

TRANSITORY RETURN OF THE BENTHIC FAUNA OF THE BORNHOLM BASIN AFTER EXTERMINATION BY OXYGEN INSUFFICIENCY.

by

Erkki Leppäkoski

Kristineberg Zoological Station, Fiskebäckskil, Sweden (1).

Résumé

La distribution de la faune des eaux profondes du Bassin de Bornholm a subi des changements importants pendant des périodes de stagnation et de manque d'oxygène. Depuis 1959, les hydrographes ont constaté des apports plus ou moins fréquents d'eau océanique, qui ont eu pour résultat une amélioration des conditions d'oxygénation en profondeur.

Une recolonisation de la faune benthique se poursuit depuis 1964. Sept espèces, en particulier d'assez nombreux *Scoloplos armiger*, furent trouvées en juin 1965. En mars 1967, cependant, nous y retrouvions une faune benthique réduite, *Capitella capitata*, inconnue jusqu'alors dans la faune baltique devenant l'espèce dominante.

Il n'a pas été possible, pendant ces dernières années, de retrouver les deux Lamellibranches, *Macoma calcarea* et *Astarte borealis*, caractéristiques autrefois de la faune benthique de la région.

The catastrophic disappearance of the bottom fauna of the Bornholm Basin, Southern Baltic, as a result of oxygen deficiency was demonstrated and discussed previously in this series by Tulkki (1965). In order to follow up the changes in bottom fauna connected with the sudden hydrographical variations typical for this basin, his stations were visited in June 1965 by the Finnish *R/V Aranda*, in March 1967 by the Swedish *R/V Thetis* and again in August 1968 by the Swedish *R/V Sagitta*. The stations, first located by Demel and Mulicki (1954), are shown in Fig. 1.

According to available data, no great inflow of oceanic water into the Bornholm Basin occurred in the 1950's after the great influx in 1951. During the following period of stagnation the deep water strata in this area were characterized by decreasing temperature, salinity and oxygen content, as shown by the extensive work of Fonselius (1962). This downward trend was not arrested until November 1959 when an inflow of new water caused an increase in salinity from 13.5—14.5 per mille in 1958 to 16—17 per mille in 1961. During 1959-1961 the oxygen content of the bottom water has generally been over 2 ml/l (Fonselius 1962). A new influx of water of

(1) Present address of the author: Archipelago Research Institute—University of Turku—Turku, Finland.

high salinity from the Kattegat replaced the deep water in the basin again in 1962 (Fonselius 1967). The available values for bottom water oxygen concentration in the Bornholm Basin from 1962 to 1967 are collected in Fig. 2. This figure is based in part on Swedish and Polish hydrographical observations published in *Annales biologiques* 1964-1968, in part on unpublished Swedish data. Several influxes of water occurred during this period; after each, a rapid decline in oxygen concentration is seen. The conditions following the influx in December 1964 are the most instructive: within eight months the oxygen content decreased from 4.8 to some tenths of a ml/l and the salinity from 17.8 to 15.9 per mille.

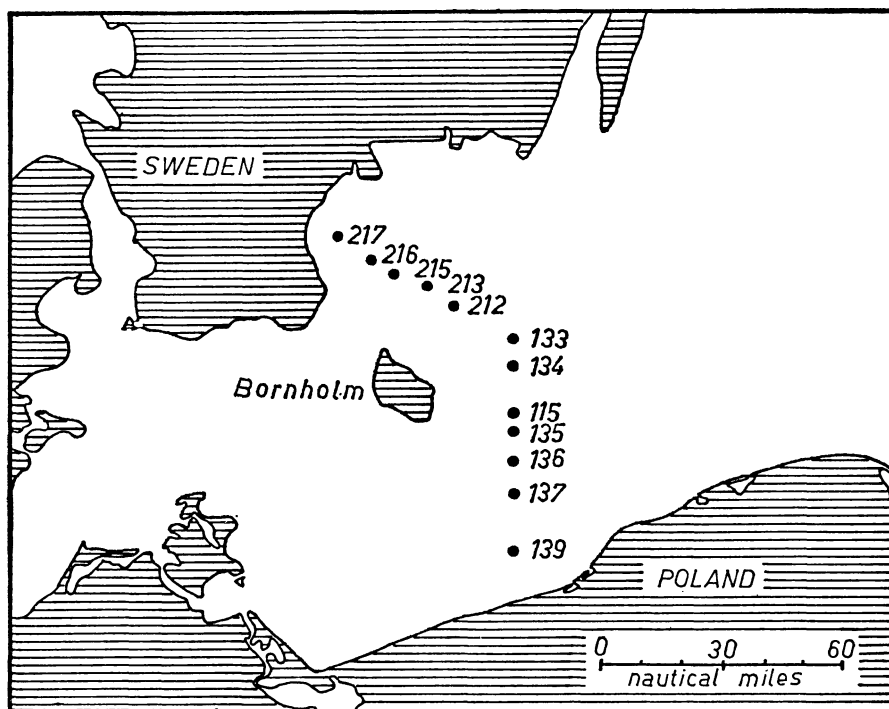


FIG. 1

The stations investigated in a cross section of the Bornholm Basin (after Tulkki 1965).

Little is known of the reactions of the bottom fauna in the deepest parts of the Bornholm Basin during these alternating periods of stagnation and influx of new water. According to several authors, Tulkki (1965) assumes that the benthic infauna has not been able to live in the basin after the mass death in the 1950's. This statement can be based on indirect conclusions. The concentration of dissolved oxygen during the period 1953-1958 had often fallen to zero and during the two years 1955-1956 no value exceeding 2 ml/l was observed (Fonselius 1962). In the winter of 1963, after the great influxes of 1959 and 1962, the sediment surface was still black and the deposits had an intense odor of hydrogen sulphide. A thin oxidizing

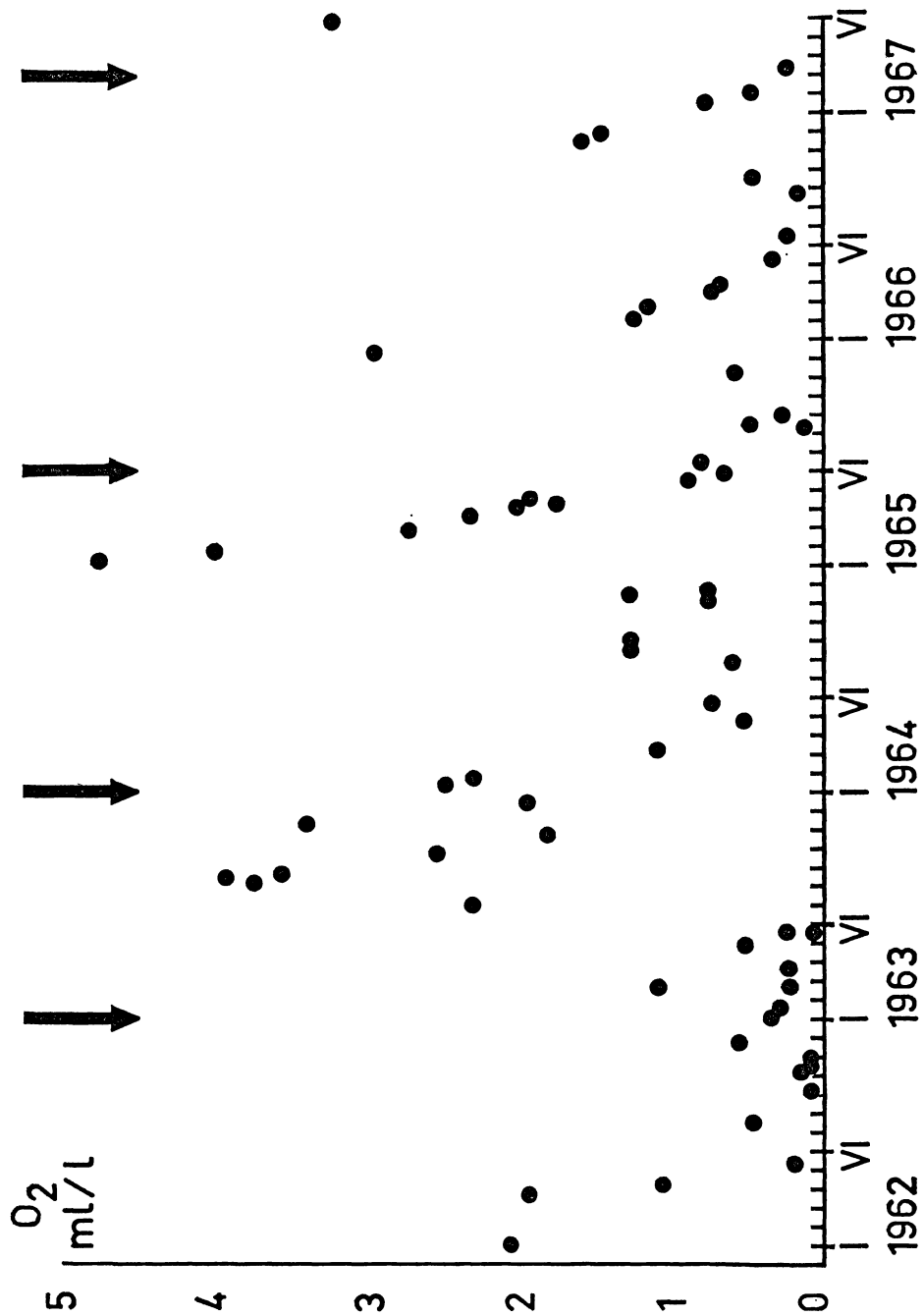


FIG. 2

Dissolved oxygen concentrations in the Bornholm Basin below 80 m, from January 1962 to June 1967 (dots). The date of benthos investigations in the 1960's (arrows). The *Sagitta*-expedition (August 1968) not included.

brownish surface layer was observed in January 1964 (Tulkki 1965) and it was well-developed in the summer 1965, during the recolonization period discussed later. This alteration of the surface sediment layer to a condition compatible with the existence of bottom fauna appears to take a long time, even in the relatively good oxygen conditions in 1963-65. In other words, the recolonization phenomena in the bottom fauna can not be followed up simply by measurements of dissolved oxygen in the deep water strata. The reasons for delayed invasion by the fauna may also be found in a study of the mud-water interface and the interstitial environment of the deposits.

The hydrographical data before the Second World War are too sparse for a reliable evaluation of stagnation periods that were possibly fatal to the bottom fauna. The long stagnation following the great influx in 1951 is without doubt, however, the most severe in the 20th

TABLE 1

Qualitative composition of the bottom fauna in the Bornholm Basin below 70 m during the period 1951-1968. Mollusc shells indicated with ().

	1951-1952	1963	1964	1965	1967	1968
<i>Nemertini</i>	+			+		
<i>Priapulus caudatus</i>	+			+		
<i>Halicryptus spinulosus</i> ..			+	+	+	
<i>Scoloplos armiger</i>	+			+	+	
<i>Harmothoe sarsi</i>	+			+	+	
<i>Capitella capitata</i>					+	
<i>Macoma calcarea</i>	+	()	()	()	()	()
<i>M. baltica</i>		()				
<i>Astarte borealis</i>	+	+	+	()	+	()
<i>Diastylis rathkei</i>	+			+	+	+
<i>Pontoporeia femoralis</i> ...				+		

century. Before this time the benthic fauna below 70 m consisted of seven species (Demel & Mulicki 1954), including the lamellibranchs *Astarte borealis* and *Macoma calcarea* (Table 1). The similarity between the faunas in 1921 (Thulin 1922) and 1951-52 (Demel & Mulicki 1954) is generally good. It should be noted, however, that the Polish workers found only empty shells of *M. calcarea* at the deepest stations below 90 m and that both the amphipod *Pontoporeia femoralis* and the priapulid *Halicryptus spinulosus* were absent below 70 m.

The species composition reported by Demel & Mulicki may be considered as a representative, although already somewhat impoverished, structure of the "original" deep water community of the Bornholm Basin. This fauna disappeared almost entirely during the stagnation period. At one station only (St. 212), living *Astarte borealis* were found in 1963 and 1964 (Tulkki 1965).

In June 1965, seven macrobenthos species were again found in the Bornholm deep below 70 m (Table 2). The lamellibranchs were totally absent. The polychaet *Scoloplos armiger* dominated, making up 88-100 per cent of the total number of specimens of the entire bottom fauna. This species occurred in densities of 55-565 individuals/m², which are several times greater than those found in 1951-1952. *Scoloplos*, being one of the most tolerant to low oxygen content

among all the benthic inhabitants of the Southern Baltic deep basins (Mulicki 1957), appears to be the organism most able to utilize the accumulated nutritives after a prolonged stagnation.

The other species are of secondary quantitative importance. They indicate, however, ecological conditions suitable for the majority of

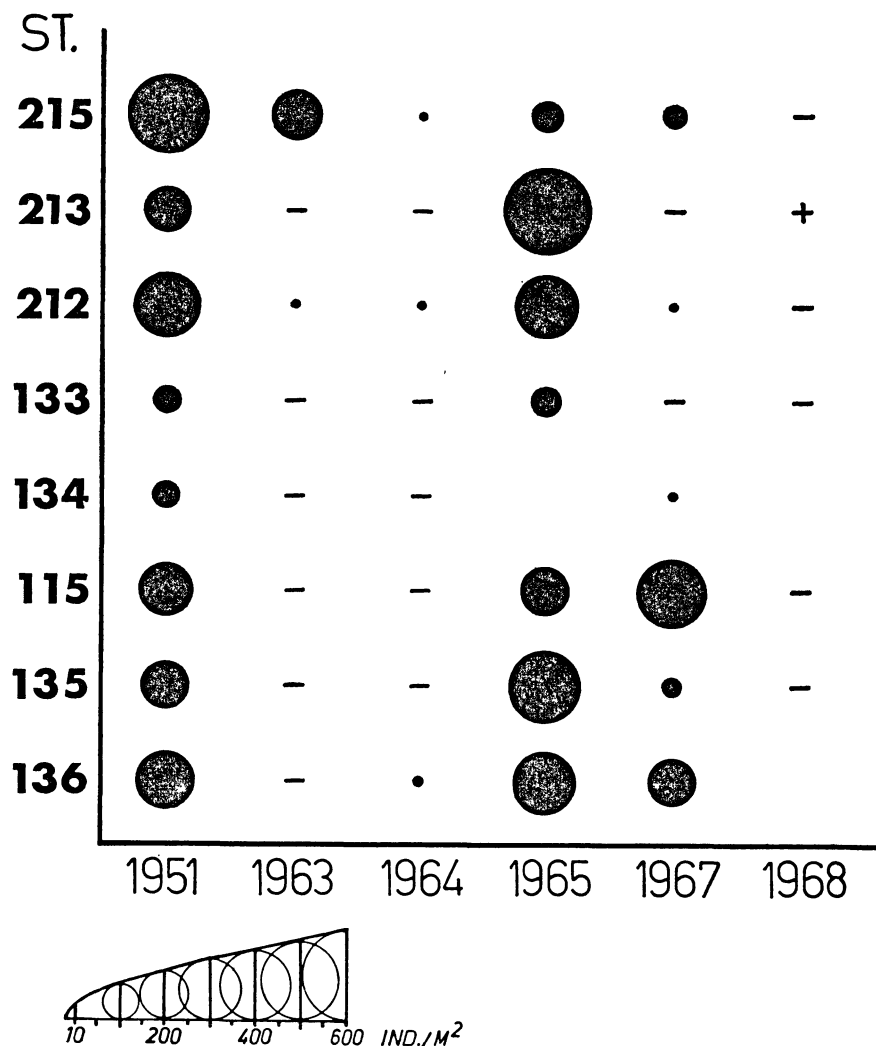


FIG. 3

Densities of the bottom fauna at the middlemost stations in the section over the Bornholm Basin 1951-1968. St. 134 not visited in 1965 and 1968. St. 136 not in 1968.

the invertebrate species normally living in this area. Thus, the oxygen requirements of *Pontoporeia femorata* and *Priapulus caudatus* exceed those of *Scoloplos* (Mulicki 1957).

The abundant bottom fauna recorded in 1965 had greatly declined by March 1967. Fig. 3 shows the decrease in densities and compares the actual data with earlier records.

TABLE 2

The Bornholm Basin. Biomasses and densities of the bottom fauna in 1965, 1967, and 1968. A 0.1 m² Petersen grab and 1 mm mesh have been used. The biomass is given as formalin raw weight. For earlier records (1951-52, 1963, and 1964) see Tulkki (1965). Depths are given according to Tulkki. Empty mollusc shells are indicated with ().

	1965		1967		1968	
	ind./m ²	g/m ²	ind./m ²	g/m ²	ind./m ²	g/m ²
St. 215 55 m 55°37'N, 14°52'E						
<i>Peloscolex benedeni</i>	—	—	—	—	3	0.00
<i>Scoloplos armiger</i>	75	1.35	—	—	—	—
<i>Terebellides stroemi</i>	—	—	5	0.01	—	—
<i>Capitella capitata</i>	—	—	10	0.05	—	—
<i>Harmothoe sarsi</i>	—	—	20	0.40	—	—
(<i>Macoma calcarea</i>)	—	—	—	—	()	—
<i>Pontoporeia femorata</i> ..	—	—	5	0.02	—	—
<i>P. affinis</i>	—	—	—	—	6	0.03
Total	75	1.35	40	0.48	9	0.03
St. 213 80 m 55°30'N, 15°07'E						
<i>Micrura</i> sp.	5	0.05	—	—	—	—
<i>Scoloplos armiger</i>	565	10.60	—	—	—	—
(<i>Astarte borealis</i>)	()	—	()	—	()	—
(<i>Macoma calcarea</i>)	()	—	()	—	()	—
<i>Pontoporeia femorata</i> ..	10	0.05	—	—	—	—
Total	580	10.70	0	0	0	0
St. 212 84 m 55°29'N, 15°19'E						
<i>Scoloplos armiger</i>	300	6.10	—	—	—	—
<i>Capitella capitata</i>	—	—	5	0.01	—	—
(<i>Macoma calcarea</i>)	()	—	—	—	—	—
<i>Diastylis rathkei</i>	5	0.10	—	—	—	—
Total	310	6.25	5	0.01	0	0
St. 133 92 m 55°23'N, 15°45'E						
<i>Scoloplos armiger</i>	55	0.55	—	—	—	—
(<i>Astarte borealis</i>)	—	—	—	—	()	—
(<i>Macoma calcarea</i>)	—	—	()	—	()	—
<i>Diastylis rathkei</i>	5	0.01	—	—	—	—
Total	60	0.56	0	0	0	0
St. 134 92 m 55°13'N, 15°45'E						
<i>Astarte borealis</i>	not		5	0.80	not	
(<i>Macoma calcarea</i>)	sampld		()	—	sampld	
Total			5	0.80		

TABLE 2 (suite)

	1965		1967		1968	
	ind./m ²	g/m ²	ind./m ²	g/m ²	ind./m ²	g/m ²
St. 115 						

In 1967, *Scoloplos armiger* was absent at all the deepest stations. A single living *Astarte borealis* was found at St. 134. All the specimens of *Astarte* found occasionally during 1963-1967 were old. In addition, the high degree of erosion of the empty shells of *Astarte* and *Macoma* indicates that no recruitment of lamellibranchs has taken place during and after the long stagnation. Two of the stations (St. 213 and 133) had no macrofauna at this time. The other deep stations were populated by polychaets *Harmothoe sarsi* (uncommon in 1965) and *Capitella capitata*. The last named has not been reported previously from this area and the present record is obviously the innermost in the Baltic. In the Arkona Basin, Thulin (1922) found a single individual of *Capitella* at the depth of 46 m.

The invasion of *Capitella* into the Bornholm Basin is of ecological significance in two ways. Firstly, the great depth of occurrence of this species, usually found in shallow bays and estuaries e.g. along the North Sea coast, is an example of brackish water submergence, a phenomenon peculiar for the arctic and boreal marine components of the Baltic benthos. Secondly, this species is often considered as a cosmopolitan indicator organism for marine pollution of organic origin. Thus, the conditions in the Bornholm Basin in 1967 resemble those in the category of "polluted bottoms" in the system of marine pollution zones created by Reish (1956, 1960). In most cases, *Capitella* is the last species living just outside the azoic badly-polluted zone. The peculiar environmental conditions usually coinciding with mass occurrence of *Capitella*, such as oxygen deficiency, enrichment of nutrition, presence of H_2S , decreased biological competition and consumption due to the impoverishment of the benthic community, etc., are in the Bornholm Basin not directly affected by human activities.

The altered species composition of the bottom fauna and the succession at the community level can provide some clues for predicting what species will recolonize marine recipients in cases of pollution abatement.

The total biomass has decreased considerably, due to the disappearance of the two lamellibranchs, which made up 60-98 per cent of biomasses below 70 m in 1951-52. The biomass values in 1960's even during the recolonization period in 1965, do not exceed those in 1951-52 (Table 3). The biomass of *Scoloplos* was then (1965) however more than 90 per cent of the total at all the deepest stations. In consideration of the short life span of *Scoloplos*, the productivity of the benthic community must have been very high in 1965.

The potential immigrants in the Bornholm Basin belong to the fauna of the shallower peripheral regions of this area and are thus able to invade the unpopulated bottoms effectively during the breeding seasons. In the case of *Capitella*, it is not sufficiently known if this species is more common in the Southern Baltic (and perhaps reported as an unidentified oligochaetous annelid by previous authors) or if the larval stages of it have been carried in the Kattegat water.

In August 1968, the benthic macrofauna was absent again (Fig. 3, Tables 1-3). Only a single specimen of *Diastylis rathkei* was found at St. 213 sampling with the Ockelmann-sledge. The meiobenthos

(100 μ mesh) consisted only of nematods. Studying of core samples at some of the deep stations gave following densities:

Station	Nematoda ind./m ² x 10 ³
215	230
213	248
133	38
115	162
135	168

Through the above-described stages, characterized by *Scoloplos* and *Capitella*, the fluctuation in the bottom fauna had reached in 1968 the level of more complete disappearance than in 1963-64. Benthic recolonization of this temporary type may be repeated in the near

TABLE 3
Total biomass of the bottom fauna in the Bornholm Basin 1951-1968.

Station	Depth m	Biomass g/m ²					
		1951-1952	1963	1964	1965	1967	1968
217	19	915	not quantit.	not quantit.	158.1	not sampled	not quantit.
216	45	3.05	31.03	10.67	45.2	»	not sampled
215	55	98.02	33.03	0.03	1.4	0.5	0.03
213	80	13.60	0	0	10.7	0	0
212	84	27.00	0.23	1.25	6.3	0.01	0
133	92	7.15	0	0	0.6	0	0
134	92	2.08	0	0	not sampled	0.80	not sampled
115	81	47.91	0	0	10.6	0.75	0
135	83	15.26	0	0	6.1	0.05	0
136	73	9.54	0	0.05	8.0	0.55	not sampled
137	57	10.15	16.88	2.07	21.1	24.45	»
139	45	23.93	0.30	3.30	11.85	not sampled	»

future. Acquaintance with these phenomena in the Bornholm Basin is of great importance when studying the expanding desolation of bottoms in the Baltic proper discussed e.g. by Segerst le (1965). The given image of the development in the present area is far from the complete due to too few sampling expeditions. It is proposed therefore that all observations at the international hydrographical stations in the Southern Baltic should be completed by routine sampling of benthos.

Grateful acknowledgement is paid to the staffs aboard and to the respective research boards in Sweden and Finland for permission to use the *Aranda*, *Thetis* and *Sagitta*. Dr. A. Eliason, Gothenburg, kindly confirmed the identification of the polychaets.

Резюме

Фауна на дне глубочайших частей бассейна Борнхольма вымерла почти совершенно во время длинного застойного периода в 1950-ых годах. Новая вода из Каттегата часто протекала после 1959-го года и течение поправляло содержимость кислородного газа в воде близ дна. Первые признаки того, что грунтовая фауна снова появилась, были отмечены в 1964 г. Во июне 1965 г.

были найдены семь пород грунтовой фауны; и особенно морской щетинный червь *Scoloplos armiger* появился в большом количестве. В марте месяце 1967 г. грунтовая фауна снова оскудела и доминировала *Capitella capitata*, порода, которая — по сообщению — теперь в первый раз находилась на дне этого бассейна. *Macoma calcarea* и *Astarte borealis* пластинчатожаберные моллюски, которые раньше были отмечены снова находящимися в 1960-ых годах.

Sammanfattning

Bottenfaunan i Bornholmsbäckens djupaste delar försvann nästan helt under en lång stagnationsperiod på 1950-talet. Nya vatteninflöden från Kattegatt har inträffat ofta sedan 1959 och förbättrat syreförhållandena i botten nära vatten. De första tecknen av bottenfaunans återkolonisering konstaterades 1964. I juni 1965 påträffades sju bottenfaunarter och särskilt havsborstmasken *Scoloplos armiger* förekom i stora mängder. I mars 1967 var bottenfaunan utarmad igen med *Capitella capitata* som dominerande art, vilken rapporteras för första gången från detta område. Någon nyrekrytering av musslorna *Macoma calcarea* och *Astarte borealis*, som tidigare var bottenfaunans viktigaste komponenter, har inte kunnat konstateras på 1960-talet. I augusti 1968 repeterades 1963 års situation igen: endast ett enda exemplar av *Diastylis* hittades under expeditionen i bäckens djupaste delar.

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