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Some results of the Norwegian capelin investigations 1960-65

by

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1. Introduction

The capelin is a very important member of the fish community of Arctic waters. In the Barents Sea it is one of the main food organisms for cod and other fish, and fluctuations in its abundance and distribution are therefore affecting the commercial fisheries to a marked extent.

The Barents Sea capelin are spawning during early winter and spring at the northern shores of Russia and Norway, and as yet, only during this period is the capelin itself being commercially exploited. Notably in Norway the capelin fishery has in postwar years developed rapidly with landings in 1961 and 1965 of nearly 220.000 tons, and with a record catch of 390.000 tons in 1966. (Table 1).

The chief method of fishing is purse seining, but in the most recent years one- and two- boat pelagic and semi-pelagic trawling has become of some importance.

The annual yield of the Norwegian capelin fishery has varied rather widely because of great fluctuations in abundance and availability of the capelin, as well as in time and duration of the fishing season. In 1960, therefore, the Institute of Marine Research, Bergen, started a program of capelin investigations with the aim of establishing the causes of these fluctuations, and, if possible, making prognosises of the catch.

Each year in February-March, and in late summer and fall, research vessel surveys have been carried out in the Barents Sea. The work has included sonar and echo-sounder searching, sampling with mid-water trawls and making hydrographic obsevations.

Since the season of 1961 extensive sampling of the commercial landings has been carried out, and a record of the material of otoliths and length measurements is given in Table 2. The data also

includes fairly complete and detailed catch statistics for the last decade and yearly records since 1868 of the time of arrival and locality for the first spawning runs.

2. Observations on the distribution of the 0-group

During the summer and fall surveys numerous observations of 0-group capelin have been made. However, prior to 1963, when a more systematic program for the study of fish fry distribution was introduced (Dragesund and Olsen 1965), the observations were rather casual and samples were few.

The 0-group capelin are during summer and fall pelagically distributed in the top layers of water. Together with other pelagic fish fry and macro-plankton organisms they form scattering layers or groups. This facilitates hydro-acoustic location and mapping (Dragesund and Olsen loc. cit.), and samples are readily obtained with a suitable mid-water trawl.

In September 1960 capelin fry were found in abundance in the Hopen Island area. No fry were caught east of the 40° longitude, but scattered concentrations were observed on the Central Bank, on the Thor Iversen Bank, to the north of Skolpen Bank, and at Bear Island.

Very few capelin fry were taken during the 1961 survey, but this was, at least partly, due to the loss of the fine meshed trawl at the start of the cruise.

In 1962, the eastern part of the Barents Sea was declared nuclear test area at the time of the survey, and consenquently closed for civil traffic. In the western part very few capelin fry were observed.

In 1963 capelin fry were distributed over a wide area to the west of Novaya Zemlya (between 45°E and 51°E), but none were found in the central, western and north-western areas.

The 1964-survey yielded hardly any capelin fry, except some few specimens which were all taken in the south-eastern and central parts of the Barents Sea.

The Joint Soviet-Norwegian Barents Sea Investigations in September 1965 (Anon. 1965) showed that capelin larvae were centrally distributed from the North Cape to 41°E. Most certainly the total abundance was much larger than in 1964, but the data for the previous years does not justify a comparison in this respect.

Scanty as these observations are, they nevertheless clearly show that great variations do occur with regard to both abundance and distribution of the 0-group capelin. It is conceivable that the distribution as determined in August-September is greatly influenced by the time and area of spawning, and, as will be discussed later, these two factors may also significantly affect the survival rate of the larvae, and thus become major causes of the fluctuations in year-class strength.

3. Distribution of immatures and adults during the feeding season

In September 1960 one, two and three year old capelin were found to be concentrated along the cold/warm water borders. The adult, maturing capelin were especially abundant in the Hopen Island area, while the younger, immature fish were also found further east and at the south-east edge of the Central Bank. All size groups were feeding heavily on euphausiids and they were in a very fat condition.

In 1961 the capelin appeared to be very sparsely distributed over large areas north of about 75°N, and no clear, simple relationship between distribution and temperature was established. Only in the north-western areas, near the ice edge more dense concentrations were occasionally located. This year the capelin were rather lean.

No investigations were in 1962 carried out east of the 35th° longitude. Concentrations of both immature and adult capelin were in August and September located in restricted localities to the east and south of Hope Island. Similar to what was observed in September 1960 these concentrations were found in areas of great horizontal temperature gradients, but the total abundance in the Hopen Island area was evidently smaller in 1962 than in 1960.

During the 1963 survey some small schools of capelin were observed at the south-western tip of the Central Bank, but apart from these, hardly any capelin were located, in spite of a very extensive survey of the entire area from Bear Island to Novaya Zemlya.

Also in 1964 the August-September survey covered the major part of the Barents Sea, as well as the western Bear Island and Spitsbergen banks. However, only very few capelin were found, some north of the Skolpen bank and some to the south-west of the Central Bank. These capelin were mixed with the fish fry found in the top layers of water, where temperatures ranged up to 9.5°C.

The Joint Soviet/Norwegian Barents Sea Investigations in September 1965 yielded scattered observations of immature and adult capelin

in the north-eastern part of the area covered i.e. between Hopen Island and Novaya Zemlya, but no-where were capelin recorded in dense concentrations.

4. The spawning migration

According to Prokhorov (1965) in late November the adult capelin start to concentrate in the central part of the Barents Sea to commence the spawning migration. In order to gain more knowledge about this pre-spawning phase, which might throw some light on the mechanism behind the great fluctuations in spawning time and area, in November 1962 and 1963 special surveys were carried out. The results were rather poor, hardly any capelin were found.

In November 1965 another attempt was made, and this time large concentrations of maturing capelin were observed along the southern edge of the Central Bank and also in the Hopen Island area (Olsen 1966).

Since the season of 1961 research vessel surveys have been conducted immediately prior to and during the spawning season (i.e. in February and March). Much information about the distribution of the spawning stock is also deduced from the records of the capelin fishery, for which detailed statistics of catch and locality are available for the post-war period.

It appears that in most years there are separate spawning runs which may approach the coast in different localities. Thus, in 1961 there were three independent influxes, the first of which came in the middle of February at the North Cape. The second spawning run struck land in the first week of March at Vardø on the Varanger peninsula, and the third batch came in the beginning of April to the northern shores of the Varanger peninsula. In most cases, however, the capelin comes first to the Varangerfjord, and during the following weeks there is always a movement in westerly direction along the Finnmark coast.

The date of the first spawning run at the Norwegian coast has in this century varied between the beginning of February and the end of April, and nearly always has an early arrival of the capelin been associated with a westerly distribution, and vice versa. During the period 1938 to 1942 and again in 1962 no capelin came to the Finnmark coast, and the available information suggests that in these years there was an extreme easterly distribution of the spawning area.

The approach towards the coast in such an extreme year was closely watched in 1962. At the beginning of March numerous schools of capelin were recorded in the Goose Bank - Prestneset area. There was a slow movement in south-westerly direction during the next four weeks, and at the same time disintegration and dispersal of the schools

was observed. Some spawning apparently took place at and off the coast, in the Kildin - Cape Teriberski area, but no schools of capelin were ever located west of the Kildin Bank.

Little is known about the causes of the great variations in spawning area and time, but there is evidence to support the theory of environmental factors, for instance temperature, being of major importance; i.e. in years of high water temperatures the capelin are spawning mainly at the Russian coast and vice versa. However, the temperature at the coast does not seem to be the sole and decisive cause.

According to Pitt (1958), capelin in Newfoundland waters are rather tolerant with regard to spawning temperature, and this is also apparent from our observations of the Barents Sea stock. Thus, the temperatures at the Finnmark caost during the 1961 season ranged between approximately 2.5°C and 5°C, whereas in 1962 the capelin was spawning in an area where temperatures probably did not exceed 2.5°C.

Already Hjort (1914) suggested that also ice and temperature conditions in the eastern and northern Barents Sea, prior to the spawning season, as well as the conditions at the coast at the time of spawning, may be of decisive influence on the choice of spawning locality. Hjort further reported that there is a general experience of a subsequent good fishing season at the West-Finnmark coast when capelin the previous summer have been observed in abundance at Bear Island, while in years with an easterly summer and fall distribution of the capelin the best fishing will occur at the East-Finnmark coast.

The distribution during the feeding season is probably a result of a number of factors such as, temperature, currents, the abundance, concentration and composition of food organisms, as well as the composition and total abundance of the capelin stock itself. It may, therefore, be concluded that the spawning run and spawning area of the capelin is determined by the sum of all the abiotic and biotic environmental factors which are, and have been for some time, affecting the spawning stock, rather than merely the hydrographic conditions at the coast during the time of spawning.

5. Age and growth

The samples from purse seine catches taken in August - September in the Hopen Island area vary considerably with regard to size, age and probably also sex composition. This shows that also capelin, similar to what is apparent in other pelagic species, are forming schools which may be fairly homogeneous with regard to distribution of size, age etc., and during the feeding season schools of different compositions may be present in the same locality. Furthermore, the material

indicates that, within a larger area, e.g. the main feeding area, the frequency occurance of the different types of schools may very well vary in a systematic fashion. Consequently, the problem of sampling the stock during this stage, when no commercial fishing is carried out, is rather difficult.

The available material collected during the feeding season does not in any one season cover the entire area of distribution, the samples being mainly derived from localities where fishable schools of capelin were observed. The data, therefore, does not suffice for reliable estimates of relative year-class strength, sex proportions, percentage maturity of the different age groups, and similar parameters.

Great caution should also be exercised in the analysis of the available growth data. Thus, in the samples from August-September 1961, the only season for which data from a substantial part of the feeding area is available, (Møller and Olsen 1962), a clear trend is apparent of an increase in mean size at age with increasing latitude (Table 3). In other words, the largest and most fast-growing fish of a year-class seemed to be distributed farthest to the north where the maturing capelin at that time appeared to be most abundant.

On the other hand, in November 1965, at the time of the formation of pre-spawning concentrations, the more slow-growing, immature capelin of the 1963 year-class were dominating in the northernmost samples, while the southernmost schools mainly consisted of large maturing fish of the same year-class (Olsen 1966), Consequently, the observed length distribution and estimated mean length of an age group is greatly dependant on the area and time of season from which the samples are derived.

Fortunately, in the spawning stock at the time of arrival to the coast, there seem to be little variation in size and age distribution, with the exception of the latest females to arrive, being in general somewhat younger and smaller than those coming in to spawn early in the season. For the males no such trend is apparent.

Table 4 gives a record of the percentage age distribution and mean length at age in the spawning stock from 1961 to 1965. From this and the data published by Prokhorov (1965) it is evident that the Barents Sea capelin spawn mainly at ages 3, 4 and 5, and the lack of older fish strongly indicates a very heavy post-spawning mortality. This is confirmed by the regular observations towards the end of each spawning season of masses of dead capelin drifting afloat.

Templeman (1948) and Prokhorov (1960) have reported observations suggesting that at least some capelin do survive to spawn for a

second time. Similar observations, of spent females maturing for another time, were made in August 1961 during a cruise with the R/V "G.O.Sars" to the Hope Island banks.

However, the available age and length data strongly suggests that the age of maturity is greatly affected by growth. Thus, the fast-growing fish may attain maturity at an age of 3 and some already as 2-year olds, while those fish for which the growth is retarded may not spawn until they are 5 years of age. In fact, the mean length of the 4-year olds is not much different from that of the 5-year olds of the same year class, and for the 1957 year-class it was even greater in the case of the males. Furthermore, the rich 1962 year-class which dominated the fishery in 1965, was of little importance in the present spawning stock, and similarly, according to Prokhorov (1965) the 1954 year-class which made up nearly 80 per cent of the spawning stock in 1957 was practically extinct the following year. All this suggests that post-spawning survival and repeated spawning is for all practical purposes negligible, and the changes in age distribution which do occur are mainly a result of variations in year-class strength and maturity age.

Table 5 gives a record of the deviations from the mean in length at age pf the spawning stock for the years 1961 to 1965. Negative deviations are particularly high in 1963 and 1964 when the abundance of the spawning stock was very low, while the rich years of 1961 and 1965 are marked with an above average length at age. There is thus a positive correlation between growth and abundance, indicating that the number of capelin which eventually attain sexual maturity is dependent on the general living conditions during the juvenile phase as well as on the initial year-class strength.

6. Fluctuation in abundance

Reference has already been made to the frequently occurring variations in stock abundance. Conventional methods for abundance estimates based on catch and effort statistics proved to be unapplicable, and the author therefore applied a method based on age distributions alone (Olsen 1965). This method may provide fairly unbiased estimates of relative spawning stock abundance provided no great changes in maturation age occur, and during the period 1959 to 1964 conditions in this respect appeared to remain reasonably steady.

The estimates indicate fluctuations in spawning stock abundance in the order of 1 to 20 or 30, being directly caused by corresponding variations in year-class strength. Observations during the most recent years have confirmed that abundance fluctuations of at least this order of magnitude may occur from one year to the next, and it is

established that the year-classes of 1956 and 1957, and again those of 1962 and 1963 were very numerous, while those of the years in-between were generally low, the 1960 and 1961 year-classes being exceptionally poor. The spawning stock, therefore, being very abundant in 1960, and especially in 1961, in the subsequent seasons declined rapidly, reaching a very low level of abundance in 1963 and 1964, after which it revived suddenly to reach a very high level of abundance in 1965; and most likely a further increase took place in 1966. This was due to the very rich year-classes of 1962 and 1963, which matured mainly at the low age of 3 years.

7. About the causes of variations in distribution and abundance

It is noteworthy that the two most recent strong year-classes (i.e. 1962 and 1963) were derived from very low spawning stocks, and vice versa, the very numerous spawning stocks of 1960 and 1961 produced the poorest year-classes within the period of observation. At a first glance this suggests a sort of peculiar negative stock/ recruitment relationship. The number of years for which paired observations on parent/progeny abundance are available is, however, too small to justify such a conclusion, but the attention is drawn to the following facts which may reveal some of the mechanisms behind the stock size oscillations which seem to occur in the Barents Sea capelin.

The recent rich year-classes (1956, 1957, 1962 and 1963) were all derived from late eastern spawning in relatively low temperatures, and at least in 1962 and 1963 the spawning stocks producing these abundant year-classes were very small. On the other hand the vast number of capelin which in 1960 and 1961 were spawning already in February and March in relatively warm waters, mainly at the western coast of Finnmark and in Troms, produced very poor year-classes. It is further noticed that these early spawners were above average size and in excellent conditions, whereas the 1962 and 1963 runs consisted of very lean capelin of medium or below average size.

It is evident that the pattern of drift and distribution of larvae must be quite different for eastern and western spawning, and since the variations in spawning locality also seem to be linked with changes in spawning time, (i.e. late spawning always being associated with easterly distribution), this may further aggravate the year to year differences in living conditions and subsequently the survival rate of the larvae.

However, growth rate and age of maturity in post-larval life of capelin may very well vary sufficiently from year to year to be other significant causes of fluctuations in spawning stock abundance.

Thus, some year-classes are spawning mainly at the age of 3 while in others the mean age of maturity is 4 years or more. Furthermore, there is evidence of a generally high growth rate and good condition factor during the feeding season in years of high abundance. The few years of observations so far available also indicate that in such years the distribution is predominantly westerly, in the areas of transition between cold and higher temperature, and ripening of the gonads under these conditions probably progresses quicker than in years when the capelin mainly sojourn in the cold Arctic waters farther north and east. This may go a long way in explaining the apparent link between early and westerly spawning in years of high abundance, but it would be premature at this stage of knowledge to suggest which factor or factors are of primar importance in triggering the whole system.

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Table 1. Norwegian landings of capelin 1950 - 1966.

Year	Total landings in tons
1950	3 924
1951	9 986
1952	9 305
1953	18 780
1954	30 443
1955	42 790
1956	68 122
1957	72 188
1958	91 680
1959	78 997
1960	92 765
1961	217 167
1962	363 *)
1963	28 33[illegible]
1964	19 62[illegible]
1965	217 15[illegible]
1966	391 31[illegible]

*) From experimental fishing in August/September.

Table 2. Record of material 1960 - 1965.

Year	Season	Length	Otoliths
1960	Feeding	1 747	145
1961	Spawning	13 491	2 633
	Feeding	12 189	982
1962	Spawning	4 606	537
	Feeding	5 055	704
1963	Spawning	7 902	1 842
	Feeding	94	74
1964	Spawning	2 620	1 078
	Feeding	134	103
1965	Spawning	5 053	1 948
	Feeding	1 636	648

Table 3. Mean length at age (in cm) in different localities, August - September 1961.

Locality	Year class	1960	1959	1958	1957
	Age group	I	II	III	IV
Hope Island W		10.16	12.55		
Hope Island E		11.63	12.45		
Central Bank NE		11.83	12.45		
Great Bank SW		12.05	13.15	14.96	
Hope Island N		12.45	14.31	15.80	16.86
Great Bank NW		13.18	14.49	16.65	18.37
Average		11.88	13.23	15.80	17.62

Table 4. Percentage age distribution and mean length at age (in cm) in the spawning stock, 1961 - 1965.

		Age									
		2		3		4		5		6	
Season	Sex	%	$\bar{l}$	%	$\bar{l}$	%	$\bar{l}$	%	$\bar{l}$	%	$\bar{l}$
1961	♂			1.2	16.97	94.2	18.76	4.6	19.79		
	♀			4.7	15.76	94.5	17.12	0.8	18.54		
1962	♂			2.0	16.22	63.9	17.30	33.9	18.48	0.2	20.40
	♀			8.4	14.99	66.9	16.06	24.4	17.16	0.2	18.43
1963	♂	0.2	14.42	2.3	15.76	93.5	16.67	4.0	17.95		
	♀	0.1	12.86	7.7	14.50	91.1	15.29	1.1	16.77		
1964	♂	.		1.9	15.91	47.2	17.14	50.9	17.60		
	♀	0.3	13.88	6.5	14.85	58.0	15.82	35.2	16.41		
1965	♂	0.7	16.09	89.6	17.60	9.5	18.25	0.2	19.40		
	♀	1.0	14.65	92.4	16.02	6.0	16.85	0.4	17.71	0.2	

Table 5. Length at age, deviations from mean (in cm), 1961 - 1965

	Age					
	3		4		5	
Year	♂	♀	♂	♀	♂	♀
1961	.47	.54	1.12	.89	1.15	1.22
1962	-.22	-.23	-.32	-.18	-.16	-.16
1963	-.74	-.77	-.95	-.94	-.69	-.55
1964	-.49	-.37	-.48	-.41	-1.04	-.91
1965	1.10	.80	.63	.74	.74	.39