Oceanological and Hydrobiological Studies
International Journal of Oceanography and Hydrobiology
Vol. XXXVI, No. 1

Institute of Oceanography	(17-27)	University of Gdańsk
ISSN 1730-413X	2007	eISSN 1897-3191

DOI 10.2478/v10009-007-0005-6
Original research paper

Received: *October 14, 2006*
Accepted: *November 17, 2006*

Microbiological changes in the environment caused by deep dredging. A case study: post-dredging pit Kuźnica II (Puck Bay)

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Key words: bacteria, dredging, sediments, Puck Bay

Abstract

In this study psychrophilic, mesophilic and denitrifying bacterial abundances were studied seasonally (summer, autumn, winter and spring) in the water column and surface sediment layer (0-5 cm) in the post dredging pit Kuźnica II and natural areas of Puck Bay. The research was conducted between VI 2001 and III 2003.

In the pit area an increase in mesophilic bacteria and a decrease in denitrifying bacteria numbers were observed, when compared to the natural areas. In the case of the mesophilic bacteria, the increase was visible in the near-bottom waters and surficial sediments during the period of well developed vegetation – in summer and autumn. In the case of denitrifying bacteria, the decrease of number concerned the sediments. Numbers of psychrophilic bacteria in both the natural and dredged areas did not differ significantly over the course of the study.

These results suggest that deep dredging can cause the self-purification potential of the ecosystem to be diminished and induce strong bacteriological pollution.

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INTRODUCTION

Deep dredging was undertaken in Puck Bay from 1989 to 1995 in order to extract material for reinforcing the shores of the Hel peninsula. In effect, five dredging pits were formed in the bottom of Puck Bay (Fig. 1). They are characterized by deeper bottom depths than the surrounding area, and their topography clearly differs from natural depressions occurring in the bay (e.g. Kuźnicka, Chałupska and Rzucewska Hollows). Dredging sites create sediment traps for material transported along the bottom and sedimenting from the water column (Bolałek et al. 1996, Graca et al. 2004). Particulate matter gathering in deeper parts of the post-dredging pits is subject to anaerobic degradation, accompanied by hydrogen sulfide formation (Bolałek et al. 1996, Graca et al. 2004, Graca 2004), creating unfavorable environmental conditions for benthic organisms (Wawrzyniak et al. 1993, Szymelfenig et al. 2006).

The purpose of this study was to assess if, and in what way, deep dredging affects the number of microorganisms. Microbiological processes control organic matter cycling in the environment, and hence the number of bacteria and their species composition determine the trophic status of water bodies (Starmach 1976). Initial bacteriological studies in the area of post-dredging pit Władysławowo have been conducted by Bolalek et al. (1996). This work suggested, that in the former dredging areas an increase in the total numbers of bacteria in sediments and bottom waters occurred, in comparison to non-dredged areas. Similar observations concerning sulfate reducing bacteria were made by Graca et al. (2004) in studies of the dredging pit Kuźnica II.

The total number of meso-, psychro-philic and denitrifying bacteria were measured in the water column and sediments of both the natural sea bottom areas and dredging pits of Kuźnica II. These results can be used to aid considerations of the impacts of future dredging works, in an effort to reduce negative environmental consequences.

General characteristics of the dredging pit (Kuźnica II) and internal Puck Bay have been previously published in Graca et al. (2004) and Bolałek and Graca (1996).

MATERIALS AND METHODS

Following the pilot study reported in Graca et al. (2004) one representative sample site was selected for each of the deep areas of the dredging pit Kuźnica II and the natural bottom depression Kuźnicka Hollow. Additionally research included an area of shallow water over a natural sea bottom region neighboring the dredging pit (Fig. 1). The three sites sampled were; Station PP (9.5 m deep) in the area of the dredging pit, Station NP (7.5 m deep) situated at Kuźnicka

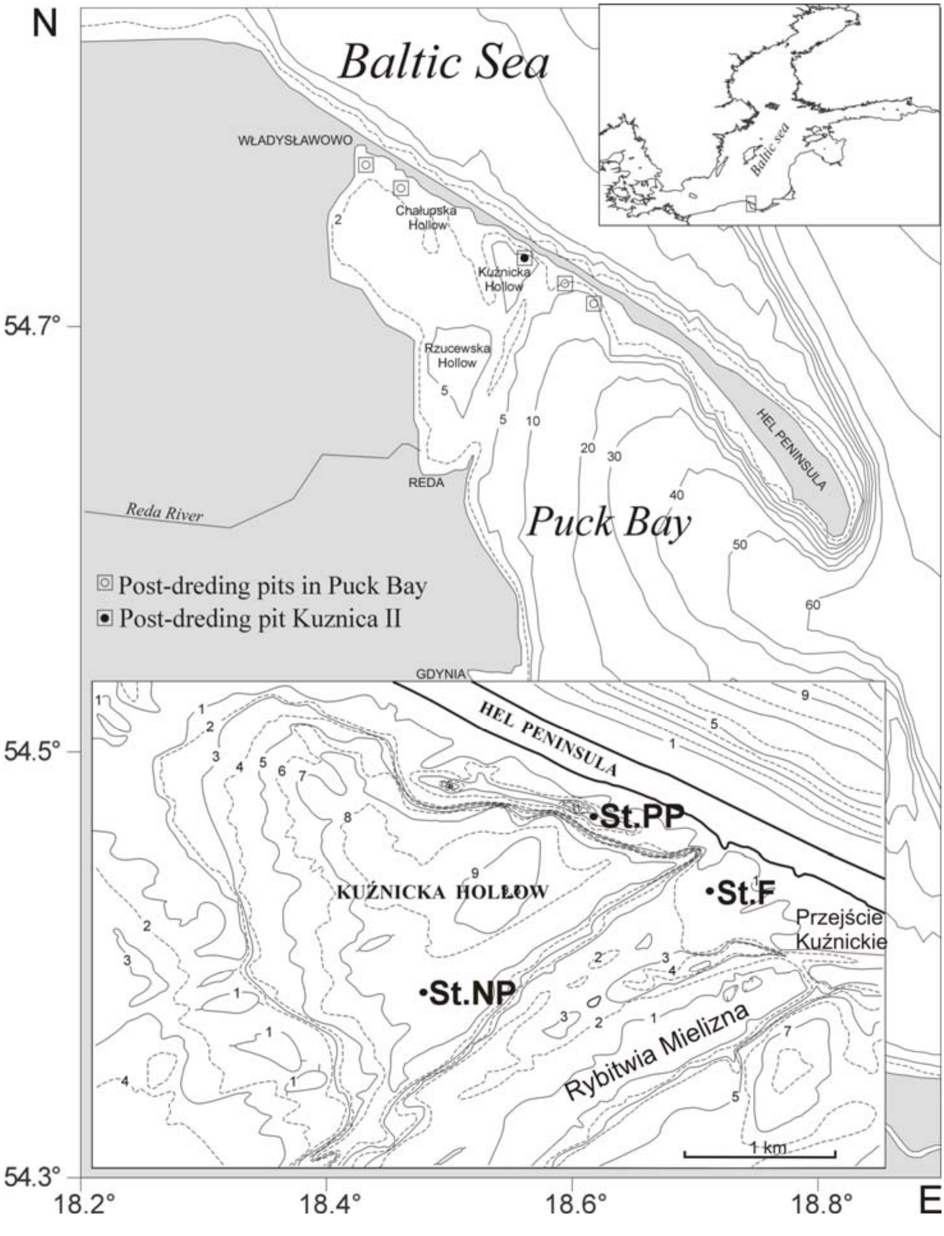

Fig. 1. Location of dredging pits and sampling stations (St.PP, St.NP and St.F) in Puck Bay.

Hollow and Station F (2 m deep) neighboring the dredging pit (Fig. 1). Stations F and PP are situated in an erosion – transport area of the seabed, whilst Station NP lies in a region of low hydrodynamic activity, where accumulation prevails (Wajda and Witkowski 1985). Samples were collected four times in; summer (VI 2001), autumn (X 2001), spring (IV 2002) and winter (III 2003)

Sediment characteristics of the study area are shown in Table 1. At each of the sites samples were collected by divers from surface waters (approx. 0.1 m below the sea surface), near-bottom waters (approx. 0.1 m above the sediment) and the topmost (0-5 cm) layer of sediment. Seawater samples were collected directly into sterile plastic or glass bottles, while sediment samples were collected in a Plexiglas tube (3.6 cm diameter). Samples were transported to the laboratory at 4°C, and analyses started within 4 h of collection. Total numbers of mesophilic (B.M.), psychrophilic (B.P.) and denitrifying bacteria (B.D.) were assessed. Samples were diluted with Ringer's solution for culturing; sediments by $10^{-1}$and 10^{-2} and water samples by 10^{-1}, 10^{-2} and 10^{-3}. The total number of meso- and psychrophiles was measured by direct colony counting method on Zo-Bell media (Monczak 1974) after 24 hours of incubation at 37°C (mesophiles) and 72 hours of incubation at 20°C (psychrophiles). Denitrifying bacteria were measured according to PN-75/C-04615/19 specification, using

Table 1

General physical characteristic of analysed sediments (0-5 cm) (Graca et al. 2004)

Station	Depth (m)	Sediment type		Water content %	LOI (loss of ignition - 550°C) %
F	2.0	medium-sands	mean	22	0.4
			minimum	20	0.3
			maximum	26	0.5
NP	7.5	sandy-mud	mean	53	4.5
			minimum	48	3.9
			maximum	64	4.8
PP	9.0	sandy-mud	mean	64	13.6
			minimum	32	1.9
			maximum	93	36.0

Giltay media and a three-tube system of culturing. The results presented here represent the mean of two replicates for each dilution, calculated for 1 cm^{-3} of water or 1 g of dry sediment.

RESULTS AND DISCUSSION

Denitrifying bacteria are common in aquatic environments, their presence in large numbers being considered a marker of ecosystem self-purification capability (Olańczuk-Neyman 1992). Mesophiles, which include many pathogenic bacteria, may originate from the alimentary canal of humans and other mammals. *E.coli* and Enterococci, which are regular components of alimentary canal microflora (Pawlaczyk-Szpilowa 1980), belong to this group. Psychrophiles occur in water, air, soil and bottom sediments (Rheinheimer 1977) and play an important role in the degradation of organic matter (Olańczuk-Neyman 2001). The total bacterial numbers observed in the investigated cultures displayed large variability, both regional and seasonal, throughout the period of this study (Fig. 2A,B,C).

Seasonal variations

The seasonal variations in the numbers of bacteria observed are shown in Table 2. At times with more vegetation (summer and autumn) higher average numbers of psychro- and mesophilic bacteria were observed in the water

Table 2

Seasonal variation of total number (10^3 cm^{-3} of water or g^{-1} of wet sediment) of mesophilic (B.M.), psychrophilic (B.P.) and denitrifying (B.D.) bacteria in the water column and sediments (mean ± standard deviation).

Season and year		B.M.	B.P	B.D.
		number of cells (10^3 cm^{-3} of water or g^{-1} of wet sediment)		
Summer (VI 2001)	s.w.*	24.17±27.88	28.17±16.63	0.65±0.56
	n-b.w**.	11.73±12.07	11.10±9.53	5.20±6.84
	s.***	11.53±1.75	9.07±9.22	5.47±2.65
Autumn (X 2001)	s.w.	31.40±32.10	36.73±36.59	8.53±13.41
	n-b.w.	13.00±5.76	29.67±20.23	8.13±13.73
	s.	146.66±47.26	335.00±90.14	16.97±12.18
Spring (IV 2002)	s.w.	0.31±0.25	3.57±2.48	8.11±13.76
	n-b.w.	7.23±0.80	12.92±15.87	0.17±0.05
	s.	6.03±4.31	44.76±33.71	8.10±13.77
Winter (III 2003)	s.w.	0.28±0.19	4.00±2.64	0.17±0.03
	n-b.w.	0.63±0.75	3.97±0.95	0.18±0.06
	s.	3.16±1.04	15.80±25.30	16.05±13.77

* - surface water, ** - near-bottom water, *** -sediment.

column than at other times (Table 2). High average numbers of psychrophilic bacteria were also observed in spring in the bottom waters of the naturally formed Kuźnicka Hollow (Station NP) (Fig 2). These observations support previous studies showing that the density of the heterotrophic microflora depends on the seasonal productivity of local photosynthetic organisms (Starmach 1976). The increase of food substratum in parallel with the temperature increase in summer and autumn creating favorable conditions for mesophilic bacterial growth. Land outflow is considered to be the source of these bacteria, as the study area is located close to the shore. In the sediments the highest average numbers of meso- and psychrophiles were observed in the autumn (Table 2). This increase coincides with maximal concentrations of sedimentary organic matter (Graca et al. 2004), a food source for the microorganisms. In the case of denitrifying bacteria no seasonal trends were observed in the water column samples. However in the sediment the lowest numbers were recorded in summer. This probably reflects the seasonality of photosynthetic productivity, which starts in Puck Bay in April, and is accompanied by a rapid decrease of nutrients. Low concentrations of nutrients are usually sustained until September (Bolałek et al. 1993). Simultaneously, in the summer, inhibition of nitrification occurs in the sediments, due to worsening of oxic conditions in the reservoir. This is typical for deeper areas of the Bay, and is connected to temperature increases and the concurrent oxygen consumption of organic mineralisation processes (Bolałek et al. 1993). Such a situation occurred in the area of Station NP, where oxygen concentration in the bottom waters dropped to 1.12 cm^3 dm^{-3} (Graca 2004). As a result of the decreased availability of nitrates the number of denitrifying bacteria observed in the summer was lower than at other times.

Regional variations

The results of the regional variations in the bacterial numbers are shown in Table 3. It might be expected that the observed results would be similar for the post dredging pit and station F as a result of their geographical proximity. However, as a result of the dredging both the depth and the sediment type of the dredging pit were altered and it is, in fact, more similar to Kuźnicka Hollow (Table 1). It is assumed that the major differences in the measured parameters between station F and the dredging pit, and between station NP and the dredging pit are primarily effects of dredging. The significance of any differences were assessed by means of a Kruskal-Wallis ANOVA. However the analyses were complicated by the large interseasonal variability of the bacterial numbers and the relatively short sampling period. Seasonal variability was great compared to regional variability, which resulted in the only statistically

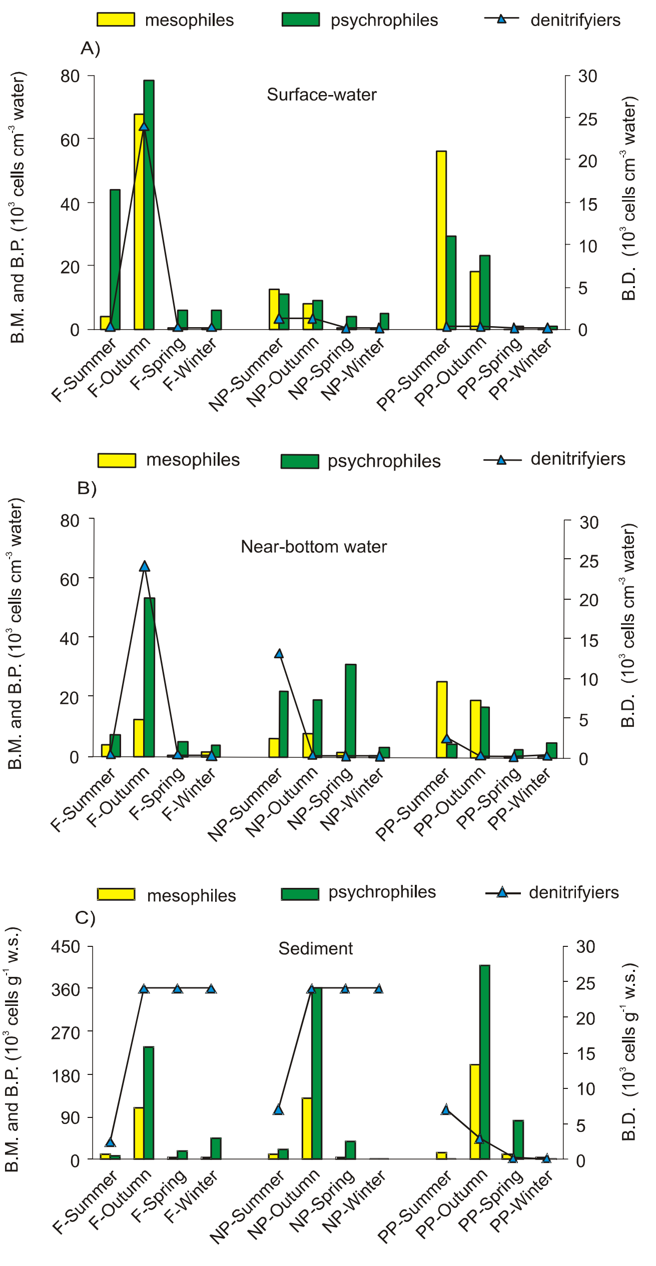

Fig. 2. Seasonal and regional variations in the total numbers of mesophilic (B.M.), psychrophilic (B.P.) and denitrifying bacteria (B.D.) in A) surface water, B) near-bottom water, and C) sediments of the sampling stations.

Table 3

Number (10^3 cm^{-3} of water or g^{-1} of wet sediment) of mesophilic (B.M.), psychrophilic (B.P.) and denitrifying (B.D.) bacteria in the water column and sediments at each of the three sampling stations. Results are shown as minimum – maximum counts (top row), mean / median (bottom row) in each case.

Station		B.M.	B.P	B.D.
		number of cells (10^3 cm^{-3} of water or g^{-1} of wet sediment)		
PP	s.w.[1)]	0.2-56.0[4)] 18.6./9.2	0.9-29.3 13.6/12.0	0.1-0.3 0.2/.0.2
	n-b.w.[2)]	0.2-25.6 11.3/9.7	2.7-17.0 7.2/4.6	0.1-2.4 0.7/0.2
	s.[3)]	3.5-200.0 56.9/12.0	1.4-410.0 123.9/42.0	0.1-7.0 2.6/1.5
NP	s.w.	0.2-12.4 5.2/4.1	4.0-11.0 7.3/7.0	0.1-1.3 0.7/0.7
	n-b.w.	0.2-7.8 3.9/.3.8	3.0-31.2 18.8/20.5	0.1-13.0 3.4/0.2
	s.	2.0-13.0 36.4/6.7	4.0-360.0 103.9/27.6	7.0-24.0 19.8/24.0
F	s.w.	0.5-68.0 18.3/2.4	5.8-78.2 33.6/25.1	0.2-24.0 6.2/0.3
	n-b.w.	0.3-12.0 4.4/2.6	4.0-53.0 17.2/6.0	0.2-24.0 6.1/0.2
	s.	3.2-110.0 32.3/8.0	6.5-235.0 75.7/30.7	2.4-24.0 18.6/24.0

1) - surface water, 2) - near-bottom water, 3) - sediment, 4) - minimum-maximum / mean/median

significant differences being obtained for the denitrifying bacterial numbers in the sediments ($p<0.05$). The number of those bacteria in dredged sediments was clearly lower (on average six fold) than in the natural sediments. This suggests that the self –purification potential of the ecosystem has been decreased by the deep dredging. Statistical confirmation of the significance of differences in the abundance of the other bacterial communities between dredged and natural areas requires further, long-term research. So far actual differences could be found by considering each season separately (Fig. 2).

Differences in mesophilic bacteria numbers between dredged and non-dredged areas, if observed, occurred in periods of limited wind induced water mixing and extensive vegetation (summer, autumn), and were most pronounced in the near-bottom waters and sediments. The total number of mesophiles in the near-bottom waters and sediments of the dredging pit were, on average, three and two-fold higher, respectively, than in the non-dredged areas.

According to the criteria for freshwater, waters with mesophilic bacteria exceeding 5000 colonies per 1 cm^{-3} can be considered polluted (Paluch 1973). If this were to be applied to the brackish, low saline waters of Puck Bay, then the surface and bottom waters would qualify at all the sampling sites in autumn, and in the dredging pit and Kuźnicka Hollow in the summer.

The psychrophilic bacterial numbers did not show any geographical trends, although some regularity was observed in the mesophile to psychrophile ratio in the bottom waters of the dredging pit in summer and autumn. In natural regions the psychrophile numbers were always greater than mesophile numbers, whereas the reverse was seen in the dredging pit.

The number of denitrifying bacteria observed in water column in a post-dredging area was usually lower or close to values found in natural bottom areas (Fig. 2). No relationship was detected between denitrifying bacterial numbers and denitrification rates in the sediments (Fig. 3). This may be a caused by the

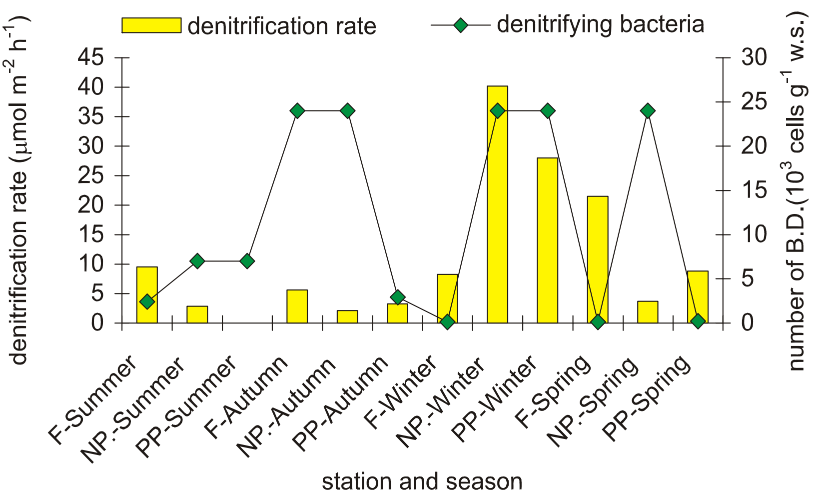

Fig. 3. Relationship between the number of denitrifying bacteria and denitrification rate in sediments (Graca 2004).

fact that most denitrifying bacteria reduce nitrates to nitrites, with only 5% capable of further reduction of nitrites to free nitrogen (Zobell 1938). Comparisons of the obtained results with other studies are difficult because of methodical differences and the limited number of bacteriological studies of the researched area.

The total number of psychrophilic bacteria observed in water column in this study were close to values reported by Czerwińska (1994, 1995) for the inner Puck Bay and coastal zone of the Gulf of Gdańsk.

SUMMARY

The research conducted shows that,
- denitrifying bacterial numbers were observed to be lower in dredged sediments than in unperturbed, natural bottom sediments,
- mesophilic bacterial numbers were higher in near-bottom waters and sediments in a post-dredging area in summer and autumn than in unperturbed areas,
- the number of psychrophilic bacteria observed in post-dredging areas was not significantly different from those in natural areas.

The results show that deep dredging might cause a decrease in the self – purification potential of the ecosystem, and strong bacterial pollution.

ACKNOWLEDGEMENTS

Research was conducted within the project entitled 'The impact of dredging on the Puck Bay ecosystem' (No 201/PO4/2000/19) financed by the polish State Committee for Research.

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