 10-20 cm to be 1½ year old. With the study of growth rings in the statoliths of squid (LIPINSKI 1978, 1980, 1981, SPRATT 1978, 1979, KRISTENSEN 1980,

HURLEY and BECK 1980), a method of more reliable age determination has been introduced. KRISTENSEN (1977) estimated the mantle length at hatching of G. fabricii to 3 mm, and the growth rate during the summer in west Greenland waters to 8 mm a month. From growth rings in the statoliths KRISTENSEN (1980) calculated a growth rate of about 10 cm a year.

We counted growth rings in statoliths from gonatus with DML 16-75 mm, and from a few larger ones, with DML maximum 250 mm. Some results have been published (WIBORG 1982). At hatching, the statoliths of gonatus larvae have a diameter of 160 µ (KRISTENSEN 1980). KRISTENSEN (l.c.) started the counting of growth rings outside this part (his Zone 1) but in Fig. 9 in his paper a number of rings are visible inside Zone 1. In our material, we also found growth rings inside this zone. From a nuclear area of 25 µ we counted 68-98 rings, averagely about 80 rings.

KRISTENSEN (1981b) described a mature female of G. fabricii with mature eggs, 4-5 mm in diameter. He assumed that gonatus spawns on the bottom in relatively deep water.

According to AKIMUSHKIN (1965) the development of cephalopod eggs may be slow at lower temperatures.

In Loligo opalescens the eggs hatch after 30-35 days at 13.6°C (MCGOVAN 1954). This corresponds to 408-476 day-degrees. In the Norwegian Sea, the temperature at 400-500 m will be about 4-5°C in the eastern part, below 1°C in the western part (DIETRICH 1969). If G. fabricii deposits the eggs on the bottom at 400-500 m, and if a similar number of day-degrees is needed as in L. opalescens, the incubation time at 5°C will be 80-100 days, which corresponds very well with the number of growth rings within Zone 1 of the statolith. Some time may also be allowed for the development of the nucleus.

Fig. 4 shows the relationship between the total number of primary growth rings (GR) in the statoliths and the mantle

length (DML) in samples from the Norwegian Sea. If only the rings outside the supposed nuclear area are considered, the scale of the abscissa should be moved about 80 days to the left.

If samples of juveniles from June 1980, July 1981 and August 1981 are considered separately, they have correlation coefficients $r = 0.89$ ($n = 19$), $r = 0.44$ ($n = 25$) and $r = 0.74$ ($n = 39$) respectively. If these samples are considered as samples from one statistical population, $r = 0.73$ ($n = 84$).

Two samples of adults are included in Fig. 4, but not in the calculations.

For several species of fish and cephalopods the primary rings are formed daily and can therefore be used for ageing. If these rings are formed daily also in G. fabricii the following relationships between DML and age are found:

June 1980	DML = 0.13 GR - 2.15	Sy•x = 2.50
July 1981	DML = 0.14 GR - 2.62	Sy•x = 6.78
August 1981	DML = 0.26 GR - 25.33	Sy•x = 8.19
Total	DML = 0.20 GR - 10.16	Sy•x = 8.03

Discarding the first 80 rings, possibly formed before the hatching would not change the slope, but give a higher intercept. The differences between the slopes and the elevations of these lines were tested by analysis of covariance (see ZAR 1974, p. 230-235). For slopes, $F = 3.74$. This corresponds to a probability between 1% and 5% for all slopes being equal. For elevation, $F = 11.74$. The corresponding probability is much less than 1%. As the criterions for using this method are probably not totally fulfilled, the result must be treated with caution.

The difference between the various regressions are probably not large enough to warrant separate treatment. As a first estimate of age/length relationship for G. fabricii smaller than about 7 cm the total regression line could be used. This line suggest

a mean growth rate of about 0.20 mm a day for mantle lengths between 1 cm and 7 cm. If a function regression is used instead of the predictive one (see RICKER 1973), the estimated growth rate would be about 0.27 mm/day, or 6-8 mm a month, depending on the method used. This is in good agreement with the estimate given by KRISTENSEN (1977).

For the larger gonatus the number of growth rings are maximum about 300, which does not fit very well into the picture. If the readings are correct, G. fabricii must increase its growth rate considerably with the change from an epipelagic life to a deep-pelagic or bottom life, probably also correlated with a change in quality and quantity of food. Changes in growth rate from juveniles to adults are indicated for Illex illecebrosus (HURLEY and BECK 1980).

KRISTENSEN (1980) found an increasing number of growth rings with increasing mantle length in G. fabricii from Disco Bay, western Greenland, calculating ages of 1, respective 2 years for individuals with pen lengths 10 cm and 17 cm. Pen length is about 9/10 of mantle length (KRISTENSEN 1981a, Fig. 2).

For G. fabricii from the Norwegian Sea, the present investigation does not indicate ages beyond one year.

If we accept an incubation period of averagely 80 days for the eggs, hatching in the Norwegian Sea may take place as follows:

Date of sample	Month of hatching						
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
June 25, 1980	2	1	2	4	9	1	
July 16, 1981				1	11	7	6
August 23-28, 1981		2	4	8	14	9	2

The hatching period is very extended, November-May, with a peak in March. This is in agreement with earlier conclusions (WIBORG 1979, 1980). The presence of larvae with mantle lengths of 6.5-10 mm throughout December-August (NESIS 1965, WIBORG 1980, 1982) may also indicate hatching during a greater part of the year.

Distribution and spawning areas of G. fabricii in the Norwegian Sea

The distribution of G. fabricii in the Norwegian Sea may largely be related to the current system (Fig. 5). The juveniles, living in the surface layers, are carried northwards in the eastern part, and concentrate in various eddies, e.g. between Jan Mayen and Vesterålen. With increasing size, gonatus goes deeper, and may settle along the slopes of the continental shelf. Some may follow the current farther north and northwestwards, and again southwards, either in cooled Atlantic water, or perhaps joining the East Greenland current. Finally, they may reach the Jan Mayen or East Iceland slopes.

The spawning areas of G. fabricii have previously been related to the feeding areas of the beaked whale (WIBORG 1979), with four areas of major importance: off Møre, off Vesterålen, west of Spitsbergen, and between Iceland and Jan Mayen (WIBORG 1979, Fig. 7). Larger gonatus have been located in most of these areas, either in stomach contents of whales and seals, or in trawl hauls at greater depths, but with the exception of the observation of KRISTENSEN (1981b), no adult gonatus in spawning or near-spawning stage have yet been taken.

Food of gonatus

The stomach contents of gonatus from pelagic trawl hauls were studied (WIBORG 1980, 1982). Various organisms, mostly crustaceans, were identified. The average frequencies of the most important groups were: Amphipoda 62.8%, Copepoda 33.6%, Chaetognatha 21.9%, Euphausiacea 7.7%. Larger gonatus had also taken fry of Sebastes sp., Maurolicus muelleri, and small gonatus.

The following species were identified: Amphipoda: Parathemisto abyssorum, P. libellula and P. gaudichaudii; Copepoda: Calanus finmarchicus and Pareuchaeta norwegica; Chaetognatha: Sagitta sp. and Eukrohnia sp.; Euphausiacea: Meganyctiphanes norwegica; Pteropoda: Spiratella sp.

Fishing potential

G. fabricii may be a potential fishery resource. In North Norway the juveniles are highly estimated as bait, but only available when stranded on the beaches during the autumn. Fishing experiments with pelagic trawls off northern Norway have been unsuccessful. The adults are supposed to aggregate during spawning time, but as already mentioned the spawning areas are probably in deep water and difficult to locate.

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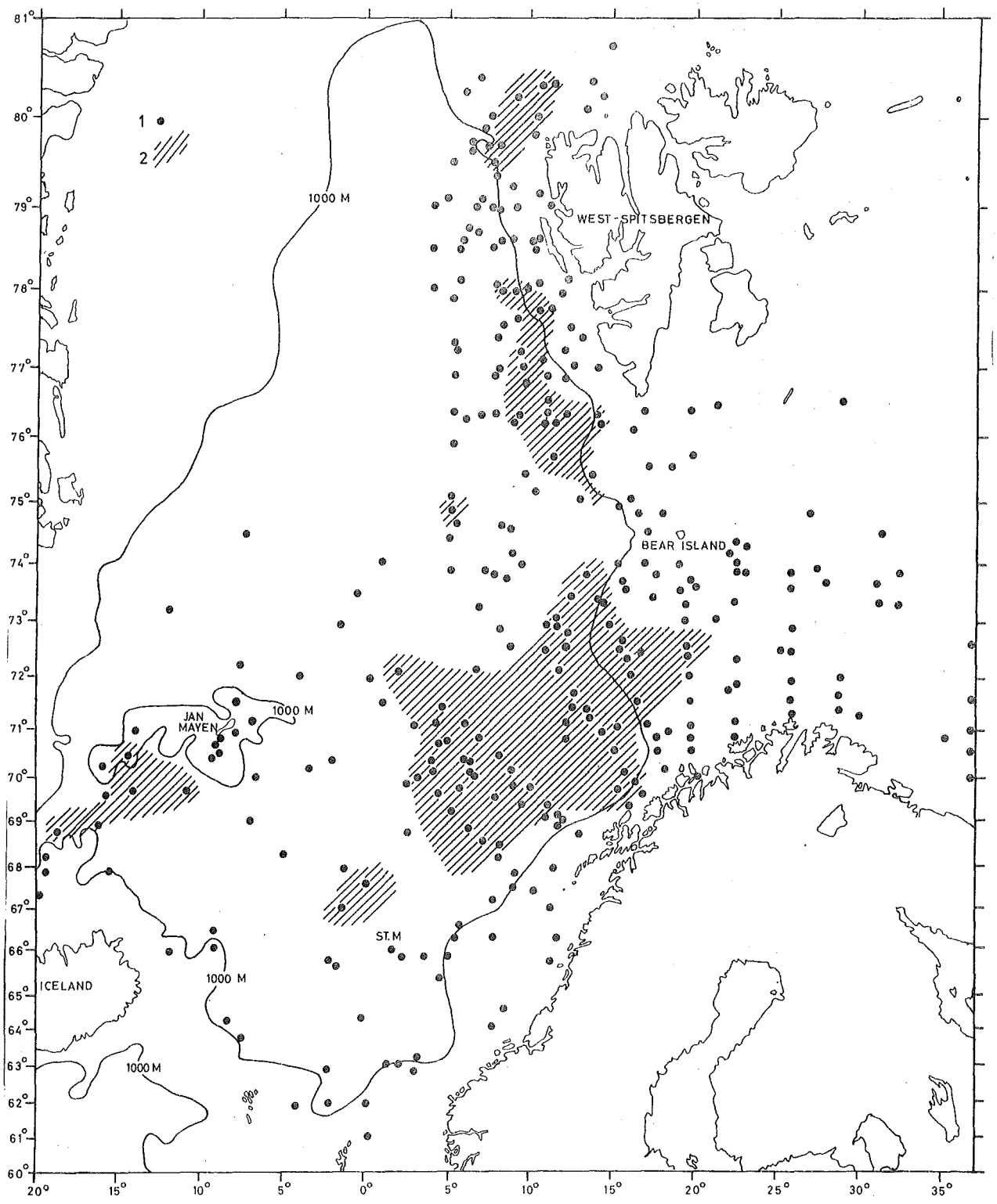

Fig. 1. Distribution of juvenile G. fabricii in the Norwegian Sea based on half hour's hauls in the upper 50 m with a Harstad trawl, 18 x 18 m opening in June - September 1978 - 1981. Hatched: more than 100 gonatus per haul.

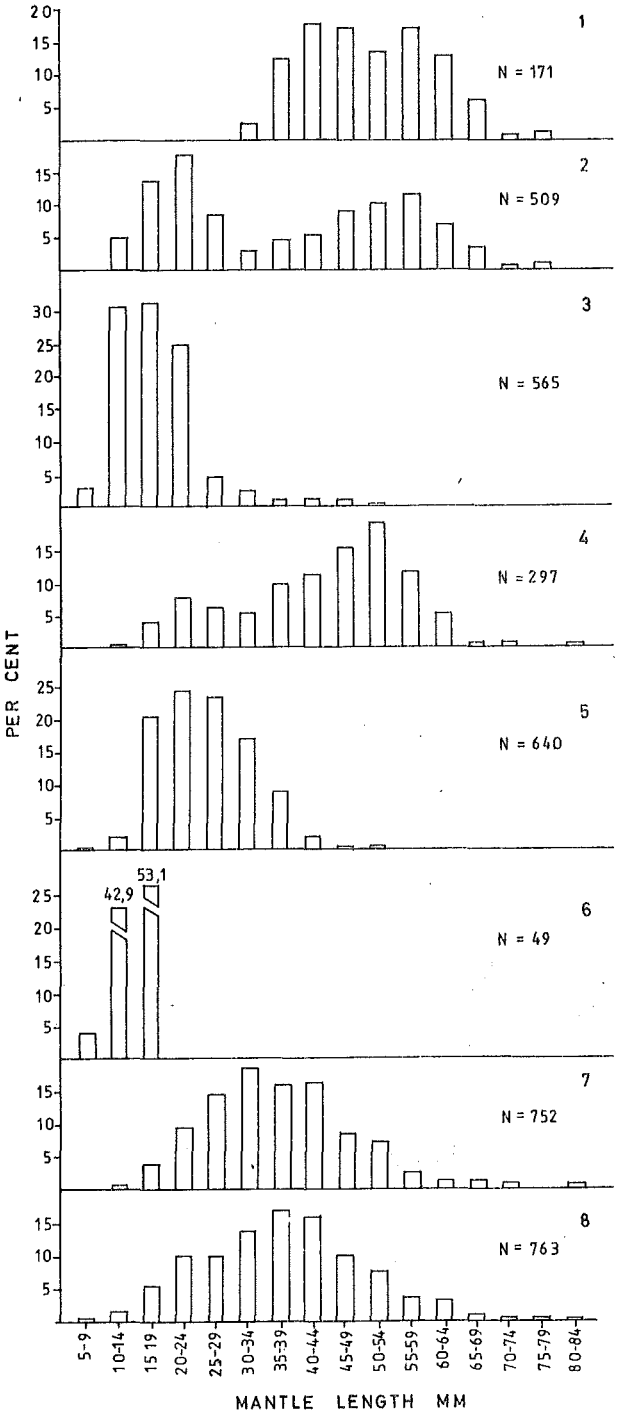

Fig. 2. Distribution of mantle lengths of juvenile G. fabricii. 1) West of Jan Mayen, 20-29 July 1980. 2) Off North Norway, 68°30'N - 70°30'N, 25-26 June 1980. 3) 65°00'N - 71°00'N, 3-15 July 1981. 4) 70°30'N - 74°00'N, 29-30 June 1980. 5) 71°00'N - 74°00'N, 15-18 July 1981. 6) Norwegian Sea, 70°30'N, 05°00'W - 72°00'N, 16°00'E, 20-26 August 1980. 7) North Norway - West Spitsbergen, 72°00'N - 80°30'N, 27 August - 6 September 1980. 8) Latter area, 23-31 August 1980.

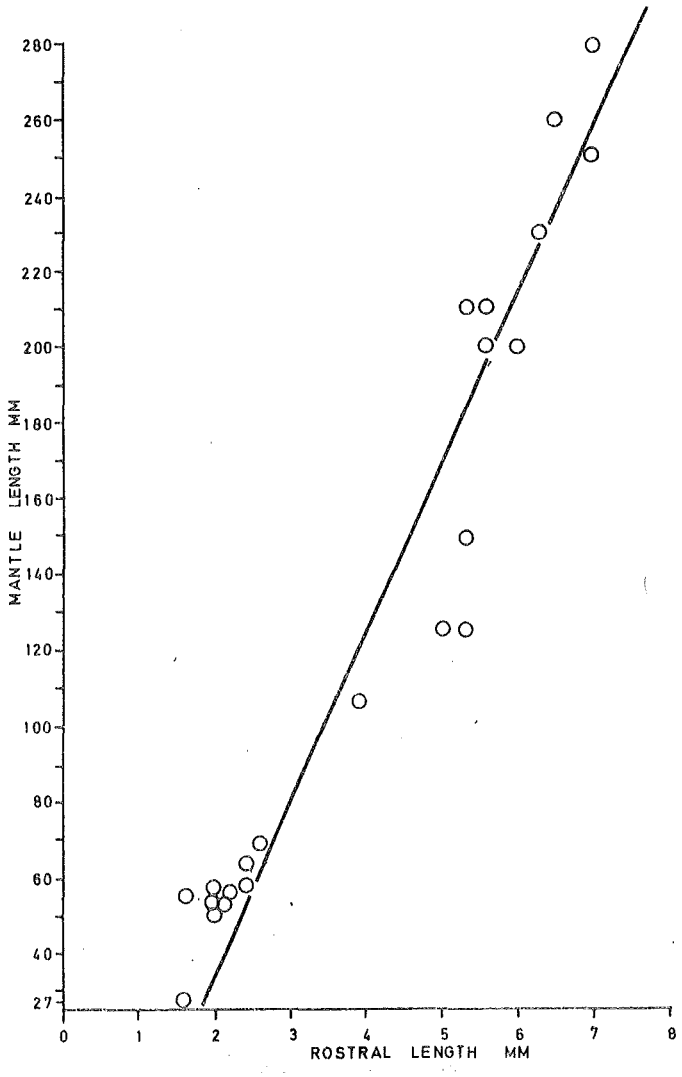

Fig. 3. Relationship mantle length (DML) - rostral length (RL) in G. fabricii. DML(mm) = 41.3RL(mm) - 38.6 n = 21, r = 0.96. See text.

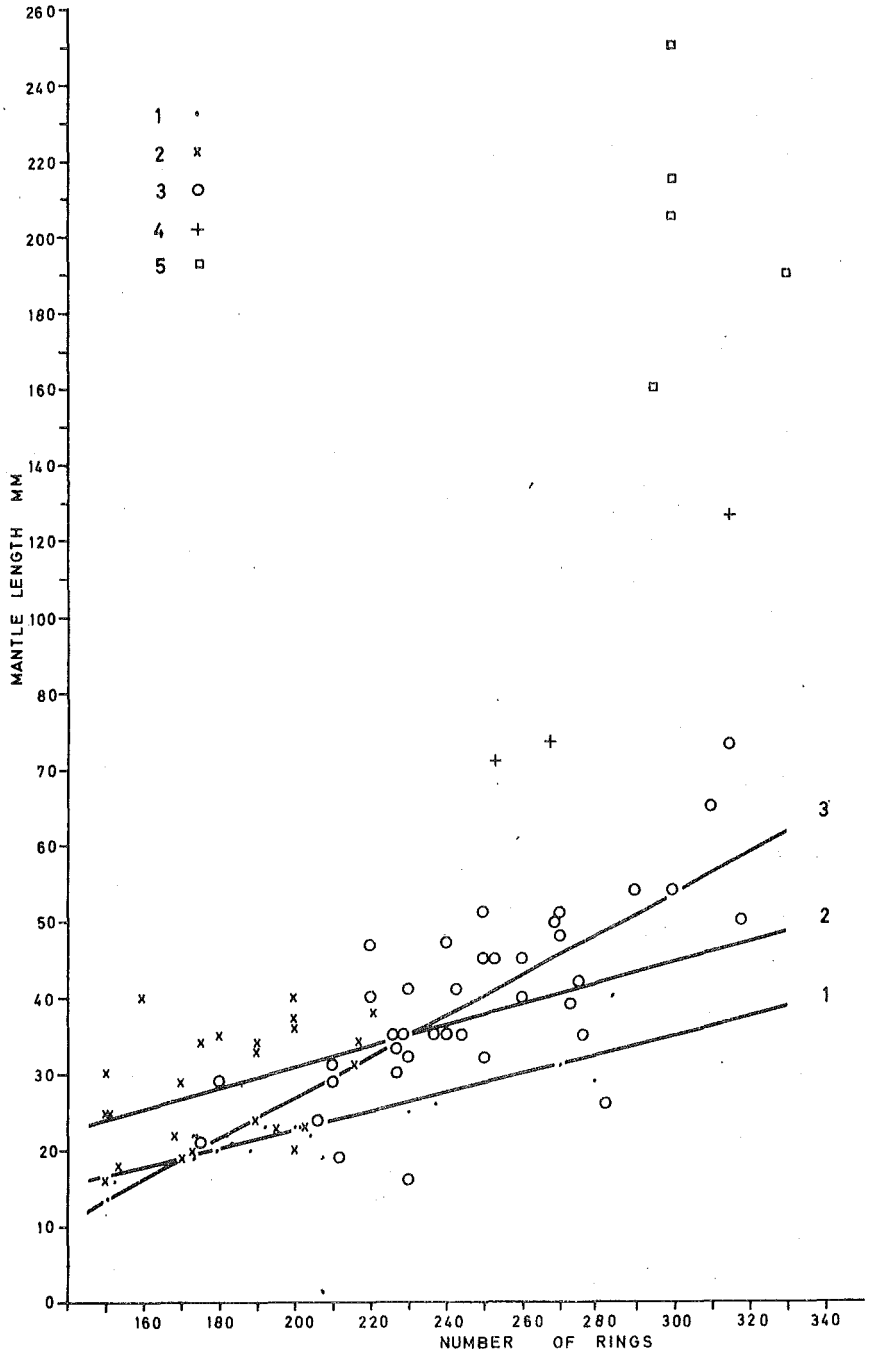

Fig. 4. Relationship mantle length (DML) - number of growth rings (GR) in the statoliths of G. fabricii from the Norwegian Sea.

1) June 25 1980, 72°00'N, 12°00'E
   DML(mm) = 0.13GR - 2.15. n = 19, r = 0.89
2) July 16 1981, 73°48'N, 13°24'E
   DML(mm) = 0.14GR - 2.62. n = 25, r = 0.44
3) August 23-28, 1981, 71°51'N, 05°00'E to 80°20'N, 10°30'E
   DML(mm) = 0.26GR - 25.33. n = 39, r = 0.74
4) July 16, 1981, 73°48'N, 13°24'E
5) September 25, 1980, 74°30'N, 08°54'E
   1-3: 0-50 m, 4: 550 m, 5: 400 m

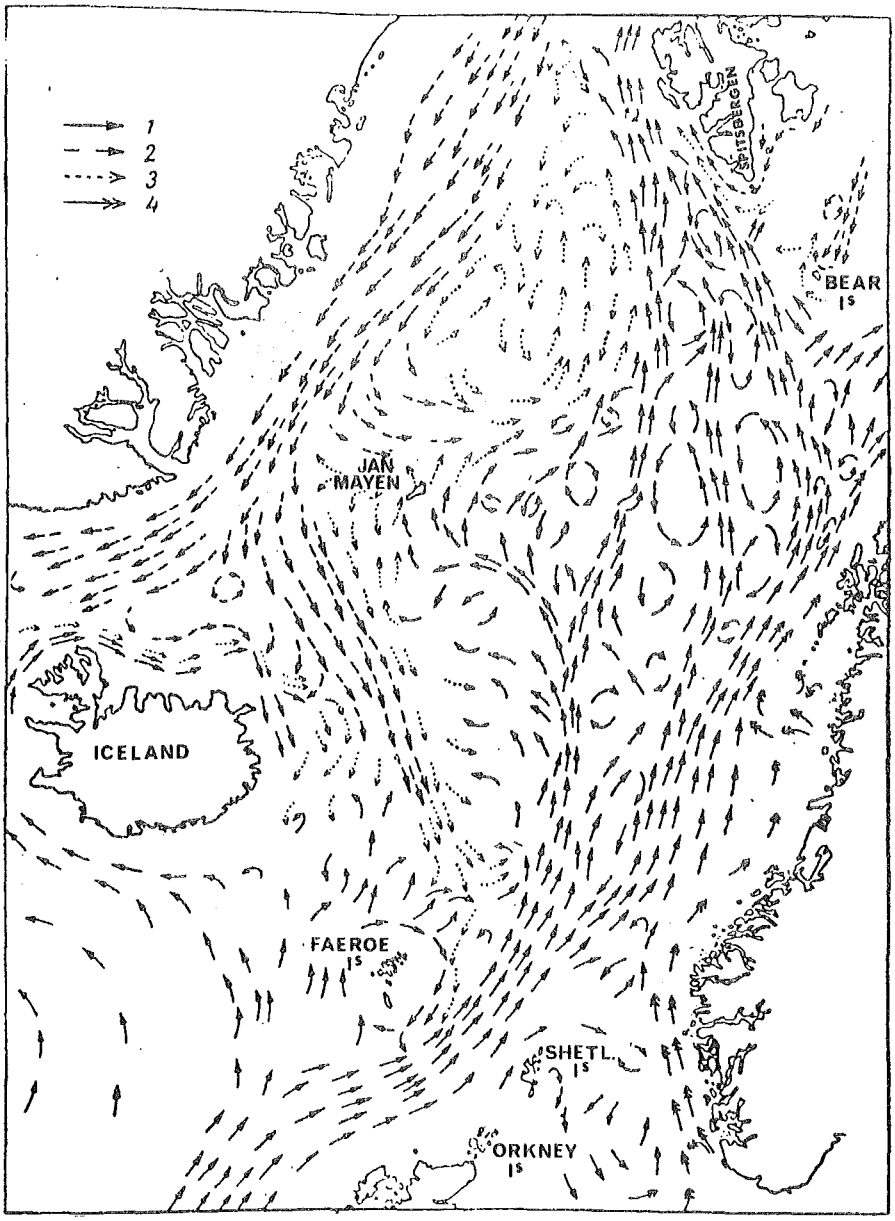

Fig. 5. Surface currents in the Norwegian Sea and adjacent areas. 1) Warm currents. 2) Cold current. 3) Mixed waters. 4) Coastal waters. (From ALEKSEEV and ISTOSHIN 1956).