International Council for
the Exploration of the Sea

C.M. 1980/J:14
Baltic Fish Committee

An investigation of Baltic herring (*Clupea harengus membras* L.) spawning grounds in the Askö - Landsort area, northern Baltic proper.

by

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ABSTRACT

In a spawning area survey in the Askö area, northern Baltic proper, undertaken in the beginning of summer 1978, 100 randomly established and sampled transects were studied by diving. Herring spawn was found at 45 of the transects. The eggs were usually found on *Pilayella littoralis*, a filamentous brown algae at the more exposed transects. Eggs were only found down to a depth of 11 m. In a neighbouring oil spill area spawn was found at only 4 out of 20 transects. Of eggs brought to the laboratory for hatching, 54% hatched but only 25% hatched from the oil spill area.

I. INTRODUCTION

In the Baltic Sea the Baltic herring (*Clupea harengus membras* L.) is the most important commercial fish species (Anon. 1978). Although extensively studied for many years little is known about its spawning habits (Lisivnenko 1958, Weber 1970, Rannak 1971). This is unfortunate since spawning ground data is a valuable tool in stock assessment. For example, given the number of eggs deposited in an area it is theoretically possible to estimate the number of spawning fish in the spawning stock provided the fecundity and average number of egg depositions of females are known. It is also possible to estimate hatching success and eventual larval mortality if correct sampling procedures are carried out. Runnstrøm (1941) investigated spawning grounds of Norwegian herring along the Norwegian coast but at present, as far as we know, regular investigations of herring spawning grounds with the aim of stock assessment are carried out only in British Columbia, Canada (Humphreys and Hourston 1978).

The study presented aims at a first, rough picture of the location, distribution and substrate type of spawning grounds used by Baltic herring within the primary research area of the Askö Laboratory (ca. 160 km^2). A comparison between frequency of spawning grounds and hatching success of herring eggs in this area and an area affected by the "Tsesis" oil spill (October 1977) was also carried out.

II. MATERIAL AND METHODS

This pilot study was carried out in the primary area of investigation of the Askö Laboratory (58°49'N, 17°39'E) in the Trosa archipelago about 80 km south of Stockholm (Fig. 1) between May 31 and June 29, 1978. One hundred transects perpendicular to the 3 m depth curve within the area were chosen randomly using the same method and background material as Jansson and Kautsky (1977) in their quantitative investigation of hard bottom communities in the Askö area. Twenty transects were chosen in the oil spill area (Fig. 1).

Two SCUBA divers swam along the bottom on transects from the surface or from the most shallow point down to a depth of 15 m or not further than approximately 400 m horizontally in the direction of the transect if the depth did not reach 15 m. The divers noted temperature, type of vegetation, bottom substrate and presence of herring eggs (dead or alive) and also to which substrate they adhered. The location of the transects are shown in Fig. 1. No quantitative samples were taken.

To compare hatching success between the two areas, eggs attached to *Pilayella littoralis* and *Fucus vesiculosus* were brought to the laboratory and put in a hatching chamber system where eggs from unaffected and affected spawning grounds could be studied under identical conditions. The temperature in the hatching system was kept as close as practically possible to natural conditions. For a closer description of the hatching chamber system and the hatching study see Nellbring *et al.* (in press). The statistical treatment of the hatching samples included chi^2- and the "rank-sum" test (Dixon and Massey 1969).

III. RESULTS

Primary research area

The temperature varied during the investigation period. Maximum and minimum temperatures recorded were 17.9 - 8.0 ^{o}C and 14.6 - 7.0 ^{0}C at the surface and deepest points respectively. Figure 2 shows the average temperature measured for five day periods during the study at the uppermost and at the deepest points where eggs were deposited. It must be noted that the transects were visited in suitable groups with regard to travelling distances and not randomly, but Fig. 2 gives a good idea of the temperature development in the area.

Spawn was found at 45 of the 100 transects but the quantities varied greatly, from single eggs to centimetre thick clumps. Most of the eggs, however, were found in single layers, minor aggregations or singly. Spawn did not seem to cover any large areas but appeared to be deposited more or less patchily in thin layers.

Table 1 shows the frequency of substrates found along the transects for localities both with and without spawn. There are clear indications that spawning sites were more exposed to water movement than transects without spawn. Most of the eggs were found on the filamentous brown algae *Pilayella littoralis* but were also found on *Fucus vesiculosus* and *Ceramium* spp. No eggs were found on rocks, boulders, stones, sand or on soft sediment.

Spawning took place from a depth of about 0.4 m down to a maximum depth of 11 m and visually (Fig. 2) a slight downward shift of the average spawning zone could be noted during the study period although not statistically significant. On average the depth range was 4.7 ± 2 m (st. dev.) to 7.7 ± 2 m (st. dev.). If the presented depth range is representative for the spawning of Baltic herring in this area this means that about 2% of the area of investigation is used for spawning according to the areal distribution of different depth intervals in the Askö area (Jansson and Kautsky 1977).

Comparisons between the primary research area and the oil spill area.

The frequency of transects in which spawning occurred was significantly lower in the affected area, 20% compared to 45% for the reference area ($chi^2 = 3.3$; d.f. = 1, significant at the 7% level) but the number of transects was only 20 compared to 100.

According to the "rank-sum" test (Dixon and Massey, 1969) the average hatching success was significantly different between the two areas. Eggs from the reference area had about double the success rate as those from the spill area, 53.9% and 24.4% respectively. At the most affected transect the average observed hatching success was only 9.8% but according to the "rank-sum" test performed on three different samples from this transect these were also significantly different from each other (Nellbring *et al.* in print). The range in hatching success was very wide for both areas. For the reference area it was 0.05 - 94.3% and for the oil spill area 0 - 54.7%.

IV. DISCUSSION

The investigation was begun in the innermost part (NW) of the Hållsfjärden Bay (Fig. 1) where the temperature was expected to be higher than in the outer parts. According to information from Sjöblom (1963) and Ojaveer and Simm (1975) there were reasons to believe that spawning might start earlier in more sheltered areas where a more rapid temperature increase might be found. The reports of these authors also pointed to an outward and successively downward shift of the spawning grounds following the movement of the suitable temperature gradient. This could not be proved statistically which may be a result not only of the limited study period but also of the relatively few transects visited per time period and their large variations in upper and lower depth limits. However, Fig. 2 indicates such a downward shift. Aneer (1979) showed that newly hatched larvae were found all through the summer until the end of September. With the exception of areas closest to the shore the temperature development in different parts could be expected to be quite similar. Measurements of salinity and temperature at one of Askö Laboratory's regular sampling stations in the middle of the Hållsfjärden Bay pointed to great water exchange during the study period (Aneer, 1979) also reflected in Figure 2. Similar rapid exchanges in the water mass have also been reported by Schaffer (1975) for an autumn period in the same area. The temperature ranges recorded were well in agreement with those reported for Baltic spring spawners by Weber (1970), Rannak (1971), Ojaveer and Simm (1975) and others.

Ojaveer and Simm (1975) reported that Gulf of Riga herring spawn in areas with suitable temperature and where the highest abundance of copepod nauplii is found. According to them this should ensure maximum adaptation to a good supply of food at the period of transition from endogenous to exogenous feeding. In our investigation the abundance of nauplii was not studied directly but from the regular zooplankton sampling programme at the aforementioned station in the middle of the bay no such relationship between number of nauplii and time of spawning could be demonstrated. As no diving was undertaken before

May 31 and no larval sampling programme was carried out it is not possible to prove whether spawn had been deposited earlier in connection with a minor increase in the number of nauplii recorded in the middle of May. In 1976, however, the abundance of herring larvae <10 mm and the abundance of copepod nauplii did not coincide very well (Fig. 3). The nauplii were not abundant until the end of June and thus a mismatch seemed likely. A linear regression analysis with subsequent statistical treatment performed on the correlation between abundance of copepod nauplii and herring larvae <10 mm in length in the Askö area in 1976 (Fig. 3) did not show any significant correlation between the two parameters. No correlation such as reported by Ojaveer and Simm (1975) could therefore be demonstrated. Thus we cannot exclude the possibility that other food items play important roles in the food of young herring larvae in the Askö area. Other organisms such as the rotifers *Synchaeta* spp. were very abundant and displayed a maximum at the end of May and throughout June 1976 (maximum ca. $2 \cdot 10^6$ ind$\cdot$m^{-2}, $\approx$50 000 ind$\cdot$m^{-3}, K. Skärlund, pers. comm.). No significant correlation between *Synchaeta* spp abundance and herring larvae <10 mm could be found for the 1976 material. Lishev *et al.* (1961) reported that Baltic herring larvae fed on Rotatoria only when copepods were scarce.

Barnes and Barnes (1977) discussed the importance of littoral meroplankton species to fish such as herring and showed with examples that nauplii of *Balanus balanoides* in certain areas could make up about 99% of the zooplankton. In the Baltic it is very likely that *Mytilus edulis* larvae, when meroplanktonic might be very important as fish food in accordance with the discussion in their (1977) paper. In June, larve of *Mytilus* sp. are very abundant and have a maximum occurrence in the area. The exact amounts are not known but an average for the total 160 km^2 area of about 3 g C$\cdot$m^{-2}, corresponding roughly to $40 \cdot 10^6$ ind$\cdot$m^{-2}, has been estimated from observed weight changes in the adult population during a couple of weeks (Kautsky, in press). Schnack (1972) reported that larvae of bivalves were found to constitute a considerable part of the food consumed by herring larvae in a southwestern Baltic fjord. He also wrote that the mussel larvae were found at the end of the gut seemingly undigested as a result of their protective shells. The average size of these mussel larvae was 230 μ. This corresponds to the size of *Mytilus* larvae just before settling (ca. 240 μ, prodissoconch-II stage (Lubet 1973, Bayne 1976) when the second shell layer is being secreted. This layer probably makes the larva less digestible. During the estimated three week period from the time of release (ca. 50 μ, trochophora-stage) until the second shell layer is formed *Mytilus* larvae might be a suitable food item for herring larvae.

The quantities of eggs found in the spawning grounds were comparatively small. Nothing approaching the aggregations reported by McKenzie (1964) could be found. The spawn was deposited more or less patchily in thin layers and did not cover any larger areas in contrast to the Pacific herring (*Clupea harengus pallasi* Valenciennes) reported by Stevenson (1962) and Hourston and Outram (1972). For the year 1969-70, they found the average spawning area to be about 1 200 m long and 30 m wide. Rannak (1971) reported on the spawning of Baltic herring in the northeastern Baltic proper and her results seem to agree with ours both with regard to relative density of eggs and to the kind of substrate to which they adhered. The egg deposits reported by Hourston *et al.* (1977) were well in agreement with those found in the Askö area. Runnstrøm (1941) showed that at 32% of his grab stations the roe of Norwegian herring made up less than 1 $cm^3 \cdot m^{-2}$ and at about 50% there were ≤10 $cm^3 \cdot m^{-2}$. He also occasionally found very heavy deposits.

Although no eggs were found on rocks one cannot exclude this possibility. Weber (1970) reported that autumn spawners in the southwestern part of the Baltic often spawned on exposed sand or gravel bottoms sometimes covered by *Zostera marina*. Lisivnenko (1958) showed that Gulf of Riga herring spawned on rocky grounds overgrown by *Mytilus edulis*, *Balanus* sp. and the sea-weeds *Sphacelaria*, *Polysiphonia* and *Furcellaria* between depths of 4 and 17 m. Our recorded depth range, 0.4 - 11 m is well in agreement with his findings and also with those of

Rannak (1971) but compared to the figures of Runnstrøm (1941), 5 - 150 m, it seems very narrow. However, conditions in the Baltic and on the Norwegian coast are not comparable. A longer study period might have shown whether the indicated downward shift of spawning grounds, as discussed above, was significant or not and whether the lower depth limit should be extended further.

The filamentous brown algae *Pilayella littoralis*, which is the dominant substrate for herring eggs, is normally attached to hard substrates down to depths of about 5 m (Kautsky and Wallentinus, pers. comm.). In time much of it is torn loose and transported downwards, forming still living mats. During the subsequent decomposition of dying algae in these mats, oxygen deficiency and H_2S formation is a normal occurrence. Herring eggs attached to these algae run the risk of dying due to lack of oxygen. Only those eggs which happen to be on the top of these mats are able to survive these conditions. Such algal mats were found to smell of H_2S and the mortality of attached herring eggs was locally almost 100%. Deposits of eggs in more exposed areas have a greater chance of survival. Indications that spawning grounds are situated in areas more exposed to water movements have been reported by Weber (1970) and Rannak (1971).

The mean hatching figure for the reference area, 54% is in good agreement with the results presented by Birjukov and Shapiro (1971) for Baltic herring eggs and by Taylor (1971) for Pacific herring eggs in 10 $^{o}/oo$ salinity and in a single layer. At present it is unknown if the affected area normally has hatching results similar to those from the reference area. The oil spill area is somewhat more sheltered from exposure and no previous data exists. As pointed out by Hempel (1971) in connection with Galkina's (1971) study on the hatching success of Pacific herring eggs, one cannot exclude the possibility of an increased mortality of the eggs used in the hatching experiments following the transfer from the sea to the laboratory.

In *Clupea harengus* egg mortality is generally very low (Runnstrøm

1941, Baxter 1971), normally less than 10% (Hempel 1971). As discussed above, the downward transportation of the filamentous algae and their successive decomposition whereby H_2S may form, seems to play a not completely negligible role for the survival of the herring eggs.

In our hatching study (Nellbring *et al.* in print) the presence of fungi on the eggs was noticed in some samples. Oseid (1977) showed the importance of *Gammarus pseudolimnaeus* and *Asellus militaris* as controllers of fungus on fish eggs. *Gammarus* spp and other amphipods and isopods are normally very abundant in the spawning zones (Haage 1975, Jansson and Kautsky 1977) of the Baltic and may play an important role as "health guards" for herring as well as for other fish eggs deposited in the algal belts. Oseid (1977) reported that *Gammarus* sp. probably used some of the eggs as food, causing a 10 - 15% mortality, but at the same time the overall hatching success was higher compared to the control experiments. The lower hatching success observed in samples from the oil spill area could possibly be a result of the absence or reduced abundance of amphipods and isopods noted at the time of spawning (Notini, in press).

Predation on herring eggs by other fish, reported by Runnstrøm (1941), Hempel and Hempel (1971) and Caddy and Iles (1973) is probable although the bottom trawl material dealt with by Aneer (1975) did not give enough evidence about the origin of eggs found except in those cases when sculpin roe was present. Outram (1958) cited in Hardwick (1973) reported predation rates on Pacific herring eggs of between 56 and 99% and birds accounted for the major portion. About 66% of the predation took place within three days after spawning. According to local fishermen in this area, gulls are often regarded as indicators of herring spawning as they seem to gather in the areas where spawning takes place but whether they constitue any predatory factor is not at present known.

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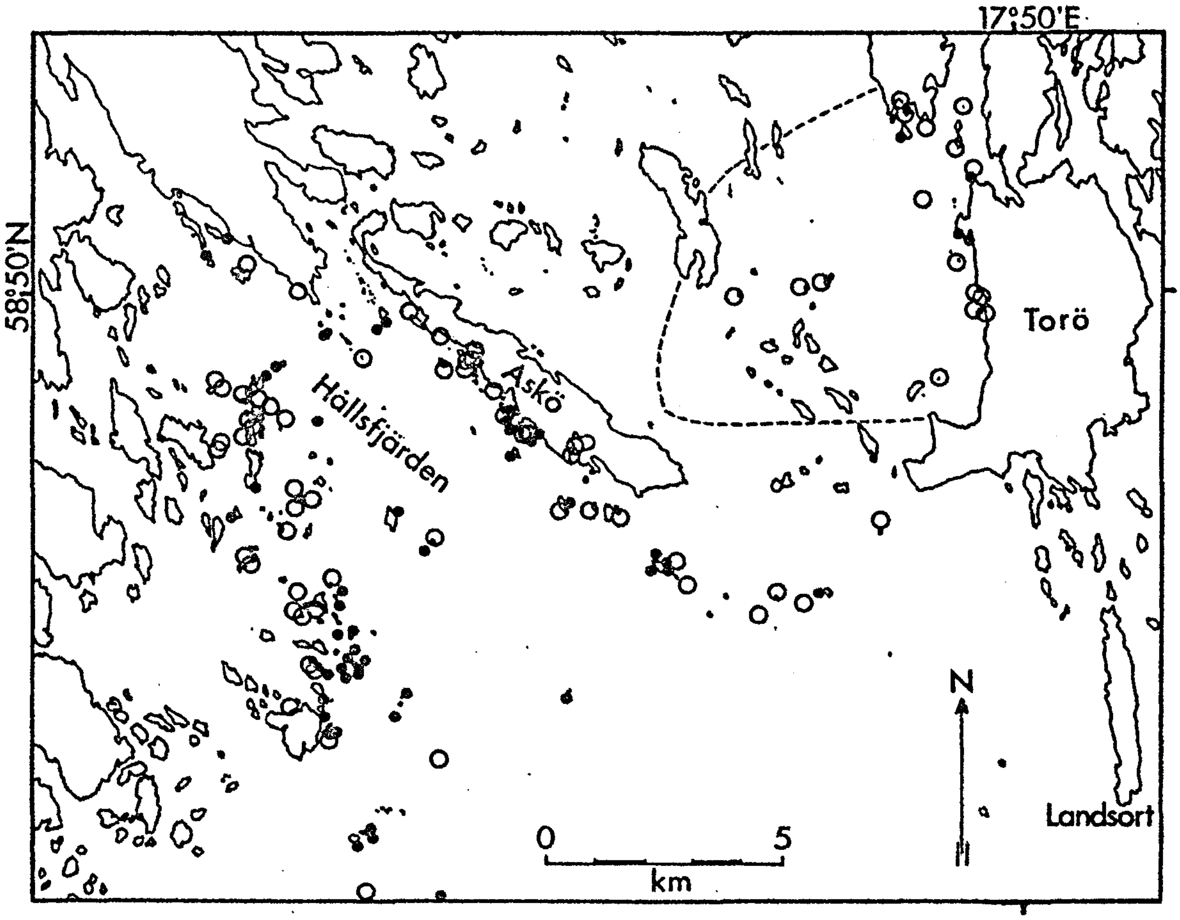

Figure 1. Map showing the herring spawn study area and location of transects investigated. o = transects where no spawn was found. ● = transects where spawn was found. - - - - = border of oil spill area.

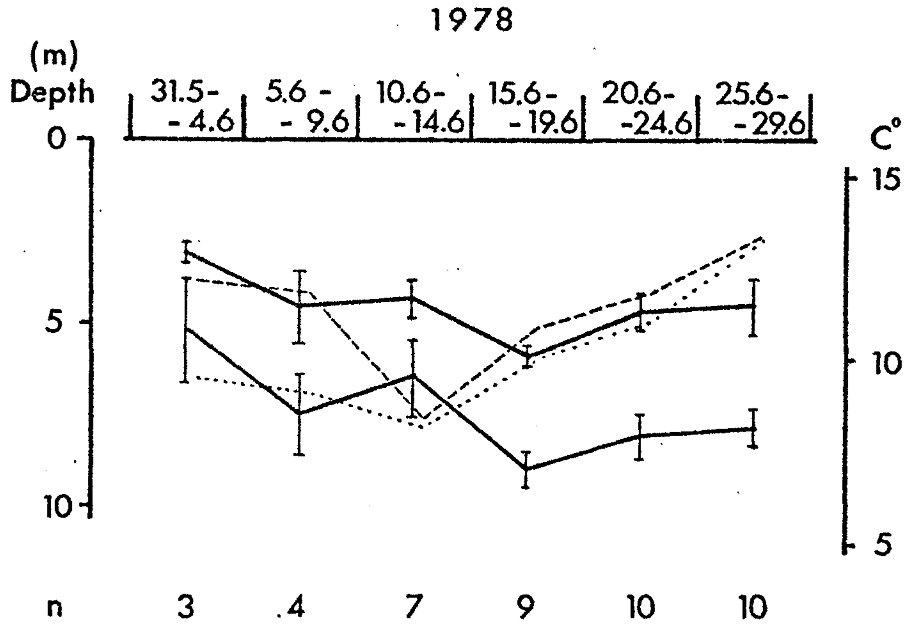

Figure 2. Upper and lower limits for depth distribution of herring spawn (———) in the area not affected by the oil spill. Vertical bars = standard error. - - - - - = mean temperature at upper limit of spawn deposition. · · · · = mean temperature at lower limit of spawn deposition.

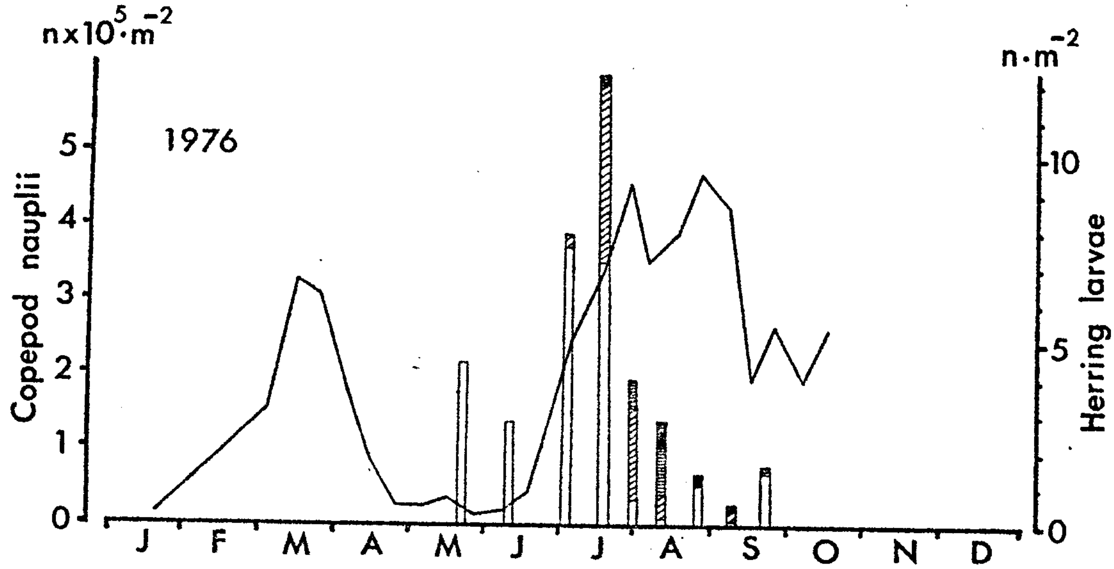

Figure 3. Number of copepod nauplii and herring larvae per m^2 in the Askö area in 1976. ——— = copepod nauplii. ☐ = herring larvae <10 mm. ▨ = larvae 10 - 14 mm. ▤ = larvae 15 - 19 mm. ■ = larvae ≥20 mm.

Table I. Occurrence of different plant species and bottom substrates in per cent of total number of transects with and without spawn respectively. Data for two transects with spawn is missing, therefore n=47 instead of 49. X = species or substrates where indications of differences in exposure can be seen.

Plant species or bottom substrate	Without spawn (n = 71)	With spawn (n = 47)
Cladophora spp.	80.3	72.3
Pilayiella sp.	97.2	95.7
Ceramium spp. X	15.5	36.2
Fucus vesiculosus X	56.3	40.4
Ruppia	9.9	4.3
Chorda filum	70.4	83.0
Potamogeton spp. X	32.4	10.6
Zostera marina X	31.0	14.9
Eudesme sp. X	31.0	74.5
Mytilus edulis	88.7	53.2
Rock - pebbles	94.4	95.7
Sand X	35.2	14.9
Softer sediments X	23.9	14.9