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INVESTIGATIONS ON EUPHAUSIIDS IN SOME FJORDS ON THE WEST COAST OF NORWAY IN 1966 – 1969

By

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ABSTRACT

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In 1966—1969 euphausiids (krill) were sampled in some fjords in Western Norway. Drained volumes of krill constituted 13—82 ml, exceptionally 100—167 ml per 1 000 m³. *Meganyctiphanes norvegica, Thysanoessa inermis* and *T. raschii* dominated in the order mentioned. During the day, *Thysanoessa spp.* kept at higher levels than *M. norvegica;* during the night *T. raschii* and part of the stock of *M. norvegica* accumulated close to the surface. *M. norvegica* had densities of 0.1—1 specimens per m³, but higher concentrations were induced in spring with electric light. Vertical layering was observed with large specimens at deeper levels. *M. norvegica* spawned in March—June one year old. Part of the stock survived a second spawning, a few lived for nearly three years. One year olds measured 22—31 mm (average 27 mm), two year olds 32—41 mm (average 37 mm) and three year olds 43—47 mm.

In *T. inermis* a maximum of 1—4 specimens per m³ occurred in the upper 10—50 m during the night in January—February and October—November, at other times only 0.05—0.3 specimens per m³. *T. inermis* is annual in the area, spawning in March—June, with maximum in April. Length of one year olds was 17—20 mm, single second year survivors 26 mm. The two-spined form was observed in 1—3 % of the stock.

T. raschii had maximum densities of 3.5 and 5.0 specimens per m³ in the upper 10 m in February and November respectively, at other times figures were very low. *T. raschii* is annual; spawning occurs in April—June, starting somewhat later than in *T. inermis*. Growth and length distributions are as a rule similar to those of *T. inermis*.

INTRODUCTION

During the later years attention has been focused on euphausiids or krill as a source of marine protein that may be exploited commercially. In Norway a small-scale fishery started in 1965, the krill mainly being used in fish farming. The biology of krill in fjords of Western Norway has been studied since 1965 (WIBORG 1966, 1968).

MATERIAL AND METHODS

In the period 21 November 1966—29 January 1969 samples of krill were collected from the R/V «Peder Rønnestad». A three-foot

Isaacs—Kidd midwater trawl (IKMT), mesh size three mm, was towed at four knots for 10—25 minutes at different levels between the surface and 260 m in some fjords on the west coast of Norway (Fig. 1). The Byfjord near Bergen was visited most regularly, with monthly samples in the period January—June. The depths fished were checked occasionally with a Benthos depth recorder. Most hauls were made during the night. Figures have been adjusted to 1 000 m^3 filtered. Additional hauls were made with Clarke-Bumpus plankton samplers (CB), mesh size 0.5 mm, speed 2—3 knots, in the upper 40 m, and some

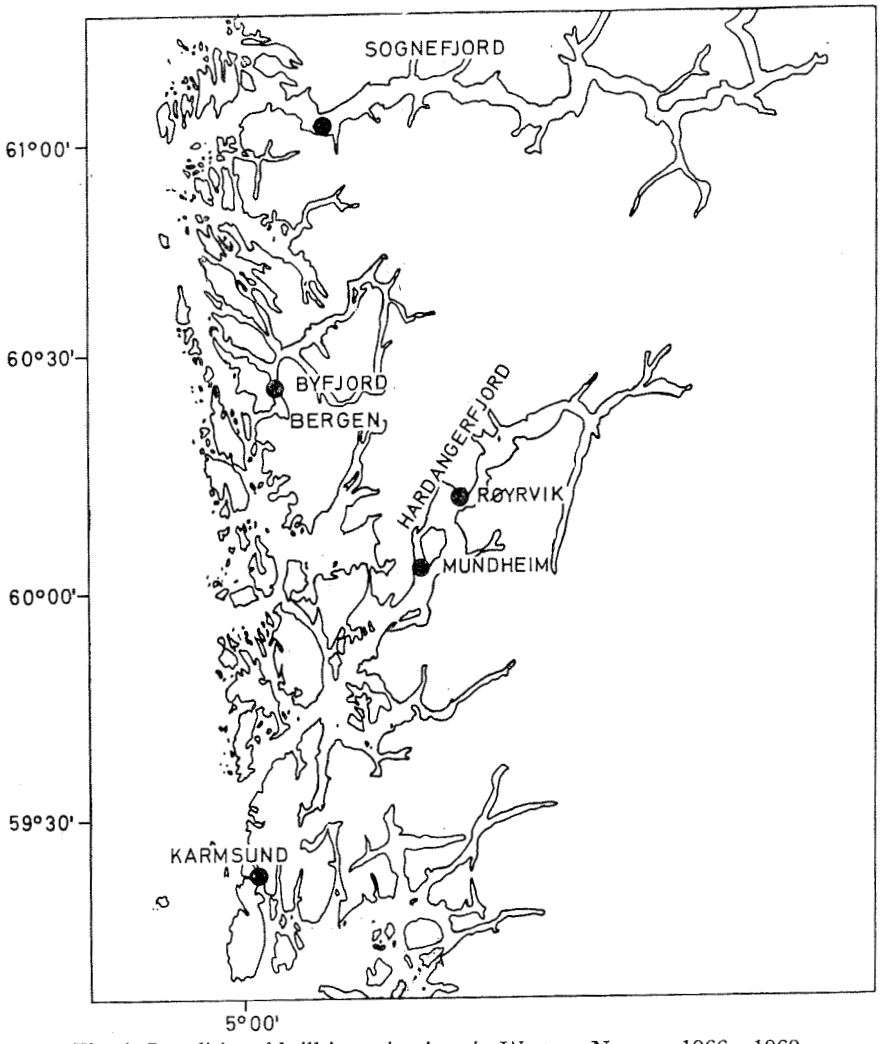


Fig. 1. Localities of krill investigations in Western Norway 1966—1969.

vertical hauls with a 40 cm Juday net, mesh size 0.2 mm, from bottom to surface. A few samples were also taken with light and ketcher in the Hardanger fjord. During the cruises bathythermograph casts were made to 260 m, and salinity and temperature were measured in the upper 60 m with a portable «salinity-temperature bridge».

In 1969 additional material was collected in the Byfjord during monthly cruises in day hauls with IKMT and a low-speed midwater trawl designed by BEYER (in preparation). The samples were preserved in 5—10 percent formalin and examined a few days after the catch. The krill and mysids were sorted out and their displacement volume measured together, then investigated under a stereoscopic microscope, and finally the total length was measured under a 2 X magnifying lens (WIBORG 1966). When the sex could be determined from external characters, males and females were measured separately.

TOPOGRAPHY AND HYDROGRAPHY OF THE BYFJORD AND THE HARDANGERFJORD

The Byfjord (Fig. 2) is part of a fjord system; in the southwestern part with a sill depth of 140 m towards the Hjeltefjord; in the north with connection to the Salhusfjord and Herdlefjord, the latter in the northwest ending in shallow sounds less than 10 m deep. The Byfjord has a central trough, 317—383 m deep. According to LINDE (1970) the temperature below 100 m is usually 7.0—8.2 C, the salinity 33.34—34.90 $^0/_{00}$. Below 200 m the water is renewed each year, as a rule in November—February.

In 1966—1968 the temperature of the upper 10 m reached 15 C in June, the 10 C isotherm descending to 50 m in November 1966 and October 1967. At the surface the extreme temperatures were 3.6 C in January 1967 and 15.1 C in June 1967.

Below 10 m the salinity was usually 30 $^0/_{00}$ or more. At 5 m the lowest figure was about 22 $^0/_{00}$ in October 1967, otherwise close to 30 $^0/_{00}$. At the surface, there were records of about 10 $^0/_{00}$ and 18 $^0/_{00}$ respectively in June and October 1967.

The topography and hydrography of the Hardangerfjord (Fig. 1) has been described by SÆLEN (1962, 1967). There is a sill of 150 m in the outer part, and maximun depths of more than 900 m are found in the middle fjord. At the surface the water is sometimes very brackish, especially in the inner fjord during summer and autumn. Below 20 m the salinity is above 30 $^0/_{00}$ all the year, in the deeper layers 34.4—35.5 $^0/_{00}$. Temperature below 100 m is 6.5—8.0 C all the year, at the surface 2.5—15.7 C.

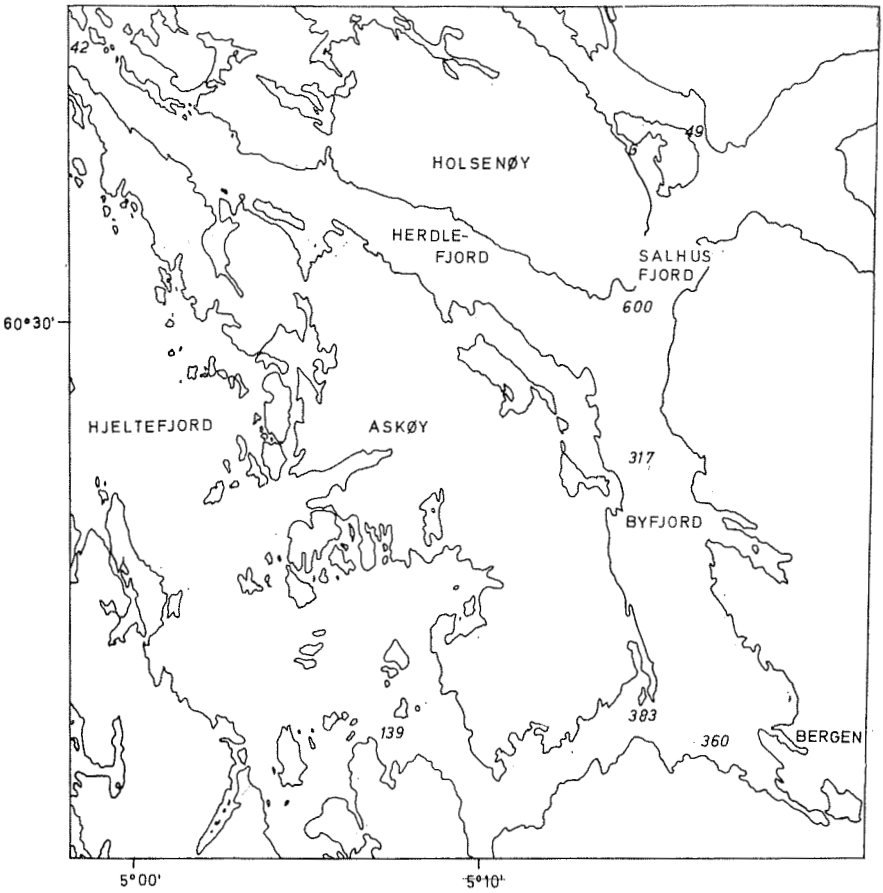


Fig. 2. The Byfjord and adjacent areas. Depths in m.

During the present investigation the extreme temperatures at the surface in the middle of the fjord were 4.9 and 16.6 C in March and June respectively, with the corresponding salinities of 30.4 $^0/_{00}$ and 12.2 $^0/_{00}$.

VARIATIONS IN THE VOLUMES OF KRILL AND MYSIDS IN 1967—1969

With a mesh size of three mm in the net of the IKMT some of the smaller krill will probably pass through the meshes. As the hauls were taken without any closing, the conclusions as to the vertical distribution must be taken with some precaution. However, the time of hauling in of the net was usually short as compared to the fishing time, and it

Table 1. Volumes of krill and mysids in ml per 1 000 m³ in the Byfjord near Bergen 1967—1969. 3' IKMT, mesh size 3 mm, trawling speed 4 knots. Night hauls, day hauls in italics.

Depth m	Jan.	Febr.	March	April	May	June	Oct.	Nov.
5.....	3	—	—	29	25	—	14	36
10.....	14	28	—	32	37	6	—	—
15.....	—	—	—	16	28	—	—	—
25.....	24	37	14	—	—	5	—	16
	—	—	—	—	—	—	—	—
50.....	82	6	13	6	13	13	12	22
	9	*3*		*1*			*2*	
100.....	39	38	—			13	6	
	—	*15*	—	*2*	*3*	—	*17*	
130.....	15	31	15	—	—	—	—	—
	17	*41*	—	*20*	—	—	—	—
180.....	38	38	—	—	—	13	14	—
	—	*29*	—	*11*	*8*	—	*15*	—
230.....	34	13	—	—	13	7	9	—
		41	—	*10*	*26*	*11*	*7*	—

is inferred that the figures give some information on the relative abundance of krill. In the Byfjord (Table 1) the volumes per 1 000 m³ varied between 13 and 41 ml, with one single figure of 82 ml in January. In a CB haul at 3 m level during the night of 19 November 1968 the volume was about 100 ml/1 000 m³.

Some IKMT hauls were made at varying times of day and night (Table 2). In January 1967 maximum in volume was observed at 50 m during the afternoon and evening, but after midnight the krill were evenly dispersed below 50 m. In February no krill were taken at 50 m or above during the day, the volume increasing from 100 m to 230 m. At dusk krill were taken from 25 m, increasing to a maximum volume in 150—200 m. In October the maximum was found in 100—200 m during the day, but at 10 m during the night. In February 1968 maximum was again below 200 m during the day, and at 10 m during the night, but in 50—230 m the krill were rather evenly distributed.

In the Hardangerfjord the volumes of krill in IKMT night hauls in 10—50 m usually were 7—30 ml/1 000 m³, but in April 1968, 83—104 ml/1 000 m³ were taken at 5 m level. In the Karmsund (Fig. 1) 167 ml/1 000 m³ were taken in a night haul at 5 m in November 1968.

None of the quantities taken indicate densities comparable with those induced by artificial light (Wiborg 1966).

Table 2. Volumes of krill and mysids in ml per 1 000 m³ in the Byfjord 1967 and 1968.

Year	Date	Hour	Depth, m							
			5	10	25	50	100	150	200	230
1967.....	6—7 Jan.	1630—1700	—	—	24	45	18	17	17	33
		2000—2100	—	—	13	82	27	—	31	34
		0020—0150	—	—	16	36	39	—	38	38
1967.....	6 Febr.	1306—1430	—	—	0	0	14	—	29	41
		1630—1835	—	—	11	6	26	31	38	13
1967.....	16 Oct.	1020—1230	—		—	2	17	—	15	7
		2115—2330	14		—	11	6	—	13	9
1968.....	5 Febr.	1020—1200	—	0.4	—	0.4	2.0	—	20	30
		2050—2330	7	37	—	18	23	—	25	21

RELATIVE COMPOSITION OF KRILL AND MYSIDS IN THE IKMT CATCHES

Nine species of krill have been identified in the catches, viz. *Meganyctiphanes norvegica* (M. Sars), *Thysanoessa inermis* (Krøyer), *T. raschii* (M. Sars), *T. longicaudata* (Krøyer), *Nyctiphanes couchii* (Bell), *Thysanopoda acutifrons* (Holt and Tattersall), *Nematoscelis megalops* (G. O. Sars), *Euphausia krohnii* (Brandt) and *Stylocheiron maximum* (Hansen). The last four species have been dealt with earlier (Wiborg 1968). In this paper the main emphasis will be laid on *M. norvegica, T. inermis* and *T. raschii,* both in number and volume dominating the catches.

The mysids, *Boreomysis arctica* (Krøyer), *B. megalops* (G. O. Sars), *Siriella norvegica* (G. O. Sars) and *Lophogaster typicus* (M. Sars) have been included in the counts used in Fig. 3, but otherwise not dealt with.

According to Jerde (1967) krill below a size of 13 mm are not caught quantitatively in a net with a mesh size of four mm. As will be shown later, this also seems to be the case with the three mm net used in the present investigation. Reservations must also be taken that the deeper hauls contain krill taken at upper levels. The composition of the samples may nevertheless indicate the relative abundance of the different species, especially during winter and spring when the smaller species have reached their adult size. In Fig. 3 are shown the relative numerical abundance of *T. raschii, T. inermis, M. norvegica,* and the group other krill and mysids (mainly *B. arctica* and *L. typicus*, in the Byfjord in 1967—1968.

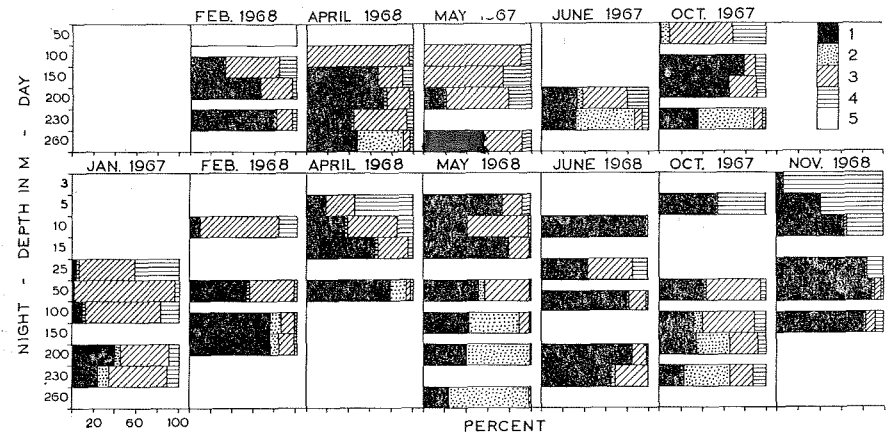


Fig. 3. Relative numerical importance of the most abundant species of krill and mysids in Isaacs-Kidd 3' pelagic trawl in the Byfjord in 1967—1969. 1) *Meganyctiphanes norvegica,* 2) Mysids, 3) *Thysanoessa inermis,* 4) *Thysanoessa raschii,* 5) hauls with no catch.

During the day, *T. inermis* and *T. raschii* dominate the uppermost hauls, in May also in 200 m. During the night conditions vary, sometimes with *T. raschii* dominating in the upper 5—10 m and *T. inermis* second, but *M. norvegica* dominates at 10—15 m in April—May, and at 5—10 m in May—June and October. In September 1967 (not figured), October 1967 and November 1968 only *T. raschii* and *M. norvegica* were taken in the upper 10 m during the night, *T. inermis* appearing at 25—50 m. This feature is in accordance with the observations of LACROIX (1961) in Canadian waters.

M. norvegica as a rule dominates below 150—200 m during the day. Mysids, mainly *B. norvegica,* sometimes also *L. typicus,* are occasionally rather numerous below 100—200 m, especially during the night, sometimes ascending to 10 m (April 1968).

In volume *M. norvegica* will nearly always dominate the samples because it is 10—15 times as big as *T. inermis* and *T. raschii.* More details about the vertical distribution will be given later in this paper.

THE KRILL SPECIES

MEGANYCTIPHANES NORVEGICA

Abundance

As the sampling did not include the entire water column from bottom to surface, the material is not very well suited to give information on the variation of the stock as a whole.

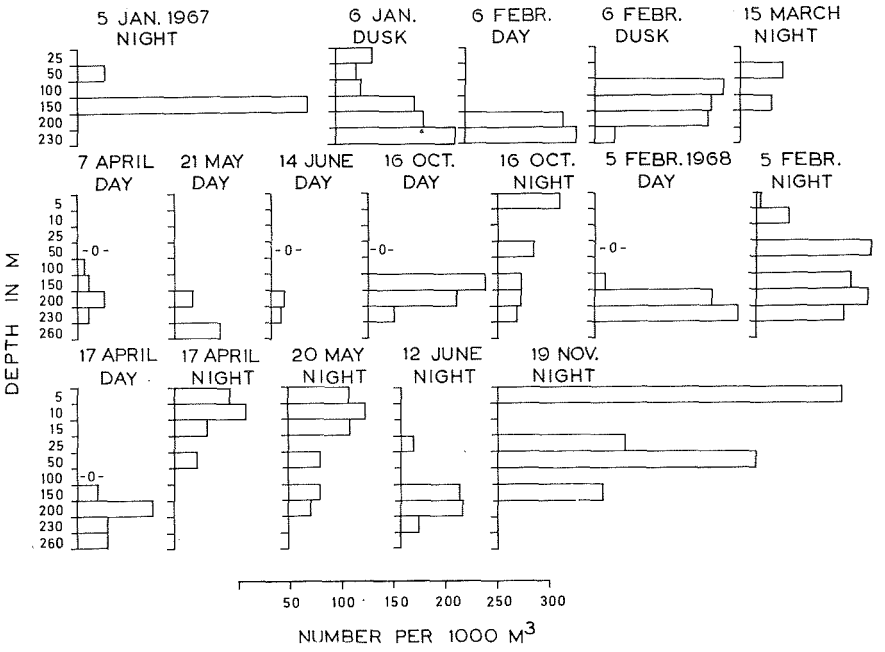


Fig. 4. Numbers of *Meganyctiphanes norvegica* per 1 000 m³ at different levels in the Byfjord in 1967—1968. —0—) no catch.

In Fig. 4 are given numbers per 1 000 m at various levels during day and night in the Byfjord in the period from January 1967 to November 1968. The figures were fairly high in January—February 1967, 125—220 specimens/1 000 m³ in the deeper hauls. In March—June numbers were low, 42 or less. In February 1968 the stock seemed to be of the same size as in February 1967, but with less reduction to April—June than in the year before. In June 1968 the new generation appeared as furciliae in the upper 10 m. In November the stock was possibly more abundant than in November 1967.

During January—June 1967 night hauls in the Hardangerfjord in 10—50 m yielded 20—55 specimens/1 000 m³. A day haul at 200 m in February 1967 at Røyrvik yielded 190 specimens/1 000 m³; in Karmsund a night haul at 4 m in November 1968 yielded 1 370 specimens/1 000 m³.

Vertical distribution and migration

As is evident from Fig. 3 and 4, *M. norvegica* in the Byfjord as a rule keeps below 100—150 m during the day, but may ascend to the surface at night. According to Einarsson (1945) and Maughline (1960) larger

individuals as a rule stay deeper than the smaller ones. This was also observed in the Byfjord (Fig. 5). In February 1967 small individuals (less than 28 mm) during the day dominated at 200 m and 230 m. In the evening a few larger specimens appeared at 100 m. In 150—230 m large specimens constituted more than half the stock. In February 1968 distribution was similar, most of the larger individuals evidently staying below 200 m during the day. During the night a few large specimens were taken at 10 m, the proportion increasing to a maximum in 175—210 m. In April 1968 larger individuals (I-group) during the day were very scarce at 150 m and 220 m, but relatively abundant at 260 m. During the night this group was well represented even at 15 m. In October specimens larger than 30 mm appeared in increasing percentage from 100—150 m and downwards during the day. During the night only small *Meganyctiphanes* were taken at 5 m, but the proportion of those above 30 mm increased from 6 % in 25—75 m to 54 % in 220—260 m.

During February—June adult males stayed somewhat deeper than

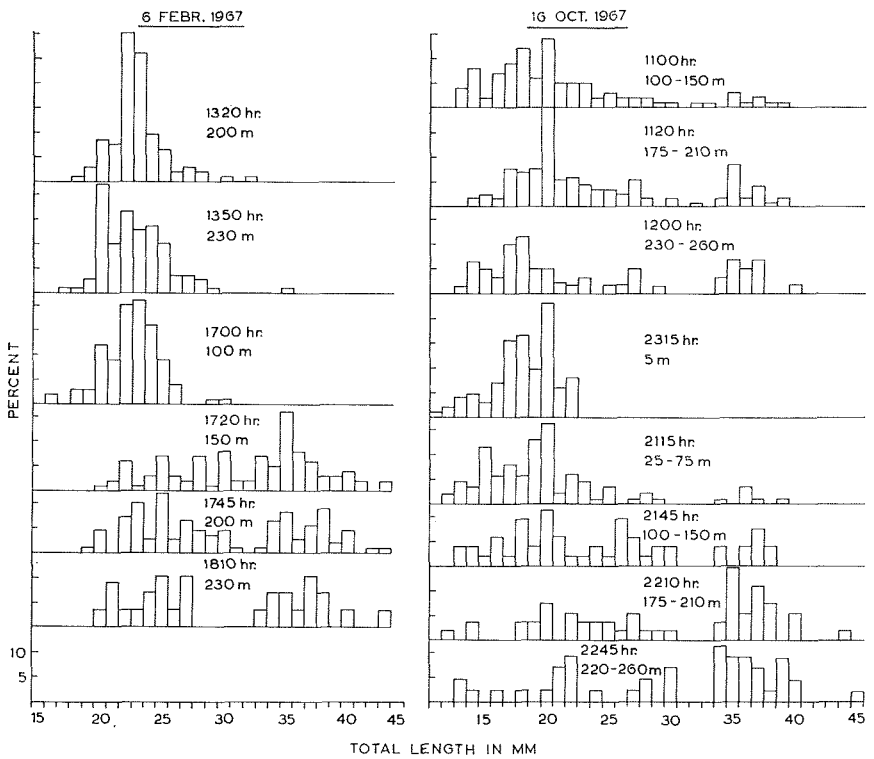
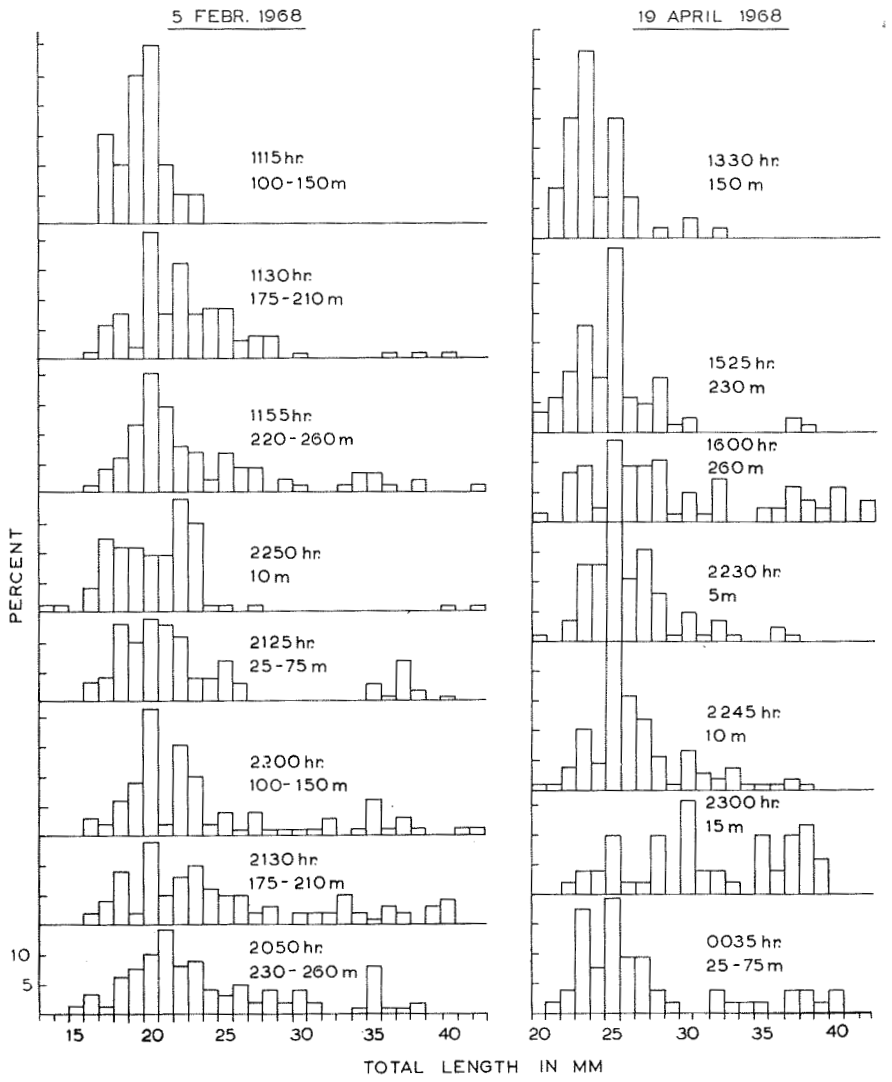


Fig. 5. Size distributions of *Meganyctiphanes norvegica* at different levels during day and night in the Byfjord in February and October 1967, and in February and April 1968.

Fig. 5. continued.



the females as indicated by the increase in the proportion of males with increasing depth (Table 4).

In samples taken with light and dipnet from a pier in the Hardangerfjord in November 1965 and January 1966 (Table 3) the proportion of larger individuals in November increased from midnight to a maximum in early morning. In January large individuals appeared already in the evening.

Table 3. Percentages of the various size groups of *Meganyctiphanes norvegica* taken with light and ketcher in the Hardangerfjord area in 1965—1966.

Year	Date	Hour	26 mm	27—30 mm	33—40 mm	25 mm	26—36 mm
1965.....	25 Nov.	2100	100	0	0		
		2300	98	2	0		
	26 Nov.	0300	92	8	0		
		0500	66	24	10		
		0745	58	20	20		
1966.....	14 Jan.	1830				97	3
		2300				90	10
	15 Jan.	0400				73	27

Growth

In the Byfjord (Fig. 6) two size groups were generally found, the O-group and I-group and I-group. In November 1966 the O-group measured 14—27 mm, mean 19 mm. A few I-group specimens measured 29—34 mm. In January 1967 the O-group ranged from 19 mm to 30 mm, mean 24 mm, increasing in June to 28—33 mm. The I-group had

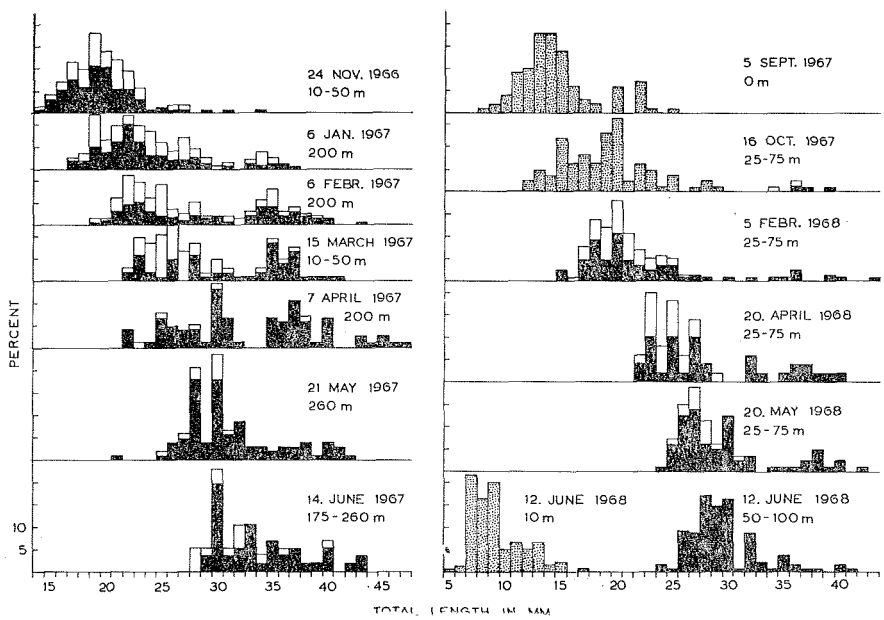


Fig. 6. Size distributions of *Meganyctiphanes norvegica* in the Byfjord (selected hauls) in 1967—1968. Black) females, white) males.

a less pronounced increase, with the peak moving from 34 mm in January to 38—39 mm in June. Individuals probably belonging to the II-group, 43—47 mm, appeared in February and April 1967.

In September 1967 the new 0-group measured 8—25 mm with a peak at 13—14 mm. From October 1967 to June 1968 the development was similar to that of the preceeding season, but in February the 0-group individuals were smaller than the 0-group one year before. In June 1968 the brood of the year appeared as furciliae and adolescents, measuring 5—15 mm.

In the Hardangerfjord (Fig. 7) the variations in size distribution from November 1966 to June 1967 were similar to those in the Byfjord, but the 0-group individuals were slightly larger. This may be due to local growth conditions which may vary from year to year.

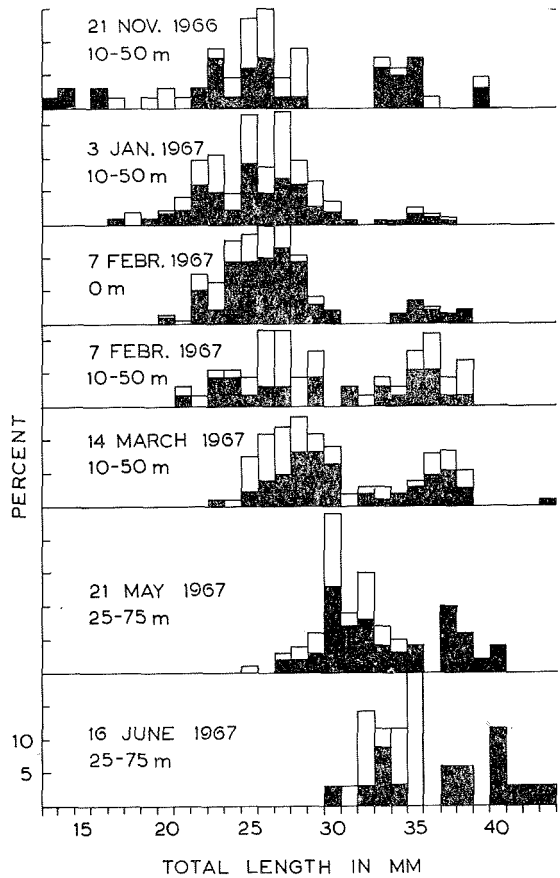


Fig. 7. Size distributions of *Meganyctiphanes norvegica* in the Hardangerfjord in 1967. Black) females, white) males.

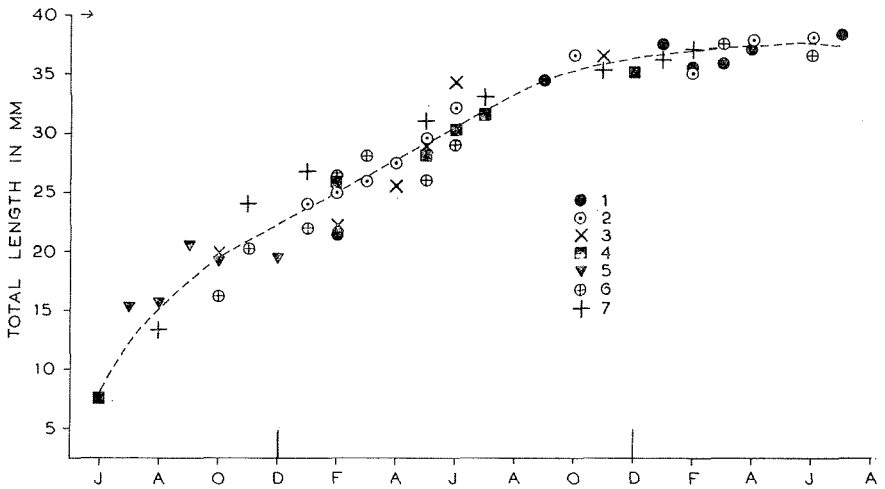


Fig. 8. Mean length of various year classes of *Meganyctiphanes norvegica* as 0-group and I-group in the Byfjord (1—5) and in the Hardangerfjord (6—7) in various months of the year. 1 and 6) 1965, 2 and 7) 1966, 3) 1967, 4) 1968, 5) 1969.

In Fig. 8 the mean length of the 1965—1969 year classes of *M. norvegica* has been plotted, using all the data available for the Hardangerfjord including data from WIBORG (1966). Variations in growth are most evident during the first year. The length increases from 7.5 mm in June to about 22 mm in December, further to 27 mm in April, and to 30—34 mm in June. During the second year of life the growth rate seems to decrease, the *Meganyctiphanes* reaching a mean length of 37—38 mm two years old. Individuals, 43—47 mm in length, taken in April 1967 (Fig. 6) are possibly nearly three years old.

It is difficult to find retardation of growth during the autumn and winter as was stated by MAUCHLINE (1960). This may be due to a long spawning period. The growth rate is similar to that found by PAULSEN (1926) for *M. norvegica* in the Skagerrak.

Maturity, sex proportions and spawning

Males have been characterized as mature when spermatophores could be clearly seen in the spermatheca and females when the thelycum could be distinguished. Percentages of mature individuals, of males, and of females with spermatozoa in the thelycum (fertilized) in the Byfjord in 1967—1968 are given in Table 4.

Table 4. *Meganyctiphanes norvegica*. Percentages of: 1) mature individuals in the samples, 2) males of the mature animals, 3) females with attached spermatophores of all the females in the Byfjord in January—June 1967 and February—June 1968. IKMT hauls.

Year	Date	Day or night	Depth m	1. mature %	2. males %	3. females with spmtf. %
1967.....	6 Jan.	night	25	0		0
		»	50	45	about 50	0
		»	100	60		0
		»	200	33		0
		»	230	52		0
	6 Febr.	night	100	56		11
		»	150	92	about 50	55
		»	200	90		47
	15 March	night	10— 50	100	47	95
		»	150	100	73	100
	7 April	night	100	100	0	100
		»	150	100	6	86
		»	200	100	7	85
		»	230	100	9	86
	21 May	day	200	100	10	40
		»	230	100	10	73
	14 June	night	175—210	100	25	16
1968.....	5 Febr.	night	10	31	—	0
		»	25— 75	40	42	(33)
		»	100—150	50	53	(33)
		»	230—260	55	49	(31)
	19 April	night	4	100	5	91
		»	10	100	12	99
		»	15	100	0	100
		»	25— 75	84	30	78
	20 May	night	4	100	1	100
		»	10	100	0	100
		»	15	100	0	100
		»	25— 75	100	21	100
		»	100—150	100	50	100
		»	200	100	63	100
		»	260	100	79	100
	12 June	night*)	10	100	0	100
		»	25	100	0	100
		»	50—100	100	0	100
		»	200	100	33	97
		»	230	100	33	100

*) The new 0-group excluded.

No mature individuals were found in November 1966, probably because no deep hauls were taken. In January the percentage of mature individuals increased from 0 at 25 m to 33—60 below 50 m, in February to 56—90 and fertilized females were observed. In March the whole stock was mature, and nearly all females were fertilized. In April the proportion of fertilized females was still high, but decreased throughout May to a low level in June.

Males and females were nearly equal in number from November 1966 to the middle of March 1967. In April the percentage of males decreased to below 10, remaining low in May and June. In 1968 the proportions of mature individuals and of fertilized females were lower in February than one year before, but had increased considerably until April. The percentages of fertilized females remained high in May and June. Males decreased very much in percentage from February to April and were scarce in the upper hauls in May, but the percentage increased to 79 at 260 m. In samples taken in 1969 the percentage of fertilized females

Table 5. *Meganyctiphanes norvegica.* Percentages of: 1) mature individuals in the samples, 2) males of the mature animals, 3) females with attached spermatophores of all the females in the Hardangerfjord, January—June 1967 and February—April 1968. IKMT night hauls. Italics: Catches with light and ketcher.

Year	Date	Depth m	1. mature %	2. males %	3. females with spmtf. %
1967.....	3 Jan.	10— 50	70	42	7
		20	67	61	0
	4 Jan.	40	80	65	25
		60	80	72	13
	7 Febr.	0	90	26	46
		10— 50	85	56	42
		150	98	33	58
	14 March	10— 50	100	46	100
		150	100	39	100
	21 May	25— 75	100	32	100
	16 June	25— 50	100	50	100
		75—100	100	89	100
1968.....	12 Febr.	10	74	47	46
		25— 75	91	68	43
		100—150	(93)	(20)	(33)
	23 Febr.	*0*	*100*	*34*	*100*
	27 March	*0*	*100*	*14*	*100*
	18 April	*0*	*100*	*0*	*100*
		4— 15	100	18	100

was 60—80 in June and dropped to 20 in the middle of July. As was found earlier (WIBORG 1966), larger females were fertilized before the smaller ones. In February 1967, 70 % of the females above 31 mm were fertilized, of those below 31 mm only 30 %. In February 1968 the corresponding figures were 75 % and 24 %.

In the Hardangerfjord (Table 5) 67—80 % of the individuals were mature in January 1967, increasing to 85—90 % in February and to 100 % from the middle of March. The proportion of males was relatively high in January—June 1967; minimum 26 % in a sample taken with ketcher and light in February. Fertilized females appeared in January, the percentage increasing with increasing depth. In February about half of the females, in March all, were fertilized.

In 1968 nearly all individuals were mature in the middle of February and half of the females fertilized. On February 23 individuals lured with light were all mature, the females fertilized. In March—April the percentage of males was reduced to 0—18. In 1967 the females fertilized in January measured 34—42 mm (I- and II-group), in February 87 % were above 31 mm.

Mortality

As already mentioned, the stock as a whole is considerably reduced from February to March, and the proportion of males decreased from March to April both in the Byfjord and the Hardangerfjord. It is also expected that older individuals (I- and II-group) would die at a higher rate during spring than the 0-group. The proportion of I-group to 0-group males and females in the Byfjord in 1967—1968 is shown in Table 6.

During February—June old males were less frequent than old females, in some samples entirely absent. In 1967 the percentage of old females in January was about 25, of males 20. In February old females were mainly taken below 150 m during the night. In March these females were relatively frequent at higher levels, males at 150 m. In April—June old males were scarce or absent, and the percentage of old females was also reduced.

In October the 0-group dominated during the day and above 175 m during the night. At and below 175 m the I-group constituted more than 50 %.

In 1968 old males were poorly represented, only taken in deep hauls in February. Old females were also generally scarce, indicating a poorer survival than in the spring of 1967. In the Hardangerfjord (Table 7) conditions in 1967 varied very much in the different parts of

Table 6. *Meganyctiphanes norvegica:* Proportions of I-and II-group to 0-group of males and females in the Byfjord, January 1967 to May 1968. IKMT-hauls. ÷) no males present.

Year	Date	Day or night	Depth m	I-II gr. / 0-gr. males %	I-II gr. / 0-gr. females %
1967.....	5 Jan.	night	10— 50	7	20
		»	150	14	26
	6 Jan.	»	100	6	24
		»	200	20	24
		»	230	32	32
	6 Febr.	day	240	0	2
		»	100	÷	0
		»	150	38	77
		»	200	26	43
	15 March	night	10— 50	8	53
		»	150	33	55
	7 April	day	150	0	18
		»	200	20	49
		»	230	0	60
	21 May	day	200	0	0
		»	230	0	19
	14 June	»	175—210	7	26
	16 Oct.	»	100—150		13
		»	175—210		21
		»	230—260		25
		night	5		0
		»	25— 75		8
		»	100—150		27
		»	175—210		54
		»	230—260		61
1968.....	5 Febr.	day	175—210	0	3
		»	230—260	9	9
		night	10	0	8
		»	25— 75	0	28
		»	175—210	14	38
		»	230—260	28	34
	17 April	day	150	÷	0
		»	200	0	2
		»	230	0	4
		»	260	0	36
	19 April	night	4	0	4
		»	10	0	5
		»	15	0	40
		»	25— 75	0	27
	20 May	night	4	÷	6
		»	10	÷	3
		»	15	÷	15
		»	25— 75	÷	17

Table 6(cont.). *Meganyctiphanes norvegica:* Proportions of I-and II-group to 0-group of males and females in the Byfjord, January 1967 to May 1968. IKMT-hauls. ÷) no males present.

Year	Date	Day or night	Depth m	I-II gr. / 0-gr. males %	I-II gr. / 0-gr. females %
	10 May	»	100—150	0	24
		»	200	0	67
1968	12 June	night	10	÷	0
		»	25	÷	10
		»	50—100	÷	4
		»	200	0	9
		»	230	0	0

the fjord, but the proportion of old males generally decreased considerably after March. The impression is also that the stock as a whole was heavily reduced after spawning. Occasionally old females dominate catches taken with dip net and light, in February 1968 constituting up to 95 %. Similar observations have been made earlier (WIBORG 1966).

Table 7. *Meganyctiphanes norvegica:* Proportions of I- and II-group to 0-group of males and females in the Hardangerfjord January 1967 — April 1968. IKMT night hauls. At 0 m, catches with light and ketcher. ÷) no males present.

Year	Date	Depth m	I-II gr. / 0-gr. males %	I-II gr. / 0-gr. females %
1967.....	3 Jan.	10— 50	55	57
	7 Febr.	0	1	15
		10— 50	37	42
		150	44	55
	14 March	10— 50	39	41
		10— 50	27	38
	21 May	25— 75	0	40
	16 June	150	8	27
1968.....	12 Febr.	10	0	31
		25— 75	50	50
	18 Febr.	0	0	95
	23 Febr.	0	23	69
	27 March	0	21	33
		0	8	21
	18 April	0	÷	10
		4— 15	0	20

Conclusions

In the investigated area *M. norvegica* was seldom taken in densities higher than 150 specimens/1 000 m³, with a single exception of 1 170 specimens/1 000 m³. However, dense agregations at the surface have been induced with artificial light.

During the day *M. norvegica* keeps below 150 m with maximum concentration at 200—260 m or deeper. During the night the population migrates towards the upper layers, sometimes close to the surface. A certain layering was observed, 0-group individuals in the top layer, older individuals successively deeper. Some of the I-group males stay in deeper water both during day and night. This pattern of vertical migration is similar to that described by EINARSSON (1945) and MAUCHLINE (1960, 1969). Occasionally older individuals arrived at the surface later in the night or early morning. Surface swarms of *M. norvegica*, attracted by artificial light in February—March, sometimes consisted mainly of 0-group females. A similar segregation of I-group individuals was observed by AITKEN (1960, quoted by MAUCHLINE 1969).

The growth of *M. norvegica* was comparable with that in the Skagerrak (PAULSEN 1926). Hatched in April—May, the 0-group attains a length of 22 mm in December, 27 mm in April, and 30—34 mm as I-group in May—June. During the second year the growth decreases, the animals in May—June measuring about 38 mm. Individuals surviving for one more year measure 43—47 mm next April.

Maturing and copulation starts in January, the I-group females being fertilized first. All individuals are usually mature and all females fertilized in the middle of March. Spawning starts in March—April, sometimes continuing throughout June.

As was found by MAUCHLINE (1960), there is a high mortality in the males during and after the transference of spermatophores in March—April and also a higher mortality in the I-group than in the 0-group in March—May. Because of the vertical segregation of the different size groups in the water mass, it is difficult to give exact figures of the mortality. In the Byfjord the survival of the I-group in the spring was definitely better in 1967 than in 1968.

THYSANOESSA INERMIS

Abundance and vertical distribution

In night hauls in the Byfjord 395 specimens/1 000 m³ were taken in November 1966, 1 500—3 600 specimens/1 000 m³ at 40—50 m level in January—February 1967 (Table 8). During April—June and in October

Table 8. *Thysanoessa inermis*. Number per 1 000 m³ in hauls with 3' IKMT and Clarke—Bumpus plankton sampler (CB) in the Byfjord in 1967—1968.

Year	Date	Day or night	Depth m	Number of *T.inermis*	Number of *T.inermis* at other levels
1966.....	24 Nov.	night	10— 50	395	
1967.....	5 Jan.	»	10— 50	580	
	6 Jan.	»	50	3 600	52—215
	6 Febr.	day	100	290	4—125
	9 Febr.	night	10— 50	94	
	9 Febr.	»	10 (CB)	350	
	9 Febr.	»	40 (CB)	1 560	
	15 March	»	10— 50	63	
	7 April	day	150	19	5— 9
	21 May	»	260	63	54
	14 June	»	175—210	63	10
	16 Oct.	night	25— 75	38	5— 25
1968.....	5 Febr.	»	5	27	
	5 Febr.	»	10	1 500	
	5 Febr.	»	10 (CB)	4 000	22—112
	17 April	»	10	32	7— 30
	20 May	»	25— 75	26	3— 21
	12 June	»	100	9	1— 7
	19 Nov.	»	50	35	0— 7

figures were low. High figures, 4 000 specimens/1 000 m³, were again obtained at 10 m level in February 1968.

In the Hardangerfjord *T. inermis* was taken in low numbers, maximum 125/1 000 m³.

In Karmsund an IKMT haul at 5 m in November 1968 yielded about 1 100 specimens/1 000 m³.

The irregular variation in abundance indicates an extensive degree of shoaling. Large numbers were only taken in night hauls and even then, only at one single level. The greater number usually taken in CB sampler as compared with the IKMT hauls, indicates that the smaller specimens pass through the meshes of the IKMT. There seems to have been a general decrease in the stock after February, both in 1967 and 1968. During the day *T. inermis* was usually most abundant at 100—200 m, during the night at 10—50 m.

Size distribution

In the Byfjord there was a major peak in the size distribution of *T. inermis* at 15 mm from November 1966 to the middle of March 1967

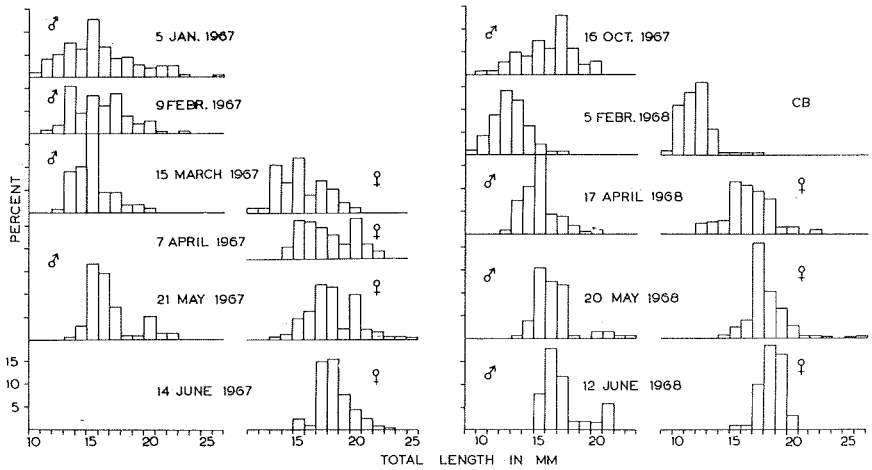


Fig. 9. Size distributions of *Thysanoessa inermis* in the Byfjord in 1967—1968. CB) from samples taken with Clarke—Bumpus plankton sampler.

(Fig. 9). In the March—June samples males and females were measured separately. Females were somewhat larger than the males with the peaks in May at 17 mm and 15 mm respectively. In both sexes there is a second peak at 20 mm, also observed in the females in April. In June the females were slightly larger than in May. In all samples taken in October 1967 there was a peak at 17 mm, in February 1968 at 12 mm. Comparing samples taken at the same level with IKMT and CB, it is evident that more small individuals are caught in the CB indicating escapement of the smaller sizes through the meshes of the IKMT.

In May 1968 the females passed the males in size, with peaks in June at 18 mm and 16 mm respectively.

T. inermis seems to be mainly annual in the Byfjord as was also found for the Hardangerfjord (WIBORG 1966). Individuals, 24—26 mm, taken in January—February 1967 may belong to the I-group.

Spawning and mortality

In the middle of March 1967 males constituted 35—40 % of the stock. Of the males 11 % carried spermatophores. At the beginning of April males were reduced to 7—8 %, indicating a heavy mortality, whereas all females carried spermatophores. In May males were again relatively more frequent, 4—48 %, possibly related to an increased mortality in females after spawning (MAUCHLINE 1966). In June 58 % of the females carried spermatophores, and the males constituted 17—20 %, but the stock was very small. Eggs and nauplii of *Thysanoessa*

sp. were found in vertical Juday net hauls from the middle of March. Maximum of spawning probably occurred in early April. In 1968 males constituted 18—24 % in April, 34 % in May. Nearly all the females carried spermatophores both in April and May except from hauls at 200—230 m where 19 % were not fertilized.

In the Hardangerfjord the samples were too scarce to give sufficient information of the spawning.

Occurrence of the two-spined form of T. inermis

According to HANSEN (1911, 1916, quoted by JONES, FORSYTH and COOPER 1967) *T. inermis* from the Pacific Ocean has two dorsal spines, on respectively the fifth and sixth abdominal sediment; in the Atlantic generally only one, on the sixth segment. Recently, JONES *et al.* (1967) found the two-spined form in the North Sea occurring in about three percent of the individuals investigated.

During the present investigation the two-spined form has also been found in the Hardangerfjord, in the Byfjord and in the Sognefjord (Fig. 1). The frequency was from 1 to 3 percent, the size of the individuals 11—20 mm.

One specimen has also been recorded in samples taken at station M at 66°N, 02°E.

The finding of the two-spined form in the coastal areas of Western Norway links very well with the occurrence in the North Sea.

THYSANOESSA RASCHII

According to MAUCHLINE (1969) *T. raschii* is a neritic species widely distributed in the northern oceans and also found along the coast of Norway. EINARSSON (1945) states that it prefers sheltered fjords, but occurs also in coastal areas.

Abundance and vertical distribution

During the present investigation *T. raschii* was taken regularly in the Byfjord (Table 9), but in numbers second to *T. inermis* except in February 1967 and November 1968. In 1967 maximum numbers were taken in January and February (3 500 specimens/1 000 m^3), in 1968 in February and November. Figures then amounted up to 700 and 5 000 specimens/ 1 000 m^3 respectively. In the Hardangerfjord *T. raschii* was always very scarce, maximum 2—3 specimens/1 000 m^3. In Karmsund (Fig. 1) 85 and 230 specimens/1 000 m^3 were taken in May and November 1968 respectively.

Table 9. *Thysanoessa raschii.* Number per 1 000 m³ in hauls with 3' IKMT and Clarke—Bumpus plankton sampler (CB) in the Byfjord in 1967—1968.

Year	Date	Day or night	Depth m	Number of *T.raschii*	Number of *T.raschii* at other levels
1966.....	24 Nov.	night	10— 50	230	
1967.....	5 Jan.	»	10— 50	440	
	6 Jan.	»	25	163	
			50	150	1—40
	6 Febr.	day	100	147	6—26
	9 Febr.	night	10— 50	68	
			10 (CB)	3 500	
			40 (CB)	100	
	15 March	night	10— 50	2	1
	7 April	day	150	9	1— 7
	21 May	»	200	19	6
	14 June	»	175—210	19	3
	16 Oct.	night	5	100	3— 9
1968.....	5 Febr.	»	5	165	
			10	315	3— 7
	6 Febr.	night	10 (CB)	720	
	17 April	»	5	125	0— 3
	20 May	»	5	9	1— 6
	12 June	»	25	4	0— 1
	19 Nov.	»	5	365	10—22
			25	22	
			3 (CB)	5 000	
			8 (CB)	730	

During the night *T. raschii* was nearly always most abundant in the upper 5—10 m, and in November 1968 it was more numerous at 3 m than at 8 m. During the day maximum number was usually taken at 100—150 m.

Size distribution

Size distributions (Fig. 10) are similar to those of *T. inermis,* but there are some differences. From November 1966 to February 1967 there were peaks at 13 mm and 15 mm. Few individuals were caught in March. In April males and females had peaks at 15 mm; in May the females were larger (18 mm) than the males (15—16 mm). In June the peaks were at 17 mm and 20 mm respectively. From September 1967 to February 1968 the peak was mainly at 12—13 mm. Figures from catches with IKMT and CB samplers 1968 are compared, showing the escapement of smaller individuals through the meshes of the IKMT.

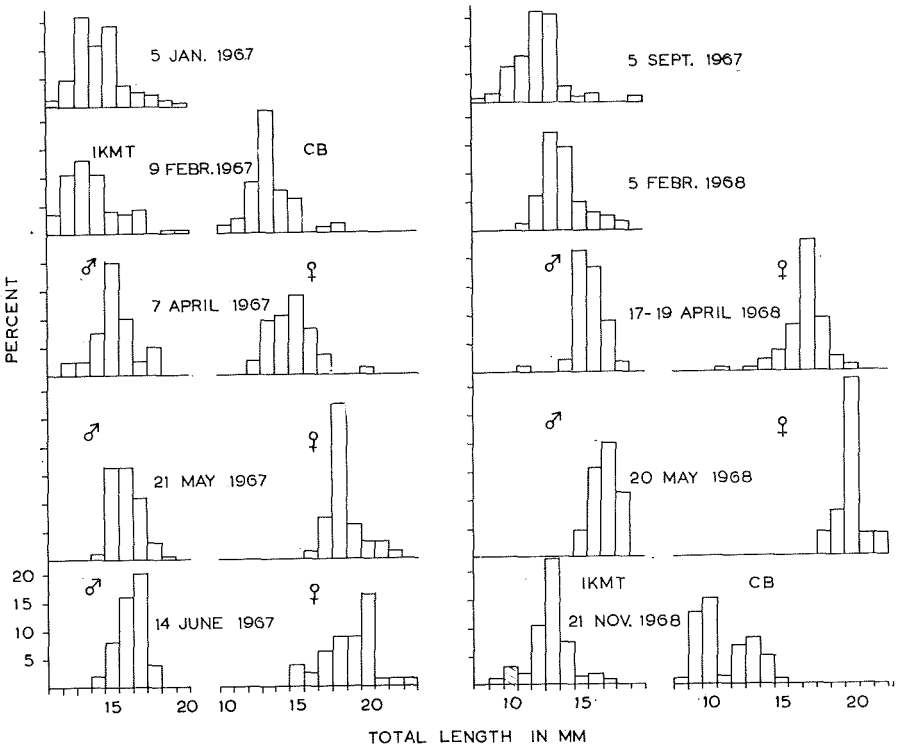


Fig. 10. Size distributions of *Thysanoessa raschii* in the Byfjord in 1967—1968. CB) from samples taken with Clarke—Bumpus plankton sampler.

T. raschii was slightly larger in April and May 1968 than in the same months the year before. In November two peaks are indicated, at 10 mm and 13 mm, and escapement of smaller individuals from the IKMT hauls is again apparent.

Spawning

In March 1967 the few individuals taken were immature. At the beginning of April 76 % of the females carried spermatophores. Males constituted 20 % of the stock. In May males were more numerous than females, (70 %), probably indicating a high mortality in the females after spawning as was found by MAUCHLINE (1960, 1969) for *M. norvegica*. In June 58 % of the females carried spermatophores, and the percentage of males had increased to 40.

In 1968 all females were fertilized in the middle of April and the male percentage was 33, increasing to 63 in May.

In Karmsund the same picture was observed in May 1968, most of the females fertilized and males dominating.

Conclusion

The preference of *T. raschii* for the upper 5—10 m layer during the night has already been mentioned. This fact in addition to the mesh size of the trawl may possibly lead to an underestimate of the numerical importance of this species. This is clearly evident in the figures for 9 February 1967 (Table 9). The size distributions are on the whole more uniform than in *T. inermis,* usually with one main peak. In May and June the mean lengths are greater than those of *T. inermis,* but the survival of individuals beyond one year seems to be insignificant, indicated by a few individuals of 22—23 mm in May—June.

Spawning occurs from April to June with maximum in the middle of April and, to judge from lack of mature individuals in March, somewhat later than in *T. inermis.* The same difference was also observed in the Barents Sea (ZELIKMAN 1958). The two peaks in the size distributions in January—February 1967 and in November 1968 may indicate a spawning period with two maxima for the years 1966 and 1968 while there seems to have been only one main period in 1967. Similar year to year differences are reported by MAUCHLINE (1966).

REFERENCES

BEYER, F. (in preparation). A low-speed midwater trawl.

EINARSSON, H. 1945. Euphausiacea. I. Northern Atlantic species. *Dana Rep., 5*(27) : 1—192.

JERDE, C. W. 1967. A comparison of euphausiid shrimp collections made with a micronecton net and a one meter plankton net. *Pacif. Sci., 21* : 178—181.

JONES, L. T., FORSYTH, C. T. and COOPER, G. A. 1967. The occurrence of the two-spined form of *Thysanoessa inermis* (Crustacea: Euphausiacea) in the North Sea. *Bull. mar.Ecol., 6*(6) : 181—184.

LACROIX, G. 1961. Les migrations verticales journalières des euphausides a l'entrée de la Baie des Chaleurs. *Contr. Dep. Pech. Queb.,* (83) : 257—316.

LINDE, E. 1970. Hydrography of the Byfjord. *University of Bergen, Geophysical Institute, Div.A. Physical oceanography. Report No. 20*: 1—39, 11 fig. [Mimeo.]

MAUCHLINE, J. 1960 The biology of the euphausiid crustacean, *Meganyctiphanes norvegica* (M. Sars). *Proc. R.Soc. Edinb. B, (Biol.), 67*: 141—179.

MAUCHLINE, J. 1966. The biology of *Thysanoessa raschii* (M. Sars), with a comparison of its diet with that of *Meganyctiphanes norvegica* (M. Sars). Pp. 453—510 in BARNES, H. ed. *Some contemporary studies in Marine science.* George Allen and Unwin Ltd., London.

MAUCHLINE, J. and FISCHER, L. R. 1969. The biology of euphausiids. Pp. 1—454 in RUSSEL, F. S. and YOUNGE M. ed. *Advances in marine biology 7.* Academic Press, London and New York.

POULSEN, E. M. 1926. Om den store Lyskrebs (*Meganyctiphanes norvegica*) Betydning som Fiskeføde i Skagerrak. *Dansk Fisk, Tid., 24*: 286—289.

SÆLEN, O. H. 1962. The natural history of the Hardangerfjord 3. The hydrographical observations 1955—1956. Tables of observations and longitudinal sections. *Sarsia, 6*: 1—25.

— 1967. Some features of the hydrography of Norwegian fjords. Pp. 63—70 in LAUFF, G. H. ed. *Estuaries*. Publ. No. 83, American Association for the Advancement of Science.

WIBORG, K. F. 1966. Undersøkelser av krill (lyskreps) i Hardangerfjorden og tilstøtende områder, samt på stasjon M i Norskehavet. *Fiskets Gang, 52*: 754—761.

— 1968. Atlantic euphausiids in the fjords of western Norway. *Sarsia, 33*: 35—42.

ZELIKMAN, E. A. 1958. Materialy o raspredelenii i razmnozhenii evfauziid v pribrezhnoi zone Murmana. *Trudy murmansk biol.Sta. 4*: 79—118.

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