

DISTRIBUTION OF MACKEREL EGGS AND LARVAE IN THE SKAGERRAK, 1957—1959

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INTRODUCTION

The Skagerrak is one of the most important spawning areas for mackerel (*Scomber scombrus* L.) in Nordic waters: the planktonic eggs and small larvae are found in considerable numbers in June—July, especially off the south coast of Norway (EHRENBAUM 1923). The following data on the geographical distribution of mackerel eggs and larvae in the Skagerrak during different parts of the spawning season have been collected between May and July 1957—1959 in connection with a spawning study of sprat (*Clupea sprattus*) and made available by the Marine Biological Station at Flødevigen.

MATERIALS AND METHODS

Samples were collected from the middle of May to the beginning of July with a plankton net 1 m in diameter lowered to a depth of 50 or 100 m and hauled up vertically. On most stations two hauls were made, one A-haul always from 50 m to the surface, and one B-haul sometimes from 50 m, otherwise from 100 m.

In all, 495 hauls were made at 269 stations in the Skagerrak and Oslofjord. In the Skagerrak all stations were outside the skerrygard, but mackerel are known to spawn frequently further inside the fjords as well (DANNEVIG 1948).

Description and sizes of mackerel eggs are given by many authors (e.g. HOLT 1893, BUCHANAN—WOLLASTON 1911, DANNEVIG 1919, EHRENBAUM 1923, BIGELOW and WELSH 1925, DEMIR and ARIM 1957 and HIEMSTRA 1962). Identifications were based mainly on structural characteristics, as well as on size of eggs and of the oil droplet. Eggs diameters vary with the salinity of the waters and the geographical locality: in the North Sea and Skagerrak eggs are reported to be 0.95—1.38 mm in diameter (usually 1.2—1.3 mm), the oil droplet 0.28—0.35 mm. This

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was in general the case with the present material, but a few eggs were found (identified by the embryo) measuring up to 1.45 mm in the brackish Kattgat waters late in the season.

Some eggs without embryo were indistinguishable from those of the ling (*Molva molva*), which according to EHRENBAUM (1905—09) have a diameter of 0.97—1.13 mm, with an oil droplet diameter of 0.28—0.31 mm. However, as the main spawning of ling takes place in April, and as practically no ling eggs with embryo were found, this source of error is probably an insignificant factor in the identification.

Larvae were identified on the basis of descriptions by CUNNINGHAM (1891) and EHRENBAUM (1905—09 and 1923) and measured to the nearest 0.1 mm.

Larvae and, in 1959, eggs from all stations were identified. In 1957 and 1958 the eggs from A-hauls only were identified. From the 269 A-hauls a total of 31,469 mackerel eggs and 2,914 larvae were collected (Table 1).

Table 1. Number of mackerel eggs and larvae in A-hauls.

Year	Date	Number of stations	Eggs		Number of larvae			Total
			Number	Without visible embryo	Total length in mm			
					<4.05	4.05—4.50	>4.50	
	<i>Skagerrak</i>							
1957	21/5—30/5	42	1 268	87%	—	—	—	—
1957	7/6—13/6	21	2 274	82%	7	6	—	13
1958	29/5— 9/6	36	8 505	59%	—	1	—	1
1958	23/6—25/6	22	3 305	62%	218	70	23	311
1958	30/6— 3/7	27	2 576	32%	202	64	53	319
1959	19/5—22/5	27	3 292	38%	7	—	—	7
1959	8/6—11/6	28	9 302	29%	1 329	435	79	1 843
1959	30/6— 2/7	18	237	37%	7	2	3	10
Total		221	30 759		1 768	578	158	2 504
	<i>Oslo-fjord</i>							
1957	23/5—24/5	16	71	18%	—	—	—	—
1958	29/5—31/5	16	141	98%	—	—	—	—
1959	12/6—13/6	16	498	28%	210	176	24	410
Total		48	710		210	176	24	410
Grand total		269	31 469		1 978	754	182	2 914

RESULTS

Table 1 shows the number of stations on different cruises and gives the numbers of mackerel eggs and larvae in various size-classes in the A-hauls. Only 182 (6.2%) larvae were longer than 4.5 mm, probably a result of heavy mortality, known to be 10—14% per day in American Atlantic waters (SETTE 1943), and also of the fact that the larger larvae may be better able to escape the nets (AHLSTRØM and NAIR, cited in MARR 1956).

Depth of eggs and larvae

The eggs and small larvae are free-floating, at a depth which varies according to the density of the waters. Larvae, especially those longer than 5 mm, are known to move to upper layers for the night (JOHANSEN 1925b and SETTE 1943).

No attempt was made to find the accurate depths of eggs and larvae. The following observations, however, may be indicative:

In 1959 there were on the average only a few more eggs and larvae in B-hauls taken from 100 m than in A-hauls (Table 2). This is, however, not definite evidence for the occurrence of eggs and larvae between 50 and 100 m, as wind and current will sometimes lead the net to surface more obliquely from 100 than from 50 m, thus resulting in relatively larger catches from the upper water layers of the B-hauls. The number of eggs in B-hauls was 114% that of A-hauls, larvae in B-hauls 125% that of A-hauls, and the difference between A- and B-hauls was significantly greater ($P < 0.001$) for larvae than for eggs. This might indicate that a few of the larvae (but very few, if any, of the eggs) were taken below 50 m.

If this is the case, net samples taken from 50 m and upwards should be sufficient for investigating mackerel spawning localities.

Spawning period

In the North Sea and Skagerrak spawning takes place from the second half of May and into the month of July with a maximum in June (EHREN-

Table 2. Number of mackerel eggs and larvae from Skagerrak stations in 1959.

	A-hauls 50—0 m	B-hauls 100—0 m	Number in B-hauls as percentage of that in A-hauls
Eggs	9 890	11 289	114.1%
Larvae	2 005	2 499	124.6%

BAUM 1923, JOHANSEN 1925a, REVHEIM 1951 and DANNEVIG 1962); the earliest record along the Norwegian coast is 14 May (DANNEVIG 1948). Cases of very late spawning are known from British waters where the peak occurs in May—June (ALLEN 1917, LEBOUR 1918, CLARK 1920, CORBIN 1947 and STEVEN 1949) but from the present data nothing can be said about the conditions after 3 July.

Mackerel eggs were found on all cruises, i. e. from 19 May to 3 July. In 1959 great quantities were found as early as 19—22 May (an average of 122 per haul), and as many as 62% had visible embryos (Table 1). That year the first larvae were found on 22 May off Lindesnes, all in the egg-sac stage. In 1957 eggs were also collected late in May (21—30 May, 30 eggs per haul, 13% with visible embryos), but no larvae were found at any of the many stations investigated. In 1958 the first cruise was from 29 May to 9 June, and a great number of eggs, but only one larva, was found. These data indicate that in 1959 heavy spawning started as early as the middle of May, in 1957 and probably also in 1958, in the last days of May.

In 1957 there was no cruise after 13 June. In 1958, around the first of July, the average number of eggs and larvae per sample was 95 and 12 respectively. Greatest averages per haul (332 eggs and 66 larvae) were taken about 10 June 1959; around 1 July of that year the average had fallen considerably (to 13 eggs and 0.6 larvae), indicating that in this year with an early start, spawning was practically over at the beginning of July.

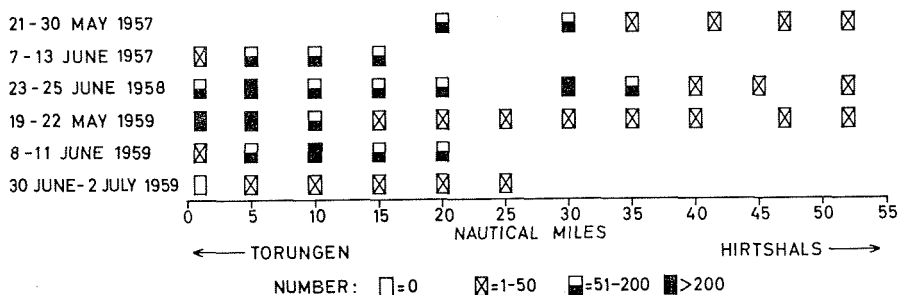


Fig. 1. Number of mackerel eggs collected in A-hauls on different cruises from Torungen, Norway to Hirtshals, Denmark.

Spawning area

Mackerel eggs were found at all localities, in all parts of the Skagerrak.

Figure 1 shows the number of eggs collected on different cruises from Torungen off Arendal to Hirtshals. Early in the season large quantities were found mainly off the Norwegian coast, (e.g. 19—22 May, 1959)

but later great numbers were found further out as well; few eggs were ever taken off the Danish coast.

The data as a whole show the same tendencies, with the largest quantities of eggs found along the Norwegian and Swedish Skagerrak coast, especially between Jomfruland (Kragerø) and Väderøbod. The greatest number in one haul (937) was taken 4 nautical miles south of Ferder Light (Tønsberg) on 11 June, 1959.

From cruises in the Oslofjord, the only significant quantities of mackerel eggs or larvae were collected in 1959, off Drøbak. In the inner fjord the number was always negligible.

As the eggs float passively, a study of this type cannot indicate exactly where spawning has taken place. However, as hatching probably takes about one week in natural conditions (WORLEY 1933 and SETTE 1943) even the oldest eggs had not been adrift for more than a few days. Along the Norwegian coast Baltic Water runs westwards near the surface, with lowered salinity in the spring owing to the melting of snow. In late spring and summer this water is warmer than the surrounding waters, and in summer it spreads out over the Skagerrak as a result of its low specific gravity (DANNEVIG 1933 and SCHULZ 1940).

As mackerel usually spawn near the surface (DANNEVIG 1962) and as the eggs and larvae are usually found in the Baltic Current, it seems a fair assumption that spawning also takes place mainly in this current, but further "upstream" than the localities registered for the eggs and larvae.

Temperature

According to DANNEVIG (1962) mackerel generally spawn in waters of about 12°C. The eggs found earliest in the Norwegian part of the Skagerrak occurred at a temperature of 8° (DANNEVIG 1948). From other waters the main bulk of spawning seems to take place from 11° to 14° (JOHANSEN 1925a, GALL 1939, SETTE 1943 and KÄNDLER 1954), with extremes in American Atlantic waters of 7.3—17.6°C (SETTE 1943). Spawning is thus not "restricted to any fixed degree of temperature" (EHRENBAUM 1923b, p. 6).

To characterize temperature conditions at the different stations the average temperature at a depth of 0 and 10 m is used as spawning is believed to occur in the upper water layers (DANNEVIG 1962), at least early in the season.

According to Table 3 the highest concentrations of eggs prior to 11 June were found in the warmest areas of the Skagerrak. The same tendency was noted also on individual cruises, in May at least; later, in the summer water temperatures were evidently high enough in all parts of the sea.

Table 3. Number of mackerel eggs collected per haul in relation to water temperature. (The cruise of 30 June to 2 July 1959, is excluded (average temperature 14.2°) as no station had more than 50 eggs).

Date	≤ 50 eggs			51—200 eggs			> 200 eggs		
	Number of Stations	Temperature		Number of Stations	Temperature		Number of Stations	Temperature	
		Mean	Extremes		Mean	Extremes		Mean	Extremes
19/5—11/6	67	9.9	8—12.5	41	10.9	9—13.5	47	12.9	9.6—15.9
23/6— 3/7	16	14.8	13—17.3	25	14.4	11.7—16.7	8	13.5	11.3—15.9

Hauls of over 200 eggs were, with one exception, all taken between 10° and 16°C. Only 6 hauls of 51—200 eggs were made in waters below 10° (3 of them at stations where even the maximum temperature was below this). Thus it seems probable that spawning takes place mainly between 10° and 16°C.

Salinity

Mackerel usually spawn in waters with a salinity of about 34⁰/₀₀ (FARRAN 1939, FURNESTIN 1939 and GALL 1939); in the Skagerrak and Kattegat the eggs are seldom found in waters whose salt content is less than 26⁰/₀₀ (NILSSON 1914).

Table 4 shows the number of eggs collected in relation to salinity given as the average of measurements at 0 and 10 m. In very brackish

Table 4. Number of mackerel eggs collected per haul in relation to salinity in ‰. (East and West Skagerrak — east and west respectively of a line from Risør, Norway to Skagen, Denmark).

Date	≤ 50 eggs			> 50 eggs		
	Number of stations	Salinity		Number of stations	Salinity	
		Mean	Extremes		Mean	Extremes
<i>East Skagerrak</i>						
21/5—11/6	41	28.8	21.4—33.1	54	25.5	20.3—31.6
30/6— 3/7	11	23.9	17.7—29.8	16	25.2	21.3—32.9
Total	52	27.8	17.7—33.1	70	25.4	20.3—32.9
<i>West Skagerrak</i>						
19/5—11/6	26	32.4	28.8—34.4	34	29.4	28.1—33.2
23/6—25/6	6	27.6	26.9—28.4	16	28.0	22.9—29.2
Total	32	30.5	26.9—34.4	50	28.7	22.9—33.2

areas, however, the eggs were probably taken from greater depths and more saline waters than the surface measurements indicate.

In the eastern Skagerrak the upper layers in the spawning centres had an average salinity of 25.5‰, in the western Skagerrak, 28.7‰. Before 11 June salinity was a little lower in the centres than elsewhere.

DISCUSSION

Mackerel usually winter at great depths in the North Sea and Skagerrak (REVHEIM 1955, NEDELEC 1958) and migrate in April—May towards the coast, where spawning takes place in waters which are relatively warm and of low salinity.

Comparing the Skagerrak with other areas, where mackerel move from the coast in spring, STEVEN (1948) suggests that this "spawning" migration is primarily directed towards deeper waters. Although this may be true in part, it is possible that, in the Skagerrak at least, the mackerel are migrating to those parts of the sea where temperature conditions are most suitable for spawning. In the Kattegat the numbers of spawning mackerel seem to be dependent on the strength of the in-running current (JENSEN 1960), indicating that still other factors, such as deep-water currents and hydrographic conditions, may influence the migrations.

In 1959 spawning apparently started earlier than in 1957 and 1958, and, according to Table 5, May temperatures in coastal waters were higher in 1959 than in the two preceding years, indicating a relationship between high May temperatures and early spawning. The commencement of spawning probably also depends on other factors such as winter temperatures (STEVEN 1949), and in some years a region of cold water just below the surface might inhibit mackerel from coming to the upper layers (DANNEVIG 1952).

Table 5. Average temperature at sea surface in the month of May.

Locality	Author	1957	1958	1959
Flødevigen, Norway	G. DANNEVIG pers. comm.	9.1	7.1	11.1
Anholt, N. Denmark	THOMSEN 1959, 1960, 1961	9.2	8.3	11.1
"Vinga", Sweden	JERLOV 1959 and SVANSSON 1960, 1961	9.1	8.3	11.2

SUMMARY

Numbers of mackerel eggs and larvae collected from 495 vertical hauls at 269 stations in the Skagerrak and Oslofjord, 1957—59 are analysed.

Eggs were found in practically all areas of the Skagerrak during the sampling period: from the middle of May to the beginning of July.

A few larvae, but very few if any eggs, were probably taken from below a depth of 50 m.

Early in the season spawning seems to take place mainly in the comparatively warm waters of low salinity in the Baltic Current. In 1959 spawning started about mid-May, in 1957 and 1958 in the last days of May; in 1959 May surface temperatures were higher than in the two preceding years. Spawning seems to take place mainly in water temperatures of 10—16°C.

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