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Spawning, first feeding and larval behavior of the North-Sea-Sole.

by

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Repetition of rearing experiments in sole as done in 1965 was hindered by a number of calamities which reduced the number of spawners. Unexpected results in rearing enables me to give, more or less, only a summary. An exact exploitation of designs is planned in the near future.
The first time that I observed the adult soles spawning, the fishes were swimming close to the water surface, and pressed together but with normal swimming carriage. Sometimes a head projected out of the water, the male in the upper position. Spawning was observed one time in the evening when it was rather dark and one time in the afternoon in daylight (table 1). Soles (caught Oct. 1964) spawned in 1965 and also this year. No dead unfertilized eggs were found. Mature fish, freshly caught, also spawned but yielded only 5% fertilized eggs. I would estimate that several females had spawned without males (table 2).
The incubation time of eggs is very short (table 3), and the larvae are very undeveloped at hatching. Newly hatched larvae (ca. 2,6 mm long) were somewhat motionlessly floating at the surface, with the yolksac to the upperside. After a time (compare table 4), depending on the temperature, the larvae began - always passively - to leave the surface and drift vertically with the head downward. A swarm of them looked like small sailing boats upon a lake. I think at this stage, namely in this vertical position, the larvae are more easily swept with the current, and gradually, retaining this upright position, sink to current free places at the seabottom. When they reach the bottom, the differentiation of the digestive tract allows food intake. The eyes, colorless at hatching, are now pigmentated and the diameter of the yolksac is half of that at hatching. The larvae are now 3,6 mm long and begin to feed. Their continous hitting against the bottom, and snapping, reminds one of a band of pecking chickens. So, in their natural habitat, it seems that the larvae successively are raining to the seabottom, and accumulate at current free places. The importance of this behavior for the survival of larvae becomes visible in the results of rearing experiments this year.
When I again tried to rear larvae in containers which this time were round for better filtration and homogenity of conditions and had an "inside filter", no larvae survived the absorption of the yolksac. I assumed that there were a number

of reasons responsible for this total mortality. The observation that larval survival was markedly better in containers with unfiltrated water, depending on the origin of this water and the larvae counts per unit, gave reason for the suspicion that the larvae are protist-feeders. It is difficult to demonstrate the intake of protists from the larvae because the vulnerable, and colorless protists cannot be seen in the digestion-tract.

Evidence of protist feeding was possible to determine in the following way: A culture of the ciliate Holosticha reared at Helgoland was fed, when very hungry, with a dense culture of the green flagellate Dunaliella. One hour later the ciliates were completely filled with the green flagellates and had a dark green color. When the sole larvae were added to this mixed culture, after an hour, their digestive tract was filled with dark-green mass. Pure cultures of Dunaliella alone do not give this effect. All larvae fed with this ciliate (Holosticha) survived and started feeding on Artemia nauplii, when they had reached a length of 4,2 to 4,5 mm. However at this stages the ciliates may not yet be omitted from their diet. When they were fed with artemia, ciliatefree by washing them with freshwater, the larvae became more and more darkly pigmentated, and eventually almost black before dying. This was after metamorphosis and eye migration, with a length of 11 mm. In the same way as done with the ciliate, the intake of the flagellate Oxyrris can be made visible. But larvae which fed only with Oxyrris and Artemia die at the beginning of bonification. The best growth was observed when the rearing-water contains the ciliate Uronychia.But since it eat no Dunaliella, and is colorless Uronychia is impossible to detect in the digestive tract. When I tried to rear the larvae with Artemia nauplii only, they always starved. Only a few larvae took Artemia, but these also died.

On the other hand, exclusively protist-food for an unnaturally long period seems to be responsible for the defective development of pigmentation on the upperside of the soles. For instance several larvae growing up in the spawning pond ate their first Artemia nauplii when more than 5 mm long. A few of these

specimens were rather quite colorless.
The obligatory protist-feeding presented difficulties in temperature experiments. Up to now a quicker development at higher temperatures (15 to 20°C or more) is perceptible if the larvae get food enough. As compared with results obtained in a steady 15°C experiment, rearing-experiments carried out at temperatures changing daily from 13 to 17°C showed that eggs required a prolonged incubation time and that larvae are smaller at hatching. The yolk resorption does not correspond to the morphological differentiation of the larvae but is quicker. For instance the eyes are not pigmentated when the yolksac has half the diameter at hatching and food-intake should normally begin. Young fish reared under the same temperature conditions grow more slowly than those at a constant 15°C. So adaptation to a new temperature seems to expend additional energy. The temperature-change was produced by a heater connected with a switching-clock, switching the illumination tube for the artifical 12 hour day. Thus the temperature rose successively during two hours to its higher level. After switching off, the temperature descended slowly to the level of the climatic-room containing the aquaria.
It may be of interest that the behavior of the larvae is influenced little by changing light-intensity or angle of penetration. Their orientation is always directed to the substrate. It is obvious how very well they can find their way around a morphologically complex environment. I think this ability may originate from the fact that possibly their symmetrical ancestors inhabited the strongly articulated rocky sublitoral zone.
The behavior of the sole-larvae presents great difficulties in catching samples representing the stock. For this reason, laboratory investigations may be the best method to imagine how the nature of a natural sole-nursery is constructed.
One may estimate that sole-fry are likely to be found where dead plankton sink to the sea-bottom, and therefore good feeding conditions are available to the small mesopsammal organisms which the larvae need.

The obligatory protist-feeding seems to be a special characteristic of sole-larvae but, probably the "green-food-remains" as described by several authors, may be the result of protist-feeding by pelagic fish-larvae also.

Table 1

Water temperature of the spwaning pond (soles caught Oct.1964, 3 females, 2 males).
Spawning days underlined.

date	temperature
26.1.66	5°C
9.2.	4,8°
15.2.	3,2°
17.2.	7,0°
5.3.	11,0°
6.3.	13,0°
8.3.	10,5°
12.3.	10,0°
13.3.	8,5°
16.3.	9,0°
17.3.	11,0°
18.3.	13,0°
11.4.	8,5°
13.4.	8,0°
14.4.	8,0°
16.4.	8,0°
<u>24.4.</u>	<u>9,5°</u>
26.4.	10,2°
<u>27.4.</u>	<u>10,4°</u>
<u>29.4.</u>	<u>11,0°</u>
30.4.	11,3°
<u>1.5.</u>	<u>11,8°</u>
2.5.	12,8°
3.5.	13,2°
4.5.	13,2°
<u>8.5.</u> spawning observed 9⁰⁰ p.m.	<u>13,6°</u>
9.5.	13,6°
<u>10.5.</u>	<u>13,8°</u>
11.5.	13,6°
12.5.	13,6°
<u>14.5.</u>	14,2°

date	temperature
15.5.66	14,8°C
16.5.	14,8°
17.5.	14,6°
18.5.	15,2°
<u>20.5.</u> spawning observed 4⁰⁰ p.m.	<u>14,0°</u>
21.5.	14,0°
22.5.	14,0°
<u>23.5.</u>	<u>13,6°</u>
24.5.	12,6°
25.5.	12,8°
27.5.	12,5°
29.5.	12,5°
30.5.	14,0°
<u>31.5.</u>	<u>13,8°</u>
1.6.	12,5°
<u>2.6.</u>	<u>12,8°</u>
3.6.	13,8°
4.6.	14,2°
<u>5.6.</u>	15,4°
6.6.	15,7°
8.6.	16,0°
9.6.	16,8°
10.6.	17,0°
11.6.	17,0°
<u>12.6.</u>	17,5°
13.6.	17,8°
14.6.	18,6°
15.6.	18,7°
16.6.	19,0°
17.6.	19,8°
18.6.	19,8°
19.6.	18,5°
20.6.	18,3°
21.6.	18,3°

Table 2

Water temperature of the spawning pond (mature soles freshly caught 12.5.1966, sea-temperature 6,8°C).

date	temperature	date	temperature
15.5.66	12,2°C	4.6.66	13,4°C
16.5.	12,0°	5.6.	15,2°
17.5.	10,6°	6.6.	15,5°
only dead eggs		8.6.	16,6°
18.5.	13,2°	9.6.	16,8°
21.5.	8,8°	10.6.	17,0°
22.5.	8,6°	11.6.	17,0°
23.5.	7,6°	12.6.	17,3°
24.5.	7,4°	13.6.	17,8°
25.5.	7,8°	14.6.	18,4°
only dead eggs		15.6.	18,5°
27.5.	8,2°	16.6.	18,8°
29.5.	8,4°	17.6.	19,5°
30.5.	9,0°	18.6.	19,8°
31.5.	9,0°	19.6.	18,6°
1.6.	9,3°	20.6.	18,3°
2.6.	9,6°	21.6.	18,3°
3.6.	9,4°		

Table 3

Incubation time of eggs

temperature		
10° C	6 days	(50% hatched)
14° C	3 days	(50% hatched)
20° C	2,5 days	(50% hatched)

Table 4

Development of early larval behavior at 14° C.

date		
20.5.66	4.^{30} p.m.	spawned
23.5.	11.^{00} a.m.	50% hatched
25.5.		drifting close to surface
26.5.	10.^{00} a.m.	50% "drifting vertically" and sinking
26.5.	5.^{00} p.m.	all drifting vertically and sinking
27.5.	3.^{00} p.m.	80% "pecking like chickens"
28.5.	11.^{00} a.m.	all "pecking like chickens"