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Thomas K. Kristensen

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Three hundred adult and subadult *Gonatus fabricii* and about 7000 juveniles from West Greenland waters were examined. In spring and early summer large numbers of juvenile *G. fabricii* hatch in Davis Strait. Their abundance fluctuates from year to year. In Disko Bugt the juveniles hatch in autumn and early winter. Juvenile *G. fabricii* hatch over a large area in Davis Strait at depths exceeding 200 m. At night juveniles south of the polar circle perform vertical upward migrations. Likewise it seems that shoals of juveniles disperse at the same time. The number of juvenile *G. fabricii* is found to be about the same as the number of larvae of the Greenland halibut, *Rheinhardtius hippoglossoides*, a common commercial fish. The growth of *G. fabricii* was found to be 8–9 mm per month. The development of the gonads in relation to pen length is describable by the allometric equation. The testis begins to develop at a pen length of about 8–10 cm, the penis at a pen length of 3–5 cm. The largest mature male measured 29.3 cm pen length. The ovary begins to develop at a pen length of 6–8 cm. No mature females were found. In Greenland waters males probably mature at about 20 cm pen length, females between 25 and 30 cm pen length.

51% of specimens had empty stomachs, 27% were half full and 22% full. Crustaceans, fish and cephalopods were found in the stomachs and crustaceans were the most important. The protein percent was found to be 12.5 and in the liver the lipid percent was 63.

Spawning and predators of *G. fabricii* are also discussed.

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Introduction

Gonatus fabricii (Lichtenstein, 1818) (Fig. 1) is the dominant squid in the arctic and subarctic waters of the North Atlantic.

Due to the abundance of the juvenile stage in West Greenland waters (Nesis 1965, Kristensen 1977a) and its frequent occurrence in the stomachs of marine mammals, birds and fishes (Clarke 1966), *G. fabricii* is considered an important element in the marine ecosystem in West Greenland and might have a value as a potential fishery resource (Wiborg 1979).

As part of a project concerning this species, the present work deals with the biology of *G. fabricii* from West Greenland waters. Previous parts include studies on the systematics of *G. fabricii* (Kristensen 1981a), the infraspecific variation (Kristensen 1982), the characteristics of the mature female (Kristensen 1981b) and periodical growth rings in statoliths of *G. fabricii* (Kristensen 1980).

Material and methods

This investigation comprises about 300 subadult and adult specimens used for qualitative studies and about 7000 juveniles measured and used for quantitative studies. The material covers all available samples of *G. fabricii* caught by the Greenland Fisheries Investigation and The Danish Institute for Fishery and Marine Research through several decades.

The demonstration of the occurrence of at least two morphologically different populations within West Greenland waters, one in Davis Strait off Holsteinsborg and one in Disko Bugt (Kristensen 1982) made it necessary to consider this in the qualitative studies. Therefore the Disko Bugt specimens were studied separately, and from off the west coast only specimens from Davis Strait between 63° and 68°N were included in the analysis of size, growth and reproduction.

Three types of nets were used for collecting: a 2 m stramin net, a midwater trawl and a shrimp trawl, with the following specifications: 1) *S 200*, a stramin ring net 2

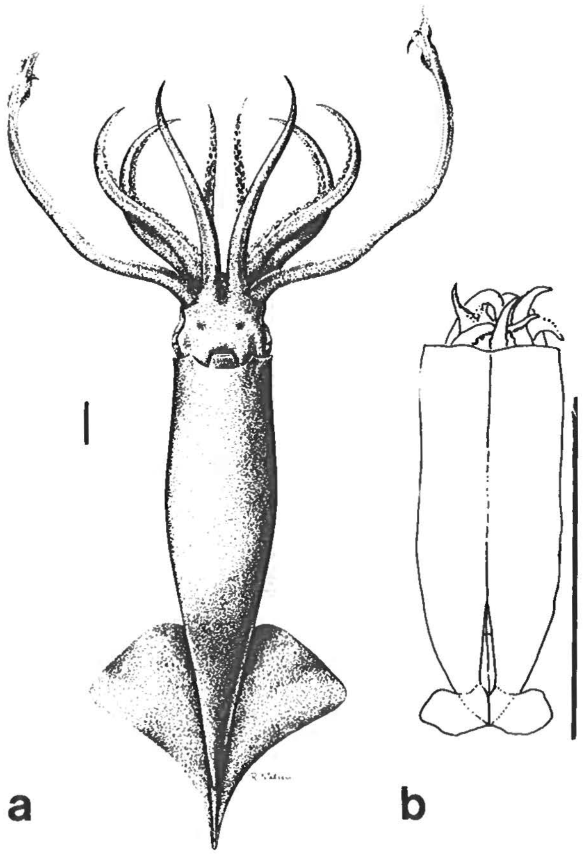

Fig. 1. Adult (a) and juvenile (b) *Gonatus fabricii* (Lichtenstein, 1818). Scales: 1 cm.

m in diameter with mes 500 threads per metre, fishing in the uppermost layers of the water column. In the years 1950–1966 (except 1951, –52, –60 and –65) juveniles of *G. fabricii* were caught by standard stramin hauls at definite station webs off West Greenland each year in July, by the Danish research vessel "Dana". At each station a specified procedure was used. The hauls were taken at two levels, A and B. A was taken with 100, 50 and 25 metre wire (mW) and B with 200, 150 and 125 mW, for 30 minutes. This corresponds to a fishing depth down to 70–80 metres. A few hauls were made at greater depths but were not included in the quantitative analysis. In 1963 the station web was especially extensive, being part of the international investigation "Norwestlant". The catch in that year was previously treated (Kristensen 1977 a) and the size distribution is included in this paper.

2) *Midwater trawl*, which is a 10 fathoms commercial midwater trawl, with 18 mm meshes (inside measurements). This net was operated in depths of 60–80 metres.

3) *Shrimp trawl*, which is an ottertrawl with cod-end with 35–40 meshes (inside measurements) fishing on and just above the bottom.

The three nets supplemented each other, covering the whole size range of *G. fabricii* from 0.3 cm pen length (PL) at hatching size to maximum PL at about 30 cm (Kristensen 1977a) (Fig. 2). The operation depths of the nets also covered the vertical distribution of the species from surface to the bottom. The minor overlapping in size range of the catch between midwater trawl and shrimp trawl, which is less satisfactory than between stramin net and midwater trawl, was found sufficient (Fig. 2), but had to be considered in the analysis of the size distribution.

Most specimens were fixed in formalin immediately after capture and later kept in 70% ethanol. Specimens for statolith investigations were kept frozen until use and later transferred to ethanol.

All specimens were measured by a slide gauge and recorded to the nearest mm. All measuring was done on fixed specimens. The pen length was measured from anterior tip of middorsal point of mantle to posterior conus of mantle.

The time of appearance of the juveniles off the west coast, as indicated by the size distribution, is almost the same from year to year (Fig. 3), and the size distribution including adult specimens is believed to cover the same range from year to year. On this background it was found acceptable to pool specimens from all years in order to analyse the size distribution of the whole material.

Weighing of whole specimens was done as follows: each specimen was weighed wet, after having dripped off. Small specimens, less than about 5 cm PL, were weighed on a Metler weight and larger specimens with weights up to 250 g were weighed on a feather weight. The few larger specimens were weighed on a table weight.

The gonads, testis and ovary were taken out and

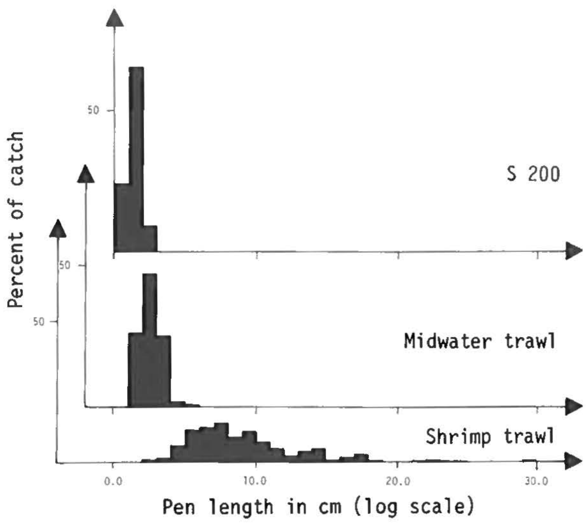

Fig. 2. Pen length frequency histograms of specimens from the three different types of gear by which the investigated material was caught. For gear specification see text.

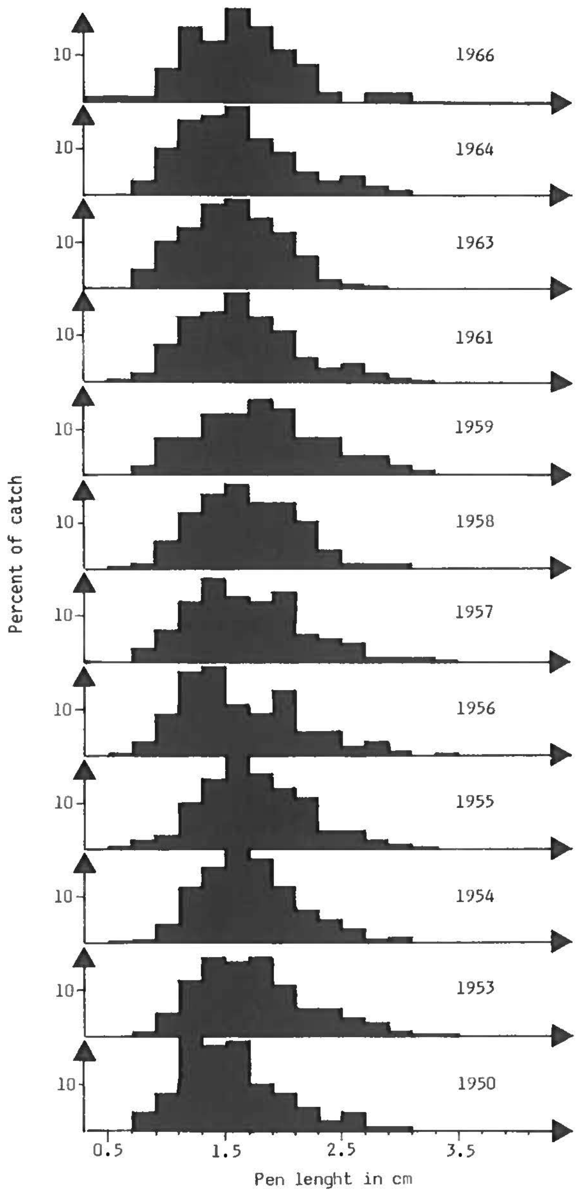

Fig. 3. Size frequency distribution of juvenile *Gonatus fabricii* caught in 2 m stramin net in Davis Strait each July in the years 1950–1966 (except 1951, 1952, 1960, 1962 and 1965).

placed on filter paper before they were weighed on a Metler weight.

Occurrence of juveniles

Young *G. fabricii* are considered as juveniles (Fig. 1) from the time of hatching at about 3 mm PL (Kristensen 1977a) to a size of about 30 mm PL, the point at which the large central hook on the tentacle club develops (Kristensen 1977b).

Annual occurrence

In Davis Strait juvenile *G. fabricii* hatch in spring and early summer and subsequently occur in high numbers (Kristensen 1977a). The time of hatching is probably fairly constant from year to year, since juvenile *G. fabricii* each year show almost the same relative size distribution (Fig. 3). An equal distribution might be due to gear selection, but probably not in this case, as the stramin net can, for example, catch smaller as well as larger specimens of copepods (Kristensen 1977a).

The number of specimens in Davis Strait, expressed as catch per 30 minute haul, changes from year to year and indicates fluctuating abundance with peaks in 1953–54 and 1961 (Fig. 4). Although the number of years in succession is not enough to show a regular oscillation pattern, the present results are not incompatible with the period of about eight years found for other arctic animals and for climate oscillations (Dr. C. Vibe, personal communication). The present fluctuations of the larval abundance probably influence the overall stock size and, as in fish, strong to weak year classes occur in this squid.

In Disko Bugt juveniles have been found in October and January only (Fig. 7) though a large number of stramin hauls were made in the spring and summer months. Consequently, in this area *G. fabricii* is believed to spawn and hatch in the autumn and early winter.

Horizontal distribution

To estimate the horizontal distribution of juvenile *G. fabricii* in Davis Strait the number of specimens per 30 minute hauls in defined squares (Fig. 5) of 30′ latitude and 1° longitude between 62° and 70°N was calculated.

Moreover, in order to localize possible spawning grounds of *G. fabricii* by tracing squares of the smallest juveniles, the pen length of the juveniles in two rows of squares at right angles to each other was measured and referred to 2 mm size classes (Fig. 6).

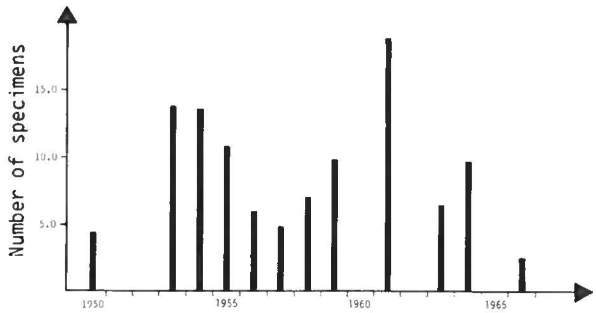

Fig. 4. Number of juvenile *Gonatus fabricii* caught in Davis Strait each July 1950–1966 (except 1951, 1952, 1960, 1962 and 1965), expressed as number per 30 minute stramin haul.

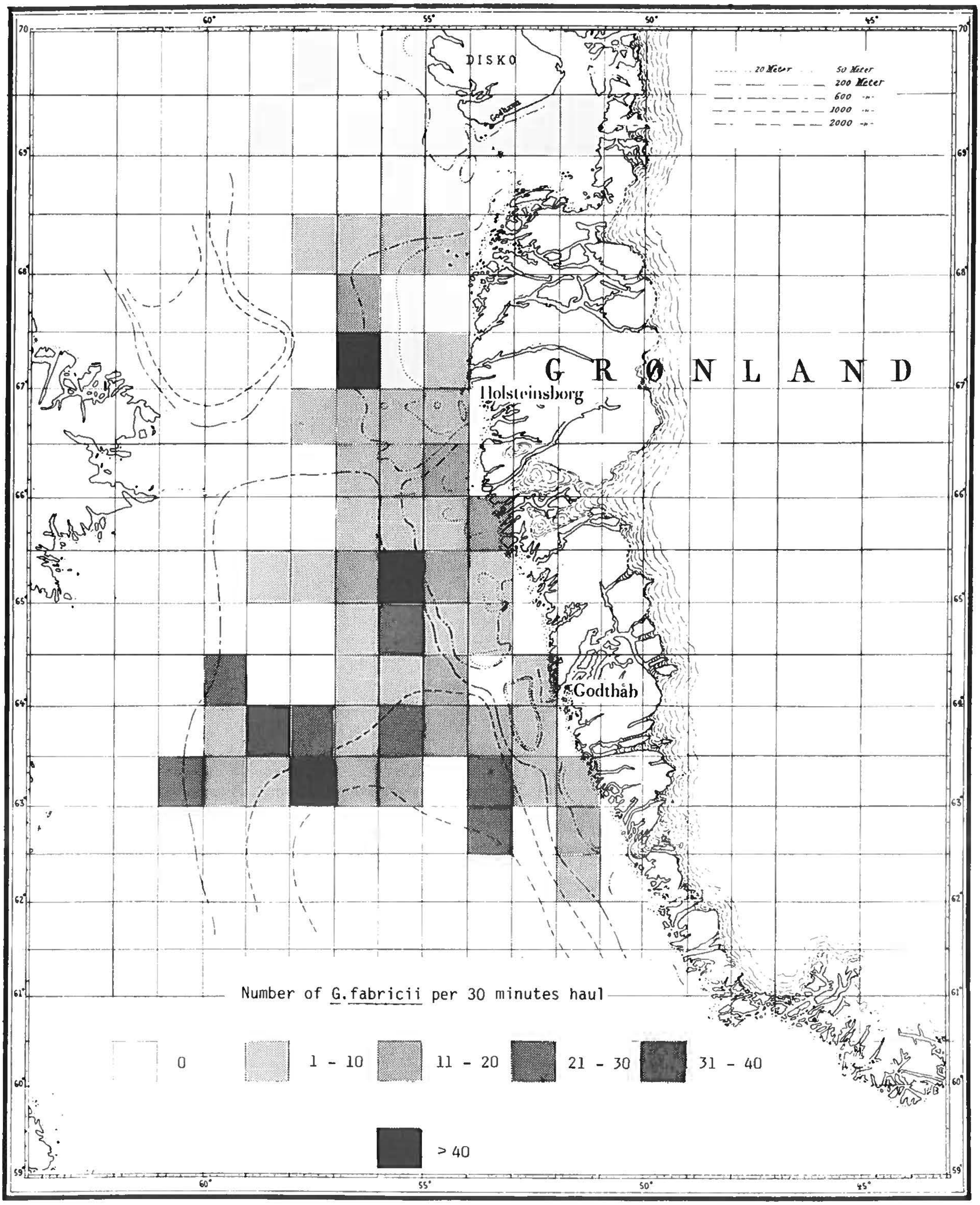

Fig. 5. Quantitative distribution of juvenile *Gonatus fabricii* in the Davis Strait between 62°N and 70°N and in Disko Bugt, indicated as number per 30 minute hauls in squares of 30′ latitude and 1° longitude. Hauls were carried out in shaded squares only. Juveniles caught in the years mentioned in Figs 2 and 3.

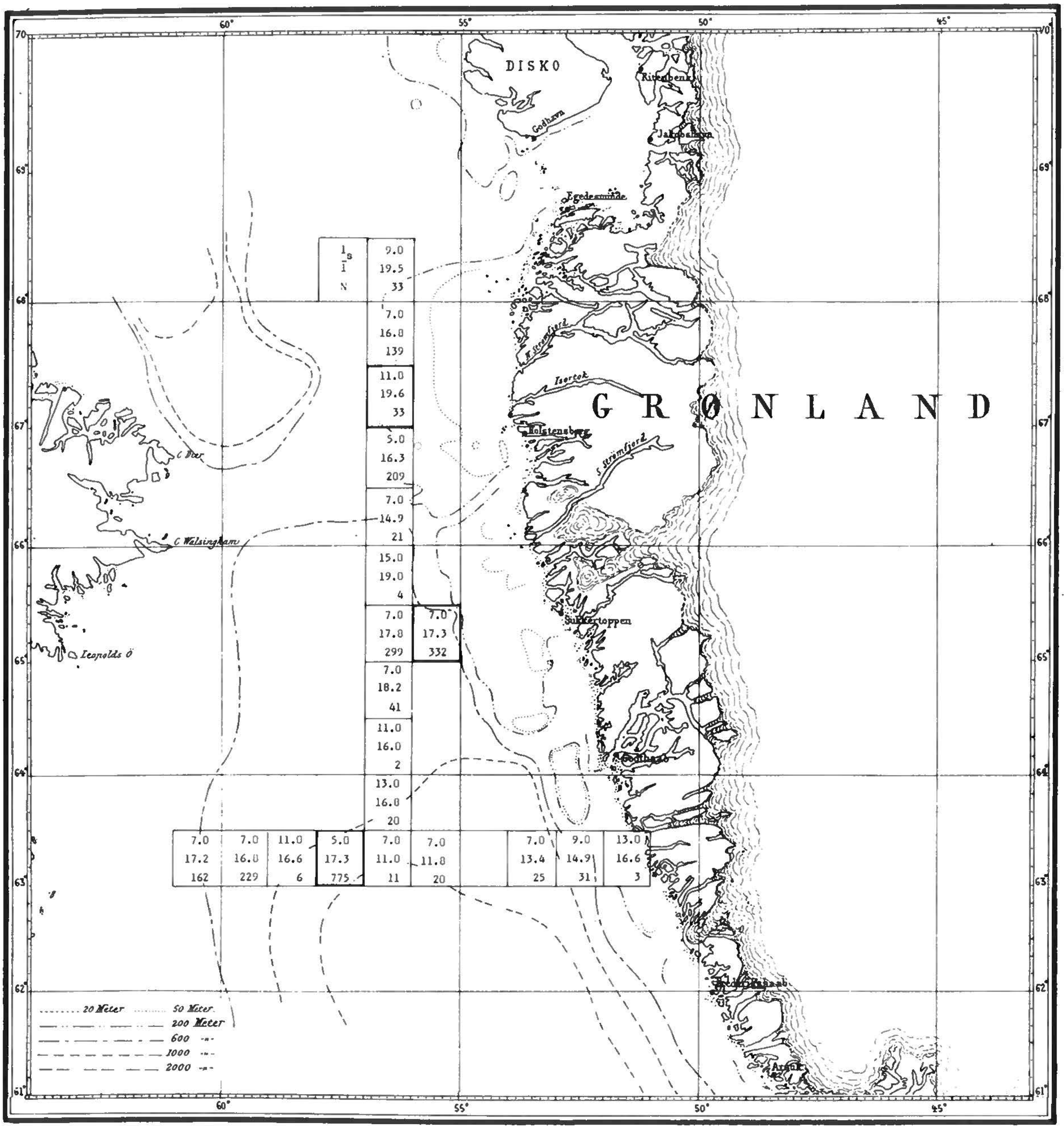

Fig. 6. Smallest size group found in each square indicated by the lower limit (l_s) of the size group, mean length of pen ($\bar{l}$) and number of hauls (N) in each square. Squares with exceptionally high number of juveniles (cf. Fig. 5) are indicated by thick border lines.

The abundance of juveniles is somehwat scattered (Fig. 5). It is characteristic that the squares with the highest numbers nearly all occurred at depths exceeding 200 m.

The smallest juveniles (5.0–7.0 mm) were found in several squares (Fig. 6). As *G. fabricii* hatches at a size of 3 mm PL, and since the juvenile growth was estimated at about 8 mm per month (Kristensen 1977a), the small specimens were recently hatched. Consequently, *G. fabricii* seems to hatch over a large area in Davis Strait.

The presence of juvenile *G. fabricii* in the northern part of Davis Strait was previously believed to depend on hatching in the south and transportation up the west coast of Greenland by the currents (Kristensen 1977a). The fact that the mean size of specimens is fairly uniform in the area studied (Fig. 6), and that small newly hatched specimens occur in several squares, points at a widespread spawning. This agrees with the discovery of local populations of *G. fabricii* within Greenland waters (Kristensen 1982).

Vertical distribution

Most hauls were carried out in the uppermost 70–80 m (225mW) of the water column where the highest number of larvae was found. Juvenile *G. fabricii* have been caught in stramin net hauls down to a depth of about 2000 m (Lu and Clarke 1975), but in the present investigations only a few specimens were taken below 70–80 m.

Diurnal vertical migration of juvenile *G. fabricii* south of the polar circle with a concentration at night in the upper 50 m, has previously been stated (Kristensen 1977a).

Because of the method by which the present material of juveniles was obtained it was possible to determine whether the number of specimens per haul at the two depth levels (A and B) changed during certain periods of the day. On level A 82.5% of the hauls were positive in the dark period from 2100 hrs to 0300 hrs (Table 1). At the same time 75.8% were positive on level B. This was the only time of the day when the percentage of positive hauls was highest on level A. This apparently confirms the previous record of a vertical upward migration at night. At the same time the percentage of positive hauls on level B was higher than during the rest of the day, which indicates migration from below the depth of level B.

Though a high percentage of positive hauls is found on level A at night, the catch per haul seems surprisingly low (13.6), both in level A and B compared to the numbers in level B in the intervals 0300–0900 hrs and 1500–2100 hrs. This might be due to dispersal of the shoals at night, a well known phenomenon in large squids of other species, where high concentrations of adult specimens are seen early in the morning and early in the evening. Thus juvenile *G. fabricii* not only perform vertical migrations at night but apparently also disperse at this time.

Relative abundance of juveniles

Compared to the number of juvenile *G. fabricii* caught in West Greenland waters, adult specimens were caught only in small numbers. Likewise it has never been possible to estimate the stock size of this species as has been done on commercial fish species. However, a comparison of the number of juvenile *G. fabricii* and the number of fish larvae might provide some information on the possible stock size of *G. fabricii* in West Greenland.

Fortunately, the number of larvae of the Greenland halibut, *Rheinhardtius hippoglossoides,* a common commercial fish, has been estimated from the same kind of stramin hauls, in most years even for the same hauls as those which have provided the present material of juvenile *G. fabricii* from the Davis Strait.

The mean number of juvenile *G. fabricii* per 30 minute hauls in 1953–66 was 8.3 (calculated from Fig. 4); the mean number of larval Greenland halibut in the period 1950–64 was 8.0 (Smidt 1969). Thus the number of juveniles of these two species seems to be very similar in the area.

It seems reasonable to presume that the nearly similar number of squid juveniles and Greenland halibut larvae is due to a true abundance of the former and not to less ability to avoid the net, because the juvenile squid has a great ability to escape predators, an observation I myself have made on shoals of juvenile *G. fabricii* with about 25 mm PL, pursued by the fiord cod *Gadus ogac*. The juvenile squids were able to discover attacking fish 2–3 m away, and usually escaped by jet propulsion. The sparse catches of adult specimens probably show that they are difficult to catch rather than of sparce occurrence.

Tabel 1. Percent positive hauls and number of specimens per haul of *Gonatus fabricii* larvae in levels A (100 – 50 – 25 metres wire (mW)) and B (200 – 150 – 125 mW) south of the polar circle.

	Local time (hrs.)	2100–0300	0300–0900	0900–1500	1500–2100
A	% positive hauls	82.5	58.8	51.3	54.3
	Number of specimens per haul	13.6	10.6	6.6	12.9
B	% positive hauls	75.8	65.4	70.0	67.7
	Number of specimens per haul	13.2	20.9	14.9	22.1

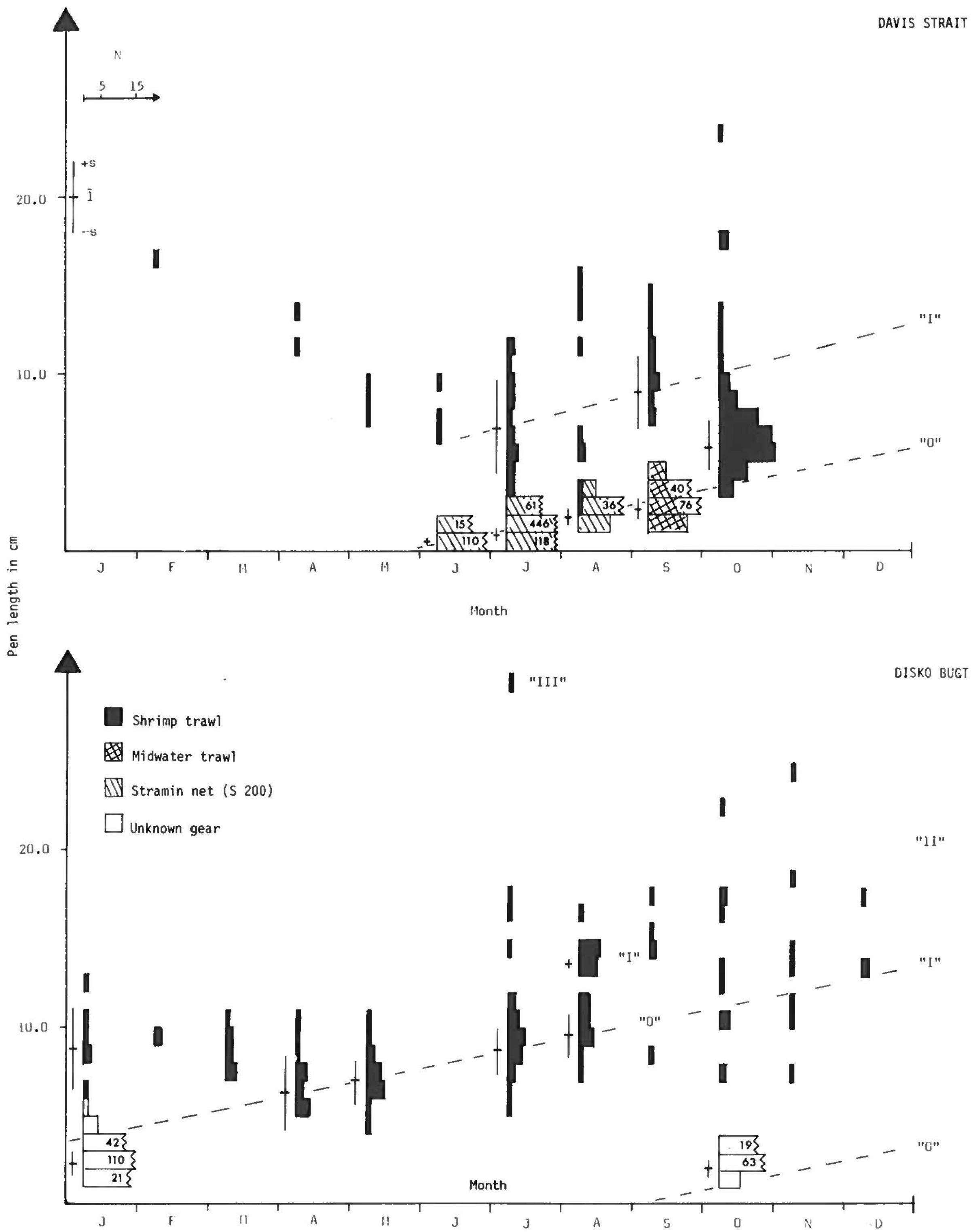

Fig. 7. Pen length frequency distribution and growth of *Gonatus fabricii* from Davis Strait and Disko Bugt. Up to 4 year classes ("0", "I", "II" and "III") are represented. Average ($\bar{l}$) and standard deviation ($\pm$ s) are given. An estimated modus for growth is presented. For details of nets see text. Number of specimens indicated (N).

Growth and age

Weight-length relationship

A close relationship exists between log body weight and log length of the pen in *G. fabricii*. A collection of 99 randomly selected specimens gave the following regression of log weight in g(Y) and log length of pen in cm(X): Y = 2.43 X – 0.86. Correlation coefficient = 0.98.

No statistically significant difference between regression coefficients of the two sexes was found.

The pen length has previously been shown to provide a suitable estimate of age (Kristensen 1977a, 1980). Consequently, length of the pen is used in the present study of growth.

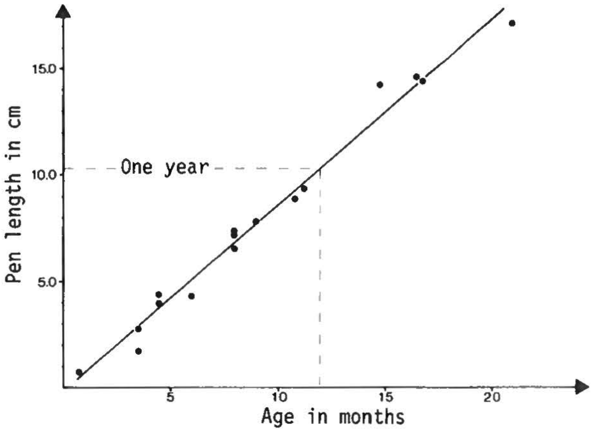

Fig. 8. Age in months as indicated by counting periodical growth rings in statoliths for *Gonatus fabricii*. The estimated regression line is shown. The pen length of a one year old specimen is indicated.

Growth in Davis Strait

By plotting length distribution on probability paper, as described by Cassie (1954), the mean and standard deviation of each year-class were estimated when possible (Fig. 7). Based on material from Davis Strait the growth in the "0"-year-class was estimated at 8–9 mm per month (Fig. 7). The samples mean of "0"-year-class in October was greater than expected, probably due to gear selection, i.e. the change from the fine meshed nets used in June, July, August and September to the shrimp trawl used in October, is not completely overlapping (Fig. 2) but makes the mean "jump".

The method of estimating the growth as the difference between two year-classes was not used, as year-class "I" was too poorly represented, probably because large specimens may have escaped the gear and older specimens are generally less numerous. The difference between "0"- and "I"-year-classes was only about 6 cm against 10–11 cm calculated from the monthly growth.

Growth in Disko Bugt

In Disko Bugt the growth from month to month of the "0"-year-class was estimated at 8–9 mm as in Davis Strait. This makes 10–11 cm per year. The year-class on which this growth rate was estimated hatches in September and grows to about 11 cm the first year (Fig. 7). The single juvenile sample from October shows a greater mean, and that from January a smaller one than expected. The breeding season probably is extended as in Davis Strait (Kristensen 1977a), and the samples might represent the earliest and latest hatched specimens of the hatching wave.

As in the collection from Davis Strait, the "I"-, "II"- and "III"-year-classes are too sparse to be used to estimate the growth.

Direct age determination

Gear selection and a poor representation of the oldest year-classes make growth studies based on size distribution difficult and occasionally the results are coupled with large errors.

To find a safer method for ascertaining the age and thereby a method for determining the growth, the statoliths of *G. fabricii* from Disko Bugt were studied (Kristensen 1980). Periodical growth rings were described from the statoliths, and by means of the periodical rings, which were analysed to be daily and fortnightly, the age could be estimated. The yearly growth was found to be about 10 cm. This study also showed that the growth of the pen is linear for the first two years.

Based on the available statoliths, including those previously studied (Kristensen 1980), age determined in relation to pen length is shown in Fig. 8. A high correlation exists between the age determined and pen length. By this method the pen length of a one-year old specimen was between 10 cm and 11 cm. This correlation confirms previous results (Kristensen 1977a and 1980) and present results based on the analysis of the polymodal size distribution. Consequently, this is probably the true yearly growth of *G. fabricii* in West Greenland waters. This result indicates that specimens with a pen length of about 10 cm are about one year old, but probably also that those with pen lengths of 20 and 30 cm are two and three years old, respectively. However, it must be emphasized that an extrapolation of the age of large specimens more than one year old should be taken with reservation.

A growth rate of 8–9 mm per month is only half the growth of what Wiborg (1980) found in subadult specimens in the Norwegian Sea. His surprisingly high figures are, however, based on fewer specimens and from slightly warmer waters than found off West Greenland.

Reproduction

Very little has previously been known of the reproduction of *G. fabricii*. Time and localities of spawning and hatching were always based on presence or non presence of juveniles and on studies of size distribution (Nesis 1965, Kristensen 1977a). The present section deals with the development of the gonads, and an attempt is made to elucidate the reproduction and life cycle of *G. fabricii* in West Greenland waters.

Gonadal development

In order to describe the development of the gonads during growth, their relation to pen length was analyzed by means of the allometric equation: log Y = b log X + log a.

In males the analysis of the gonadal development was based on the weight of testis and the length of penis respectively, in relation to pen length. An analysis of the gonadal development in females was based on weight of ovary and length of the nidamental glands.

In accordance with the previously described existence of different populations with separate time of breeding in Greenland waters (Kristensen 1982), the relationships were studied in two separate materials as in the analysis of growth, one from Davis Strait and another from Disko Bugt.

It was shown that for all four gonadal parts a high correlation was found with the length of the pen. Likewise, all four relationships were described by the regression equation (Table 2). No statistically significant difference was found between the regression coefficient representing each of the two populations in any of the four relationships examined. However, for each of them the pattern of the regression lines was the same: the lines representing Davis Strait material cross the lines representing the specimens from Disko Bugt suggesting a faster growth rate (Fig. 9–10, 12–13).

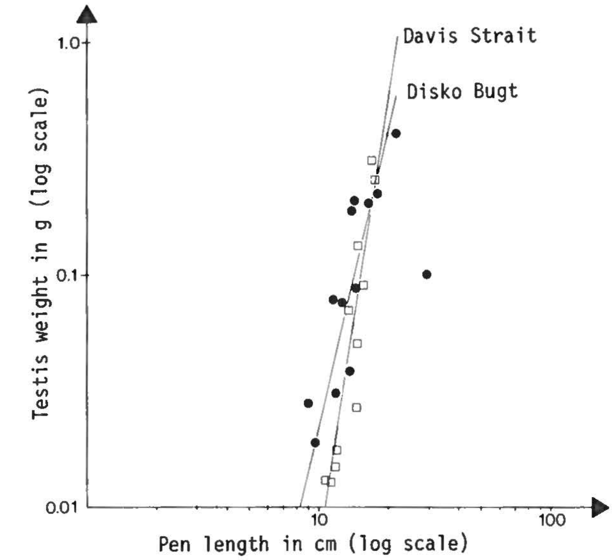

Fig. 9. Relation of testis weight to pen length in *Gonatus fabricii* from Davis Strait (open squares) and Disko Bugt (black dots).

Males

The development of the testis begins at a pen length of about 8 to 10 cm, i.e. at an age of about one year and seems to continue to an age of about two years (20–25

Table 2. Values of regression coefficients b, log to the y intercept a, and correlation coefficient r in the allometric equations calculated to show the development of the gonads in relation to the pen length of *Gonatus fabricii* from Davis Strait and Disko Bugt, West Greenland. The P-values for correlation coefficients are presented. N = number of specimens examined.

Area	Relation	N	b	log a	r	P-correlation
Davis Strait	Testis weight/pen length	11	6.1889	–8.3291	0.8978	0.01
Disko Bugt		13	4.1611	–5.8111	0.8995	
Davis Strait	Penis length/pen length	16	2.9061	–3.2667	0.9495	0.01
Disko Bugt		22	2.2559	–2.4368	0.9358	
Davis Strait	Ovary weight/pen length	12	4.2300	–5.8770	0.8587	0.01
Disko Bugt		20	3.1674	–4.5780	0.9020	
Davis Strait	Nidamental gland/pen length	13	1.6045	–1.8448	0.9006	0.01
Disko Bugt		29	1.2293	–1.4362	0.8429	

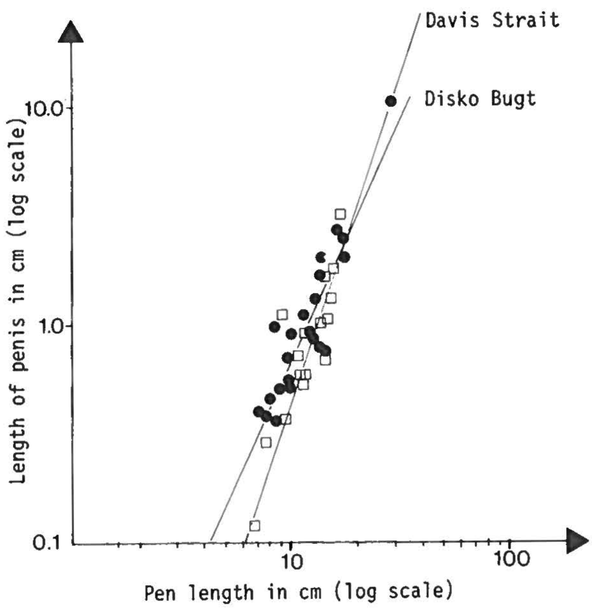

Fig. 10. Relation of penis length to pen length in *Gonatus fabricii* from Davis Strait (open squares) and Disko Bugt (black dots).

cm), (Fig. 9), which probably is the size range in which males mature. A specimen of 21.9 cm PL with an advanced (heavy) testis contained spermatophores about 0.6 cm long in the penis, but not in the spermatophoric sac, which indicates that copulation has taken place. In the largest male ever recorded, 29.3 cm PL, and probably about three years old, the weight of the testis was surprisingly low (Fig. 9). In this specimen spermatophores, about 1 cm long, were found in the spermatophoric sac as well as in the penis, which probably shows that copulation had not yet happened. Degeneration of testis is known in males approaching their maximum age (Arnold and Williams-Arnold 1977). Consequently this large male may be in the mating stage for the last time.

The penis begins to develop at a pen length of 3–5 cm (Fig. 10). In the larger male (29.3 cm PL) the penis was very long (10.6 cm), reaching nearly to the funnel (Fig. 11), which may be necessary for copulation. Unfortunately, the outermost part of the penis was missing in the other male with spermatophores (21.9 cm PL).

These two mature males (spermatophores present in spermatophoric sac and/or in penis) were both caught in Disko Bugt in the autumn, which agrees with the previous statement of breeding time in this area. Unfor-

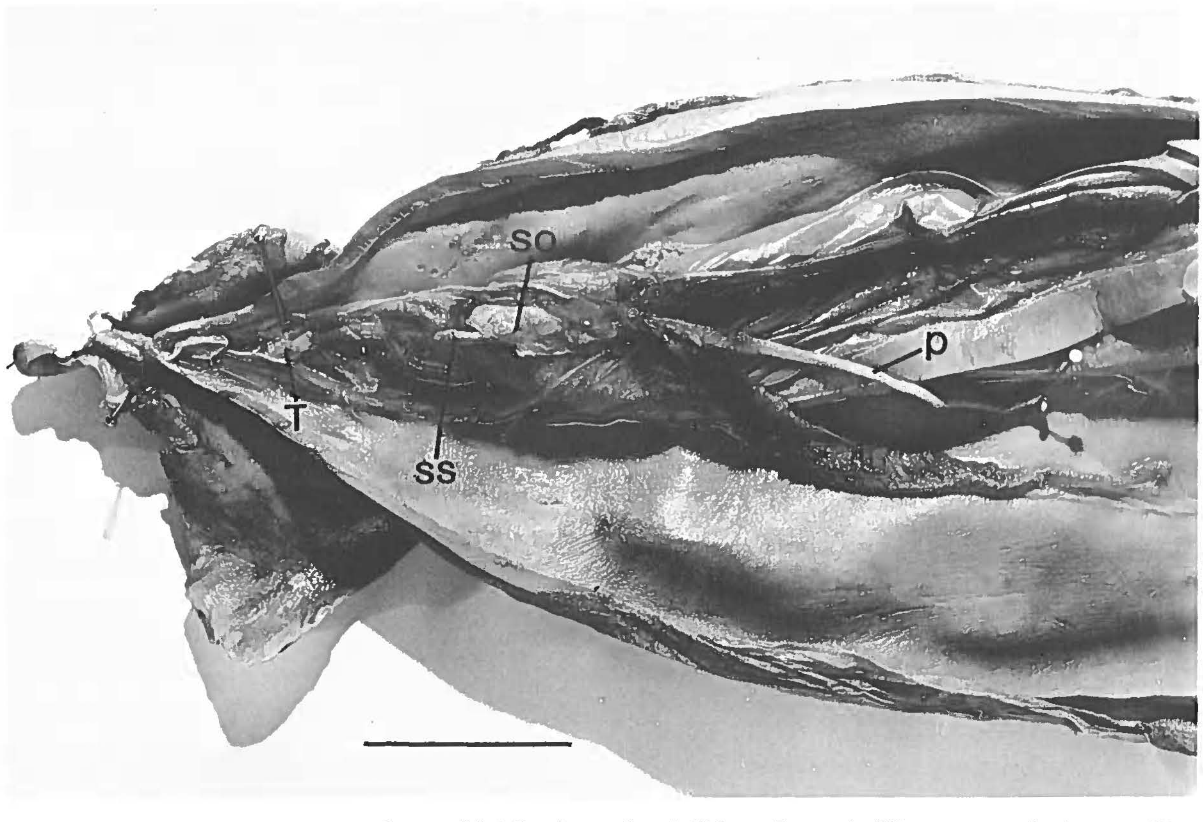

Fig. 11. Reproductive organs of mature *Gonatus fabricii* male, pen length 29.3 cm. P = penis, SO = spermatophoric organ, SS = spermatophoric sac, T = testis. Scale: 5 cm.

tunately, no mature males were found in the material from Davis Strait.

Females

In females the ovary begins to develop at a pen length of about 8 cm (nearly one year old) in Davis Strait and about 6 cm in Disko Bugt (Fig. 12), and increases to a weight exceeding that found in the present specimens of 20–25 cm PL, which could not be considered as mature.

A large female (28.9 cm PL), approximately three years old and found in South Greenland, showed a surprisingly low ovary weight (Fig. 12) equalling a one year younger female from the Davis Strait. This large female, caught in September, possibly failed to breed during the summer and a degeneration of the ovary may have occurred because of a lower autumn temperature, a phenomenon known from other species (Arnold and Williams-Arnold 1977).

The nidamental glands were never swollen as found in a mature female from the Norwegian Sea (Kristensen 1981b), though females of the presumed reproduction size were examined.

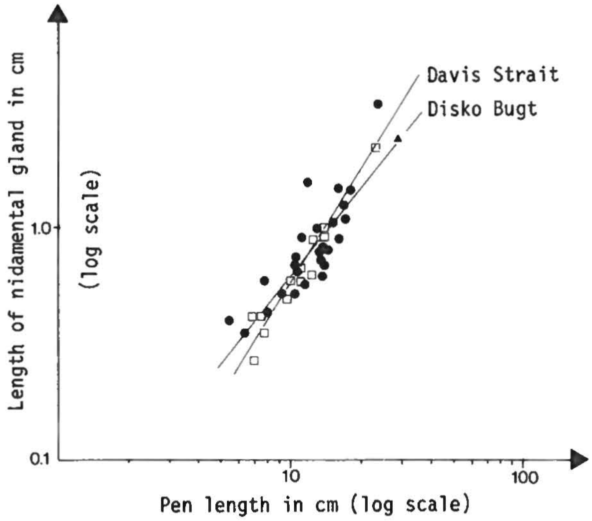

Fig. 13. Relation of length of nidamental glands to pen length in *Gonatus fabricii* from Davis Strait (open squares) and Disko Bugt (black dots). Black triangle indicates a large female from South Greenland.

Discussion

Richard (1966, 1967) showed that the development of gonads in *Sepia* sp. is induced by long night/short day and that the growth rate increases at high temperatures. Richard's conclusions may explain the present findings.

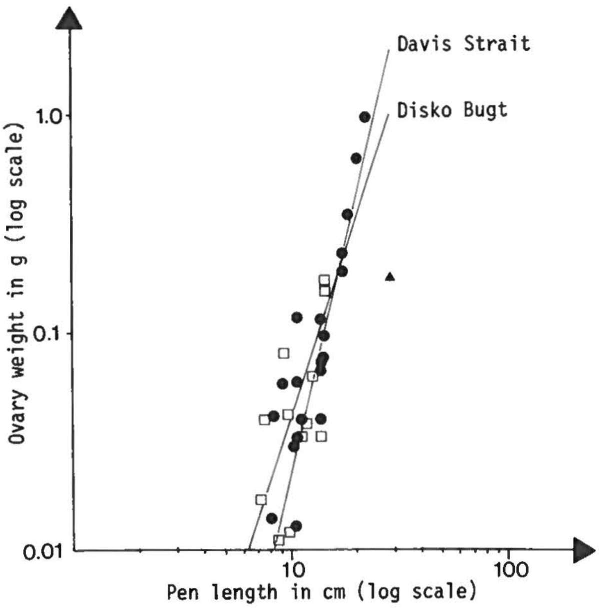

Fig. 12. Relation of ovary weight to pen length in *Gonatus fabricii* from Davis Strait (open squares) and Disko Bugt (black dots). Black triangle indicates a large female from South Greenland.

The development of gonads in *G. fabricii* may have been induced by the dark winter period. This means that the "0"-year-class hatched in Disko Bugt in the autumn and early winter is always smaller in length (see p. 5) at the time when the gonads begin to develop in the spring, than the same generation from Davis Strait hatched in late spring or early summer. Moreover, the temperature in Davis Strait at a depth of about 200–600 m, where *G. fabricii* is supposed to live, is generally up to 4°C higher than in Disko Bugt (Andersen 1981). This would explain a higher growth rate of the gonads in specimens from the Davis Strait, though no difference in the general growth rate of the pen length in these two areas has been found. A statistically significant difference between the regression coefficients, not demonstrated here, may be possible to find in a study with a larger material.

Age at maturity

Referring to the two males, one with a pen length of 21.9 cm which had already copulated, and the other with a pen length of 29.3 cm ready for copulation, males of *G. fabricii* apparently mature at an age of two years and may be able to copulate when they are three years old, too. Since no sign of degeneration, as described in females (Kristensen 1981b) was found in the two year old male which had copulated, the larger male may have been ready to copulate for the second time. This would indicate a capability of reproducing when both two and three years old, but due to a smaller testis weight this possible second breeding season must be the last.

A pregnant female from the Norwegian Sea (Kristensen 1981b) shows that several morphological changes occur in a mature female: the tentacles and suckers of the arms disappear, the tissue in the mantle and arms becomes distended, the nidamental glands increase in size to nearly one third of the pen length and the oviductal glands become distended. Moreover, roughly spherical eggs, about 5 mm in diameter, occur in the ovary and oviduct. During copulation the male deposits the spermatophores on the buccal membrane of the female. Reservoirs are found here in females at the last stage of maturity. Since none of these features were seen in the specimens from West Greenland, they had not yet reached maturity.

Clarke (1962) stated that the degree of pigmentation of the beaks was related to maturity, and mature specimens had almost dark beaks. This agrees well with a spent *Gonatus* sp. described by Young (1973) from the Arctic Ocean, and in a mature female of *G. fabricii* from the Norwegian Sea (Kristensen 1981b).

Completely darkened beaks were also found in the two mature males presented here. Dark beaks occurred in females with pen length from 21 cm and more, but in spite of the degree of pigmentation of the beaks, none of the females was mature. Apparently, this feature is not an indication of maturity in females in West Greenland, but is a trait existing in specimens which have reached a certain size.

Immature females from Davis Strait and Disko Bugt measured up to about 25 cm PL. In all probability females from these areas mature at lengths between 25 and 30 cm PL, the maximum length which they are known to reach, corresponding to an age of two and a half to three years. After breeding they most probably die.

Spawning

The eggs of *G. fabricii* are probably deposited on the bottom on the continental slope (Kristensen 1981b). In West Greenland waters juveniles of this species appear in high numbers outside the fishery grounds, where depths are 200 m or more (Fig. 5), coinciding with the depths where adult specimens are caught. Due to the few catches of mature specimens, spawning may occur at even greater depths. As previously mentioned, spawning is supposed to occur in several places off West Greenland.

Trophic relations

Prey

Stomachs from 146 *G. fabricii* from West Greenland in the size range of 43–293 mm PL were examined. The degree of stomach fullness is expressed as empty, half full or full. 51% of the specimens had empty stomachs, 27% were half full and 22% full. The degree of fullness was not found to be related to size.

An explanation of the high percentage of empty stomachs in the present material might be that *G. fabricii* feeds at night in the upper part of the water column and that the animals were caught in the digestive phase or a post digestive phase, when they are at the bottom, as proposed by Amaratunga (1980) for *Illex illecebrosus*. Though *G. fabricii* occur in slightly colder waters than *I. illecebrosus*, the digestive time is probably as fast as in *I. illecebrosus*, which was found to clear its stomach in about 12 hours (average of the results of Boucher-Rodoni 1975 and Wallace et al. 1980). I have received much verbal information on observations of adult *G. fabricii* near the surface at night in West Greenland, where they were probably hunting for prey.

This explanation agrees with Wiborg (1980) who found empty stomachs in 15% and 3% only, of subadult specimens (35–69 mm PL) from two areas of the Norwegian Sea. As the specimens were caught in the upper part of the water column, they were probably engaged in predation. Nesis (1965) found empty stomachs in 49% of juveniles (7–43 mm PL) also caught in the upper layers of the water column. He gave the explanation that the juveniles, with their chubby mantles and short arms, were unable to catch enough food to fill their stomachs to maximum capacity, due to a very rapid digestion.

The stomach usually contains only one or two species, most often only one. This was also found by Nesis (1965), although he found up to three species in a few specimens.

The stomach contents can be divided into four main categories: crustaceans, fish, cephalopods and an unidentifiable hyaline mass. Crustaceans constitute the main categori, but fish are also frequently represented (Table 3). The unidentifiable hyaline mass is probably highly digested food items. The three recognizable categories were examined qualitatively. They were fragmented after having passed the radula, but most of the prey could be referred to genus and some even to species.

In the fish category vertebrae, ribs, fin rays, scales and eye lenses were found, which could all be identified as belonging to the capelin, *Mallotus villosus*. All stomachs containing fish were dark due to the melanophores of the fish skin.

Nesis (1965) did not find any fish, but remains of redfish, *Sebastes marinus*, were found in a few stomachs of subadult specimens from the Norwegian Sea (Wiborg 1980). It is surprising that only the capelin occurred in the present stomachs, because small redfish are abundant and dominate the catches in the areas where *G. fabricii* were caught. My results seem to support the concept that *G. fabricii* hunt their prey in the uppermost part of the sea, where the capelin occurs, and not near the bottom where the redfish live.

The crustacean category comprises amphipods, isopods and probably prawns and mysids. The amphipod

Table 3. Stomach contents in *Gonatus fabricii* from West Greenland, indicated by number of stomachs containing one of the four categories of prey.

Pen length of predator cm	Number of stomachs examined	Prey			
		Crustaceans	Fish	Cephalopod	Indeterminable
4.0– 5.9	4	1			3
6.0– 7.9	26	4	7	5	10
8.0– 9.9	13	7	4		2
10.0–11.9	10	6	3		1
12.0–13.9	5	1	2	1	1
14.0–15.9	7	3		2	2
16.0–17.9	3	2			1
18.0–19.9	1		1		
20.0–21.9	1			1	
22.0–23.9					
24.0–25.9					
26.0–27.9					
28.0–29.9	1	1			
N	71	25	17	9	20
% af N		35	24	13	28

genus *Parathemisto* was represented among one or two other hyperiid amphipods, but this genus was the only recognizable one among the crustaceans. Although these groups were also recognized in the smaller specimens studied by Nesis (1965) and Wiborg (1980) copepods and chaetognaths were found to be predominant. Nesis found a fairly high percentage of euphausids (mainly furcilia-stages) in the stomachs of the juvenile stages. Pteropods were found in a few stomachs by both authors.

In the present study, muscle tissue and hooks of *G. fabricii* were recognized. A few stomachs contained only tissue, pens and beaks from unidentified cephalopod species.

Though it has not been possible here to show a clear difference in preference for one of the food categories in relation to size group of the predator, *G. fabricii*, (Table 3), the results compared with those of Nesis (1965) and Wiborg (1980) indicate that the prey of *G. fabricii* changes from juvenile to adult. Though crustaceans are the main prey found in small as well as large specimens, the group preference changed with age. Copepods did not occur in the present investigation but in those of Nesis (1965) and Wiborg (1980), and isopods, mysids and decapods occurred in the present study only. Large specimens contained a higher percentage of fish and cephalopods than did the subadult specimens examined by Wiborg (1980). Fish and cephalopods did not occur in juveniles (Nesis 1965).

Predators

G. fabricii is an important prey for several toothed whales (Nesis 1965). It is the main prey of the bottlenosed whale, *Hyperoodon ampullatus*, in which it has been found to constitute 99% of the cephalopod beaks found in the stomach (Clarke & Kristensen 1980). Benjaminsen & Christensen (1979) found only *G. fabricii* in the stomachs of bottlenosed whales from the iceland area. Already Murray & Hjort (1912) reported the importance of *G. fabricii* as food for the bottlenosed whale on the so-called "Bottlenose Grounds" in the Norwegian Sea.

Grimpe (1933) stated that the Narwhale, *Monodon monoceros*, was an important predator of *G. fabricii*, and I myself have found beaks of *G. fabricii* in the stomachs of narwhale from Melville Bugt, West Greenland (unpublished data).

Moreover, *G. fabricii* has been found in the stomach of sperm whales, *Physeter catodon*, from off Iceland (Clarke & MacLeod 1976).

Since juveniles occur in high numbers in the zooplankton in certain periods of the year off West Greenland, the squid is probably also an important prey for several baleen whales, e.g. the mink whale, *Balaenoptera acutorostra*, but no records exist as yet.

Seabirds, e.g. albatrosses, sea gulls (Nesis 1965) and fulmars, *Fulmarus glacialis*, (Hagerup 1926), have been reported to contain beaks of *G. fabricii* in their stomachs. However, these beaks might originate from vomit of whales.

G. fabricii has been found in the stomach of cod, *Gadus morhua*, (Grimpe 1933) and redfish, *Sebastes marinus*, (Nesis 1965). Moreover, juvenile *G. fabricii* have been recorded as dominant in the stomach contents of herring, *Clupea harengus*, (Nesis 1965) and numerous in the salmon, *Salmo salar*, (Lear 1980).

As shown in the present paper, cannibalism is known in *G. fabricii*, but also *Illex illecebrosus* feed on them in the Newfoundland area (Amaratunga 1980).

Nutritive value of *G. fabricii*

Intact specimens of *G. fabricii* with bowels removed were examined to ascertain the nutritive value of this species.

As in fat fish, the water content in *G. fabricii* is relatively low, only about 75%, and the protein percentage high, about 12.5, which is a little less than in the squid *Loligo vulgaris* and in the most common commercial fish, in which the protein content is about 15–19% (Murray & Burt 1969).

Several amino acids including the Essentials are represented and in nearly the same proportions as in fish.

The lipid content in muscle tissue is small, only about 1%, as in white fish, but the digestive gland nearly drips of lipid, its lipid content being about 63%, which is high compared to fish (31% in cod, Johansen et al. 1977) and other squids (11.6%, Nash et al. 1978).

G. fabricii might become an important resource for a commercial fishery (Wiborg 1979), and with the nutritive value stated, the species would be very suitable for human consumption. The very high lipid content also makes *G. fabricii* suitable for industrial use.

Summary of life history

In West Greenland *G. fabricii* occurs off the coast and in the larger fiords from Upernavik in the north to Kap Farvel in the south. At least two populations, differing in time of breeding, have been reported from West Greenland waters. In Davis Strait a population exists which hatches in spring and early summer. In Disko Bugt the population is supposed to hatch in the autumn and early winter.

Juveniles occur in the uppermost layer of the sea and seek to the bottom when they grow older. Adult specimens are often caught in shrimp trawls at depths of 200–600 m during the day but probably migrate upwards at night for feeding.

Juveniles of *G. fabricii* are very numerous in summer months all over Davis Strait. The numbers fluctuate from year to year. Hatching probably occurs in several places in Davis Strait at depths exceeding 200 m outside the fishery grounds.

South of the polar circle, juvenile *G. fabricii* perform diurnal vertical migration, with apparent dispersal of the shoals at night.

Juveniles are numerous compared to larvae of most commercial fish, and are almost equally as abundant as the larvae of the common Greenland halibut, *Reinhardtius hippoglossoides*. This suggests a large standing stock of *G. fabricii*.

The growth of *G. fabricii* is about 8–9 mm PL per month. This gives a yearly length increase of about 10–11 cm.

The testis of the male starts to develop at about a pen length of 8–10 cm in the first spring after hatching, and maturity probably occurs at an age of approximately two years. Also in females, the gonads begin to proliferate in the first spring after hatching and continue to develop until maturity, which in West Greenland waters probably is at a pen length of about 25–30 cm, corresponding to an age of two and a half to three years. Females are supposed to breed only once, whereupon they die. Males might be able to copulate twice, at an age of two and three years. A maximum age of three years is suggested.

Acknowledgements

This investigation was carried out at the Zoological Museum, University of Copenhagen, and financially supported by the Danish Natural Science Research Council. The material was kindly provided by the Zoological Museum and the Greenland Fisheries Investigation. I wish to thank the following persons from the Zoological Museum, University of Copenhagen: Dr. Jørgen Knudsen for help and advice throughout the study, Dr. Jean Just and Knud Rosenlund for help in identifying the remains in the stomachs, Tom Sciøtte for help in measuring the numerous juveniles and Robert Nielsen for making the drawings of the adult and juvenile specimens. Civil Engineer Vibeke B. Jensen, Water Quality Institute, Hørsholm, Denmark, kindly examined the specimens for lipid content.

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Meddelelser om Grønland, Man & Society

1980

1. Isi Foighel:
   »Home Rule in Greenland«. 18 pp.

By Danish Act of 29 November, 1978, Home Rule was established in Greenland within the Unity of the Danish Realm. The Act was prepared by a Danish-Greenlandic Commission.

The Act on Home Rule is discussed with special reference to the historical and political background.

By the establishing of Home Rule, powers which hitherto had been vested in the Danish Government and Parliament were transferred to the Greenlandic authorities. The scope of these powers and their legal characteristics are outlined.

Home Rule makes no changes in the international competence or in the relationship between Greenland and the international or interregional organizations. Greenland's membership of the EEC creates some special problems.

The question of ownership of the natural resources was of great importance in the debate in the Home Rule Commission. The Act contains a solution which seeks to give the Danish Government as well as the Greenlanders equal rights in the decision-making procedure, in the administration, and in the sharing of the revenue.

Furthermore, the financing of the Home Rule system, the language problem, the organizing of fishing and trade are being dealt with.

1981

2. H. O. Bang & Jørn Dyerberg:
   »The Lipid Metabolism in Greenlanders«. 18 pp.

In the years 1970, 1972 and 1976 the blood lipids in Greenlanders living in the Umanak district and the composition of their food, especially that of their dietary fat were examined in an attempt to explain the rarity of ischaemic heart disease in Greenlanders.

Decreased concentrations of serum cholesterol, triglycerides, low density and very low density lipoproteins and increased concentration of high density lipoprotein in male Eskimos were found. The fatty acid pattern of the serum lipids was different from that of Danes. Especially remarkable was the high concentration of eicosapentaenoic and low concentration of arachidonic acids compared with Danes. The serum lipids of Greenlanders living in Denmark were found similar to that of Danes.

The Eskimo food was found rich in protein and poor in carbohydrate. The fatty acid pattern of the dietary fat was similar to that found in their blood.

We could show – by in-vitro experiments – that eicosapentaenoic acid can act as precursor for thrombocyte active prostaglandins in stead of arachidonic acid in Europeans, giving rise to an anti-aggregatory prostaglandin, probably PGI_3, but to no pro-aggregatory thromboxane. This causes a shift in the balance towards the anti-aggregatory – and consequently anti-thrombotic – side.

During a fourth expedition in 1978 to the Umanak district our theory from the in-vitro experiments was confirmed by in-vivo observations in the Eskimos. We found decreased platelet aggregability and increased bleeding time.

The rare incidence of ischaemic heart disease and other thrombotic diseases in Greenlanders can be explained by their low serum lipids, their high content of α-lipoprotein and – probably most important – by their special serum fatty acid pattern giving rise to a decreased platelet aggregability and consequently a decreased tendency to thrombosis.

1981

3. Jens C. Hansen:
»A survey of human exposure to mercury, cadmium and lead in Greenland«. 36 pp.

Analyses of lead, mercury and cadmium in tissues from seal and fish have shown high concentrations of mercury and cadmium. A toxicological evaluation of the actual concentrations has revealed that in some districts of Greenland, the population may exceed the provisionally tolerable weekly intake (WHO, 1977) of cadmium with from 2 to 20 times and of mercury with from 2 to 40 times. Lead intake was below the provisionally tolerable weekly intake. As these high dietary intakes might have adverse health effects in the consumers, an investigation was undertaken in order to evaluate the human exposure as reflected in blood and hair concentrations. Five districts in Greenland and a control group of Greenlanders living in Denmark have been examined.

A total of 144 persons (including the control group) have participated.

Samples were taken in September and October 1979.

Mercury. Strong evidence was found for a connection between mercury exposure and seal-eating. The mercury levels found indicate that the exposure calculated from food analyses is overestimated, but still the most highly exposed groups are on an exposure level where subclinical effects may be anticipated.

Cadmium. In general the blood cadmium concentrations are higher in Greenland than in Denmark, but the groups in Greenland were found to be very similar. In hair concentrations no differences between the groups were observed. Separation of data on blood cadmium between smokers and non-smokers showed the differences between the mean values to be highly significant. In spite of the presumably higher dietary intake, no influence on blood concentrations could be observed. Contrary to blood, hair reflected dietary intake but not smoking. The results indicate that neither blood nor hair as only parameter reflects total cadmium exposure.

A positively significant correlation was demonstrated between lead and cadmium concentrations in hair, but not in blood.

Lead. Blood concentrations were found to be at the same level as found in Western European countries, but all to be below the limit of 35 µg/100 ml which is the upper individual limit in the EEC-countries.

The highest blood-values were found in the two northern districts, where the level is significantly higher than the level in the two southern districts. The difference was found to be related to varying eating habits, also smoking habits were found to be reflected in blood and hair. Blood was found to be a better index medium than hair for evaluating lead exposure.

Selenium. A potentially toxicity-modifying micronutrient selenium was determined in a limited number of hairsamples. No evidence of a high selenium intake could be provided.

Further research is needed especially concerning mercury exposure. Concerning lead and cadmium, the levels found are well below what is regarded a critical level. As, however, the concentrations are on the same level as those found in industrialized countries, follow-up studies seem to be needed in order to observe trends of exposure.

1983

4. Michael Fortescue:
»A comparative manual of affixes for the Inuit districts of Greenland, Canada, and Alaska«. 130 pp.

The information gathered in the present work is aimed at use both by students of the Eskimo languages and by Inuit speakers wishing to comprehend and communicate more directly with speakers of dialects other than their own. Productive affixes for fourteen dialect areas from East Greenland to North Alaska are presented for the first time in one place and in common orthographical form. These morphological elements, often difficult to isolate and subject to continual innovation within individual dialects, represent one of the most problematic areas for mutual comprehension. Particular emphasis has been placed on divergences from Central West Greenlandic in three other cardinal dialects, namely Tarramiut for the eastern Canadian Arctic, Copper for the western Canadian Arctic (where the author carried out field work in the summer of 1980), and North Slope Iñupiaq for Alaska. For each of these dialects comprehensive lists containing morphophonemic information and English glosses are arranged in parallel columns according to twenty-six easily comparable semantic groups. Divergences from the main lists for the remaining ten dialects are presented in alphabetical lists. The introductory sections describe the phonological correspondences between the dialects (plus important grammatical differences) and explain how the book can be used in practical terms. To this end a translation into West Greenlandic is included. Linguistic isogloss maps and examples of usage of affixes with no direct equivalent in West Greenlandic are supplied, as is a short sample text for each dialect treated (with English glosses). Further, there is included an overview of the various orthographic systems to be encountered for material in Canada and Alaska, an essay on successive affix ordering, and, for the sake of comparison, a similarly organized list of affixes for Central Alaskan Yupik.

5. Bjarne Grønnow, Morten Meldgaard & Jørn Berglund Nielsen:
»Aasivissuit – The Great Summer Camp. Archaeological, ethnographical and zooarchaeological studies of a caribou-hunting site in West Greenland«. 96 pp.

An interdisciplinary analysis of an archaeological source material from the caribou-hunting site Aasivissuit in central inland West Greenland is presented. Subsistence changes over the years are the subject of ethnographical, archaeological and zoo-archaeological investigations.

The following main points are treated:

1. Resource dynamics: The inland game – the caribou population – undergoes drastic changes in the course of time.

2. The ethnography of caribou-hunting: Ethnographical description of the caribou hunt and of life in the inland area based on hitherto largely unpublished ethnographical material.

3. Hunting structures: Cairn systems, shooting-hides, meat caches, etc., document the extent of the Aasivissuit site catchment area and the hunting activities carried out there – *i.a.* large-scale battues.

4. Occupation phases: Excavations in the stratified ossiferous midden deposits reveal 6 occupation phases of varying duration and intensity at Aasivissuit. The phases represent different segments of the period from about 200 B.C. to the present, the neo-Eskimo layers from the 18th–19th centuries in particular holding much information.

5. The game: Osteological analyses of the comprehensive bone material show total dominance of caribou (selective late summer and autumn hunting of bucks and young animals) and that the excavation covers an area where coarse butchering took place.

Subsistence changes (changes in hunting forms and exploitation of game) and the discontinuity of inland occupation can be documented ethnographically, archaeologically and zoo-archaeologically. The changes are seen as a function of resource fluctuations and socio-historical changes.

Instructions to authors

Manuscripts will be forwarded to referees for evaluation. Authors will be notified as quickly as possible about acceptance, rejection, or desired alterations. The final decision rests with the editor. Authors receive two page proofs. Prompt return to the editor is requested.

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Double space throughout and leave a 4 cm left margin. Footnotes should be avoided. Desired position of illustrations and tables should be indicated with pencil in left margin.

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Journal: Macpherson, A. H. 1965. The origin of diversity in mammals of the Canadian arctic tundra. – System. Zool. 14: 153–173.

Book: Marsden, W. 1964. The lemming year. – Chatto & Windus, London: xxx pp.

Chapter (part): Wolfe, J. A. & Hopkins, D. M. 1967. Climatic changes recorded by Tertiary landfloras in northwestern North America. – In: Hatai, K. (ed.), Tertiary correlations and climatic changes in the Pacific. – 11th Pacific Sci. Congr. Tokyo 1966, Symp.: 67–76.

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