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ANNEX XIV

NEW INVESTIGATION AND EVALUATION CONCEPT TO DETECT EFFECTS OF DREDGING AND DUMPING ON MACROZOOBENTHOS

Presentation of the concept and first results: investigation of submarine disposal sites

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Due to sedimentation of sand or mud within coastal waterways continuous maintenance dredging is necessary, to guarantee the legally fixed water depth. The sediment masses to be dredged in the different waterways on the German North Sea coast sum up every year to several million m³ (Elbe estuary, Ems estuary, Jade) with the exception Weser estuary (less than 1 million m³).

As a result of the transformation of international agreements (dredging guidelines from OSPAR and HELCOM), for the Federal Water and Shipping Administration the "manual for the handling of dredged material in the coastal areas (HABAK-WSV)" was developed. An important issue was the investigation of the impact of dumping activities on macrozoobenthos.

The typical dynamic abiotic parameters in estuaries are responsible for the great variability in aquatic coenosis, as well as in the number of species, the species composition and in the abundance and biomass. This strong "basic noise" complicates identification of anthropogenic disturbances on macrozoobenthos. To optimise the planning and evaluation of investigations, the following working hypothesis was formulated and on that basis a sampling concept was developed. With data sets of current investigations a new evaluation concept was tested and further developed. The consideration and evaluation of a number of statistical and ecological evaluation methods made it possible to receive by far a more detailed answer to the question "are there ecological effects on macrozoobenthos by dumping at sea?". By that, additional characteristics of the biocoenoses will increasingly be included. This will result in described effects being more quantifiable and more reconstructable.

General conditions while dumping

- a part of the dumped sediment sinks to seabed and deposits itself there.
- a part of the sediment goes into suspension, increases the concentration of suspended material and drifts with the current, within a given time and space in a limited manner. Partly higher particle concentration occurs close to the seabed (fluid mud).
- Sedimented material can be resuspended and transported by currents.

Working hypothesis

Sediment deposition and/or raised turbidity have effects on a different scale on benthic organisms. This is dependent on the tolerance of the species, the volume and the frequency of covering and/or increase of turbidity. Under these conditions, an initial assumption is that the zoobenthos community in the dumping area itself can become modified compared to reference areas, which are not influenced directly by dumping. Species and individual density of benthic invertebrates may be reduced compared to reference areas. Due to the recurring disturbances by regular disposal within the framework of maintenance measures, a zoobenthos community, which is characteristic for undisturbed sites, could possibly not develop itself. The number of adult individuals can be atypically low while juvenile stages dominate. For this reason, the relation number of individuals to biomass can also be modified compared to undisturbed sites.

The described effects on macrozoobenthos are most intense inside the dumping areas (centre of disturbance). Those areas, in which the suspended part of the dumped material drifts close to ground (plume area), can also be influenced. However, the effects are presumably to a lesser degree and will still decrease with distance from the centre. In the plume areas of dumping sites for mud, the level of concentration of suspended material is normally higher both in the water column and close to the seabed than in the zones of dumping areas for sand. It is expected that more intense effects will be observed at mud dumping sites. On the other hand, at sand dumping sites, an increased sand drift close to ground could potentially occur, which could mechanically damage benthic organisms (sand scour effect).

With increasing distance from the dumping area, the possibility of detecting the disturbance will decrease to a point, where no ecological effects of dumping at sea are discernable.

Sampling concept
On the basis of this working hypothesis, the following sampling concept was developed, which is designated as the 'c-p-r concept'. The sampling stations are sub-divided into three groups and positioned as follows:

- Strongly influenced stations in the center (c)
- Stations in the lesser influenced plume area (p)
- Undisturbed reference stations (r).

Figure 1 illustrates the approach, which is briefly described as follows. The effects of are expected to be most noticeable within the actual dumping area (cf. working hypothesis). Therefore the stations set up accordingly.

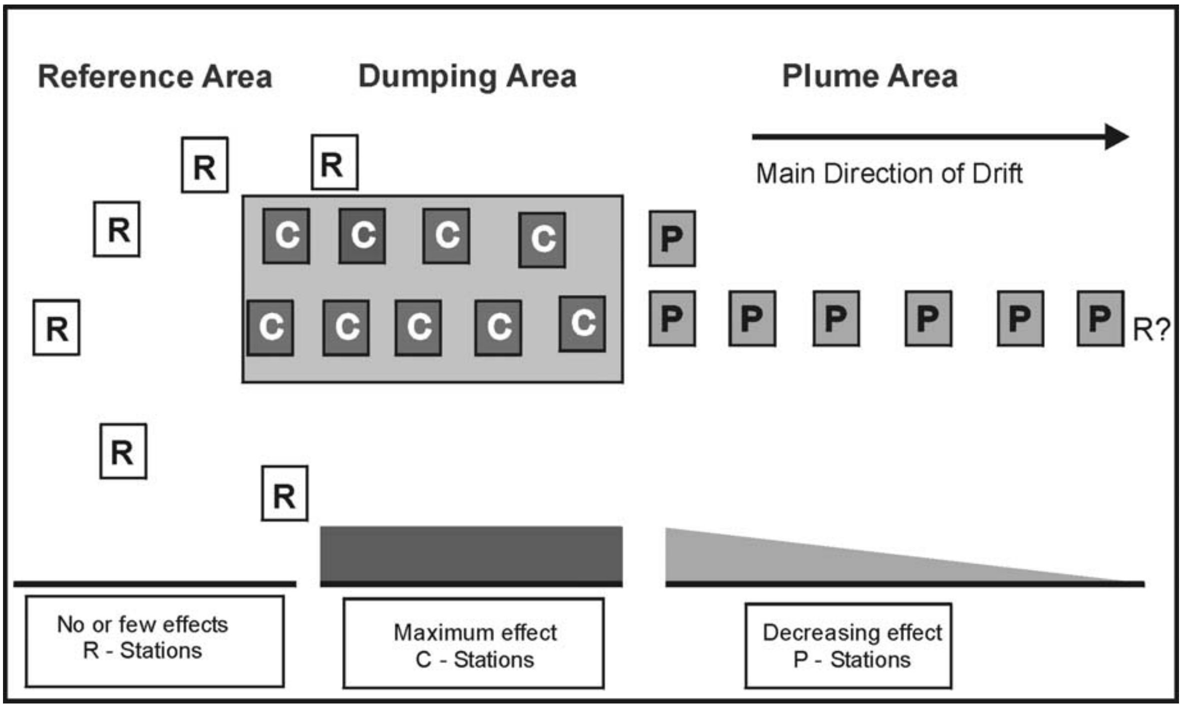

Fig. 1: Simplified representation of the working hypothesis (c-p-r concept) for the effects of dumping of dredged material on macrozoobenthos.

In the area of the main drift direction, there are potential effects of the plume on the macrozoobenthos. In this area, further sampling stations are positioned along a longitudinal transect (p). Stations P. were selected on the basis that the furthest station would presumably show limited effects on the benthic community since the potential for effects cannot be completely eliminated, the external plume stations not defined as reference stations (see below). Between the center and the external sampling station, the intervening stations were placed at more or less regular distance intervals.
Furthermore, sampling stations were positioned in direct proximity of the dumping area as well as in surrounding areas into which material was not expected to drift. The sampling stations outside the dumping area and outside the influence of the plume are defined – with restriction - as 'reference area' (r). The positioning of the reference stations is very difficult in a complex system such as an estuary where many natural and man-made gradients exist. It has to be considered that this sampling concept is adequate for dumping areas where strong currents exist and where the main direction of drift of material (plume) is approximately definable.
An important criterion for the quality of investigations about macrozoobenthos is, in addition to sampling method the underlying data record and particularly the number of stations and/or the number of replicate samples. The present biotope structure in the investigation area must be considered when fixing the position of the stations and the number of samples.

Evaluation concept
The described sampling concept was developed during a number of investigations of dumping areas carried out within the last few years. It has been used and further developed within ongoing HABAK investigations in the Weser and Ems Estuary. The data of several dumping areas have been analysed in each using a number of evaluation procedures (Table. 1). Both data of single samples and grouped samples were used as the basis for comparing dumping area (c), plume area (p) and reference area (r) (Table. 1). The more these procedures resulted in indications of effects (black rectangles in table 1), the clearer the general conclusion that differences exist between dumping and reference areas.

Evaluation process
Important descriptive parameters including number of species, diversity, abundance and biomass at different levels (all species, species group, single species) are used to biologically characterise the dumping site and allow a basis for the comparison of the different areas (c, p, r).
Species with rare occurrences may produce a less precise result within the analyses. Therefore a second evaluation which concentrated on regularly occurring species was carried out in order to eliminate the inaccuracies introduced by rarely occurring species. The definition of continuous species is based on the frequency of its occurrence and abundance (see. below).
A new ecological evaluation process developed by BioConsult, Bremen, Germany is being used to compare the biocoenosis with an internal reference and is based on the 'amoeba-approach' from COLJIN (1989). The abundance of single species is compared to a reference abundance (always 100%). In the 'internal reference approach' (developed by BioConsult, Bremen) the reference is the mean abundance for each continuous species in the whole set of data which is then compared to the mean abundance of the related species for the data set from the different areas (c, p, r). In this procedure a species is taken into account when the likelihood is not too low of detecting the species in the investigation with the given number of samples. The species is defined as a constant species when the frequency of occurrence is greater than 20% and additionally the abundance is greater or equal to 1 ind/m². The abundance of a species from one of the tested areas and the reference abundance are 'measured' against each other. The means from the whole dataset were compared with means from a part of the set. The result is presented graphically in deformations of a circle diagram (Fig. 2).

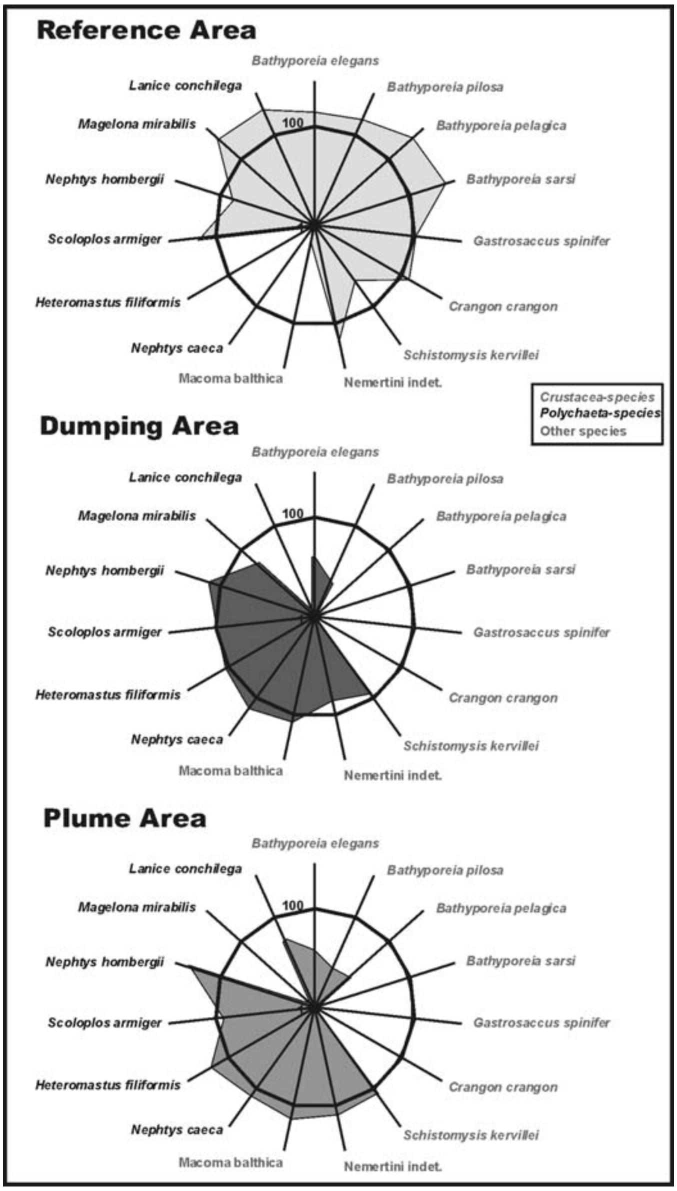

Fig. 2: Evaluation method "internal reference": Arrangements of dumping, plume and reference areas are on the basis of the abundance of continuous macrozoobenthos species (HABAK EMS, dumping area 6).
Explanation: The similarity of the species compositions between dumping and plume area (dominated by Polychaeta) is by far higher than its similarity to the reference area (dominated by Crustacea), This is an indication of modification due to dumping. Black ring = reference value 100%.

In order to assess the differences statistically between the several groups of stations with respect to abundances and biomass, a set of statistical tests were carried out: cluster analyses, univariate significance tests (median and Wilcoxon tests) and a multivariate significance test (ANOSIM). In addition, ordination procedures represent an essential complement. The Principal Component Analysis (PCA) and Correspondence Analysis (CA) assess the variation of the structures of species abundances without taking into account different measured environmental parameters (which could be used for interpretation). In contrary the Canonical Correspondence Analysis (CCA) permits an estimate, at which degree specific environmental parameters can explain the width of variation of the benthos data. Therefore, combinations of environmental parameters can be computed and the ordination axes mounted (=axes of artificial factors). The analysis represents a multivariate form of regression by which the data of species abundance are modelled as a function of the environmental parameters. The CCA serve to explain the possible influence of the identified environmental parameters (type of sediment, loss of ignition from sediment, depth of water) onto the macrozoobenthos communities. The points representing species on the graph reveal their optimum level in the context of the presented environmental parameters. Additionally the situation of the stations in dependence of the environmental parameters and the structure of species abundance is presented in this ordination (Fig. 3).

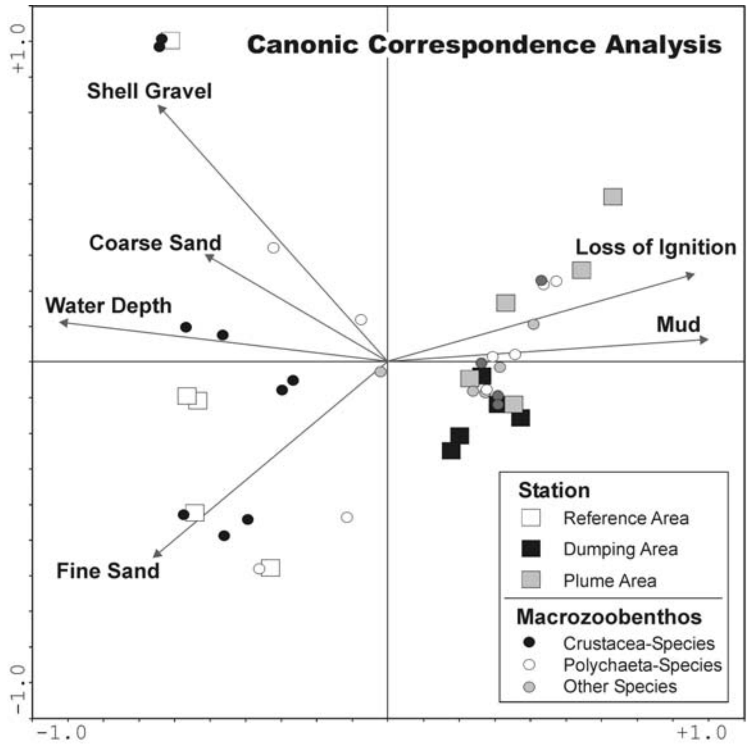

Fig. 3: Evaluation method "canonic correspondence analysis": Link between species composition of macrozoobenthos and environmental parameters, ordination of stations based on abundance data (HABAK EMS, dumping area 6).
Explanation: In the ordination, differences of species and stations are performed in accordance with the prevailing environmental parameters. The reference stations are marked by fine sandy, partially shell gravel containing and coarse sandy sediments, plume and especially stations within dumping area show higher mud contents and losses of ignition, both are results of continuous dumping activities. On the represented axes (X- and Y-axis) 70,5% of variation in variances of species abundance are traced back to the given environmental parameters and consequently, can be evaluated as a indication of modifications by dumping at sea.

Initial results

Within the framework of the investigations to the **HABAK Weser** estuary in 1997, at three dumping areas the presented sampling and evaluation concept with different statistical procedures were used (Tab. 1). This investigation in conjunction with older data sets confirmed the known high natural biotic variability in the Weser estuary on different scales of space and time. This not only applies to abundance and biomass but especially to the species composition. Only in the dumping area with 0,6 million m³ sand and mud some evidence of effects by dumping on the biocoenosis could be detected despite of the high natural variability in the biocoenosis. Effects could be detected by the slight decrease in species number and abundance, but there was no clear reduction. For the dumping area three results were even less clear. Since the internal reference analyses showed no effect, the slight differences are probably not linked to the dumping activities.

During the investigation **'HABAK-Ems'**, carried out in 1999, the evaluation concept was applied and further developed in conjunction with several statistical procedures. During the evaluation of the results from the dumping areas 5, 6 and 7 clear differences between the dumping-, plume- and reference areas could be detected with respect to number of species, number of individuals, diversity, biomass and community structures (Table. 1). Very clear differences could be seen between the reference area on one hand and the dumping- and plume area on the other hand (Fig. 2). The results of the Canonical Correspondence Analysis (CCA) showed that the difference was caused by the difference in the grain size in the 3 investigated areas. The reference area was characterised by low mud content, dumping and plume area showed a higher mud content, which was caused by the dumping of mud and sand (Fig. 3).

A comparison of the two HABAK investigations shows that the quality and quantity of the material deposited in dumping areas essentially influences the kind and scale of the effects on the benthic coenosis. On the basis of these results initial effects on the macrozoobenthos in the investigated region can be predicted, if dumping activities exceed more than ½ million m³ sand and mud a year.

Parameter	Basis	Niveau	Procedure	Weser: Dumping area 1 sand & mud 0,6 Mio m³	Weser: Dumping area 2 sand 0.1 Mio m³	Weser: Dumping area 3 mud 0.5 Mio m³	Ems: Dumping area [illegible] mud 1,7 Mio m³	Ems: Dumping area 6 sand & mud 1.9 Mio m³	Ems: Dumping area 7 sand & mud 2.2 Mio m³
Environment	Station	Sedimenttype loss of ignition	Diagram	□	■	□	■	■	■
Species number	Station	Speciest	Diagram				■	■	□
	Group of Station C-P-R	Group	Diagram				□	■	□
	Group of Station C-P-R	Constant sp	Diagram	■		■			
Diversity	Station	Species	Diagram				■	□	■
Dominance-strukture	Station	Constant sp	Diagram				■	□	□
	Group of Station C-P-R	Species	Diagram	■	□	□			
	Group of Station C-P-R	Constant sp.	Diagram	■		■			
Abundance	Station	All species	Diagram	□	□	□	■	■	■
	Station	Species	ANOSIM				■	■	■
	Station	Species	Cluster	□	□	□			
	Group of Station C-P-R	Group	Diagram				■	■	■
	Group of Station C-P-R	Group	Test				■	■	■
	Group of Station C-P-R	Constant sp	Diagram	□		□			
	Group of Station C-P-R	Constant sp.	Internal Reference	■		□	■	■	■
	Probe	Species	PCA				■	■	■
	Station	Species	PCA				■	■	■
	Probe	Species	CA				■	■	■
	Station	Species	CA				■	■	■
+ Environment	Station	Species	CCA				■	■	■
Biomass	Station	All species	Diagram	□	□	□	■	□	■
	Station	Species	ANOSIM				■	■	■
	Station	Species	Cluster	□	□	□			
	Station	Species	ABC-Plot	□	□	□			
	Group of Station C-P-R	Group	Diagram				■	■	■
	Group of Station C-P-R	Group	Test				■	■	■
	Group of Station C-P-R	Constant sp	Diagram	□		□			

Table. 1: Survey for the results of different statistical evaluation methods for elucidation of effects by dumping of dredged material on macrozoobenthos (HABAK Weser 1997, HABAK Ems 1999; Dumping areas with information of type and quantity of dumped sediments within a year each before sampling of macrozoobenthos). Differences between reference stations and stations within dumping and plume area:

black – rectangle: clear modifications in macrozoobenthos by dumping

white – rectangle: no recognizable indications of effects on macrozoobenthos by dumping

Field without rectangle: no statistical analysis carried out

Conclusion

In order to economically manage dredged material in the future with consideration of ecological issues, it is necessary to document the effects of dumping of dredged material of different origins, different quantities and in different frequencies in different regions. When carrying out this work it is essential to have an optimised tool of investigation and evaluation procedures as their quality influences the possibilities and limitations of detecting disturbances on benthic coenosis.

Due to the concepts used within the HABAK investigations, it was possible to detect relatively small anthropogenic, time limited disturbances within a system with high natural variability like the investigated estuaries. Using a number of ecological and statistical evaluation procedures enables a separation of essential ecological effects from disturbing signals and a selective interpretation of the data correspondingly.

It is the aim by checking and further developing of ecological and statistical tools to provide an extensive set of procedures which will allow consideration of the question; “are there ecological effects caused by dumping (and also caused by dredging, extraction, etc.)?” The knowledge obtained will enable an ecologically optimised management of dumping areas.

COLIJN, F. (1989) Gewässergütekriterien und naturbezogene Zielsetzungen in den marinen und brackigen niederländischen Gewässern. In: Niedersächsisches Umweltministerium (Ed.), Statusseminar - Gütekriterien für Küstengewässer. Hannover, pp 36-42.