DISAPPEARANCE OF THE BENTHIC FAUNA FROM THE BASIN OF BORNHOLM (SOUTHERN BALTIC) DUE TO OXYGEN DEFICIENCY.

by

Paavo Tulkki

Kristineberg Zoological Station Fiskebäckskil (1).

Résumé

Le présent travail a pour but de suivre les changements dans la composition et la distribution de la faune benthique des eaux profondes du Bassin de Bornholm (Baltique du Sud), changements qui résultent des conditions hydrographiques particulières de cette région, caractérisée, entre autre, par des périodes de stagnation et de manque d'oxygène.

Si l'on compare les résultats obtenus au cours de nos deux expéditions de janvier 1963 et de janvier 1964, avec ceux de Démel et Mulicki (1951-1952), il apparaît que la faune benthique, pendant la période intermédiaire, a disparu sur les fonds de plus de 70 m de profondeur. Des données hydrographiques indiquent une stagnation dans les eaux profondes au cours de la même période.

Une amélioration, indiquée par la recolonisation de certaines espèces benthiques, a été constatée en janvier 1964.

Long periods of stagnation in the lower strata of deep water cause lack of oxygen and the formation of hydrogen sulphide in the marine bottom sediment. In extreme cases, this may lead to almost total extermination of the benthic fauna. Some basins in the Baltic Sea are especially sensitive to such stagnation, which may continue for many years before it is interrupted by periodical influxes of water.

In order to attempt to register the reactions of the bottom fauna during periods of lack of oxygen in marine bottoms, I investigated, on the initiative of Dr. B. Swedmark, Kristineberg Zoological Station, on two occasions (in January 1963 and January 1964) the bottom of a section of the southern Baltic from Simrishamn on the south-east

(1) Present address: Marine Biological Station, University of Turku, Turku, Finland.

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coast of Sweden in the north to the Polish coast in the south. The section, which comprises twelve sampling stations, runs from the Swedish coast in a south-easterly direction (Fig. 1), forms an angle north-east of Bornholm and then continues due south over the Basin of Bornholm towards the coast of Poland.

Similar investigations of the bottom fauna of these localities were made in 1951 and 1952 by Polish zoologists (Demel & Mulicki, 1954), and by choosing the same localities, which, by the way, were given the same numbers as those used by the Polish workers, it was possible to compare the composition and distribution of the fauna of this interesting region during two rather distant periods of time.

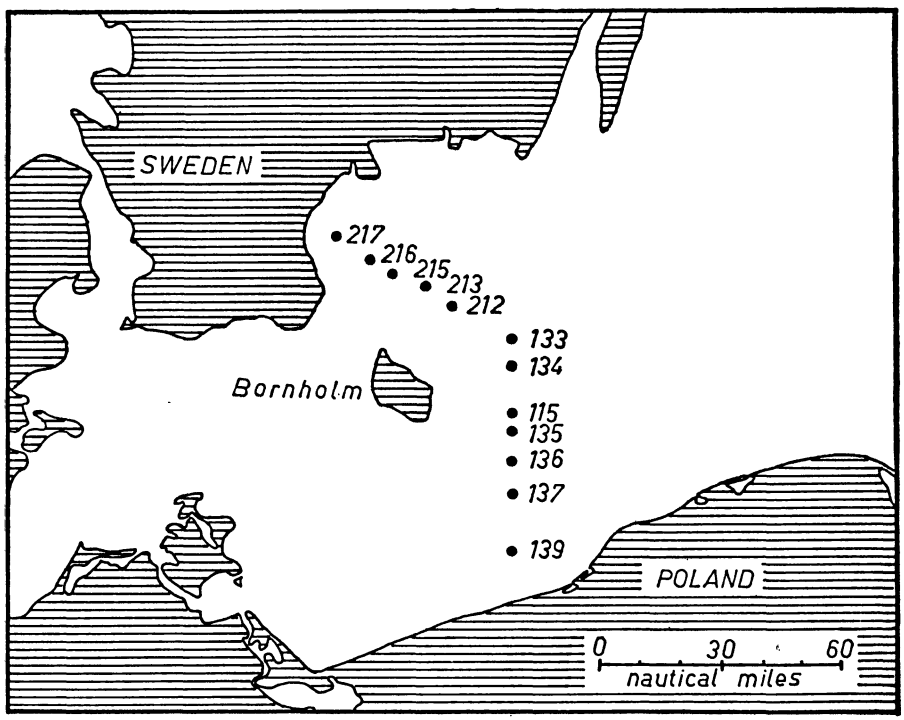

FIG. 1
Localities investigated in the southern Baltic Sea.

The 1963 and 1964 expeditions were made in the R/V *Skagerak* of the Fishery Board of Sweden, under the leadership of Dr. Swedmark.

Samples of the bottom sediment for the examination of the fauna were taken with a 0.1 sq.m. Petersen grab. The result of the study of benthic fauna, and reports of the biomass are given in Table 1. The biomass was determined by weighing the material after it had been preserved in formalin for four days. For comparison, Table 1 also shows the results of Demel & Mulicki's 1951 and 1952 investigations.

The benthic fauna studied by the Polish zoologists, from depths below 60 metres, comprised the following species:

Nemertini sp.	*Scoloplos armiger*
Halicryptus spinulosus	*Astarte borealis*
Priapulus caudatus	*Macoma calcarea*
Harmothoë sarsi	*M. baltica*
Terebellides stroemi	*Pontoporeia femorata*
Perigonimus cirratus	*Diastylis rathkei*

Measurements of oxygen were made on samples of water taken at the bottom. Such samples were taken in January 1964 only. The oxygen analyses were made at the Hydrographical Laboratory of the Fishery Board, Göteborg, according to Winkler's method.

In addition to the above-mentioned investigations by Demel and Mulicki, which provide the starting-point for the study of the changes which have taken place since 1951 in the Basin of Bornholm, the same Polish workers continued their studies of the region during the years 1952-1954. They then used, among other things, a so-called Ostroumow trawl, by the help of which epibenthic fauna can be collected from the layer of water half a metre above the bottom (Demel & Mulicki, 1959).

In the winter of 1952, Demel & Mulicki (1959) measured a biomass of 8.2—1.5 g/sq.m on these bottoms, but in the summer of 1953 they found no animals in their trawl. The following winter, 1954, they found localities with a biomass of up to 14.3 g/sq.m, although at most localities they did not find any animals at all. The species found were *Harmothoë sarsi, Mysis mixta, Diastylis rathkei* and *Sagitta* sp.

Forsman (1955) collected samples of the bottom fauna of the Basin of Bornholm in 1953, from depths between 85 and 100 metres. He found only *Aricidea suecica* (6 specimens) and empty shells of *Macoma baltica,* and he reported that the bottom sediment was dark gray or bluish clay smelling of hydrogen sulphide.

In January 1953, the oxygen content of the water at a depth of 90 metres in the Basin of Bornholm was only 1.25 ml/liter, and sank in March the same year to 0.77 ml/liter. According to available hydrographical data, the oxygen content at this depth was less than 1 ml/liter (0.12—0.88) until the winter 1956/57, when it rose to 3.8 ml/liter. With small variations it remained below 1 ml/liter until the autumn of 1959, except for a period in May-July 1958 (Filarski, 1959, 1960). These data are evidence of the stagnation and slight turnover of water which in this region affect greatly the distribution and conditions of life of the benthic fauna.

According to Filarski (1959 a), there was exchange of water in the Basin of Bornholm in 1951-1952. Local exchanges of water have been observed since 1953 in the region we are concerned with here as well as in the Gdansk Basin. Considerable influx of water was later observed during 1954 in the Danish sounds, but did not affect the Basin of Bornholm. In 1955 it was considered that the exchange of water in the Basin of Bornholm affected only the intermediate strata, and the water of the deep basin therefore stagnated.

Fishery biological investigations reveal interesting changes in the population of cod during the 1950's (Elwertowski, 1959). There was a rich occurrence of cod during the winters 1952 and 1953, but cod were rather scarce the following winter, 1953/54. Spawning cod is sensitive to the content of oxygen in the bottom layer of water. This winter the oxygen content was below 1 ml/liter, and this was assumed to be the reason why the cod remained in the peripheral parts of the region.

A collocation of the hydrographical changes (oxygen and salinity) in the Basin of Bornholm from 1951 to 1960 has been made by Glowinska (1963, p. 26).

Shurin (in Segerstråle, 1960) considers that the results of the investigation made of the bottoms of the northern and eastern parts of the Baltic indicate widespread extermination of benthic organisms since 1955. According to Shurin, the azoic region in 1958 and 1959 included not only the Basin of Bornholm, but also the basins at Gotland and Gdansk. The area of the azoic region was estimated by Shurin to be 12,000 sq, miles. The reason he gives is the lack of oxygen due to insufficient turnover of water. One contributory reason also mentioned is the slowly declining salinity observed in the region since the middle of the 1950's (Segerstråle, 1960; Glowinska, 1963). Shurin points out how important these changes in the composition and distribution of the bottom fauna are from the aspect of fishing. When the benthic fauna disappears, the fish must migrate to other regions to seek food.

The variations in the benthic fauna during the 1950's and up to the time of our expedition are shown in Fig. 2 and Table 1. It is possible that the positions of our stations and those of the Polish zoologists do not coincide exactly. Our stations were determined from the positions given by the Polish zoologists by the Decca Navigator system.

Fig. 2 shows a great reduction of the benthic fauna at stations with depths below 70 metres. In 1951-52 there were at these depths (Demel & Mulicki, 1954) eight of the species in the whole region studied, namely, *Micrura* sp., *Nemertini* sp., *Priapulus caudatus, Astarte borealis, Macoma calcarea, Scoloplos armiger, Harmothoë sarsi* and *Diastylis rathkei.* In 1963, only *Astarte borealis* (1 specimen) was found at this depth, while shells of *Astarte* and of *Macoma calcarea* were found in the samples. In 1964, live *Astarte borealis* (Stat. 212, depth 84 m) and also *Halicryptus spinulosus* (Stat. 136, depth 73 m) were found in the region. The oxygen samples taken in January 1964 showed relatively high values in the deeper strata (Table 1).

Mulicki (1957) studied the adaptability of some Baltic invertebrates to lack of oxygen. He states that, among others, *Astarte borealis* needs rather much oxygen. Nevertheless, our study shows that the species may be found in stagnated regions with otherwise seriously decimated fauna. It also shows that *Halicryptus spinulosus* is resistant to lack of oxygen. Mulicki (op. cit.) found that *Macoma calcarea* is one of the species which can resist very low concentrations of oxygen. But our study has shown that it cannot survive the

stagnation in the Basin of Bornholm, for there we found empty shells.

When the results of our own studies made in January 1963 and January 1964 (Table 1, Fig. 2) are compared, it will be found that there was some augmentation of the benthic fauna, although still very slight in the deep strata.

The oxygen contents of the deep strata in January 1964 were of the same magnitude as those given by the Polish workers for 1951-1952. It must be assumed, therefore, that the influx of new water into the Basin of Bornholm occurred before 1963, or the high oxygen values may be a consequence of the influx observed during the spring of 1963.

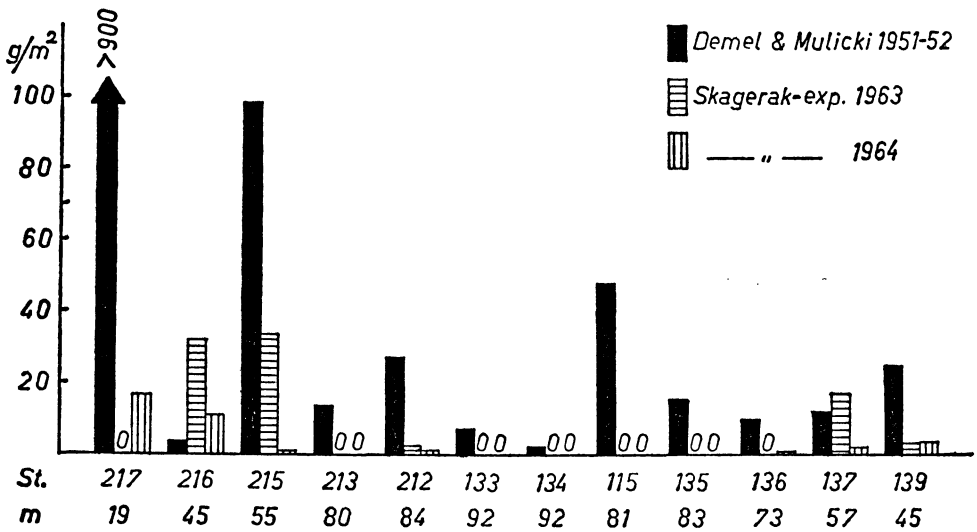

FIG. 2

Biomasses of the cross-section recorded by Polish and Swedish expeditions at the same localities. (At St. 17 the Swedish observations are not considered quantitative owing to stony bottom.)

It was found in January 1964 that the bottom sediment at the deep stations was covered with a browner surface layer 1 to 3 mm thick, while in the winter of 1963 we found only dark clay, smelling of hydrogen sulphide, without an oxydized surface layer. These changes, which can be seen in the sediment, suggest increased oxygenization (Hayes, 1964; Ignatius, 1958), and they are considered to appear very soon after a change of water has occurred. A recolonization by benthic fauna can take place in the thin oxydized surface layer. As far as the benthic fauna in the Basin of Bornholm is concerned, there is also horizontally a rather large area in which mass mortality occurred in the 1950's, and it must be assumed that recolonization, after conditions of life have been improved for the benthic fauna by an influx of new water, must take several years. In January 1964, the oxydized surface layer was still very thin, and probably insufficient to satisfy the biological demands of all the organisms formerly living on these bottoms. It is therefore important

TABLE 1

Biomasses and densities according to Polish and Swedish expeditions from a cross-section of the Baltic. In 1963 and 1964 the animals were stored preserved in formalin and weighed 3-4 days after sampling.

Species	1951-52		1963		1964		O_2 ml/l near bottom	
	ind./m²	g/m²	ind./m²	g/m²	ind./m²	g/m²	1951-52	1964
St. 217 (*) 19 m							9.20	—
Macoma baltica	85.8	16.18	—	—	—	—		
Mytilus edulis	5775.0	896.87	—	—	present	.		
Theodoxus fluviatilis	363.0	.	—	—	—	—		
Hydrobia sp.	29.7	.	—	—	—	—		
Nereis diversicolor	36.3	1.65	—	—	—	—		
Pygospio elegans	few	.	—	—	—	—		
Oligochaeta	42,9	.	—	—	—	—		
Iaera sp.	16.5	.	—	—	—	—		
Pontoporeia femorata	—	—	—	—	present	.		
Calliopius laeviusculus	3.3	.	—	—	—	—		
Gammarus locusta	19.8	0.19	—	—	—	—		
Neomysis integer	3.3	.	—	—	—	—		
St. 216 45 m							8.65	—
Nemertinea sp.	—	—	10	0.06	5	0.60		
Oligochaeta sp.	122.1	.	—	—	—	—		
Aricidea suecica	3.3	0.15	—	—	—	—		
Pygospio elegans	numerous	.	—	—	—	—		
Terebellides strömi	—	—	—	—	50	1.20		
Polychaeta sp.	16.2	.	—	—	5	0.01		
Macoma baltica	6.6	2.21	5	5.06	30	3.00		
Mytilus edulis	29.7	0.27	35	14.38	5	4.40		
Astarte borealis	—	—	5	9.97	—	—		
Pontoporeia affinis	56.1	0.30	—	—	—	—		
P. femorata	—	—	5	0.04	185	1.15		
Mesidotea entomon	—		15	1.11	5	0.30		
Diastylis rathkei	16.5	0.12	25	0.41	10	0.01		
St. 215 55 m							7.75	—
Nemertini (Micrura)	13.2	0.21	—	—	—	—		
Halicryptus spinulosus	16.5	0.29	5	0.16	—	—		
Scoloplos armiger	102.3	1.49	10	0.09	—	—		
Terebellides strömi	9.9	0.10	—	—	—	—		
Polychaeta sp. (?)	6.6	.	—	—	—	—		
Mytilus edulis	69.3	62.87	—	—	—	—		
Pontoporeia femorata	3.3	0.02	10	0.17	10	0.03		
Diastylis rathkei	9.9	0.07	40	0.45	—	—		
Astarte borealis	283.8	32.97	120	32.16	—	—		
St. 213 80 m							5.00	1.91
Micrura sp.	39.6	0.64	—	—	—	—		
Lineus ruber	9.9	0.16	—	—	—	—		
Macoma calcarea	23.1	11.68	—	—	—	—		
Astarte borealis	—	—	empty shells		empty shells			
Scoloplos armiger	72.6	1.06	—	—	—	—		
Diastylis rathkei	9.9	0.06	—	—	—	—		
St. 212 84 m							4.84	4.00
Nemertini (Lineus ruber)	3.3	0.05	—	—	—	—		
Nemertini (Micrura)	13.2	0.21	—	—	—	—		
Priapulus caudatus	3.3	0.55	—	—	—	—		
Scoloplos armiger	72.9	1.16	—	—	—	—		
Macoma calcarea	49.5	23.70	—	—	—	—		
Astarte borealis	145.2	1.31	5	0.23	5	1.25		
Diastylis rathkei	3.3	0.02	—	—	—	—		

(*) in 1963 and 1964 samples were not quantitative.

Species	1951-52		1963		1964		O_2 ml/l near bottom	
	ind./m²	g/m²	ind./m²	g/m²	ind./m²	g/m²	1951-52	1964
St. 133 92 m							2.87	2.18
Scoloplos armiger	3.3	0.05	—	—	—	—		
Harmothoë sarsi	6.6	0.15	—	—	—	—		
Macoma calcarea	—	—	empty shells		empty shells			
Astarte borealis	33.0	6.95	empty shells		—	—		
St. 134 92 m							2.06	1.94
Scoloplos armiger	3.3	0.05	—	—	—	—		
Macoma baltica	—	—	empty shells		—	—		
M. calcarea	empty shells		empty shells		empty shells			
Astarte borealis	29.6	2.01	empty shells		—	—		
Diastylis rathkei	3.3	0.02	—	—	—	—		
St. 115 81 m							2.08	2.77
Nemertini (Lineus ruber)	6.6	0.11	—	—	—	—		
Scoloplos armiger	13.2	0.19	—	—	—	—		
Macoma calcarea	49.5	29.11	—	—	empty shells			
Astarte borealis	171.6	18.50	—	—	—	—		
St. 135 83 m							2.41	2.55
Nemertini sp.	13.2	0.21	—	—	—	—		
Scoloplos armiger	66.0	0.96	—	—	—	—		
Harmothoë sarsi	3.3	0.08	—	—	—	—		
Astarte borealis	72.6	13.87	—	—	—	—		
Diatylis rathkei	19.8	0.14	—	—	—	—		
St. 136 73 m							2.36	3.23
Priapulus caudatus	3.3	0.50	—	—	—	—		
Halicryptus spinulosus	—	—	—	—	10	0.05		
Scoloplos armiger	227.7	3.33	—	—	—	—		
Macoma calcarea	3.3	1.94	empty shells		empty shells			
Astarte borealis	36.3	3.72	empty shells		empty shells			
Diastylis rathkei	6.6	0.05	—	—	—	—		
St. 137 57 m							7.29	5.22
Nemertinea sp.	9.9	0.16	15	0.55	—	—		
Halitholus cirratus	few	.	—	—	—	—		
Priapulus caudatus	—	—	15	1.30	15	0.02		
Halicryptus spinulosus	23.1	2.44	20	0.55	10	0.02		
Scoloplos armiger	42.9	0.63	170	1.20	5	0.00		
Terebellides strömi	—	—	70	0.10	—	—		
Macoma baltica	—	—	10	0.35	20	0.02		
Astarte borealis	42.9	6.26	40	12.50	—	—		
Mytilus edulis	6.6	0.06	—	—	—	—		
Pontoporeia femorata	59.4	0.32	—	—	135	2.00		
Diastylis rathkei	39.6	0.28	5	0.33	5	0.01		
St. 139 45 m							7.03	8.78
Halicryptus spinulosus	16.5	0.69	5	0.22	10	0.65		
Halitholus cirratus (juv.)?	—	—	—	—	10	0.00		
Scoloplos armiger	—	—	—	—	10	0.00		
Pygospio elegans	few	.	tubes	—	10	0.00		
Harmothoë sarsi	3.3	0.08	—	—	5	1.60		
Terebellides strömi	16.5	0.17	—	—	—	—		
Polychaeta sp. juv.	—	—	15	0.03	5	0.00		
Pontoporeia affinis	42.9	0.23	—	—	—	—		
P. femorata	3.3	0.02	—	—	30	0.05		
Mesidotea entomon	3.3	0.09	—	—	—	—		
Diastylis rathkei	79.2	0.15	5	0.05	—	—		
Macoma baltica	66.0	22.5	—	—	—	—		
M. calcarea	—	—	—	—	5	1.00		

to continue investigations, if the successive changes taking place as a consequence of momentary or continuous variations of the environmental factors are to be followed up.

The periodicity of the turnover of water in the deep basins of the Baltic has been known for some time. Hela (1960) assumes that the deep strata in the Arkona Basin are renewed every 5 to 10 years, in the Basin of Bornholm every fifteenth year and in the Gotland Trench every thirteenth year. It was not until recently, as a result of investigations of the bottom fauna made in the 1950's and later, that we began to get some idea of the corresponding periodic variations in the sediment-bound fauna. It is important to follow as carefully as possible such changes in the organic productivity of the bottoms. This is of importance for fishery biology, and these investigations are also of value for problems of water conservation in coastal areas, for they suggest a reversibility in the distribution of the populations as far as reactions to variations in environmental factors are concerned.

I owe a debt of gratitude to the Fishery Board of Sweden for permission to use the R/V *Skagerak*, to the master of the vessel, Captain Ronge, for his interest and valuable help, and to the Hydrographical Laboratory of the Fishery Board for the analyses of oxygen.

Sammanfattning

Föreliggande undersökning i Bornholmsdjupet i södra Östersjön har avsett att studera de förändringar som äger rum i bottenfaunans sammansättning och fördelning i samband med stagnation och syrebrist i djupare vattenskikt.

En jämförelse av egna resultat från expeditioner i januari 1963 och januari 1964 med polska zoologers undersökningar på samma lokaler sedan 1951 visar ett nästan totalt försvinnande av bottenfauna på lokaler med djup överstigande 70 meter. Tillgängliga hydrografiska uppgifter antyder en stagnation i vattenomsättningen under 1950-talet. Högre syrevärden konstaterades i vattnet nära bottnen under januari 1964 som antyder att ett vatteninflöde ägt rum troligen år 1963. Vi kunde i januari 1964 konstatera att en viss förstärkning av bottenfaunan inträffat och att ett par av de arter som tidigare påträffats på de djupare lokalerna, nu börjat återkolonisera dessa.

Резюме

В данной статье излагаются сведения о замечаемой в последние годы тотальной гибели фауны морского дна в впадение Борнгольм в южной части Балтийского моря. В 1951-52 г.г. здесь польскими учеными обнаружено сравнительно много разных видов, тотальная биомасса которых тогда оказалась значительной. С 1952 года замечается стагнация водных масс на морском дне, вследствие которой количество водорода держится ниже минимума для жизненных условий фауны морского дна. Автором в 1963-64 г.г. взят ряд проб из впадины Борнгольм и около нее. Анализ этих данных показывает, что стагнация все продолжается, и что фауна в глубине 70-80 м. и ниже погибла. По сведениям советских ученых площадь с тотальной гибелью жизни охватывает также впадину Готланд и впадины в западной части Финского залива.

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