Long-term changes in the biocoenosis of the Gulf of Gdańsk

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Changes in the biocoenosis
Gulf of Gdańsk
Eutrophication

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Abstract

Eutrophication and generally increasing pollution have given rise to far-reaching changes in the biocoenosis. These mainly concern the structure of communities and the intensity of growth of particular species, and to a lesser extent, their species composition, through the reduction in abundance or disappearance of some species, in particular in the Inner Puck Bay, where once-lush underwater meadows have all but disappeared.

1. Introduction

The Gulf of Gdańsk is a region of the Baltic Sea strongly exposed to environmental degradation. Eutrophication and the general increase in pollution are undoubtedly responsible for this situation. It is difficult to state categorically that any increase in the nutrients responsible for eutrophication has actually taken place in this region, because physicochemical measurements have been carried on in the coastal zone only during the last ten years. Although a general trend in the Gulf of Gdańsk is not detectable, there are signs suggesting that the changes taking place in the open Baltic waters, in particular in the surface layer of the Gdańsk Deep, are even more advanced.

In the second half of the 1980s as much as 63.5% of all Poland's organic pollutants were discharged into the Gulf of Gdańsk. About 67% of these is brought there by rivers (Korzeniewski, 1988). Apart from that, large loads of nitrogen and phosphorus arrive from the atmosphere; the average yearly load reaching the coastal zone is 1450 $kg \cdot km^{-2}$ of nitrogen and 4 $kg \cdot km^{-2}$ of phosphorus (Falkowska and Korzeniewski, 1988).

An investigation carried out by the Institute of Meteorology and Water Management indicates that a slow decrease in phosphates and a simultaneous increase in nitrates has been taking place in the surface waters of the Gdańsk Deep during the last decade. This has led to an increase in the N:P ratio in the water; in the situation where nitrogen is the factor limiting primary production, this has accelerated eutrophication (Trzosińska, 1991).

However, it cannot be said with complete confidence that such trends are also affecting the waters of the Gulf of Gdańsk, in particular its coastal zone.

Apart from the large organic input into the Gulf of Gdańsk, the input of trace and heavy metals is making an impact on the ecosystem. In the coastal Gdańsk–Sopot–Gdynia conurbation lead is a serious threat to the biocoenosis.

Eutrophication and the contamination of the water and sediments have given rise to far-reaching changes in the biocoenosis. To varying degrees, they have affected mainly the structure of communities, the growth rate of particular species, and the species composition of and dominance within communities.

2. The biocoenotic effects of the changes in the vegetation

Up to the present time the biggest changes in this respect have been observed in the Inner Puck Bay where a dwindling of particular species is apparent. The disappearance of the underwater meadows and the occasional but mass occurrence of *Ectocarpaceae* in this region is a well-known and widely discussed fact (Pliński, 1990). The gradual loss of the underwater meadows has caused the disappearance of animal species associated with the macrophytes. The population of the Baltic shrimp *Paleamon adspersum*, the isopod *Idothea* and the bivalve *Cardium hauniense* have decreased sharply. It should be pointed out that for the last-mentioned species, which lives on macrophytes, the Inner Puck Bay was its only locality in the Polish zone of the Baltic Sea.

The disappearance of the underwater meadows has, moreover, considerably reduced the extent of fish spawning grounds. An example of this is the disappearance of the roach, a species very abundant before the 1980s (Morawski, 1982).

As far as the remaining waters of Puck Bay are concerned, the diminution in species numbers applies only to the phytoplankton community (Tab. 1). In 1946–47 (Rumek, 1948) about 260 taxa were observed there, but by 1988 that number had fallen to about 200. This reduction is clearly pronounced in the case of dinoflagellates: their number dropped from 36 taxa down to about 10.

Table 1. Number of taxa in phytoplankton algae groups during various study periods

Period		1977/78			1981			1986/87	
Region	W.G.G.	(I.P.B.)	Vistula mouth	Vistula mouth	E.G.G.	W.G.G.	(I.P.B.)	Vistula mouth	E.G.G.
Cyanophytes	42	(21)	21	37	35	28	(8)	15	13
Flagellates	11	(3)	4	14	16	14	(1)	10	7
Diatoms	133	(99)	62	68	70	65	(24)	37	35
Chlorophytes	35	(10)	19	54	54	18	(3)	22	17
Total	221	(133)	106	173	175	125	(36)	84	72

where
W.G.G. – western Gulf of Gdańsk,
E.G.G. – eastern Gulf of Gdańsk,
I.P.B. – Inner Puck Bay.

The decrease in the number of taxa was simultaneously followed by an increase in the abundance of other species, which led to a change in the structure of the blooms (Tab. 2). Particularly intensive blooms of green algae and dinoflagellates (*Hetercapsa triquetra*) were observed. The blooms of this latter species are a relatively recent phenomenon in the Gulf of Gdańsk: its mass occurrence was not reported before 1981.

Table 2. Average phytoplankton abundance (thou specimens $\cdot$ dm^{-3}) (May–October)

Period	1977/78		1981			1986/87	
Region	W.G.G.	Vistula mouth	Vistula mouth	E.G.G.	W.G.G.	Vistula mouth	E.G.G.
Cyanophytes	54	37	92	164	145	57	62
Flagellates	x	x	3	26	76	68	77
Diatoms	73	104	69	27	114	193	197
Chlorophytes	2	3	215	250	43	117	136
Total	129	144	379	467	378	435	472

where
W.G.G. – western Gulf of Gdańsk,
E.G.G. – eastern Gulf of Gdańsk .

As regards the phytobenthos, no distinct changes in species composition have been reported in the Gulf of Gdańsk. However, the depth range of this group has decreased from 20–25 m at the beginning of the century to 5–6 m at the present time. This fact can be linked to the decreased water transparency due both to the higher input of organic matter and to more intensive phytoplankton growth (Pliński *et. al.*, 1989).

3. Changes in the composition and biomass of fauna

The increase in the suspended matter content may also have contributed to the changes taking place in the bottom fauna, the community structure, the domination of particular taxa and the biomass.

Generally speaking, there seem to be two conflicting trends, namely, the increase and the decrease in biomass (Tab. 3). An increase in the biomass was observed in Puck Bay between 1962 and 1986. In 1987 the bottom fauna biomass decreased to a value below the one given for 1962 (Żmudziński, 1967) and below that estimated for 1978 (Wenne and Wiktor, 1982). Between 1978 and 1987, outside the Inner Puck Bay, there was a distinct increase in the biomass at the bottom in the depth range 8–20 m, and a slow but steady decrease in the bottom biomass at depths of 30–35 m; in the eastern Gulf this decrease was observable already at 20 m.

Table 3. Changes in bottom fauna biomass of the Gulf of Gdańsk in the last 25 years

Region/depth Taxon	Inner Puck Bay	Western part 5–20 m	Western part upper 30 m	Inner Puck Bay	Western part 5–20 m	Western part upper 30 m
Bottom fauna biomass in 1962-63 ($g \cdot m^{-2}$) (Żmudziński, 1967) and percentage of components in total biomass						
Polychaeta	15.0	1.2	0.1	7.1	0.8	0.1
Crustacea	20.0	2.1	15.5	9.5	1.1	3.9
Bivalvia	148.9	144.2	95.2	70.5	93.2	85.5
(Mytilus)	(43.8)	(110.4)	(–)	(29.4)	(76.6)	(–)
Gastropoda	23.4	6.0	–	11.1	4.1	–
Oligochaeta	0.7	0.8	–	0.3	0.5	–
Others	3.4	0.1	0.5	1.5	+	0.5
Total	211.4	159.4	111.3	100.0	100.0	100.0

Region/depth Taxon	Inner Puck Bay	Western region 3–5 m	Western region 8–10 m	Western region 20 m	Western region 30–35 m	Vistula mouth 3–5 m	Vistula mouth 8–10 m	Vistula mouth 20 m	Vistula mouth 30 m	Eastern part 3–5 m	Eastern part 8–10 m	Eastern part 20 m	Eastern part 30–35 m
Bottom fauna biomass in 1978-81 ($g \cdot m^{-2}$) (Wenne and Wiktor 1982; Herra and Wiktor, 1985)													
Polychaeta	4.7	0.8	0.7	1.6	+	–	0.3	20.1	1.0	0.2	0.2	0.2	0.2
Crustacea	1.9	0.5	2.4	4.1	21.3	–	3.2	8.0	7.5	–	1.2	0.3	5.9
Bivalvia	137.3	34.6	73.5	176.5	162.8	3.0	4.7	242.2	134.3	4.2	19.1	109.9	115.7
(Mytilus)	(29.8)	(16.9)	(37.3)	(115.2)	(3.0)	(–)	(–)	(–)	(0.1)	(–)	(9.6)	(–)	(2.6)
(Macoma)	(39.8)	(7.4)	(8.6)	(49.7)	(159.8)	(3.0)	(4.7)	(128.3)	(127.1)	(0.1)	(3.5)	(88.1)	(112.8)
Gastropoda	7.7	2.0	7.6	1.3	+	0.3	0.4	3.8	0.2	0.8	0.1	3.5	0.2
Others	+	0.1	0.1	0.3	3.2	–	+	0.2	0.9	0.3	+	0.7	0.7
Total	151.6	38.0	84.3	174.8	187.3	3.3	8.7	274.3	143.9	5.5	20.6	114.6	122.7

Table 3. (continued)

Region/depth Taxon	Inner Puck Bay	Western region 3–5 m	8–10 m	20 m	30–35 m	Vistula mouth 3–5 m	8–10 m	20 m	30–35 m	Eastern part 3–5 m	8–10 m	20 m	30–35 m
Percentage of components in the total biomass													
Polychaeta	3.1	2.1	0.9	0.9	–	–	3.0	7.3	0.7	3.9	0.8	0.2	0.1
Crustacea	1.3	1.4	2.8	2.4	11.4	–	37.2	2.9	5.2	–	5.7	0.3	4.8
Bivalvia	90.6	90.9	87.2	95.7	86.8	91.0	54.8	88.3	93.3	77.1	92.9	95.9	94.4
(Mytilus)	(21.7)	(48.9)	(50.8)	(68.8)	(1.8)	(–)	(–)	(–)	(0.7)	(–)	(50.2)	(–)	(2.3)
(Macoma)	(25.0)	(27.3)	(11.7)	(29.7)	(96.9)	(100.0)	(100.0)	(52.9)	(94.8)	(21.4)	(18.1)	(80.2)	(97.7)
Gastropoda	5.0	5.4	9.0	0.8	–	9.0	4.8	1.4	0.1	14.2	0.5	3.0	0.2
Others	+	0.2	0.1	0.2	1.8	–	0.2	0.1	0.7	4.8	0.1	0.6	0.5

Region/depth Station Taxon	Inner Puck Bay	Western region 3–5 m M1 G1 So1	10 m M2 I1 G2	20 m I2 So3	30 m J23 So4	Vistula mouth 5 m Sw1	10 m Sw2	20 m Sw3	30 m Sw4	Eastern part 5 m St1 K1	10 m St K2	20 m St3 K3	30 m St4 K4
Bottom fauna biomass in 1986 ($g \cdot m^{-2}$) (Gostkowska and Turas, 1988)													
Polychaeta	11.6	0.7	0.6	0.2	+		1.5	14.2	0.6	+	+	0.5	0.5
Crustacea	0.5	2.5	3.6	6.4	4.8		+	+	2.1	+	0.1	0.2	3.2
Bivalvia	273.1	198.2	420.0	244.5	169.0		38.0	243.0	11.6	4.0	2.3	37.0	36.3
(Mytilus)	(198.1)	(178.5)	(404.4)	(207.0)	(48.9)		(–)	(+)	(0.3)	(–)	(–)	(–)	(0.3)
(Macoma)	(55.7)	(1.8)	(10.4)	(36.8)	(120.1)		(31.4)	(76.2)	(10.3)	(–)	(0.4)	(17.2)	(35.0)
Gastropoda	16.4	1.3	4.8	4.0	1.3		0.3	6.2	0.6	0.1	0.4	2.4	0.5
Oligochaeta	+	+	0.1	0.1	+		0.2	0.8	0.1	+	+	+	+
Others	+	0.2	–	0.4	1.7		+	+	–	–	+	+	0.4
Total	301.6	202.9	429.1	255.6	176.8		40.0	264.2	15.0	4.1	2.8	40.1	40.9

Table 3. (continued)

Region/depth	Inner Puck Bay	Western region 3–5 m	10 m	20 m	30 m	Vistula mouth 5 m	10 m	20 m	30 m	Eastern part 5 m	10 m	20 m	30 m
Station		M1 G1 So1	M2 I1 G2	I2 So3	J23 So4	Sw1	Sw2	Sw3	Sw4	St1 K1	St2 K2	St3 K3	St4 K4
Taxon													
Percentage of components in the total biomass													
Polychaeta	3.8	0.3	0.1	0.1	+		3.8	5.4	4.0	+	+	1.2	1.2
Crustacea	0.2	1.2	0.8	2.5	2.7		+	+	14.0	1.0	3.6	0.5	7.8
Bivalvia	90.5	97.7	97.8	95.7	95.6		95.0	92.0	77.3	96.6	82.1	92.3	88.8
(Mytilus)	(35.9)	(90.1)	(96.3)	(84.7)	(28.9)		(–)	(2.6)	(2.6)	(–)	(–)	(–)	(0.8)
(Macoma)	(20.4)	(0.9)	(2.5)	(15.1)	(71.1)		(83.7)	(31.4)	(88.8)	(–)	(4.3)	(46.8)	(94.4)
Gastropoda	5.4	0.6	1.1	1.6	0.7		0.8	2.3	4.0	2.4	14.3	6.0	1.2
Oligochaeta	+	+	+	+	+		0.5	0.3	0.7	+	+	+	+
Others	+	0.1	+	0.1	1.0		+	+	–	–	+	+	1.0

Region/depth	Inner Puck Bay	Western region 3–5 m	10 m	20 m	30 m	Vistula mouth 5 m	10 m	20 m	30 m	Eastern part 5 m	10 m	20 m	30 m
Station		M1 G1 So1	M2 I1 G2	I2 So3	J23 So4	Sw1	Sw2	Sw3	Sw4	St1 K1	St2 K2	St3 K3	St4 K4
Taxon													
Bottom fauna biomass in 1987 ($g \cdot m^{-2}$) (Legeżyńska, 1989)													
Polychaeta	8.1	0.1	0.6	0.8	0.1		0.4	+	0.3	+	+	0.4	+
Crustacea	0.2	2.3	12.6	15.5	3.0		–	—	1.5	+	+	0.3	0.1
Bivalvia	114.1	147.4	276.1	343.5	147.0		7.4	9.3	13.7	2.0	2.0	35.6	30.7
(Mytilus)	(2.6)	(125.7)	(254.4)	(304.6)	(70.8)		(–)	(–)	(–)	(+)	(+)	(+)	(+)
(Macoma)	(45.6)	(1.9)	(15.2)	(35.8)	(76.2)		(7.3)	(7.8)	(2.0)	(0.2)	(0.2)	(7.0)	(8.2)
Gastropoda	5.7	2.4	2.6	1.1	0.1		–	–	0.8	0.5	0.5	3.0	0.6
Oligochaeta	0.1	0.4	0.1	0.1	+		+	–	+	+	+	0.2	+
Others	–	–	–	–	0.7		0.3	–	–	–	–	–	–
Total	128.2	152.6	292.0	361.0	150.9		8.1	9.3	16.3	0.6	2.5	39.5	31.4

Table 3. (continued)

Region/depth	Inner Puck Bay	Western region 3–5 m	10 m	20 m	30 m	Vistula mouth 5 m	10 m	20 m	30 m	Eastern part 5 m	10 m	20 m	30 m
Station		M1 G1 So1	M2 I1 G2	I2 So3	J23 So4	Sw1	Sw2	Sw3	Sw4	St1 K1	St2 K2	St3 K3	St4 K4
Taxon													
Percentage of components in the total biomass													
Polychaeta	6.3	0.1	0.2	0.2	0.1		4.3	0.1	1.5	0.5	0.4	1.1	+
Crustacea	0.1	1.5	4.3	4.3	2.0		–	–	9.0	1.2	0.4	0.7	0.3
Bivalvia	89.0	96.6	94.6	95.2	97.4		91.4	99.9	84.4	78.2	78.1	90.2	97.7
(Mytilus)	(2.2)	(85.3)	(87.7)	(88.7)	(48.2)		(–)	(–)	(–)	(–)	(+)	(+)	(0.1)
(Macoma)	(39.9)	(1.3)	(5.2)	(10.4)	(51.8)		(90.1)	(83.5)	(87.7)	(0.2)	(7.5)	(47.7)	(92.0)
Gastropoda	4.5	1.5	0.9	0.3	0.1		–	–	4.9	20.0	20.7	7.6	2.0
Oligochaeta	0.1	0.2	–	+	+		0.1	–	0.1	0.2	0.4	0.4	0.1
Others	–	–	–	–	0.4		4.1	–	–	–	–	–	–

The region of the Vistula river mouth is characterized by considerable fluctuations in the bottom fauna biomass, which is particularly pronounced where the bottom lies within the 20–35 m depth range. From 1981 to 1986, the bottom biological efficiency remained at a high level (247.3 and 264.2 $g \cdot m^{-2}$) whereas in 1987 it plunged to only 9.3 $g \cdot m^{-2}$ (Tab. 3).

The long-term changes in the total bottom fauna biomass of the Gulf of Gdańsk reflect changes in the biomass bivalves of the main filtering organisms, which make up nearly 90% of the total biomass of this community. These changes are apparent in the increasing biomass of *Mytilus edulis* in the region of its occurrence, and in the decreasing abundance and biomass of *Macoma baltica*, a species living at greater depths. Some changes have also been reported among the bottom crustaceans. Of the 5 *Gammarus* species occurring there – *G. salinus*, *G. oceanicus*, *G. zaddachi*, *G. locusta*, *G. inaequicauda* – only the first two are relatively abundant at present. *Corophium volutator*, a species preferring a muddy bottom and unaffected by water pollution, has also increased its numbers.

It is difficult to say whether the zooplankton underwent any changes during the 20-year investigation period. The few zooplankton species in the Gulf of Gdańsk are eurytopic. The different hydrological conditions (mainly thermal conditions) in various years have resulted in different growth rates in particular species. However, it does seem that in the coastal waters of the Gulf of Gdańsk *Acartia bifilosa* and *A. tonsa* are increasingly prevalent, while farther out to the sea, *Temora longicornis* is the predominant species.

The increase in abundance of protozoans, both the free-living *Tintinnidae* and the colonial epibionts – typical filtering organisms living on the three dominant species of copepods and covering them to an extent of 10–80%, depending on the season and stage of individual development – is a new phenomenon in the biology of the Gulf of Gdańsk. Such a high intensity of growth was not reported in previous studies. Again, this phenomenon can be linked to the increased input of organic matter and with the more intensive growth of bacterio-plankton.

4. Conclusions

Increasing eutrophication has caused the intensification of phytoplankton development and an increase in the biomass of the bottom fauna down to about 20 m. In both cases, simultaneous changes in community structure were observed: in the phytoplankton, the reduction in dinoflagellate species was accompanied by the mass occurrence of *Heterocapsa tricquerta*, while in the bottom fauna, an increase in the biomass and proportions of bivalves, *e.g.* *Mytilus edulis* and *Macoma baltica* were recorded.

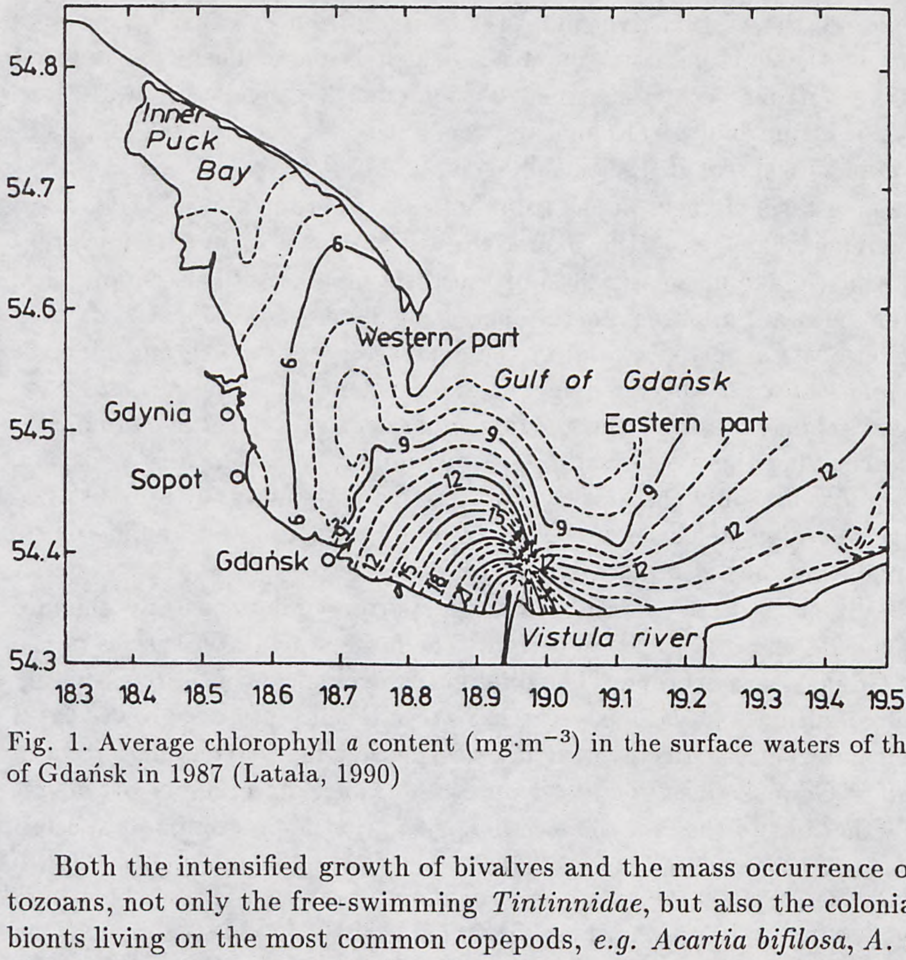

Fig. 1. Average chlorophyll *a* content ($mg \cdot m^{-3}$) in the surface waters of the Gulf of Gdańsk in 1987 (Latała, 1990)

Both the intensified growth of bivalves and the mass occurrence of protozoans, not only the free-swimming *Tintinnidae*, but also the colonial epibionts living on the most common copepods, *e.g. Acartia bifilosa*, *A. tonsa*, *Temora longicornis*, can be linked to the increased abundance of organic matter. The limited range of macrophytes is another effect.

The decrease in biomass of the shallow zone bottom fauna in the open part of the Gulf of Gdańsk is due to the generally elevated levels of pollution.

The situation observed in the Gulf of Gdańsk is additionally reflected by the composition of the local ichthyofauna and the condition of the fish (decrease in abundance of commercial species, mass mortality of eels).

The effects of advancing eutrophication are most evident near the Vistula mouth. Nitrogen and phosphorus concentrations are at their highest and concentrations of inorganic nitrogen can exceed 50 $\mu mol \cdot dm^{-3}$ the average for the Gulf being $<5 \mu mol \cdot dm^{-3}$. Phosphate concentrations there are 6 $\mu mol \cdot dm^{-3}$, whereas elsewhere in the Gulf they are less than 1 $\mu mol \cdot dm^{-3}$ (Nowacki, 1991). The most intensive phytoplankton blooms occur in this region (Tab. 2) and chlorophyll *a* concentrations reach a maximum of 21 $mg \cdot m^{-3}$ (Fig. 1).

The catastrophic situation observed in the Inner Puck Bay is due both to advancing eutrophication and to increasing pollution (including heavy and trace metals and other pollutants).

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