International Council for the
Exploration of the Sea

C.M. 1962
Plankton Committee
No. 123 P

Att: Herring Committee

On the Peculiarities of the Plankton Development and Feeding Conditions of Herring in the Norwegian Sea in 1958-1961

By

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Regular observations on the terms of plankton development and its influence upon the fattening of herring in the Norwegian Sea have been conducted for more than ten years. These researches were extended in connection with the progress of the Soviet fishery for Atlanto-Scandian herring.

As a result of the investigations in 1950-1957, the main migration pattern of feeding herring and their movement into the polar front area were studied and the approximate duration of the feeding period was estimated (Marty, 1956; Pavshtiks, 1956, 1960; Rudakova, 1956, 1958).

During 1958-1961 the scientific workers of the Polar Institute collected about 8,000 plankton samples in the Norwegian Sea; 62,315 specimens of herring were analysed. To reveal the feeding pattern of herring in 1958-1961 we examined 9,386 stomachs by the quantity-weight analysis.

These data enabled us to reveal the influence of the terms of the plankton development upon the fattening and distribution of herring.

The cold year of 1958 was characterized by a comparatively weak but prolonged development of the phytoplankton. Accordingly, the spawning of Calanus finmarchicus, which in the Norwegian coastal zone began at the end of March was considerably delayed. Comparatively low water temperatures in 1958 favoured the slower development of young Calanus. Spawning Calanus finmarchicus and euphausiids were scanty in March, April and May 1958, and herring did not find food enough during the spring fattening period. Stomachs of herring contained little food. In May, the average stomach content was 0.46 (Table 1). In the same period the average index of stomach fullness was 28.8 prodecimille (Table 3).

The development of Calanus finmarchicus in 1958 reached its maximum in June when the III-IV-V copepodite stages dominated in the eastern branch of the West Spitsbergen Current. The biomass reached 5 ml per m^3. Young euphausiids were also abundant in this area. Concentrations of Calanus hyperboreus were observed in the north-western part of the area of Mohn's Threshold.

Nevertheless, the rich food in the eastern and northern areas of the Norwegian Sea was not used by herring during the period from 1958 to 1961.

They began feeding on the pre-spawning concentrations of Calanus in the south-eastern part of the Norwegian coastal waters and went on feeding in the mixed waters of the East Icelandic Current. In July-August, herring were feeding on young Calanus and Themisto.

In September-October 1958, Salpa fusiformis appeared in the Norwegian Current for the first time since the beginning of our investigations; herring also fed on this species. In June-July, in the Faroe and Iceland areas herring fed on young fish which constituted about 35% of the weight of the food.

Stomach samples (Table 1) were collected in the fishing areas during all the years: in March off the Norwegian coast; in April-September in the East Icelandic Current area and in the Jan Mayen area; in October-December to the north of the Faroes (in the wintering area of herring).

In June-July 1958, the average indices of stomach content were high: 101.8 and 84.1 prodecimille (Table 3). In 1958, the period of herring fattening lasted from June to August (Table 3).

In 1958, herring reached the highest fat content by August, the average grade of fatness being 2.76, while in September it was 2.35. These are the maximum values of herring fat content for recent years (Tables 1 and 2).

Alekseev and Istoshin (1960) characterize the year of 1959 as a warm year in the central and southern parts of the sea and as a cold year in the West Spitsbergen Current and in the northern branch of the Irminger Current.

In 1959 the fattening of herring began at the end of March. On the Viking Bank about 60% of herring were feeding at that time.

But in March the plankton biomass was very low, the development being hampered by frequent storms. Therefore the maximum development of phytoplankton and Calanus was observed in May. As in previous years, herring migrated from the Norwegian coast westwards to the polar front area where they continued feeding. Their diet consisted of Calanus finmarchicus of stages IV-V-VI, C. hyperboreus, Metridia longa and euphausiids. According to Timokhina, the development of Calanus in the western branch of the Norwegian Current in the spring of 1959 was on average a month behind that of the eastern branch. Red Calanus (Calanus finmarchicus of stages III-IV-V) appeared in the western branch and adjacent waters as early as June. The main components of the herring food were: Calanus finmarchicus of stages III-IV-V, euphausiids, Oikopleura sp. and Themisto.

As a result of the earlier arrival of red Calanus in the western parts of the Norwegian Sea in comparison with 1958, the herring reached the highest average fatness as early as July-August (2.22; 2.31; Table 2).

The heating of the waters of the western branch which started in 1959, was continued in 1960. In 1961, the heat supply in the western areas was considerably lower.

According to the data obtained by PINRO, 1960 appeared to be the warmest year, even compared with the rather warm years of 1954 and 1959.

In 1960 the spawning of Calanus finmarchicus was observedas early as mid-March in the Lofoten area. An early and rapid development of plankton was promoted by the early spring and favourable hydrometeorological conditions (fine weather, almost no storms).

Due to a more rapid development of Calanus finmarchicus, its abundance in the Lofoten area at the end of April 1960 was six times higher than at the same time in 1959 (Table 4).

The early onset of spring was simultaneously observed in the western part of the Norwegian Sea where in 1960 the spawning of Calanus finmarchicus also took place in April.

In previous years the herring of the Faroese waters fed in April on adult pre-spawning Calanus finmarchicus and euphausiids.

In 1960, in the same area and in favourable temperature conditions herring did not feed on the pre-spawning concentrations of plankton but on the juvenile stages.

As a result the plankton biomass was much lower which influenced the fattening of the herring. In April 1960, the average stomach content of the herring in the Faroe area was 0.33 and appeared to be lower than in 1959 when it was 1.43.

The early spawning of Calanus in the south-western areas was a result of a considerable heating of the western branch and adjacent areas. In April 1959, the mean temperature in the 50-0 m layer (section along 67°30'N) in the western branch was 5.26°C, while at the same time in 1960 it reached 6.27°C, i.e. it was almost on the same level as in the Lofoten area in the eastern branch of the Norwegian Current. High water temperature (6.28°C) also prevailed in April 1961 in the western branch of the central areas of the Norwegian Sea (section along 67°30'N).

In recent years the section along 65°45'N has been warm and in April and June the following temperatures were observed in the 50-0 m layer:-

	1959	1960	1961	
April	3.28	4.39	4.45	Mixed waters of the East Icelandic Current
June	7.5	8.68	7.73	Western branch

An accelerated development of Calanus finmarchicus accompanied by a rise in water temperature has been observed by many scientists (Ruud, 1929; Sømme, 1934; Marshall and Orr, 1955; Lebour, 1916; Nicholls, 1933; Kamshilov, 1952).

Accordingly, a drop in water temperature caused delay in the development of Calanus finmarchicus which we have noted in recent years in a number of the Norwegian Sea areas.

In 1960, due to the increased influx of warm water along the western branch, Calanus finmarchicus developed both in the eastern and western parts of the Norwegian Sea approximately in the same terms. But as in previous years, herring migrated in April westwards where in 1960 they chiefly fed on red Calanus and in May-June their stomachs were full (Tables 1 and 5). As a result, by June-July 1960, the maximum fat content for that year was reached (2.8-2.11). From August the fatness of the herring began to decrease. It is

connected with the fact that in warm years early developed red Calanus provides an earlier intensive fattening of the herring which effects a further feeding of the herring in the following summer-autumn period. Thus, in the summer of 1960 during the outburst of the phytoplankton blooming herring reacted feebly upon the presence of planktonic food and began to spend the fat in their internal organs much earlier in comparison with previous years. In 1958 and 1959, the decrease in the fat content of the herring started in October and September respectively (Table 2).

In warm years in many areas early developed Calanus was descending as early as June-July as the heating of the upper layers advanced. A great number of Aglantha digitale appeared. In cold years Calanus develop slower and medusa appear much later.

The year of 1961 was warm, although the onset of the biological spring in the Norwegian Sea then began later than in 1960. Calanus near the Lofoten developed somewhat later compared with 1959 and 1960 (Table 4). Early stages of Calanus finmarchicus dominated (copepodite stage I made up 67-40%) at the end of April 1961.

Soviet scientists (Pavshtiks, 1956, 1960; Gruzov, 1960, 1961) established that herring feed on the spring and spring-summer plankton communities. Following the movement of the biological spring, herring migrate into the mixed waters and afterwards into the polar areas where the spring plankton communities are present for a longer time than in the Norwegian Current waters.

Spring and spring-summer communities were present in the mixed waters of the East Icelandic Current (Gruzov, 1961) from June to August (65°45'N) and from June to October (67°30'N). In 1958-1961 the main fattening of herring took place in these areas.

The fattening always begins in March-April on the spawning grounds off the Norwegian coast. In the spring of 1961 it was rather weak. In March-April 1961, plankton was very poor (Table 4) in the area of the Norwegian Shallows, causing a poor content of the herring stomachs (0.13; 0.66; Table 1). As in 1960, herring fed on red Calanus (stages III-IV-V), Themisto abyssorum and euphausiids in the mixed waters near the Faroes in May-June 1961. The average fullness of herring stomachs in May 1961 was somewhat lower than in 1960 but higher than in 1959 (Table 1).

In July and August 1961, the bulk of herring was feeding in the Icelandic waters where all the plankton organisms were suitable as food for herring and the biomass reached 0.50-0.70 ml/m^3. By July, the herring had become fat (2.11). In 1959 herring became fat approximately at the same terms.

In 1961 the concentrations of herring in the mixed waters of the East Icelandic Current and near Jan Mayen, i.e. the usual feeding areas, decreased appreciably in spite of the fact that in 1958, 1959 and 1961 the average amount of plankton was approximately the same (Table 5). This amount was enough to fatten the herring rapidly. In 1961, the plankton organisms were twice as numerous as in the above-mentioned years (0.95 m^3).

In recent years (1959-1961), we have observed a reduction in the feeding areas of older herring that may be explained by the following: (1) by a decrease of the numerical strength of adult herring; (2) by improved feeding conditions in May-June in the mixed waters of the East Icelandic Current. This improvement of feeding conditions in the spring of 1959, 1960 and 1961 depends on an earlier development of young Calanus there.

The plankton development was affected by the rise in water temperature caused by an increased influx of warm waters into the area along the western branch of the Norwegian Current.

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Table 1

Index of average fullness of herring stomachs

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total no. of fish
1958	-	0.14	0.06	0.83	0.46	1.46	0.67	0.74	0.29	0.58	0.17	0.05	8,186
1959	0.04	0.18	0.52	1.43	0.98	0.78	1.04	0.68	0.16	0.01	0.05	-	29,579
1960	0.06	0.21	0.35	0.33	1.70	1.39	1.22	0.87	0.64	0.57	-	-	11,550
1961	0.26	0.06	0.13	0.66	1.33	1.41	1.57	1.31	0.91	0.32	0.15	0.09	11,975

Table 2

Mean degree of fatness of herring

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total no. of fish
1958	-	0.03	0.23	0.48	0.27	1.47	1.16	2.76	2.35	1.35	0.78	0.50	8,186
1959	0.25	0.16	0.29	0.73	1.50	1.91	2.22	2.31	1.87	1.68	0.65	0.57	29,579
1960	0.31	0.16	0.20	0.89	1.00	2.08	2.11	1.87	1.77	0.65	-	-	11,550
1961	0.32	0.01	0.04	0.58	0.59	1.60	2.11	1.69	1.97	1.16	1.17*)	1.56*)	13,000

*) In November-December 1961, the average fatness increased (compared with previous years) due to an increased abundance of small fat herring of the 1959-1960 year-class in the fishing area.

Table 3

Index of average fullness of herring stomachs by months (in prodecimille)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1958	-	-	-	28.7	28.8	101.8	84.1	14.4	6.50	17.2	6.4	1.12
1959	-	-	24.27	116.58	26.50	43.16	28.32	7.72	5.26	-	-	-
1960	-	12.7	134.11	37.75	-	24.36	33.85	12.68	12.36	27.69	76.02	2.40
1961	25.79	7.76	17.98	14.99	39.69	27.56	44.43	41.80	49.56	-	10.23	4.64

Table 4

Age composition of the population of Calanus finmarchicus in April 1959, 1960 and 1961 near the Lofotens (50-0 m)

Stations	Copepod stages	24. April 1959 spec./m^3	%	27.-28. April 1960 spec./m^3	%	24.-25. April 1961 spec./m^3	%
1. 67°30'N 11°30'E	I	145	38.7	1,000	21.9	56	67.5
	II	120	32.2	1,500	32.8	14	16.9
	III	63	16.6	1,600	35.2	9	10.9
	IV	35	9.5	440	9.6	1.6	1.9
	V	6	1.5	25	0.5	0.4	0.4
	VI	6	1.5	-	-	2	2.4
Total		375	100	4,565	100	83	100
2. 67°30'N 10°30'E	I	220	31.4	200	3	60	37
	II	220	31.4	880	13	60	37
	III	180	25.6	2,000	30	27	16
	IV	75	10.7	2,800	42	10	6
	V	5	0.7	800	12	1	1
	VI	1	0.2	-	-	5	3
Total		701	100	6,680	100	163	100
3. 67°30'N 9°30'E	I	85	38	314	9	97	41
	II	40	17.6	940	28.4	75	32
	III	75	33.4	1,220	36,8	40	17
	IV	10	4.4	640	12.3	11	4.8
	V	5	2.2	200	6.1	5	2
	VI	10	4.4	5	0.1	8	3.2
Total		225	100	3,319	100	236	100
67°30'N 6°44'E	I	-	-	8	9.5		
	II	1	0.4	15	17		
	III	1	0.4	8	9.5	No samples	
	IV	-	-	7	8		
	V	10	4.4	10	12		
	VI	215	94.8	37	44		
Total		227	100	85	100		
5. 67°30'N 6°00'E	I	-	-	3	4.3	6	5.5
	II	3	2	10	14.3	2	2
	III	-	-	10	14.3	1	1
	IV	10	7.6	14	20	35	31
	V	27	21.2	11	15.7	6	5.5
	VI	90	69.2	22	31.4	61	5.5
Total		130	100	70	100	111	100

Note: The plankton samples were analysed by Milcykovsky (1959) and Degtyaryova (1960-1961).

Table 5

Average amount of plankton in the 50-0 m layer in June 1958, 1959 and 1960 in the feeding areas of herring (Faroe, East Icelandic Current and Jan Mayen areas)

	1958	1959	1960	1961
Number of stations	24	84	69	36
Average amount of plankton (ml/m^3)	0.48	0.51	0.95	0.46
According to the data of 'herring meetings'	Soviet data	Soviet, Danish, Norweg., Icelandic data	Soviet, Norweg., Icelandic data	Soviet data

Note: Limits of the feeding areas of herring were considered to be: section Langenes-Jan Mayen in the west and 4°W in the east; the Faroe-Iceland section in the south and 71°10'N in the north.