BALTIC SEA ENVIRONMENT PROCEEDINGS

No. 76

MARINE SEDIMENT EXTRACTION IN THE BALTIC SEA
- Status report -

HELSINKI COMMISSION
Baltic Marine Environment Protection Commission

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compiled by
C. Herrmann (DE), J. Chr. Krause (DE), N. Tsoupikova (RU) and K. Hansen (DK)

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Contents

List of figures

List of tables

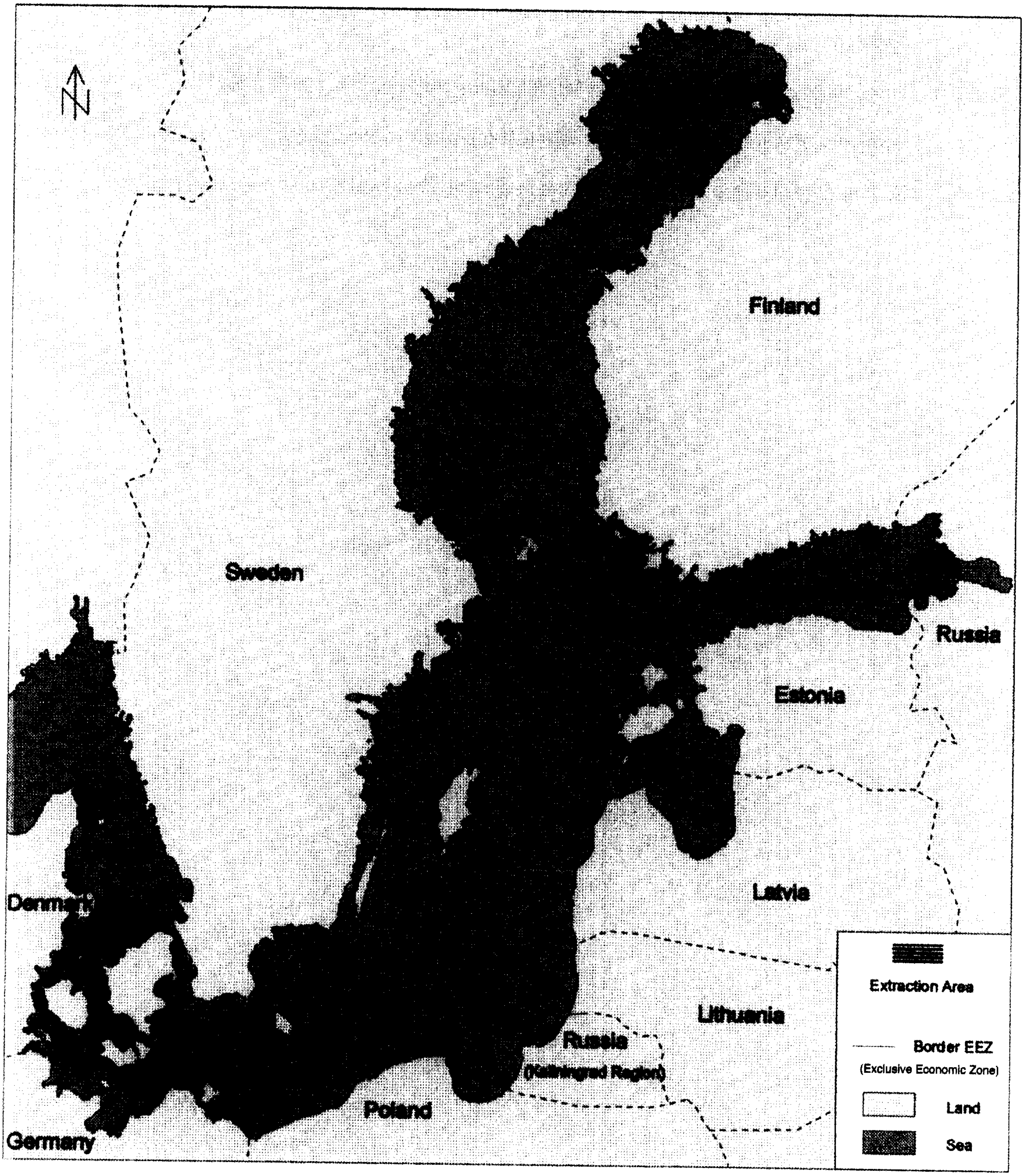


Figure 1: Sand and gravel extraction areas in the Baltic Sea region (Helsinki Convention Area). Information submitted by the Contracting Parties on request of the HELCOM Working Group EC Nature; Map according to Seifert & Kayser (1995); Borders of the Exclusive Economic Zone (EEZ) according to sea charts of the German Federal Maritime and Hydrography Agency (BSH).

Marine sediment extraction in the Baltic Sea

- Status Report -

compiled by C. Herrmann (D), J. Chr. Krause (D), N. Tsoupikova (RUS) & K. Hansen (DK)

1. Introduction

Exploitation of marine sand and gravel resources already has a long history in some parts of the Baltic Sea area. However, recently the amount of marine sand and gravel extraction has increased considerably for a number of reasons:

- increased awareness of environmental and social conflicts of terrestrial mineral extraction (loss of arable land, permanent changes of the landscape, conflicts with nature conservation aims, impacts on ground water resources, conflicts with human housing and recreation due to noise, dust, transport, impacts on the scenery, etc.)

- increasing legal restrictions for exploitation of terrestrial resources in many countries as a consequence of environmental considerations and diminished public acceptance

- progress of extraction techniques which facilitate exploitation of marine sediments

- advantages of marine sediments with respect to quality, availability, and ease of transport and delivery in many cases.

However, marine sediment extraction may nevertheless have negative implications for the environment, e.g., marine fauna and flora, feeding conditions of sea ducks and fish, as well as for fisheries and coastal protection. Beginning in the 1970s, the scientific interest has been focused increasingly on the implications of marine sediment extraction. Comprehensive work has been done, *inter alia,* by the International Council for the Exploration of the Sea (ICES). Already in 1975, ICES published its first "Report of the Working Group on Effects on Fisheries of Marine Sand and Gravel Extraction" (Res. Rep. 46). In 1986, the ICES Working Group on the Effects of Extraction of Marine Sediments on Fisheries convened with the aim of increasing the knowledge and understanding of the impact of marine aggregate extraction upon fisheries in particular, and the marine environment in general. The information gained was compiled in the "Report of the ICES Working Group on the Effects of Extraction of Marine Sediments on Fisheries" (1992), which also includes a "Code of Practice for the Commercial Extraction of Marine Sediments (including mineral and aggregates)". In the following years, ICES ACME (Advisory Committee on the Marine Environment) has elaborated several guidelines and recommendations:

- "Guidelines for environmental impact assessment of marine aggregates dredging" (draft, ACME report 1993)

- "Guidelines for environmental impact assessment of marine aggregates dredging" (ACME report 1994)

- "Environmental effects monitoring of extraction of marine aggregates" (ACME report 1995).

A new and updated ICES Co-operative Research Report was finalised in 1998 by the Working Group on the Effects of Extraction of Marine Sediments on the Marine Ecosystem (WGEXT).

The intense focus on the comprehensive ecological aspects of marine sediment extraction within the HELCOM frame is founded by Article 3 (Fundamental principles and obligations), 4 (Application) and 15 (Nature conservation and biodiversity) of the Helsinki Convention 1992:

Article 3 (1) establishes the general aim of the ecological restoration of the Baltic Sea Area and the preservation of its ecological balance.
According to paragraph (2) the precautionary principle shall be applied when there is reason to assume that living resources or marine ecosystems are harmed by direct or indirect introduction of substances or energy.

Article 4 (1) states that the Convention shall apply to the protection of the marine environment of the Baltic Sea Area which comprises the water body and the seabed including their living resources and other forms of marine life.

Article 15 obligates the Contracting Parties to take individually and jointly all appropriate measures to conserve natural habitats and biological diversity and to protect ecological processes. Such measures shall also be taken in order to ensure the sustainable use of natural resources within the Baltic Sea Area.

Recognizing the ecological implications marine sediment extraction may have, HELCOM has addressed the problem more comprehensively in most recent times. The sixth meeting of the HELCOM Environment Committee (EC 6, 1995) has requested EC NATURE to consider effects of sand and gravel extraction and the advice by ICES on this issue (document EC 6/15, paragraphs 6.38-6.39). The seventh meeting of the Environment Committee (1996) took note of the concern expressed by EC NATURE regarding the problems arising from sand and gravel extraction and invited EC NATURE to examine the existing advice by ICES (e.g., Code of Practice) and to draft a HELCOM Recommendation on the issue, as appropriate (EC 7/96, document 15/1, paragraph 7.22).

After this, in 1997 EC Nature has drafted a HELCOM Recommendation on Marine Sediment Extraction in the Baltic Sea Area, which has been approved by the Commission in 1998 as Recommendation 19/1. The Recommendation gives detailed advice on how to apply the precautionary principle in extraction operations, including criteria for areas where extraction shall not take place.

The present paper is a compilation of background information on occurrence and distribution of sand and gravel resources in the Baltic Sea as well as current and expected exploitation activities. Furthermore, an overview is given on possible environmental implications. The document is an update of the background paper written by EC Nature as a basis for Recommendation 19/1.

For the composition of this document, the work already done by ICES, other studies and references concerning the issue, as well as information submitted by the Contracting Parties has been evaluated.

2. Legal regulations for marine sediment extraction

In all Baltic Sea Countries, national authorities must grant permission to extract marine sediments.

In the EU member states, the "Directive on the Environmental Impact Assessment for certain public and private projects" (85/337/EEC) from 27/6/1985 applies, *inter alia*, to the extraction of minerals from the seabed. Mineral extraction is included in annex II of the Directive[1]. For projects according to annex II an Environmental Impact Assessment (EIA) has to be performed if the member states take the view that an EIA is required due to the nature of the project. It is at the discretion of the member states to define criteria and/or threshold values concerning EIA requirement. For instance, in Germany such threshold values are defined by the "Decree about Environmental Impact Assessment for Mining Projects" from 13/7/1990. According to this decree, an EIA is obligatory if the extraction area exceeds 10 hectares or if the daily exploitation rate is more than 3,000 tons.

In Denmark the National Forest and Nature Agency is, according to the Raw Materials Act, responsible for administration of marine aggregate dredging. A new Raw Material Act took effect on January 1st, 1997. From this date, all dredging activities will take place in permitted areas. A 10-year transitional period is allowed for dredging in existing areas.
New dredging areas are subject to a government review procedure including public and private involvement. The applicant is requested to provide sufficient documentation about volume and quality of the resources and to carry out an Environmental Impact Assessment. Permits will be granted for a period of up to 10 years.

An EU Environmental Impact Assessment in accordance with EC-Directive 85/337, during which the general public, authorities and organisations have the opportunity to state their opinion, should be carried out "on top" of the obligatory Environmental Impact Assessment, if the applied extraction activity can be assumed to have a significant impact on the environment (ICES WGEXT 1998b).

In Sweden, an Environmental Impact Assessment (EIA) for marine mineral extraction projects was already introduced in 1987 by the Act (1987 : 12) on the Management of Natural Resources.

In Finland, sand and gravel extraction does not require obligatory EIA. However, the extraction of mineral resources from marine areas requires permission from the appropriate Water Court. The Court has to weigh the economic and other profits against the impacts on the marine environment. As a result, permission can be granted or denied. In order to be able to weigh the different interests, the Water Court often demands assessment of impacts on fishery and marine environment. Since Finland joined the EU in 1995, the regulations of the EIA Directive will be implemented into Finnish legislation.

In some non-EU states like Poland and Estonia, an Environmental Impact Assessment is also required for marine sediment extraction projects.

1 - The Directive 85/337/EEC has been amended by the Directive 97/11/EC from 3/3/97. The member states are obliged to implement the new regulations into national legislation by 14/3/1999. In the new Directive the extraction of minerals from the seabed still belongs to the annex II projects. For these projects the member states may decide upon EIA requirement on the basis of an individual project study or defined threshold values or criteria. The newly introduced annex III of the Directive gives special criteria for the decision whether an EIA is required or not.

3. Marine sand and gravel resources in the Baltic Sea

Denmark

The Danish marine areas, including the North Sea, the Kattegat and the Baltic Sea, are very rich in mineral resources such as sand, gravel and stones, which are exploited at a considerable rate.

The National Forest and Nature Agency has commissioned the Geological Survey to undertake an evaluation of the total reserves of sand and gravel in Danish waters based on all existing data collected since 1979. Since 1991, mapping programmes have been carried out on Jutland Bank and Horns Reef in the North Sea and in Femer Belt, Adler Ground, Rønne Bank and Kriegers Flak in the Baltic. At present, between 80 and 90 % of potential resource areas in the inner Danish waters have been surveyed (ICES WGEXT 1998b).

Marine resources of fine sand in the North Sea and Baltic Sea are several billion cubic meters. However, the resources are not equally distributed and environmental constraints may seriously limit the reserves in some areas. It is expected that reserves are available for at least 50 years in most areas.

Resources of medium and coarse sand are limited in volume and distribution. Most of the accessible resources are located in shallow waters and are small, complicated in structure, and therefore difficult to exploit. A few larger resources have recently been identified in deeper waters and are expected to produce the majority of marine medium and coarse sand in the next 25 years.

Gravel (6 - 200 mm) is a finite resource dredged in a limited number of areas primarily located in coastal shallow waters of high environmental vulnerability, where promising resources have been identified. The total reserves have not yet been evaluated. Based on reconnaissance surveys, a number of inferred resources have been found in the North Sea and the Baltic.

Germany (Schleswig-Holstein)

There are various deposits of sand and gravel on the coastal shelf of Schleswig-Holstein.

Germany (Mecklenburg-Vorpommern)

The marine deposits of sand and gravel on the coastal shelf of Mecklenburg-Vorpommern are currently estimated to amount about 40 x 10^6 m (tab.1). The thickness of the sand and gravel layers is rather low, on average only about 1 m. The economically interesting deposits are mainly situated between the 6 and 20 m depth line (Krause *et al.*, 1996, Gosselck *et al.*, 1996).

Poland

During the last 30 years geological prospecting and reconnaissance surveys carried out by the Branch of Marine Geology of the Polish Geological Institute have located various mineral products. Natural aggregates, *i.e.*, gravel, sandy gravel, and gravelly sand, which form deposits on the seabed, are the most thoroughly investigated mineral resources in the Polish coastal waters. To date, three deposits totaling about 90 x 10^6 m have been documented: the "Slupsk Bank" deposit, the "Southern Middle Bank" deposit and the "Koszalin Bay" deposit. The results are presented in various reports (ICES WGEXT 1998a).

In 1997 about 1,641,500 m of sand was identified and geologically documented for beach nourishment in the western part of the Polish EEZ in the vicinity of Dziwnów (ICES WGEXT 1998b).

Furthermore, Poland has identified deposits of sand enriched with heavy minerals such as garnet, zircon, rutile, ilmenite, magnetite and monazite, which might become of economical interest in the future (ICES WGEXT 1998b).

Russia (Kaliningrad region)

Bottom deposits of sand and gravel are widely spread on the Sambian-Curonian plateau. The most important of them are situated near former accumulation zones of different stages of the post-glacial Baltic Sea history. One of the most prospective sites is the massive of ancient dunes, situated in the vicinity of the oil drilling installation, which covers an area of about 90 km^2. The sand resources of this site amount to not less than 300,000 m .

Another area interesting for exploitation is situated in the region of the bore hole D-6-5/1. This area is covered by a ca. 10 m thick layer of ancient marine sands of medium grain size, and an upper layer of 1 - 2 m of sand-gravel.

A vast field of medium grained sands is situated in the Sambian depression. These thick cumulative strata (up to 10 - 12 m) include shifting sands (aleurites, 0.01 - 0.1 mm) and peat layers. According to preliminary calculations, the sand resources accumulated on this site amount to more than 10^6 m .

A further sand deposit is scattered with paleogene basic rocks. It mainly consists of sand of different grain

Table 1: Prospected areas on the continental shelf of Mecklenburg-Vorpommern (UWG 1993).

location	sediment type	estimated amount (10^6 m≥)	remarks
(1) outer Wismar Bight	sandy gravel, sand	3.4	obviously severe conflicts with nature conservation aims
(2) sea area off K¸hlungsborn	sandy gravel, gravel	4.4	sediment layers of 0.2 - 2.5 m thickness, total area 218 ha
(3) sea area off Markgrafenheide	sandy gravel, sand	4.3	
(4) Plantagenet Ground	sandy gravel, gravel	5.7	shoal about 22 km NE Darfl/Zingst peninsula, water depth < 8 m
(5) sea area north of R¸gen	sandy gravel, sand, pebbles	?	only partly prospected, extraction difficult because of pebble and boulder layers
(6) Tromper Wiek	sandy gravel, sand	2.6	
(7) Landtief/Osttief	sandy gravel, sand	1.5	areas near to the R¸gen - Usedom sill (Boddenrandschwelle), sediment layers of 0.1 - 0.8 m
(8) Greifswald Lagoon	sandy gravel	1.9	108 ha, average thickness of the sediments 1.9 m; exploitation conflicts with nature conservation aims (Special Protected Area according to EU Bird Directive)
(9) sea area off Usedom	sandy gravel, sand	2.9	3 prospected areas, predominantly thin sediment layers of 0.2 - 0.3 m
(10) Adler Ground	sandy gravel, sand	> 12.5	
total amount		**> 39.2**	

size. The basic rocks at this site take up to 40 % of the whole paleogenian exposures of the Kaliningrad coastal waters. They are exposed at the bottom or covered by a thin layer (1 - 2 m) of sediments. The reserves of these sands are estimated to be several million cubic meters.

Gravel deposits are usually represented by thin (less than 1 m) lenses which are situated near former coastal banks, foots and slopes on abraded terraces. The thickness of gravel areas on slopes of abraded and polygenetic terraces occasionally may exceed 5 m.

The southeastern part of the Vistula Lagoon harbours considerable reserves of glacial sand and gravel, which form mobile ridges. These ridges are the marine continuation of the exploited terrestrial deposits.

Lithuania and Latvia
Marine sand and gravel deposits are situated also in Lithuanian and Latvian coastal waters.

Estonia
There are four proven deposits of sand and gravel which could be of interest for future exploitation in the coastal waters of Estonia (Hiiumadala, Naissaare, Prangli, Ihasalu).

Russia (St Petersburg region)
The Gulf of Finland harbours considerable marine sand and gravel deposits.

Finland
There are considerable sand and gravel resources which could be of interest for exploitation in the coastal waters of Finland. Investigations are being conducted.

Sweden
The usable sand and gravel fields are mainly situated on the southwest Baltic Sea coast of Sweden.

4. Exploitation of marine sediment resources in the Baltic Sea states

Denmark

The extraction of marine sand and gravel in Denmark represents 10 - 13 % of the total production of materials for construction and reclamation. In 1996 the dredging in the Baltic Sea, including Kattegat, amounted to about 40 % of the total dredging in Denmark and took place in 151 permitted areas. Most of the areas are located around Sjælland and Fyn. In general, all areas are located at water depths of more than six meters and outside protected areas such as Ramsar- and EU-Birdprotected Areas or areas protected by The Nature Conservation Act.

The amount of materials dredged for construction increased slightly from 1992 until 1995; since then a slight decrease has been seen (tab. 2).

The dredging of sand fill for land reclamation and beach nourishment has increased over the last 10 years as a result of several large construction works in coastal areas and a change in approach to coastal protection. From 1989 to 1993 more than 9 x 10^6 m of sand fill and till have been dredged for the construction of the Great Belt bridge and tunnel project.

During the construction of the fixed link between Denmark and Sweden approx. 2 x 10^6 m of sandfill will be dredged from the Kriegers Flak. The originally expected amount of 9 x 10^6 m has been considerably reduced by re-use of dredged material from the construction site. The dredging started in January 1996 and is expected to last four years (Øresunds-konsortiet 1998).

A major enlargement of the harbour of Århus is expected to require more than 3 x 10^6 m of sand fill in the next two years. The construction work will start in autumn of 1998 (ICES WGEXT 1998b).

For many years, fossil shells have been dredged from three areas in Roskilde Fjord. This activity was stopped for environmental reasons by the end of 1997.

Dredged material is also exported to Sweden and Germany.

It is expected that the exploitation of marine sand and gravel will increase in the future due to the expected termination of a number of licences on land and increasing environmental conflicts in potential extraction areas (ICES WGEXT 1998b).

Germany (Schleswig-Holstein)

No extraction of marine sand and gravel resources has taken place during the last ten years on the coastal shelf of Schleswig-Holstein, and no extraction is currently planned.

Germany (Mecklenburg-Vorpommern)

On the coastal shelf of Mecklenburg-Vorpommern there are currently 17 extraction fields for which

Table 2: Marine sediment extraction in Denmark 1990 - 1997 (only Helsinki Convention Area, Norden Andersen, pers. comm. 1998).

Year	Sand	Gravel fine	Gravel coarse	Sand Fill	Boulders small	Boulders large	Shells	Till	Total
	0 - 2 mm (10^3 m≥)	0 - 20 mm (10^3 m≥)	6 - 300 mm (10^3 m≥)	(10^3 m≥)	(10^3 m≥)	(10^3 m≥)	(10^3 m≥)	(10^3 m≥)	(10^3 m≥)
1990	836.0	235.9	377.4	787.3	4.6	1.8	42.4	61.8	**2,347**
1991	694.7	315.7	653.5	852.4	10.2	2.1	110.0	858.7	**3,497**
1992	551.1	188.7	958.2	589.5	4.2	0.2	164.6	1,084.5	**3,541**
1993	753.5	215.4	926.1	559.7	3.8	0	131.4	6.4	**2,596**
1994	979.7	208.1	1,098.0	225.8	5.1	0.8	101.7	7.3	**2,828**
1995	862.5	210.9	896.8	265.0	4.1	0.1	85.8	256.4	**2,325**
1996	910.7	197.1	827.5	725.4	15.4	1.4	123.1	2,190.6	**4,991**
1997	511.1	205.9	1,317.1	512.2	3.9	0	148.0	2,129.9	**4,828**

Table 3: Amounts of extracted sediments in Mecklenburg-Vorpommern 1992 - 1997.

Year	Commercial Purposes (10^3 m≥)	Coastal Protection (10^3 m≥)	Total (10^3 m≥)
1992	294.4	77.2	371.6
1993	48.2	420.2	468.4
1994	276.1	538.1	814.2
1995	671.8	246.9	918.7
1996	828.0	1,330.2	2,158.2
1997	376.7	1,892.8	2,269.5

permission has been granted by national authorities. The majority of the extraction sites are used for coastal defence purposes. These sites are not permanently exploited but only temporarily, if there are coastal defence projects executed in the respective region. In 1997, 20 fields have been designated by governmental decree for coastal defence purposes (Ministry of Economy of the State Mecklenburg-Vorpommern 1997).

From four fields, the sand and gravel are used as construction material (concrete production, filling material, road base etc.). These fields are: sea area off Kühlungsborn, Greifswald Lagoon, Adler Ground, Plantagenet Ground.

The total area of permitted extraction fields amounts 200 ha. The extraction figures of the last years are given in table 3.

Poland

Gravel: No large scale exploitation has been carried out in Polish marine areas in the past, nor is it expected in the next future. Test extraction was carried out in the Slupsk Bank area during the years 1985 - 1989, with about 0.9 x 10^6 m of sand and gravel being removed. Some test extractions were also carried out on the Southern Middle Bank and Koszalin Bay during the period 1987-1989, but only small amounts of sediments have been removed (about 2,500 - 3,750 m from each site). In 1997 about 1,200 m were extracted from the Slupsk Bank area.

Licences for extraction of gravel have been issued for two areas, but no larger exploitation is expected in the next few years.

Sand: Sand is extracted in Poland for coastal defence purposes only, *i.e.*, replenishment of beaches and dunes.

At the northeast of Cape Rozewie, a 5 km˝ area is designated for sand extraction for the needs of artificial beach nourishment. It has been exploited since 1995 at a rate of 100,000 m / year. A 1 km˝ sand extraction field 5 km north of Jurata on Hel Peninsula was used in 1993 and 1995 for beach replenishment purposes, the total amount of extracted sand being ca. 200,000 m .

In the past (1989 - 1992), sand was extracted at four sites in Puck Bay for coastal defence measures on Hel Peninsula. In 1993, two sites were closed. From the remaining two sites sand is presently extracted at a rate of 150 - 300,000 m / year (252,000 m in 1997), but this shall be stopped in 1998, except in case of emergency situations. The total amount of sand extracted from Puck Bay between 1989 and 1997 was about 6.7 x 10^6 m .

Extraction of sand regularly takes place from approach channels to ports and from sand traps related to the operation of artificial sand by-pass systems at ports. The annual amount of this sediment removal is about 60,000 m at the port of Kolobrzeg, 80,000 m at the port of Darlowo, 80,000 m at Ustka, 30,000 m at Leba and 200,000 m at Wladyslawowo.

Russia (Kaliningrad Region)

There is no actual exploitation of marine sand and gravel resources in the Kaliningrad region of Russia, and no industrial exploitation is expected in the near future. However, investigation of marine mineral resources is being conducted and exploitation can be expected in the long run if the economy recovers.

There are current plans for the construction of an artificial island for oil exploitation purposes. A total area of 67 ha will be required for the construction of the island and extraction of building material. The duration of the work is expected to be one vegetation season.

Table 4: Summary of current (1990 - 1997) marine aggregate extraction activities in the Baltic Sea states.

country	annual extracted amount of marine sediments, 1990 - 1997 (10^6 m≥)
Denmark	2.3 - 5.0
Germany (Schleswig-Holstein)	no activities
Germany (Mecklenburg-Vorpommern)	0.37 - 2.3
Poland	*gravel*: test extractions only, <10^6 m≥ *sand*: ca. 7 x 10^6 m≥ 1989 -1997 for beach replenishment
Russia (Kaliningrad)	no actual activities, but construction of an artificial island is planned which will include the use of marine aggregates
Lithuania, Latvia, Estonia	no activities
Russia (St Petersburg)	1.2
Finland	< 0.5
Sweden	no activities since 1992

The recovery time of marine fauna in the extraction area is expected to be about five years.

Lithuania, Latvia and Estonia
There is no current exploitation of marine sand and gravel resources in Lithuania, Latvia and Estonia, and no exploitation is expected in the next future.

Russia (St Petersburg region)
In the St Petersburg region of Russia sand and gravel resources are exploited from three extraction fields. The annual extraction rate of all three fields amounts about 1.2 x 10^6 m . The fields are:
Styrsuddensky Bank (800,000 m);
south of the B. Beresow Island (200,000 m)
and south of the Seskar Island (200,000 m).

Finland
Since the extraction of sand and gravel on terrestrial areas was regulated in 1982, the extraction from marine areas has increased considerably during recent years, and can be expected to increase further in the future.

Dredging of marine sediments in Finland has been almost constant, with extraction figures less than 500,000 m over the past years. The main areas of extraction are: Helsinki, Kotka, Pori and the land bridge to Hailuoto Island. The city of Kotka has extracted about 2.5 x 10^6 m of sand and gravel for harbour facility expansion. For the city of Helsinki, a permit for 5 x 10^6 m has been issued for landfill projects (housing projects, harbour facilities) (ICES 1992, 1998a).

Sweden
Marine sand and gravel extraction from the Swedish part of the Baltic Sea, mainly the sound, started at the beginning of the century. In 1966, the extraction was regulated by the Act (1966 : 314) on the Continental Shelf.

During the period from 1966 to 1992 exploitation took place at 13 extraction sites. The amount of extracted material was 12,937,282 m in the period from 1966 to 1978, and 1,711,363 m from 1979 to 1992.

The material gained has mainly been used as construction material (landfill), but also, regarding one site (V-Haken), as industrial mineral for glass manufacturing.

In 1992 sand and gravel extraction was stopped for environmental reasons.

Figure 2: Trailor suction hopper dredging vessel (by J. Chr. Krause).

Figure 3: Use of marine sediments: Coastal defence. Beach nourishment on Usedom Island (Germany) (Photograph courtesy of B. R. Gurwell).

Figure 4: Use of marine sediments: Industrial raw material. Landing and processing facilities near Greifswald (Germany) (by C. Herrmann).

Figure 5: Use of marine sediments: Construction works. Construction of an artificial island for the fixed link between Denmark and Sweden (Photograph courtesy of Øresundskonsortiet).

5. Environmental impacts of marine sand and gravel extraction

The two methods most commonly practised in aggregate extraction are anchor hopper dredging and trailer suction hopper dredging. In the former, the dredger anchors over the deposit and mines it by forward suction through a pipe (fig. 6 A). Large pits are thus formed on the sea floor, up to 10 m in depth and 10 - 50 m in diameter (Hygum 1993). Most aggregate dredging in Denmark is conducted by this method. Trailer dredgers, in contrast, extract the deposit by backward suction through one or two pipes whilst underway, thereby forming shallow furrows on the sea floor (fig. 6 B). These are generally 20 - 30 cm deep and up to two meters wide (Nielsen 1997).

In both cases, the aggregate and water are piped aboard to the ship´s hopper. As the hopper fills, the aggregate displaces the water, which overflows back to the sea (see fig. 2), carrying with it suspended fine material which forms a turbidity plume. On some dredgers, screening of the aggregate is carried out and excess sand or pebbles are returned to the seabed to maintain a specific sand to pebble ratio in the cargo (ICES 1992).

The physical and chemical impacts resulting from these activities are:

- substrate removal and alteration of the sediment composition and the bottom topography (fig. 7)
- alteration of the hydrographical situation
- formation of turbidity plumes
- resolution of chemical substances
- sedimentation of suspended material, oversanding and other problems related to screening, including resuspension of the newly sedimented material.

The impacts of marine sediment extraction and their influences on marine life are summarized in table 5.

5.1. Impacts of substrate removal and alteration of sediment composition and bottom topography

As a consequence of substrate removal, the bottom topography is changed and the character of sediments may be temporarily or permanently altered. The severity and duration of these impacts depend on extraction technology, hydrographical situation, sedimentation figures and other parameters at the extraction site. They may differ considerably.

Infill of the pits and furrows is dependent upon the exposure, *i.e.*, the ability of bottom currents to move surrounding sediments, and the availability of movable sediments in the vicinity of the extraction site. Except in areas of mobile sand, this tends to take a rather long time. For example, according to observations of van der Veer *et al.* (1985, ct. ICES 1992) in the Dutch Wadden Sea, pits in tidal channels were filled within one year, those situated in tidal watersheds took five to ten years, and those dug in tidal flat areas were still visible after fifteen years. A dredging site near to Le Havre (France) also was clearly visible some 15 years after cessation of dredging (ICES WGEXT 1998a). However, at an experimental dredge site in the English Channel off Norfolk in a depth of 25 m, dredge tracks were completely eroded within three years.

The most obvious biological impact of sand and gravel extraction is the destruction of the infaunal and epifaunal biota by the removal of the substrate. Abundance and biomass of benthic organisms are normally more drastically reduced than species number. In the Dutch studies of van Moorsel & Waardenburg (1990, 1991, ct. ICES WGEXT 1998a) soon after dredging a reduction in abundance by 70 %, in biomass by 80 %, but in species number only by 30 % was observed. In other studies (Johnson & Nelson 1985, McCauley *et al.* 1985, van Dolah *et al.* 1984, ct. ICES WGEXT 1998a) the animal densities were reduced, but the number of species was unaffected.

Recovery time of benthic communities depends largely upon the intensity and duration of changes of environmental parameters and sediment character, stock of colonizing species, and the immigration distance (Krause *et al.* 1996, ICES 1992). It also depends on physical factors such as depth, exposure (waves, currents), sedimentation characters etc. In areas with low depth and strong exposure, it is usually faster than in areas with low exposure.

If the character of sediments is not altered by the extraction, re-establishment of the former communities normally needs a time span of a few months to five years after the end of the mechanical disturbances (Hygum 1993). However, according to investigations of Rhoads & Germano (1982) and van der Veer *et al.* (1985), the re-establishment of the original communities in “low energy areas” even may take up to 10 years (ct. Krause *et al.* 1996).

Recolonization takes place by passive translocation of animals during storms or sediment sliding from nearby

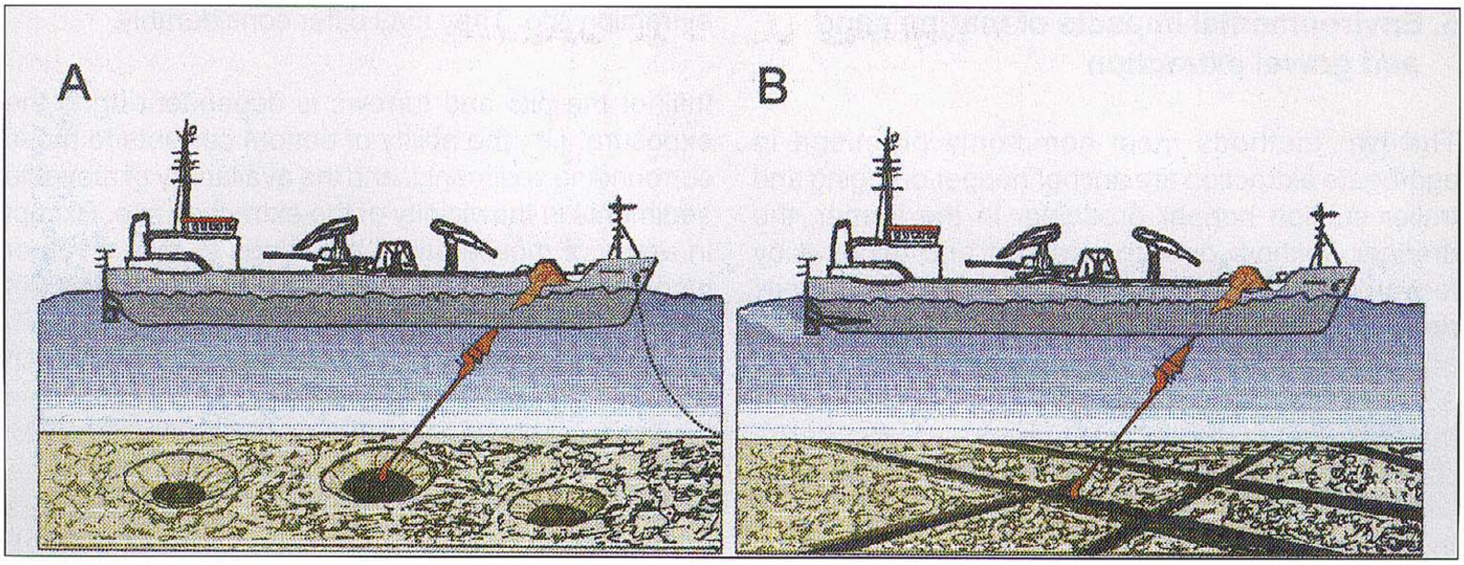
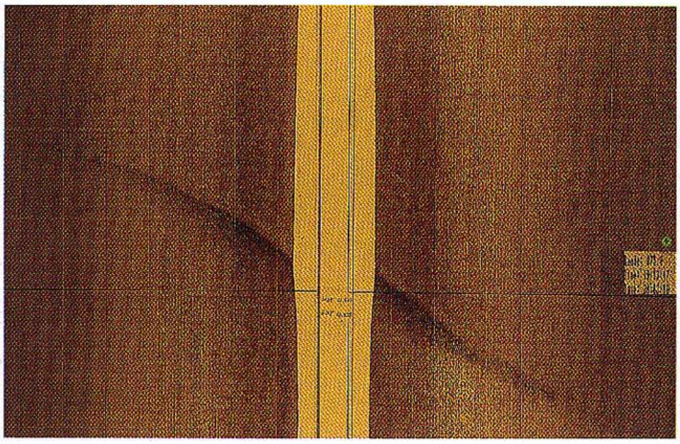
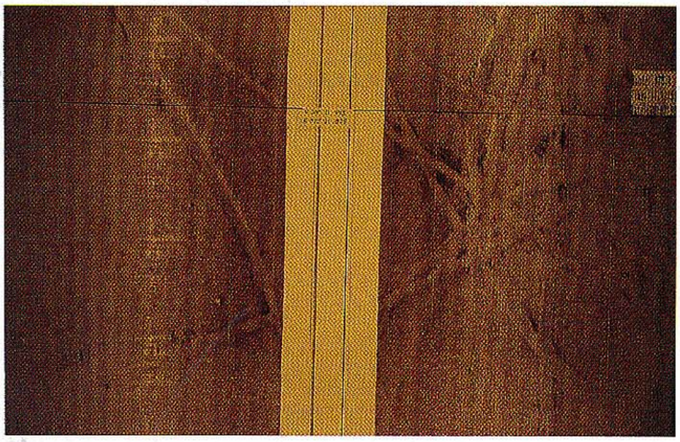


Figure 6: The two most commonly used methods for marine sand and gravel extraction: Anchor hopper dredging (A) and trailor suction hopper dredging (B).

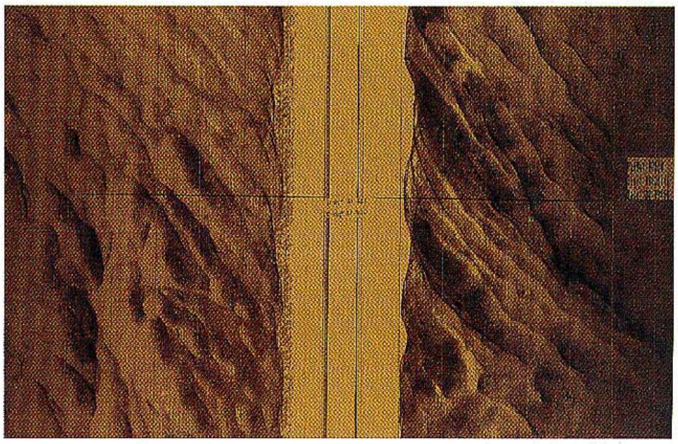


a) non-dredged area with sand ripples (distance c. 249 m)

b) dredging hole of c. 15 m width and 3 m depth (distance c. 91 m)



c) area with dredging tracks of c. 2 m width and 0.5 to 1 m depth (distance c. 100 m)



d) area after intense dredging with furrows of c. 5 m width and up to 3 m depth (distance c. 101 m)

Figure 7: Side-scan sonar images of a sandy sea floor before (a) and four months after dredging (b, c & d). Each side left and right of the non-reflecting middle white line covers 75 m. Towing direction always from the lower to the upper edge (Courtesy of J. Chr. Krause, University of Rostock; M. Diesing & K. Schwarzer, University of Kiel, Inst. of Geosciences; "RV Littorina").

unaffected areas, active immigration of mobile species and immigration of pelagic larvae or juveniles (ICES WGEXT 1998a). It normally starts quickly after cessation of the dredging, and species number may recover within short periods. Opportunistic species with rapid dispersal and high reproduction rates (e.g., polychaets like *Capitella capitata*, *Spio filicornis*) may attain increased densities already a short time after extraction. However, long-lived species like molluscs and echinoderms need a rather long time for re-establishing the natural age structure of the population (van Dalfsen & Essink 1997; Essink 1997). Therefore, the biomass very often stays reduced for several years. In the studies of Moorsel & Waardenburg (1990, 1991, ct. ICES WGEXT 1998a), e.g., densities and number of species returned to pre-dredging levels within one year, but due to the loss of the older generations of large molluscs like *Arctica islandica* and *Dosinia exoleta* this was not the case with the biomass, which two years after dredging was still much reduced compared to its pre-dredge stage. Similar results were obtained by van Dalfsen & Essink (1997) in the Dutch North Sea, where two years after dredging, recovery could not be considered as complete due to the unbalanced age structure of long-lived mollusc species. A recolonization study at the French coast of the eastern English Channel (off Dieppe) showed that 16 months after dredging, the number of taxa had fully recovered to pre-dredged levels, while densities of macrofauna had reached only 56 % and biomass 35 % of the reference site value. Twenty-eight months after dredging, abundance and biomass were still markedly reduced (ICES WGEXT 1998).

In the Baltic Sea, the recovery of benthic fauna has been monitored on the Slupsk Bank (Poland) and in the sea area off Kotka (Finland). In both cases an examination of the macrobenthos at the dredging site indicated that the total number of taxa had returned to the pre-dredging value within one year. However, abundance and biomass still remained low, suggesting that complete recovery of the community would need several years (ICES WGEXT 1997).

For the dredging of sand from Kriegers Flak for the construction of the Øresund Link, a recolonization is expected within three years following completion of extraction. The benthic community at this site can be regarded as a low diversity *Macoma* community with high recolonization ability (Øresundskonsortiet 1998).

In general, communities of short-lived species or species with a high reproduction rate may recover more rapidly than communities of slow growing, long-lived species. Representatives of the latter groups in the Baltic Sea are, *inter alia*, the bivalves *Arctica islandica*, *Astarte* spp. and *Macoma calcarea*. But also the communities of the bivalves *Mya arenaria*, *Macoma balthica* and *Cerastoderma* spp. need 4 - 7 years until the natural size and age distribution of the population has re-established itself.

Besides the time span needed for re-establishment of the population structure of long-lived species, sediment disturbances including increased sediment transport may delay also the complete recovery of benthic communities, as shown by results of Kenny & Rees (1994, 1996). The extraction of 50,000 t of marine sediments off the east coast of England resulted in a deepening of the bottom of 30 cm, but not in an alteration of sediment quality. Seven months after the extraction, many of the original taxa had already resettled on the affected area (Kenny & Rees 1994). However, whilst the dominant species recolonized quickly following dredging, many rarer species did not. Twenty-four months after dredging, the biomass was still substantially reduced. This was thought to be due to a local increase in sediment disturbance caused by tides and waves. Evidence from side-scan sonar records and underwater cameras indicated a considerable sediment transport during the first two winters following dredging resulting in an infill of the once well-defined dredge tracks (Kenny & Rees 1996).

In general, the responses of macrobenthic communities to the effects of dredging can be divided into three phases (ICES WGEXT 1998a):

Phase I: Initial recolonization by the dominant taxa present before dredging; these animals are predominately opportunistic in behaviour and they significantly contribute to a rapid increase in abundance and number of species.

Phase II: The community biomass remains low for a longer time, which may be caused by the loss of older and larger speciemen of long-lived species like bivalves, or scouring of epibenthos by increased amounts of sediments in transport.

Phase III: The biomass increases significantly and the community recovers to its natural composition.

Alterations of the benthic communities are observed in areas where the sediment character is altered by the extraction process. In that case, the affected area will be recolonized by macrofauna communities which are different from the original ones. If the original sediment type is not re-established by transport

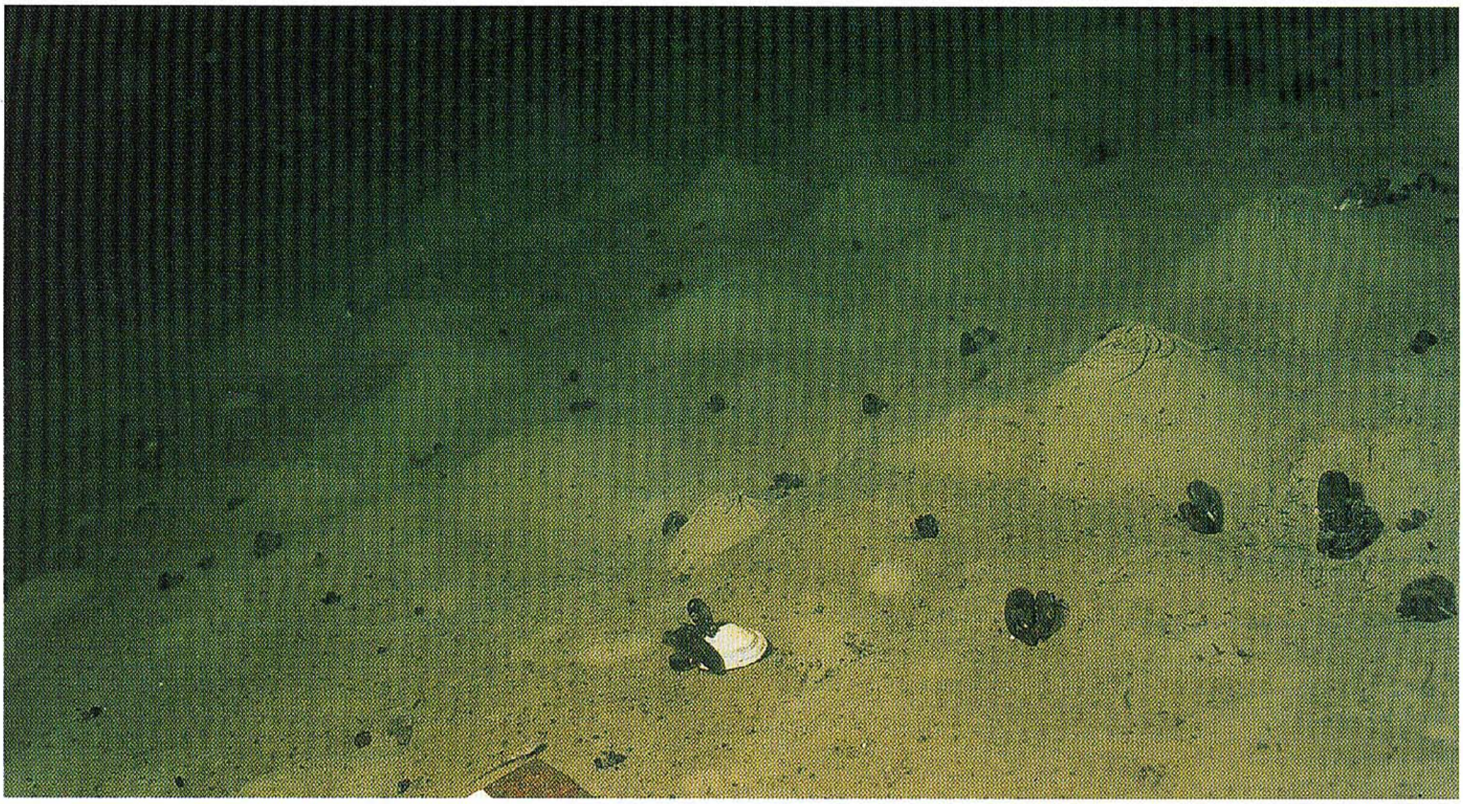


Figure 8: Extraction area prior to dredging: Sandy bottom with burrows of *Arenicola marina* in 11 m depth (by J. Chr. Krause & P. Hübner).

processes, the changes of fauna composition will be permanent. In many cases, the coenoses change towards soft bottom communities (Hygum 1993).

No hydrodynamic processes are known to concentrate gravel and stones at the sea bottom (Aagaard 1991). Therefore, the possibility of recovery of their communities after substrate removal is reduced.

Alteration of fauna composition has been observed in several cases, e.g., after a commercial sediment extraction in the Straits of Dover. The topography in the extraction area was altered, the extraction had formed furrows in the bottom which were filled by sedimentation with finer sediments than the original ones. The benthic communities of these areas changed from coarse- to fine-sand communities (Desprez 1992). Infilling of dredged pits with sediment finer than the original or the surrounding substrate and subsequent alteration of the coenoses has been noted in several cases by a number of authors (ICES 1992, COWI/VKI 1992).

Investigations of an extraction site in the Bay of Seine (France) 15 years after cessation of dredging operations showed that the original homogeneous sediment was replaced by a heterogeneous clay substrate with silty sediment depositions. The benthic communities were 2 - 3 times richer in terms of taxa, abundance and biomass than in the surrounding seabed, with mud-dwelling species being dominant (ICES WGEXT 1998a).

In some cases, permanent changes from soft to hard bottom communities may also occur. One example is reported from the Seine Bay. When sand and gravel overlying a rocky substrate were removed, no deposition of sediments on the pebbly and rocky ground occurred and, as a result, a hard bottom fauna developed (ICES 1992).

Permanent alterations of sediments and, as a consequence, of benthic communities are presumed by Krause *et al.* (1996) and Gosselck *et al.* (1996) if the rather thin sediment layers dominating on the coastal shelf of Mecklenburg-Vorpommern (Baltic Sea area) were exploited. The sand and gravel layers of the potential extraction sites have a thickness of between 0.35 and 2.7 m (UWG 1993). These sediments are of glacial origin. Re-establishment of the original sediment character after extraction therefore cannot be expected. In some areas refilling will take place with fine sediments, at other sites residual sediments (marl) will become exposed. Species-rich sand bottom coenoses will change to species-poor clay or till bottom fauna. The extraction of thin sediment layers can be expected to affect rather large areas. This gives reason to assume severe ecological effects for the marine

Figure 9: Extraction area prior to dredging: Sandy and shell gravel bottom. Shells of the common mussel (*Mytilus edulis*) in 9 m depth (by J. Chr. Krause & P. Hübner).

ecosystem, if an adequate layer of the original sediments does not remain on the bottom to allow recovery of the coenosis.

In Denmark the stone reefs, formed by residual glacial deposits of boulders, stones, pebbles, and gravel, are of special concern. Ecologically, these reefs are very valuable since they represent the only natural substrate for hard bottom communities of marine benthic flora and fauna. The development of the biological communities depends on the composition of the bottom sediment being either dense boulders, mixed boulders, and smaller stones, or pebbles and gravel. Localities with a patchy bottom consisting of areas covered with big boulders and gravely areas have the highest biodiversity. Marine aggregate extraction on stone reefs may include the reduction of hard bottom area, an alteration of the sediment character towards softer sediments and/or a decrease in the diversity of geological and biological structures (Ministry for Environment and Energy of Denmark 1997).

The effects of different extraction methods on sediment character and recovery of benthic fauna were studied by Norden Andersen *et al.* (1992). From July 1987 to March 1988, 3 x 10^6 m of sand were dredged at a depth of 12 - 16 m in Køge Bay, Denmark. Dredging was performed both by stationary suction and trailing suction. The first method left up to 10 m deep pits in the bottom, while trailing suction removed up to 2 m of the seabed, leaving a pattern of 1.5 m wide and up to 0.5 m deep furrows. About 17 months later, in the trailing suction areas annual benthic faunal species had largely recovered, whereas the larger perennial species were still low in biomass. In the pits formed by stationary suction at a depth of more than 7 m below the natural sea bottom, a dense layer of detrital matter and plant debris had brought about anoxic conditions. Recovery of macrofauna thus was not possible. Oxygen depletion at the bottom of depressions caused by sediment extraction is also reported by other authors (ICES 1992).

Macrophyte stands and sand and gravel extraction sites may coincide in some regions of the Baltic Sea. Macrophytes may occur up to a depth of 20 m, if the water transparency is appropriate (Schramm 1996). In the Kadet Trench, red algae have been found down to a depth of 24 m (Gosselck 1998). Schwenke (1996) even assumes macrophyte occurrences up to a depth of 30 m. However, during the last decades, a massive decline of macrophytes has been observed, resulting in shifting of the distribution border towards lower water depths. Eutrophication, increased plankton growth and, as a consequence, reduced light penetration are considered to be the main reasons. Due to the already naturally restricted distribution on the coastal shelf and the overall decline in the Baltic Sea, macrophyte stands are generally of high conservation value. Knowledge about recolonization of macrophytes after mechanical destruction by dredging is rather poor.

Benthic organisms are the feeding base of waterfowl (especially sea ducks) and fishes. Temporary destruction of the zoobenthos and/or permanent alteration of the composition of benthic communities as a consequence of sediment extraction may change feeding conditions for species of the higher level of the trophic chain. Gosselck *et al.* (1996), e.g., suggest possible impacts on resting or wintering conditions for sea ducks if sand and gravel extraction took place on the most favourable feeding grounds of the birds, like the exposed sand bars of the outer Wismar Bight, Hannibal, and Lieps.

Fish stocks may be seriously affected by the dredging process where spawning grounds coincide with the deposit. For example, certain groups of herring spawn on stony substrates influenced by bottom currents. Sandeels may be similarly affected (ICES 1992). In the Baltic Sea, e.g., the surface of the sand and gravel deposits of the Vistula Lagoon (Russia, Kaliningrad region) is a spawning ground of zander, bream, roach, perch, herring and other fishes. If the sand and gravel resources were exploited, fish reproduction in the lagoon would be impaired.

Fisheries practice may be impaired by the uneven sea bottom topography created by aggregate extraction, which may destroy bottom trawls and other fishery devices (Hygum 1993).

5.2. Impacts by alteration of the hydrographical situation

Alterations of bottom topography by dredging operations may cause changes in the hydrographical situation and thereby affect current strength, water exchange or sediment transport. The consequence of a significant change in bathymetry may be a localised drop in current strength resulting in deposition of finer sediments, which may result in a localised depletion of oxygen (Norden Andersen *et al.* 1992, ICES WGEXT 1998a).

Gosselck *et al.* (1996) and ICES (1992) emphasize possible effects on coastal erosion due to alteration of wave and current patterns if aggregate extraction is executed in shallow coastal waters. Possible effects on coastal protection have to be considered, either by interference with the supply of sand and gravel to the beach or by reducing offshore wave protection and thereby changing the wave energy and/or direction reaching the coast.

According to Gosselck *et al.* (1996), distinct effects can be assumed if sediments are taken from shallow submarine sills. Such sills may form typical barriers between shallow lagoons and bays and the open Baltic Sea, as it is the case with Wismar Bight and Greifswald Lagoon (Germany, Mecklenburg-Vorpommern). They are key elements for controlling the water exchange between the lagoons and the Baltic Sea. If material is extracted from the sills, water exchange may be facilitated. Depending on the special conditions of the respective area, this may have considerable ecological effects. Gosselck *et al.* (1996) assume that sand and gravel extraction on Hannibal and Lieps (the sills separating the Wismar Bight from the Mecklenburg Bay) may facilitate the entrance of anoxic bottom water from the Mecklenburg Bay into the Wismar Bight, resulting in severe effects on benthic communities and fish.

5.3. Impacts by sediment spill and turbidity plumes

Turbidity plumes of suspended material mainly arise from four distinct sources:

- the mechanical disturbance of seabed sediment by the draghead
- overspill of surplus sediment/water mixture from the vessel
- the rejection of unwanted sediment fractions by screening (ICES WGEXT 1998a)
- loading of transport vessels, transport and the reclamation process.

The amount of spill, dispersion and sedimentation patterns of suspended material depend on the composition of the dredged material, the dredging and transport equipment, the reclamation process and hydrographical factors.

In general, sediment spreading from the draghead is limited compared to the amount of sediment released with the overflow. The spill caused by transport normally can be considered negligible, but the overflow during filling of transport vessels may contain considerable amounts of suspended material (Nielsen 1997, ICES WGEXT 1998a).

According to Danish records, the overflow water of the hopper may contain between 2 and 10 % of the dredged material (Hygum 1993). Nielsen (1997) reports spill percentages between 0.5 and 25 % of the dredged material, depending on aggregate type and dredging technology.

The influence of dredging technology was demonstrated by spill monitoring during the extraction of sediments at Kriegers Flak (Denmark) for the construction of the Øresund bridge. There were significant differences between the two vessels used, the average spill percentages amounting 2.62 % and 1.26 %, respectively (Water Consult 1997). To some extent it is possible to reduce the amount of spill by adjusting the pumping and sailing speed. Technical optimization of the pumping system, ship´s hopper, entrance and outlet system also makes it possible to reduce spill. For the dredging of very fine-grain sediments (clay, silt, marl) special equipment has to be used which is capable of retaining such fine particles.

The magnitude of the turbidity plume depends on the mud and silt content of the aggregate and the natural water turbidity. In high energy areas close to the eroding coastline, usually few problems can be assumed from the extraction-related turbidity since the natural background level is already high (ICES 1992). In low energy areas the elevation of turbidity caused by dredging activities may be more distinct and last for a longer time (up to several days), especially if the aggregates contain fines or if they are covered by mud or silt layers. Eight to 400 fold increases in turbidity have been observed in connection with dredging activities (Hygum 1993, ICES 1992).

The duration and expansion of turbidity plumes depend on factors such as water temperature, salinity, current speed, and size range of the suspended material. The extension of the turbidity plume may be different between the surface water, the water column and the bottom water. Such records are, *inter alia*, reported by Bohlen *et al.* (1979) from the Thames estuary: In the surface water the turbidity plume reached up to a distance of 300 m, whereas in the water column and at the bottom no elevated concentrations of suspended material was observed only at a distance of 700 m (ct. Hygum 1993).

Although elevated turbidities may be recorded up to distances of several hundred meters from the hopper, in special cases even several kilometers, normally the concentration of suspended material decreases rapidly with increasing distance. Kioboe & Mohlenberg (1981, ct. Hygum 1993) recorded concentrations of 3,000 - 5,000 mg/l close to the hopper, but concentrations of more than 100 mg/l were restricted to a radius of about 150 m. At a distance of 650 m the concentration was 10 mg/l in the bottom water, and 1,000 m from the hopper no elevation of turbidity was observed. Studies in the English Channel by Hitchcock & Drucker (1996, ct. ICES WGEXT 1998a) showed that 80 % of the suspended sediment (> 0.063 mm) dropped to background levels over a distance of 200 m to 500 m from the point of release. However, the remaining 20 % of suspended sediment, largely composed of particles < 0.063 mm, will potentially be dispersed over much greater distances.

The elevated concentration of particles in the water poses a threat to the vegetation on the seabed, which may be shaded or covered by sedimented particles. The food supply of sea birds may be affected, and the migration of certain fish species may be disturbed (ICES 1992).

Short time exposure with suspended material does not seem to be harmful to adult mussels and fish. Filter feeding mussels may even show higher growth rates. However, eggs and larvae of the species in general are more susceptible. The effects of suspended sediments on cod eggs and larvae have been studied in laboratory work by the Swedish National Fishery Agency. The mortality studies show that the larvae are more sensitive to suspended particles than are eggs. The feeding of herring larvae is impaired at concentrations of only some mg/l of suspended material (ICES 1992, Hygum 1993). However, suspended sediments may also have effects on the buoyancy of fish eggs and on the survival rate of ichthyoplanktonic stages. The adhering of particles to cod eggs causes loss of buoyancy and the eggs sink to the bottom (ICES ACME 1997).

Avoidance behaviour of fish as a consequence of sediment plumes is well documented. In laboratory tests it was demonstrated that some fish species (e.g., visual feeders like mackerel or turbot) avoid concentrations of suspended material of more than 10 mg/l. Studies concerning the behaviour of adult herring and cod when affected by the sediment cloud during dredging showed that the avoidance to chalk and clay suspensions increases with the sediment load (ICES ACME 1997; ICES WGEXT 1998b). Other fish species may be attracted by the "odour stream" of the crushed benthos.

Similarly, primary production within the water column may be either increased or decreased depending upon the ability of plankton to deal with the increase in nutrients and other suspended material and the decrease of light penetration (ICES 1992).

However, although the concentration of suspended material caused by dredging may reach magnitudes which are harmful to organisms, normally such concentrations are reduced rather quickly by dilution effects of currents and waves.

5.4. Chemical impacts

The resuspension of sediments in relation to dredging activities may cause alterations of chemical parameters, such as release of nutrients, heavy metals or other compounds to the water phase. Also, decrease of oxygen is a possible effect if organic compounds are released.

According to reports from dredging activities in the Belt Sea, the concentration of inorganic nitrogen and phosphorus may be elevated in the overflow water 3 to 100 fold (Hygum 1993). Considerable elevation of nitrogen and phosphorus in the vicinity of the hopper is also reported from the United States and from the Thames estuary. Release of heavy metals was observed in some cases (Hygum 1993).

Measurements of nutrients and heavy metals in the turbidity plume done by Tramontano & Bohlen (1984, ct. Hygum 1993) demonstrated elevated values of nutrients up to 180 m behind the hopper, the highest concentrations being recorded within the first 50 m. An increase of heavy metals (Mn and Cu) was proven up to a distance of 12 m.

However, the chemical effects are likely to be minor due to the very low organic and clay mineral content of commercially extracted sediments. The bulk of sand and gravel which are commercially dredged show little chemical interaction with the water column. In addition, dredging operations are generally of limited spatial extent and short duration, which further limits the chemical impact (ICES 1992, ICES WGEXT 1998a).

Some minor effects on primary production are supposed for semi-enclosed sea areas like fjords and lagoons, but detailed data are rather scarce (Hygum 1993). Decrease of oxygen as a consequence of resuspension of oxygen-consuming substances may become a problem if the deposit is covered by mud and silt layers. This is the case, *inter alia*, with deposits situated in internal waters of the Baltic Sea such as in the Greifswald Lagoon (Germany) or Vistula Lagoon (Poland/Russia).

5.5. Impacts by sedimentation of suspended material and oversanding, including resuspension of the newly sedimented material

The dispersion behaviour of particles strongly depends on the content of fine material and the hydrographical situation, especially sea currents and waves. The appearance of suspended material occasionally can be recorded at distances of up to 1,000 m from the extraction site. However, most of the suspended material will settle down at the extraction site or nearby (ICES WGEXT 1998a). For the sediment extraction at Kriegers Flak (Denmark), for instance, it was estimated that with the predominant flow velocities (0.1 m/s) 99.9 % of the spill will settle close to the reclamation area and only a small proportion of very fine material (< 0.063 mm) will be carried away and scattered over a larger area (Water Consult 1997). The mean sedimentation of clay and silt in the extraction area (< 1 km) during the most intensive year of extraction will be approximately 0.4 mm/year. However, this extraction site is characterized by a very low silt and clay content of the sediment (Øresunds-konsortiet 1998).

Once settled on the sea floor, the sediment will still be liable to resuspension or transport. Results of Kenny & Rees (1996) indicate that sediments once disturbed by dredging activities are easier moved by tides and waves. Such dredging-induced increase in sediment mobility also may cause oversanding of benthic organisms and reduce their development and biomass.

The practice of screening out sand directly back to the sea floor may significantly alter the substrate and create mobile sand areas on the former gravel banks.

The effects of sediment fallout on benthic communities outside the extraction area may be quite different. The following possibilities have been recorded (ICES 1992):

- defaunation within the affected area is initially virtually complete, similar to that in the dredging area, but recolonization progresses more rapidly
- defaunation is less pronounced than in the dredging area and recolonization is more rapid
- species diversity and abundance is enhanced in the area of sediment fallout
- the effect is negligible.

Benthos monitoring at an "impact area" close to the extraction site and a "reference area" has been carried out in connection with sand extraction at Kriegers Flak (Denmark). Development of species number was similar in both areas, whereas development of abundance and biomass showed clear differences. However, detailed analysis showed that the spatial and temporal changes are rather a result of large natural variations than of the extraction process (Øresundskonsortiet 1998).

The prime risk of redeposition of fines or screened sand are the smothering of fish eggs on spawning grounds, such as herring and sandeel, and the suffocation of filter-feeding sessile benthos such as mussels and polychaets. In addition, shellfish such as lobsters may lose habitats through silting up of crevices in which they live, and edible crabs which become torpid while brooding may be especially susceptible to smothering and suffocation by sediment fallout (ICES 1992). Laboratory tests have shown that already a slight covering with sediments may reduce the hatching success of herring eggs and the colonization success of mussel larvae (Hygum 1993).

However, in general, the impact of sedimentation upon the benthic ecosystem normally is considered to be not as severe as that of the direct substrate removal (ICES 1992).

Tab. 5: Summary of possible impacts of marine sediment extraction on the environment and marine life

Possible Impacts during the Extraction Process				
Type of Impact	**Environmental Effects; Effects on other Uses and Interests**	**Influences on Marine Life**	**Severety/Duration**	**References**
substrate removal	removal of the upper sediment layer alteration of bottom topography, sediment structure and composition	complete destruction of benthic life spawning grounds of fish may be destroyed feeding conditions for fishes and sea birds may be impaired	see "post dredging impacts"	ICES 1992
sediment spill and formation of turbidity plumes	resuspension of inorganic and organic fines in the water column (mainly due to the overflow of spill water from the hoppe, filling of the transport vessel, reclamation of dredged material and, to a smaller extend, the draghead work)	potential threat for seabed vegetation (shading, coverage with sediment particles) possible effects on feeding conditions of sea birds avoidance behaviour of certain fish species, possible disturbance of fish migration possible attraction of certain fish species by the "odour stream" of crushed benthos reduced survival rates of fish eggs and larvae (effects on buoyancy of fish eggs, feeding of larvae, survival rate of ichthyo-planctonic stages) local effects on phytoplankton primary production	usually locally restricted to the vicinity of the dredge; short time effect, quick recovery to natural turbidity values due to sedimentation and dilution by waves and currents	ICES 1992, Hygum 1993, Nielsen 1997, Water Consult 1997, ICES ACME 1997, ICES WGEXT 1998a
resolution of chemical substances	release of nutrients, heavy metals and other compounds	some minor effects on primary production are supposed for semie--enclosed areas stronger impacts are only supposed for deposits which are covered by mud or silt	local and short time effect, usually of minor importance	ICES 1992, Hygum 1993, ICES WGEXT 1998a

Tab. 5: Summary of possible impacts of marine sediment extraction on the environment and marine life (continued)

Possible Impacts during the Extraction Process (continued)

Type of Impact	Environmental Effects; Effects on other Uses and Interests	Influences on Marine Life	Severety/Duration	References
sedimentation, oversanding and screening	deposition of material on the seabed, largely in the vicinity of the hopper	different effects on macrofauna have been reported: complete or partial defaunation, enhancement of species diversity and abundance in the fallout area, negligible effects most benthic organisms are able to resist a slight coverage with sedimenting particles; stronger coverage may result in suffocation of filter feeding organs of sessile organisms fish eggs and larvae of fish and benthic organisms are susceptible	in general effects are considered as temporary and/or of minor importance	ICES 1992, Hygum 1993, Kenny & Rees 1996, ÿresunds-konsortiet 1998

Tab. 5: Summary of possible impacts of marine sediment extraction on the environment and marine life (continued)

Possible Post-Dredging Impacts				
Type of Impact	**Environmental Effects; Effects on other Uses and Interests**	**Influences on Marine Life**	**Severety/Duration**	**References**
changed bottom topography, sediment structure, and composition	infill of extraction furrows and pits depends on the exposure (current strength, wave action)	immediate recolonization, if sediment composition is not altered; usually quick recovery of the number of taxa dominant before dredging; biomass and abundance remain reduced for a longer time communities of long-lived species need naturally a long time for re-establishing their typical age class distribution no information is available concerning the recovery abilities of macrophytes	recovery time depends on the intensity of changes of environmental parameters, physical factors (depth, exposure), and the natural species composition duration between few months and more than 15 years (a rather long time has to be expected in low energy areas and areas with long-lived species)	*infill of pits and furrows:* ICES 1992, Norden Andersen *et al.* 1992, ICES WGEXT 1998a, *recolonization:* ICES 1992, Hygum 1993, Krause *et al.* 1996
	removed sand may become replaced due to hydrodynamic transport processes, but removed gravel or stones do not	complete removal of gravel deposits results in a permanent change of fauna composition	permanent in case of complete removal of gravel and stones	Agaard 1991, Ministry for Environment and Energy of Denmark 1997
	finer sediments, including organic matter, may fill in the furrows and pits	recolonizing benthic communities are different to the original ones; sedimentation of organic matter may result in anoxic conditions and thus prevent recovery of macrofauna	long lasting or even permanent	Desprez 1992, ICES 1992, COWI/VKI 1992, Norden Andersen *et al.* 1992
	residual sediments or bedrock (e.g., marl, clay, rocks) may become exposed to the sea bottom	the recolonizing communities are different to the original ones; if residual sediments, such as clay and marl, become exposed, species-poor communities have to be expected; feeding conditions of fishes and sea birds may become affected	long lasting or even permanent	ICES 1992, Krause *et al.* 1996, Gosselck *et al.* 1996, ICES WGEXT 1998a

Tab. 5: Summary of possible impacts of marine sediment extraction on the environment and marine life (continued)

Possible Post-Dredging Impacts (continued)

Type of Impact	Environmental Effects; Effects on other Uses and Interests	Influences on Marine Life	Severety/Duration	References
	some fishery practices are impaired due to the uneven sea bottom topography			Hygum 1993
creation of mobile sand areas	dredging processes may increase the liability of sediments to resuspension by currents and waves	impaired development of benthic communities	long lasting (several month to years)	Kenny & Rees 1996
alteration of hydrographical conditions	localised drop in current strength, resulting in reduced water exchange and deposition of finer sediments, which may cause a localised depletion of oxygen in the extraction pits and furrows	recolonization of macrofauna may be impaired or even prevented	long lasting or even permanent effect, especially at deep extration pits	Norden Andersen *et al.* 1992, ICES WGEXT 1998a
	in case of near-coastal extraction activities coastal erosion may be enhanced and natural sediment transport and accumulation altered; possible interferences with coastal defence interests		long lasting or even permanent	ICES 1992, Gosselck *et al.* 1996
	if submarine sills separating lagoons or bays from the Baltic Sea are effected the facilitated water exchange may change ecological conditions in the lagoons and bays by, e.g., increased inflow of more saline water; in certain areas entrance of oxygen depressed bottom water from the Baltic Sea may be facilitated	effects on marine fauna and flora composition by alteration of salinity; in areas threatened by inflow of oxygen deprived bottom water occasional kill-off of marine organisms has to be taken into consideration	permanent	Gosselck *et al.* 1996

6. Conclusions

Marine sand and gravel resources are widely distributed in the Baltic Sea area. They are exploited at considerable rates in Denmark, Germany, Finland and the St Petersburg region of Russia. Poland has used marine sand and gravel in the past to a comparably small extent. Sweden stopped exploitation in 1992 for environmental reasons. In other countries, like Lithuania, Latvia, Estonia, and the Kaliningrad region of Russia, exploitation of marine sediments might become significant in the future if their economies recover.

Marine sand and gravel resources are mainly used as construction and filling material and for coastal defence purposes (beach replenishment) (fig. 3, 4 & 5).

Extraction of marine sand and gravel resources may cause considerable impacts to the marine environment and fish stocks. Especially benthic marine flora and fauna are destroyed at the extraction site and may be affected by dispersion and sedimentation of suspended material also beyond the extraction area. The recolonization requires several months to some years. Although recolonisation in some cases may be rather fast, the re-establishment of the original age distribution and biomass of the communities normally needs a longer time span of several years. If bottom substrate or character is irreversibly altered by the sediment extraction, the original flora and fauna cannot recover.

If sediment extraction affects structures with high significance for hydrographical conditions (e.g., submarine sills, banks, spits, and near-coastal shallow water areas), long lasting or even irreversible effects on water exchange and coastal sediment dynamics can be assumed. Such alterations may affect ecological conditions far beyond the extraction area. They may also have considerable economical consequences for fisheries and coastal defence.

Alteration of chemical water parameters, such as increased turbidity, release of nutrients, heavy metals and other harmful compounds or oxygen-consuming substances, is a regular side effect of the dredging process. Although these effects also may harm marine life, they are rather temporary. After termination of the extraction process the chemical parameters of the water body return rapidly to the pre-dredging state.

In the Baltic Sea, marine sand and gravel have to be considered a finite resource. Its exploitation must be accompanied by great consideration of environmental consequences. Sand and gravel deposits in the Baltic Sea are mainly of glacial origin or the results of slow postglacial erosion processes. Extracted sediment therefore cannot be replaced by natural processes. Furthermore, sand and gravel layers in many cases are very thin, thus sediment extraction may lead to the exposure of residual sediments or bedrock. This would significantly change benthic life and, consequently, feeding conditions for sea ducks and fishes.

Taking into account the possible impacts of sand and gravel extraction on the Baltic ecosystem, it is necessary to give high consideration to the precautionary principle. Decisions of national authorities on permits for marine sediment prospection and extraction shall take into account the ecological consequences and possible interferences with other legitimate uses of the sea and, for this purpose, shall be based on an adequate investigation and evaluation of the natural conditions and the presumable environmental impacts.

An Environmental Impact Assessment shall be an obligatory prerequisite to any extraction permit. Permits shall not be granted for especially sensitive areas such as regions with high protection status, rare or endangered benthic communities, important spawning grounds of fishes and feeding grounds of fishes and waterfowl. The choice of technology shall ensure minimum environmental impacts. Environmental effect monitoring shall be a regular component of extraction activities.

The “Guidelines for Marine Sediment Extraction”, as annexed to HELCOM Recommendation 19/1, which has been approved by the Contracting Parties of the Helsinki Convention in 1998, give detailed advice on how to take environmental issues into account in marine sediment extraction projects (Annex).

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Annex:

HELCOM RECOMMENDATION 19/1

Adopted 23 March 1998,
having regard to Article 13, Paragraph b)
of the Helsinki Convention

MARINE SEDIMENT EXTRACTION IN THE BALTIC SEA AREA

THE COMMISSION,

RECALLING Paragraph b of Article 13 of the Convention on the Protection of the Marine Environment of the Baltic Sea Area, 1974 (Helsinki Convention),

NOTING Articles 3, 4, 7 and 15 of the 1992 Helsinki Convention,

TAKING INTO ACCOUNT that marine sediment extraction is of increasing economical importance in many regions of the Baltic Sea Area,

BEING AWARE that marine sediment extraction may have severe impacts on marine and coastal ecosystems,

TAKING INTO ACCOUNT that marine sediment extraction beside its environmental and ecological impacts also may interfere with other legitimate uses of the sea or interests such as fisheries and coastal defence,

DESIRING to minimize environmental impacts caused by marine sediment extraction and to avoid irreversible ecosystem disturbances,

TAKING INTO CONSIDERATION the work done by ICES on this issue, inter alia the "Code of Practice for the Commercial Extraction of Marine Sediments (including minerals and aggregates)",

RECOMMENDS to the Governments of the Contracting Parties to the Helsinki Convention:

a) to carry out all sediment extraction according to the attached Guidelines (**Attachment 1**);

b) to carry out an ***"Environmental Impact Assessment"*** prior to the extraction permit;

c) that extraction permits for ***"Sensitive Areas"*** shall be granted only following the restrictions as defined by the attached Guidelines (**Attachment 1**);

d) that the ***"Extraction Practice"*** shall cause a minimum environmental impact and allow the regeneration of marine and coastal ecosystems;

e) that ***"Environmental Monitoring"*** shall be carried out as a component of any sediment extraction,

RECOMMENDS FURTHER that the Contracting Parties report to the Commission every three years, starting in 1999, using the attached reporting format (**Attachment 2**).

Attachment 1:

Guidelines for Marine Sediment Extraction

Definitions

- Marine sediment extraction means the removal of sand, gravel, stones and other sediments from the sea bed for purposes such as construction, beach nourishment, landfill or as industrial raw material.
- Environmental Impact Assessment (EIA) in the context of this Recommendation shall at least cover the items under A.1. a-i of these Guidelines. This EIA can be carried out in connection with any extraction permit procedure or on the basis of an act on environmental impact assessment.

General

Decisions of national authorities on permits for marine sediment prospection and extraction shall be based on an adequate investigation and evaluation of the natural conditions, the ecological consequences and possible interferences with other legitimate uses of the sea.

A. Environmental Impact Assessment

(1) An Environmental Impact Assessment shall be an obligatory part of the extraction permission procedure. It shall take into consideration:
  a) the amount and type of the sediment being extracted
  b) the composition of the aggregate (grain size structure, organic content, contamination with harmful substances etc.)
  c) the extraction method
  d) the species composition and abundance of benthic flora and fauna at the extraction site and other areas potentially affected by the extraction process
  e) the significance of the extraction for fish, marine mammals and sea birds (spawning, breeding, migration, feeding, resting)
  f) the possible alteration of chemical and physical parameters in the water column and sediments (increase of turbidity, release of nutrients, harmful substances, oxygen consuming compounds)
  g) the hydrological situation at the extraction site (waves, currents, salinity, water temperature, sills and other structures with significance for hydrological processes etc.), including its significance for the expansion of the turbidity plume, sedimentation of suspended material and water exchange
  h) the duration of and the parameters for monitoring during the sediment extraction activities and after its termination
  i) interference with other legitimate uses such as fishery, coastal defence, recreation and tourism or possible damage to submarine archaeological sites.

(2) The Environmental Impact Assessment shall also consider effects on the sea bottom and the water column at the extraction site, as well as outside the extraction area caused, e.g. by turbidity plumes and sedimentation of particles. It shall also consider possible effects caused by transportation of the extracted materials.

(3) The results of the Environmental Impact Assessment which has formed the basis for the decision on the extraction permit should be made available for scientific evaluation.

B. Sensitive Areas

(1) Permits for marine sediment extraction shall not be granted for:
  a) Nature reserves
  b) National Parks
  c) Areas to be included or which are proposed to the European ecological NATURA 2000 network according to the EC Habitats and Birds Directives (92/43/EEC and 79/409/EEC) except when the procedure of Art. 6 of the Habitats Directive is followed

(2) Permits for marine sediment extraction in other sensitive areas shall only be granted if a thorough EIA that covers at least point A of this Guidelines is proving that the extraction is not likely to cause significant negative ecological effects or lead to a deterioration of the area. Such areas are:

a) Baltic Sea Protected Areas (BSPA) according to HELCOM Recommendation 15/5
b) Ramsar sites
c) areas inhabited by communities of long-living threatened invertebrate species (e.g. the bivalves *Arctica islandica*, *Astarte* spp., *Macoma calcarea*)
d) important spawning areas of fish
e) important feeding grounds for migrating or wintering waterfowl within resting and wintering areas of international importance
f) large areas densely covered with macrophytes (especially such as *Fucus*, *Zostera*, *Furcellaria*)
g) submarine boulder fields on lag deposits where they represent a rare or particularly ecologically valuable habitat type
h) areas of permanent upwelling cold water which provide habitat niches for specialized threatened benthic species
i) submarine sills with significance for the water exchange
j) marine areas near to the coast with significance for coastal sediment transport or with protective function for the coastline (e.g. sand banks, spits and bars).

C. Extraction Practice

(1) All appropriate measures shall be taken in order to minimize the ecological impacts caused by sediment extraction, and transportation of the extracted material. This includes:

a) the choice of an appropriate extraction method which guarantees minimum negative impacts to the marine environment
b) application of the "best available technology" (BAT) and "best environmental practice" (BEP)
c) optimization of the extraction process particularly in terms of reduction of the turbidity plume

(2) Furthermore special seasonal susceptibilities of the affected area (e.g. bird and fish migration, reproduction period of marine organisms) shall be considered.

(3) The recovery of marine life after termination of the extraction process shall be facilitated by appropriate precautionary measures. It shall be ensured that the original surface sediment type shall remain on the bottom with an adequate thickness for recolonisation by almost the same benthic organisms assemblage that inhabited the site prior to the extraction.

D. Environmental Monitoring

Monitoring shall be a component of every kind of extraction activities.

Dredging vessels should be equipped with monitoring systems for recording the position and the amount of extracted sediments.

Spill monitoring shall be carried out, including the parameters

a) amount and composition of spill

b) dispersion of suspended particles of the turbidity plume

c) sedimentation pattern

d) biological parameters (plankton, fish, sea birds etc.), as appropriate.

Depending on the extracted material monitoring may also be necessary for oxygen and nutrients in the spill water, in the water column at the extraction site and in the turbidity plume; if the sediment contains harmful substances and release by the excavation process has to be assumed the monitoring shall also include these parameters.

After termination of the extraction the recovery of benthic communities shall be monitored as defined in the EIA.

Monitoring data should be made available for scientific evaluation.

Attachment 2:
Reporting format for HELCOM Recommendation 19/1 concerning marine sediment extraction in the Baltic Sea Area
Please fill in the required information for all extraction fields of more than 10 ha extension or an annual extraction rate of more than 10,000 m .

No.	Location (1)	Year when the permit was granted	Type of material	Purpose of the extraction (2)	Annual amount of extracted material during the reporting period [m≥]			EIA (yes/no)	Environmental monitoring during and/or after extraction (yes/no)
					19_	20_	20_		

1) please, indicate on map
2) e.g, filling material, beach replenishment, coastal defence, industrial raw material, others

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BALTIC SEA ENVIRONMENT PROCEEDINGS

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No. 64B THIRD PERIODIC ASSESSMENT OF THE STATE OF THE MARINE ENVIRONMENT OF THE BALTIC SEA, 1989-1993; BACKGROUND DOCUMENT
(1996)

No. 65 OVERVIEW ON ACTIVITIES 1996
(1997)

No. 66 BALTIC MARINE ENVIRONMENT BIBLIOGRAPHY 1993-1995
(1997)

No. 67 WORKSHOP ON THE REDUCTION OF EMISSIONS FROM TRAFFIC IN THE BALTIC SEA AREA
(1997)

No. 68 THE EVALUATION OF THE RELATION OF ATMOSPHERIC DEPOSITION TO RIVERINE INPUT OF NITROGEN TO THE BALTIC SEA
(1997)

No. 69 AIRBORNE POLLUTION LOAD TO THE BALTIC SEA 1991-1995
(1997)

No. 70 THE THIRD BALTIC SEA POLLUTION LOAD COMPILATION
(1998)

No. 71 THE FINAL REPORT ON THE IMPLEMENTATION OF THE 1988 MINISTERIAL DECLARATION
(1998)

No. 72 THE BALTIC SEA JOINT COMPREHENSIVE ENVIRONMENTAL ACTION PROGRAMME: RECOMMENDATIONS FOR UPDATING AND STRENGTHENING
(1998)

No. 73 OVERVIEW ON ACTIVITIES 1997
(1998)

No. 74 AGENDA 21 FOR THE BALTIC SEA REGION, SUSTAINABLE DEVELOPMENT OF THE AGRICULTURAL SECTOR IN THE BALTIC SEA REGION
(1998)

No. 75 RED LIST OF MARINE AND COASTAL BIOTOPES AND BIOTOPE COMPLEXES OF THE BALTIC SEA, BELT SEA AND KATTEGAT
(1998)

*) out of print
**) in print

Errata to Baltic Sea Environment Proceedings No. 76

Due to some technical errors occurred in the process of conversion of the text in the printing office, the following mistakes have been found in the publication:

- cubic metres (m^3) as well as square metres (m^2) appear without superscript or have been converted to non-existing letters
- German letters, such as "ü" (e.g. Rügen) and "ß" (e.g. Darß) have disappeared in the conversion process

3. Marine sand and gravel resources in the Baltic Sea

Denmark

The Danish marine areas, including the North Sea, the Kattegat and the Baltic Sea, are very rich in mineral resources such as sand, gravel and stones, which are exploited at a considerable rate.

The National Forest and Nature Agency has commissioned the Geological Survey to undertake an evaluation of the total reserves of sand and gravel in Danish waters based on all existing data collected since 1979. Since 1991, mapping programmes have been carried out on Jutland Bank and Horns Reef in the North Sea and in Femer Belt, Adler Ground, Rønne Bank and Kriegers Flak in the Baltic. At present, between 80 and 90 % of potential resource areas in the inner Danish waters have been surveyed (ICES WGEXT 1998b).

Marine resources of fine sand in the North Sea and Baltic Sea are several billion cubic meters. However, the resources are not equally distributed and environmental constraints may seriously limit the reserves in some areas. It is expected that reserves are available for at least 50 years in most areas.

Resources of medium and coarse sand are limited in volume and distribution. Most of the accessible resources are located in shallow waters and are small, complicated in structure, and therefore difficult to exploit. A few larger resources have recently been identified in deeper waters and are expected to produce the majority of marine medium and coarse sand in the next 25 years.

Gravel (6 - 200 mm) is a finite resource dredged in a limited number of areas primarily located in coastal shallow waters of high environmental vulnerability, where promising resources have been identified. The total reserves have not yet been evaluated. Based on reconnaissance surveys, a number of inferred resources have been found in the North Sea and the Baltic.

Germany (Schleswig-Holstein)

There are various deposits of sand and gravel on the coastal shelf of Schleswig-Holstein.

Germany (Mecklenburg-Vorpommern)

The marine deposits of sand and gravel on the coastal shelf of Mecklenburg-Vorpommern are currently estimated to amount about 40 x 10^6 m^3 (tab.1). The thickness of the sand and gravel layers is rather low, on average only about 1 m. The economically interesting deposits are mainly situated between the 6 and 20 m depth line (Krause *et al.*, 1996, Gosselck *et al.*, 1996).

Poland

During the last 30 years geological prospecting and reconnaissance surveys carried out by the Branch of Marine Geology of the Polish Geological Institute have located various mineral products. Natural aggregates, *i.e.*, gravel, sandy gravel, and gravelly sand, which form deposits on the seabed, are the most thoroughly investigated mineral resources in the Polish coastal waters. To date, three deposits totaling about 90 x 10^6 m^3 have been documented: the "Slupsk Bank" deposit, the "Southern Middle Bank" deposit and the "Koszalin Bay" deposit. The results are presented in various reports (ICES WGEXT 1998a).

In 1997 about 1,641,500 m^3 of sand was identified and geologically documented for beach nourishment in the western part of the Polish EEZ in the vicinity of Dziwnów (ICES WGEXT 1998b).

Furthermore, Poland has identified deposits of sand enriched with heavy minerals such as garnet, zircon, rutile, ilmenite, magnetite and monazite, which might become of economical interest in the future (ICES WGEXT 1998b).

Russia (Kaliningrad region)

Bottom deposits of sand and gravel are widely spread on the Sambian-Curonian plateau. The most important of them are situated near former accumulation zones of different stages of the post-glacial Baltic Sea history. One of the most prospective sites is the massive of ancient dunes, situated in the vicinity of the oil drilling installation, which covers an area of about 90 km^2. The sand resources of this site amount to not less than 300,000 m^3.

Another area interesting for exploitation is situated in the region of the bore hole D-6-5/1. This area is covered by a ca. 10 m thick layer of ancient marine sands of medium grain size, and an upper layer of 1 - 2 m of sand-gravel.

A vast field of medium grained sands is situated in the Sambian depression. These thick cumulative strata (up to 10 - 12 m) include shifting sands (aleurites, 0.01 - 0.1 mm) and peat layers. According to preliminary calculations, the sand resources accumulated on this site amount to more than 10^6 m^3.

A further sand deposit is scattered with paleogene basic rocks. It mainly consists of sand of different grain

Table 1: Prospected areas on the continental shelf of Mecklenburg-Vorpommern (UWG 1993).

location	sediment type	estimated amount (10^6 m^3)	remarks
(1) outer Wismar Bight	sandy gravel, sand	3.4	obviously severe conflicts with nature conservation aims
(2) sea area off Kühlungsborn	sandy gravel, gravel	4.4	sediment layers of 0.2 - 2.5 m thickness, total area 218 ha
(3) sea area off Markgrafenheide	sandy gravel, sand	4.3	
(4) Plantagenet Ground	sandy gravel, gravel	5.7	shoal about 22 km NE Darß/Zingst peninsula, water depth < 8 m
(5) sea area north of Rügen	sandy gravel, sand, pebbles	?	only partly prospected, extraction difficult because of pebble and boulder layers
(6) Tromper Wiek	sandy gravel, sand	2.6	
(7) Landtief/Osttief	sandy gravel, sand	1.5	areas near to the Rügen - Usedom sill (Boddenrandschwelle), sediment layers of 0.1 - 0.8 m
(8) Greifswald Lagoon	sandy gravel	1.9	108 ha, average thickness of the sediments 1.9 m; exploitation conflicts with nature conservation aims (Special Protected Area according to EU Bird Directive)
(9) sea area off Usedom	sandy gravel, sand	2.9	3 prospected areas, predominantly thin sediment layers of 0.2 - 0.3 m
(10) Adler Ground	sandy gravel, sand	> 12.5	
total amount		> 39.2	

size. The basic rocks at this site take up to 40 % of the whole paleogenian exposures of the Kaliningrad coastal waters. They are exposed at the bottom or covered by a thin layer (1 - 2 m) of sediments. The reserves of these sands are estimated to be several million cubic meters.

Gravel deposits are usually represented by thin (less than 1 m) lenses which are situated near former coastal banks, foots and slopes on abraded terraces. The thickness of gravel areas on slopes of abraded and polygenetic terraces occasionally may exceed 5 m.

The southeastern part of the Vistula Lagoon harbours considerable reserves of glacial sand and gravel, which form mobile ridges. These ridges are the marine continuation of the exploited terrestrial deposits.

Lithuania and Latvia
Marine sand and gravel deposits are situated also in Lithuanian and Latvian coastal waters.

Estonia
There are four proven deposits of sand and gravel which could be of interest for future exploitation in the coastal waters of Estonia (Hiiumadala, Naissaare, Prangli, Ihasalu).

Russia (St Petersburg region)
The Gulf of Finland harbours considerable marine sand and gravel deposits.

Finland
There are considerable sand and gravel resources which could be of interest for exploitation in the coastal waters of Finland. Investigations are being conducted.

Sweden
The usable sand and gravel fields are mainly situated on the southwest Baltic Sea coast of Sweden.

4. Exploitation of marine sediment resources in the Baltic Sea states

Denmark

The extraction of marine sand and gravel in Denmark represents 10 - 13 % of the total production of materials for construction and reclamation. In 1996 the dredging in the Baltic Sea, including Kattegat, amounted to about 40 % of the total dredging in Denmark and took place in 151 permitted areas. Most of the areas are located around Sjælland and Fyn. In general, all areas are located at water depths of more than six meters and outside protected areas such as Ramsar- and EU-Birdprotected Areas or areas protected by The Nature Conservation Act.

The amount of materials dredged for construction increased slightly from 1992 until 1995; since then a slight decrease has been seen (tab. 2).

The dredging of sand fill for land reclamation and beach nourishment has increased over the last 10 years as a result of several large construction works in coastal areas and a change in approach to coastal protection. From 1989 to 1993 more than 9 x 10^6 m³ of sand fill and till have been dredged for the construction of the Great Belt bridge and tunnel project.

During the construction of the fixed link between Denmark and Sweden approx. 2 x 10^6 m³ of sandfill will be dredged from the Kriegers Flak. The originally expected amount of 9 x 10^6 m³ has been considerably reduced by re-use of dredged material from the construction site. The dredging started in January 1996 and is expected to last four years (Øresundskonsortiet 1998).

A major enlargement of the harbour of Århus is expected to require more than 3 x 10^6 m³ of sand fill in the next two years. The construction work will start in autumn of 1998 (ICES WGEXT 1998b).

For many years, fossil shells have been dredged from three areas in Roskilde Fjord. This activity was stopped for environmental reasons by the end of 1997.

Dredged material is also exported to Sweden and Germany.

It is expected that the exploitation of marine sand and gravel will increase in the future due to the expected termination of a number of licences on land and increasing environmental conflicts in potential extraction areas (ICES WGEXT 1998b).

Germany (Schleswig-Holstein)

No extraction of marine sand and gravel resources has taken place during the last ten years on the coastal shelf of Schleswig-Holstein, and no extraction is currently planned.

Germany (Mecklenburg-Vorpommern)

On the coastal shelf of Mecklenburg-Vorpommern there are currently 17 extraction fields for which

Table 2: Marine sediment extraction in Denmark 1990 - 1997 (only Helsinki Convention Area, Norden Andersen, pers. comm. 1998).

Year	Sand	Gravel fine	Gravel coarse	Sand Fill	Boulders small	Boulders large	Shells	Till	Total
	0 - 2 mm (10^3 m³)	0 - 20 mm (10^3 m³)	6 - 300 mm (10^3 m³)	(10^3 m³)	(10^3 m³)	(10^3 m³)	(10^3 m³)	(10^3 m³)	(10^3 m³)
1990	836.0	235.9	377.4	787.3	4.6	1.8	42.4	61.8	**2,347**
1991	694.7	315.7	653.5	852.4	10.2	2.1	110.0	858.7	**3,497**
1992	551.1	188.7	958.2	589.5	4.2	0.2	164.6	1,084.5	**3,541**
1993	753.5	215.4	926.1	559.7	3.8	0	131.4	6.4	**2,596**
1994	979.7	208.1	1,098.0	225.8	5.1	0.8	101.7	7.3	**2,828**
1995	862.5	210.9	896.8	265.0	4.1	0.1	85.8	256.4	**2,325**
1996	910.7	197.1	827.5	725.4	15.4	1.4	123.1	2,190.6	**4,991**
1997	511.1	205.9	1,317.1	512.2	3.9	0	148.0	2,129.9	**4,828**

Table 3: Amounts of extracted sediments in Mecklenburg-Vorpommern 1992 - 1997.

Year	Commercial Purposes (10^3 m^3)	Coastal Protection (10^3 m^3)	Total (10^3 m^3)
1992	294.4	77.2	371.6
1993	48.2	420.2	468.4
1994	276.1	538.1	814.2
1995	671.8	246.9	918.7
1996	828.0	1,330.2	2,158.2
1997	376.7	1,892.8	2,269.5

permission has been granted by national authorities. The majority of the extraction sites are used for coastal defence purposes. These sites are not permanently exploited but only temporarily, if there are coastal defence projects executed in the respective region. In 1997, 20 fields have been designated by governmental decree for coastal defence purposes (Ministry of Economy of the State Mecklenburg-Vorpommern 1997).

From four fields, the sand and gravel are used as construction material (concrete production, filling material, road base etc.). These fields are: sea area off Kühlungsborn, Greifswald Lagoon, Adler Ground, Plantagenet Ground.

The total area of permitted extraction fields amounts 200 ha. The extraction figures of the last years are given in table 3.

Poland

Gravel: No large scale exploitation has been carried out in Polish marine areas in the past, nor is it expected in the next future. Test extraction was carried out in the Slupsk Bank area during the years 1985 - 1989, with about 0.9 x 10^6 m^3 of sand and gravel being removed. Some test extractions were also carried out on the Southern Middle Bank and Koszalin Bay during the period 1987-1989, but only small amounts of sediments have been removed (about 2,500 - 3,750 m^3 from each site). In 1997 about 1,200 m^3 were extracted from the Slupsk Bank area.

Licences for extraction of gravel have been issued for two areas, but no larger exploitation is expected in the next few years.

Sand: Sand is extracted in Poland for coastal defence purposes only, *i.e.*, replenishment of beaches and dunes.

At the northeast of Cape Rozewie, a 5 km^2 area is designated for sand extraction for the needs of artificial beach nourishment. It has been exploited since 1995 at a rate of 100,000 m^3 / year. A 1 km^2 sand extraction field 5 km north of Jurata on Hel Peninsula was used in 1993 and 1995 for beach replenishment purposes, the total amount of extracted sand being ca. 200,000 m^3.

In the past (1989 - 1992), sand was extracted at four sites in Puck Bay for coastal defence measures on Hel Peninsula. In 1993, two sites were closed. From the remaining two sites sand is presently extracted at a rate of 150 - 300,000 m^3 / year (252,000 m^3 in 1997), but this shall be stopped in 1998, except in case of emergency situations. The total amount of sand extracted from Puck Bay between 1989 and 1997 was about 6.7 x 10^6 m^3.

Extraction of sand regularly takes place from approach channels to ports and from sand traps related to the operation of artificial sand by-pass systems at ports. The annual amount of this sediment removal is about 60,000 m^3 at the port of Kolobrzeg, 80,000 m^3 at the port of Darlowo, 80,000 m^3 at Ustka, 30,000 m^3 at Leba and 200,000 m^3 at Wladyslawowo.

Russia (Kaliningrad Region)

There is no actual exploitation of marine sand and gravel resources in the Kaliningrad region of Russia, and no industrial exploitation is expected in the near future. However, investigation of marine mineral resources is being conducted and exploitation can be expected in the long run if the economy recovers.

There are current plans for the construction of an artificial island for oil exploitation purposes. A total area of 67 ha will be required for the construction of the island and extraction of building material. The duration of the work is expected to be one vegetation season.

Table 4: Summary of current (1990 - 1997) marine aggregate extraction activities in the Baltic Sea states.

country	annual extracted amount of marine sediments, 1990 - 1997 (10^6 m^3)
Denmark	2.3 - 5.0
Germany (Schleswig-Holstein)	no activities
Germany (Mecklenburg-Vorpommern)	0.37 - 2.3
Poland	*gravel*: test extractions only, < 10^6 m^3 *sand*: ca. 7 x 10^6 m^3 1989 -1997 for beach replenishment
Russia (Kaliningrad)	no actual activities, but construction of an artificial island is planned which will include the use of marine aggregates
Lithuania, Latvia, Estonia	no activities
Russia (St Petersburg)	1.2
Finland	< 0.5
Sweden	no activities since 1992

The recovery time of marine fauna in the extraction area is expected to be about five years.

Lithuania, Latvia and Estonia
There is no current exploitation of marine sand and gravel resources in Lithuania, Latvia and Estonia, and no exploitation is expected in the next future.

Russia (St Petersburg region)
In the St Petersburg region of Russia sand and gravel resources are exploited from three extraction fields. The annual extraction rate of all three fields amounts about 1.2 x 10^6 m^3. The fields are:
Styrsuddensky Bank (800,000 m^3);
south of the B. Beresow Island (200,000 m^3)
and south of the Seskar Island (200,000 m^3).

Finland
Since the extraction of sand and gravel on terrestrial areas was regulated in 1982, the extraction from marine areas has increased considerably during recent years, and can be expected to increase further in the future.

Dredging of marine sediments in Finland has been almost constant, with extraction figures less than 500,000 m^3 over the past years. The main areas of extraction are: Helsinki, Kotka, Pori and the land bridge to Hailuoto Island. The city of Kotka has extracted about 2.5 x 10^6 m^3 of sand and gravel for harbour facility expansion. For the city of Helsinki, a permit for 5 x 10^6 m^3 has been issued for landfill projects (housing projects, harbour facilities) (ICES 1992, 1998a).

Sweden
Marine sand and gravel extraction from the Swedish part of the Baltic Sea, mainly the sound, started at the beginning of the century. In 1966, the extraction was regulated by the Act (1966 : 314) on the Continental Shelf.

During the period from 1966 to 1992 exploitation took place at 13 extraction sites. The amount of extracted material was 12,937,282 m^3 in the period from 1966 to 1978, and 1,711,363 m^3 from 1979 to 1992.

The material gained has mainly been used as construction material (landfill), but also, regarding one site (V-Haken), as industrial mineral for glass manufacturing.

In 1992 sand and gravel extraction was stopped for environmental reasons.