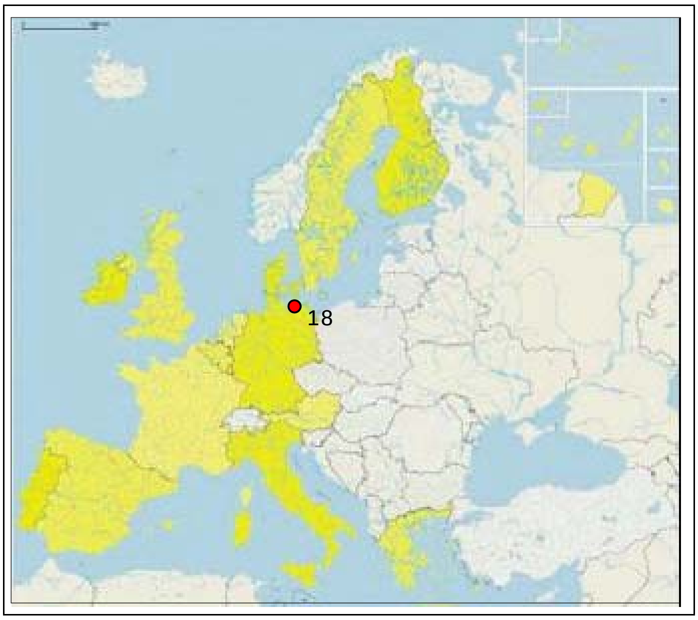
ROSTOCK
(GERMANY)



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1. GENERAL DESCRIPTION OF THE AREA

1.1 Physical process level

1.1.1 Classification

Fig. 1: Location of the case area.

Rostock is located at the eastern German Baltic coast. Erosion is extensive along this coastline. The adjacent Baltic sea is shallow. Along the low-lying sectors of the coast there are many lagoons, the lagoons are known as haffs (large) or bodden (small). Besides the bodden coast with lagoons, there are coastal plains and cliffs that form a relatively closed coastline. At the studied case area Rostock, these plains and cliffs form the coastline. The coast is a micro-tidal coast.

According to the typology in the scoping study, the Rostock coast is typified as a combination of two different kinds of coast:

2.Soft rock coasts.
Micro tidal southern Baltic
3b. Wave-dominated sediment. Plains.
Dune coasts in micro tidal zones

1.1.2 Geology

The processes of erosion and soil deposition caused by the sea have created cliffs, mounds of sand, beach lakes, dunes and so-called wind flats. The foundations were laid by the last Ice Age, which ended 12,000 years ago. Because the Baltic Sea level began to rise, land was flooded and ridges remained as islands. Constant movement of the sea separated shallow bays from the Baltic Sea, which we now know as bodden. Over time, dunes and moorlands were formed. A very varying coast has originated over the years, characterized by spits and land tongues, flat coastal plains and cliffs.

The coast at the case area is characterized by a frequent change of cliffs to coastal plains. In the combination of flat coastal plains and cliffs, the cliffs have a double function in the coastal processes:

- Cliffs can be a resting point for surrounding sedimentary beaches.
- The erosion of cliffs provides sediment to fill the downstream sedimentary beaches.

This implies that protection of a cliff against erosion causes more erosion at the downstream sedimentary beaches that are dependent of the eroded sediment from the cliffs. On the other hand, erosion of the resting point can also cause erosion of the surrounding sedimentary beaches.

1.1.3 Morphology

The case area is located at the Mecklenburger Bucht in the Ostsee. Warnemunde is located at the mouth of the Warnow, a little river which becomes a bigger lake just before flowing into the Baltic Sea. The town of Rostock is settled at the shores of this lake and by this way obtains access to the Baltic Sea.

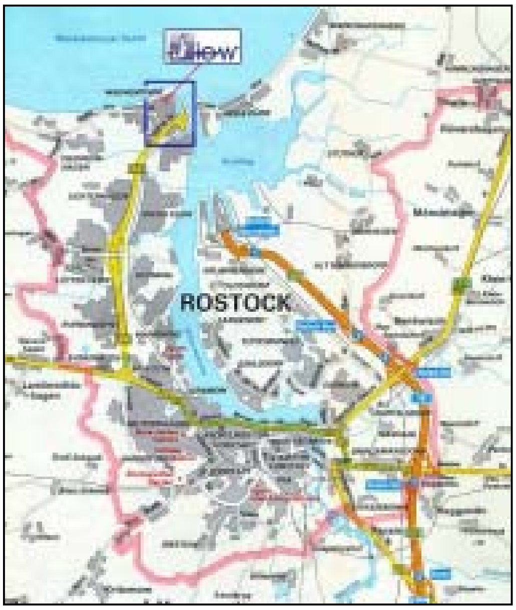


Fig. 2: Map of the case area.

The case area is shown in Figure 2, and is split in six different areas:

1. Warnemunde west	F144,550-F145,650
2. Warnemunde mitte	F145,650-F147,080
3. Warnemunde hohe dune	F148,730-F151,800
4. Markgrafenheide	F151,800-F153,250
5. Moorwiesen	F153,250-F156,390
6. Rostocker Heide	F156,390-F160,600

West of Warnemunde, the Stoltera cliffs are found (moraine cliffs). From Warnemunde west to Moorwiesen, the coast exists of coastal plains. Further east at Rostocker Heide, there are cliffs present again (sandy cliffs). Most of the locations are named in the map, only Moorwiesen and Rostocker Heide are not on the map.

In between Warnemunde mitte and Warnemunde hohe dune, the harbour entrance of Rostock is located. A breakwater has been built at the western site of the harbour entrance.

1.1.4 Physical processes

Tide

Normal tidal ranges in the adjacent Baltic Sea are less than 0.25 m. Tidal action plays practically no role in this area.

Waves

Average wave height at Warnemunde: 0.5-1.4 m
Maximum wave height at Warnemunde: 2.5 m
Westerly wave are predominant in this area and the long shore transport is mainly wave-induced.

Storm events

Seiches and storm surges can raise or lower coastal water levels by at least a meter. Major storm surges occurred at this coast in 1864, 1867 and 1954. The 1954 surge caused coastline recession of up to 11 m on dune coasts, especially between Warnemunde and the

Darss foreland. The maximum storm surges in the Ostsee are being produces by winds from northeasterly direction; the fetch length can reach up to 750 km in this direction.

Ice

The coastal waters and shallow lagoons freeze in winter. When the ice breaks up, wave action piles it onto the shore, redistributing beach and nearshore sediments, especially boulders, some of which are rafted by ice and carried along shore or offshore.

1.1.5 Erosion

Structural erosion

About 70 % of the coast at Mecklenburg-Vorpommerns has a negative sediment sum and is receding. 23 % is stabile and 7 % has a positive sediment sum and is prograding. In the case area the maximum erosion is 120-210 m in 100 year at the Rostocker Heide (cliffs).

As was said before, the beaches only exist in this area thanks to the presence of the cliffs and the sediment that is being eroded from the cliffs. Spits and land tongues have originated in this way. Because of erosion of the resting point, the cliffs, and/or a reduced sediment supply from the cliffs, the originally accreting spits and land tongues are currently eroding. Coastal protection works are therefore necessary to prevent a breakthrough of these beaches.

The underwater longshore bars also play an important role as transport system for sediment. Because of the reduction of the bars, the width of the beach decreases and the coast recedes.

The net long shore transport at the coast of Rostock is eastward, caused by the prevailing westerly winds, and has a magnitude of about 0,3 M m3 per year.

Acute erosion

Acute erosion due to storm surges (waves and water levels at extreme hydraulic conditions) causes extreme changes of the coast in a very short time. These storm surges are normative for the design of the coastal protection works. In Warnemunde, the dikes have collapsed 8 times in the last hundred years due to heavy storm surges. In the picture one example is shown of a dike collapsing due to a heavy storm surge.

Fig. 3:Result of the collapsing of a dike due to storm surge.

1.2 Socio-economic aspects

1.2.1 Population rate

The entire province of Mecklenburg-Vorpommern covers 1,020 km2 of possible flooding areas, with 90,000 people living in these areas = 88 persons / km2. The number of people living in Rostock is about 248,000.

1.2.2 Major functions of the coastal zone

Rostock, situated north of Berlin, is one of the biggest cities in the northeast of Germany. Rostock is a traditional historical Hanseatic town. Where the river Warnow reaches the Baltic Sea there is an old fishing village called Warnemunde, now part of the growing city.

- **Industry, transport and energy:** Rostock is an important seaport and, with Warnemunde, constitutes one of the major shipping centers of Germany, receiving a large part of the oil supplies imported into the country.

Fig. 4:Old fishery port Warnemunde.

- **Fisheries and aquaculture:** There is a large fishery port present in the Rostock harbour.
- **Tourism and recreation:** The first tourists came in the early 20th century, bringing income to the inhabitants, replacing the declining income from the fishing and shipping industry. Tourists still are an important part of income for Rostock and Warnemunde.
- **Nature conservation:** In spite of the measures taken, natural areas still remained and in 1957 the area was declared a National Park ending the intensive land cultivation. There are several natural parks such as "Vorpommersche Boddenlandschaft" and "Jasmund".
- **Urbanisation (protection of life and value)**

1.2.3 Land use

The coastal areas east of the harbour entrance breakwaters are mainly untouched areas where nature can take its course. The natural areas consist of dunes, cliffs and forestry. West of the breakwaters, the urban area of Warnemunde is present.

1.2.4 Assessment of capital at risk

According to Bryant [1995], the coast of Rostock is at moderate risk.

High risk: city or major port or > 150 persons/km2 or >150 m road/km2 or > 10 m pipeline/km2
Moderate risk: 150 < persons/km2 > 75 and 150 < m road/km2 > 100 and 10 < m pipeline/km2 > 0
Low risk: persons/km2 < 75 and m road/km2 < 100 and no pipelines

For Mecklenburg-Vorpommern the average population rate of possible flooding areas is 88 persons/km^2. This indeed implies a moderate risk. However, this is an average population. In Figure 3, the green area implies the possible flooding area at Warnemunde. This area is not so densely populated, however it does represent great economic values because of the presence of the harbours. The case area can be considered as being at moderate risk.

As an example of the economic values: a flood like has happened in 1872, would now bring about a total damage of about €1.65 million in <u>entire</u> Mecklenburg-Vorpommern.

2. PROBLEM DESCRIPTION

2.1 Eroding sites

In Figure 3, the case area is shown in more detail. In the figure, the erosion and sedimentation in the last 100 years is shown. The red letters imply an erosion rate, while the black letters imply a sedimentation rate. Also, the years that a flooding took place due to a heavy storm surge are indicated at different locations.

Fig. 5: Storm surge at the dunes of Warnemunde.

The average erosion in the entire province of Mecklenburg-Pommern is 34m/ 100 years. West of the harbour entrance the erosion is about average, 35m/ 100 years. A flooding took place at the coastal plains of this area in two occasions. Because of the easterly directed net long shore transport, west of the break water accumulation of sand occurs; 150m/ 100 years.

East of the harbour entrance, the erosion increases. At the coastal plains, the coast has receded 70 to 40m in a 100 years. At the cliffs of the Rostocker Heide, the erosion rate increases dramatically; 210-120 m/ 100 years. On the coastal stretch of Kkm F154,000 to F156,500 (plains Rostocker Heide) severe flooding occurred ten times in the last 100 years. The last severe flooding at the case area took place in 1954.

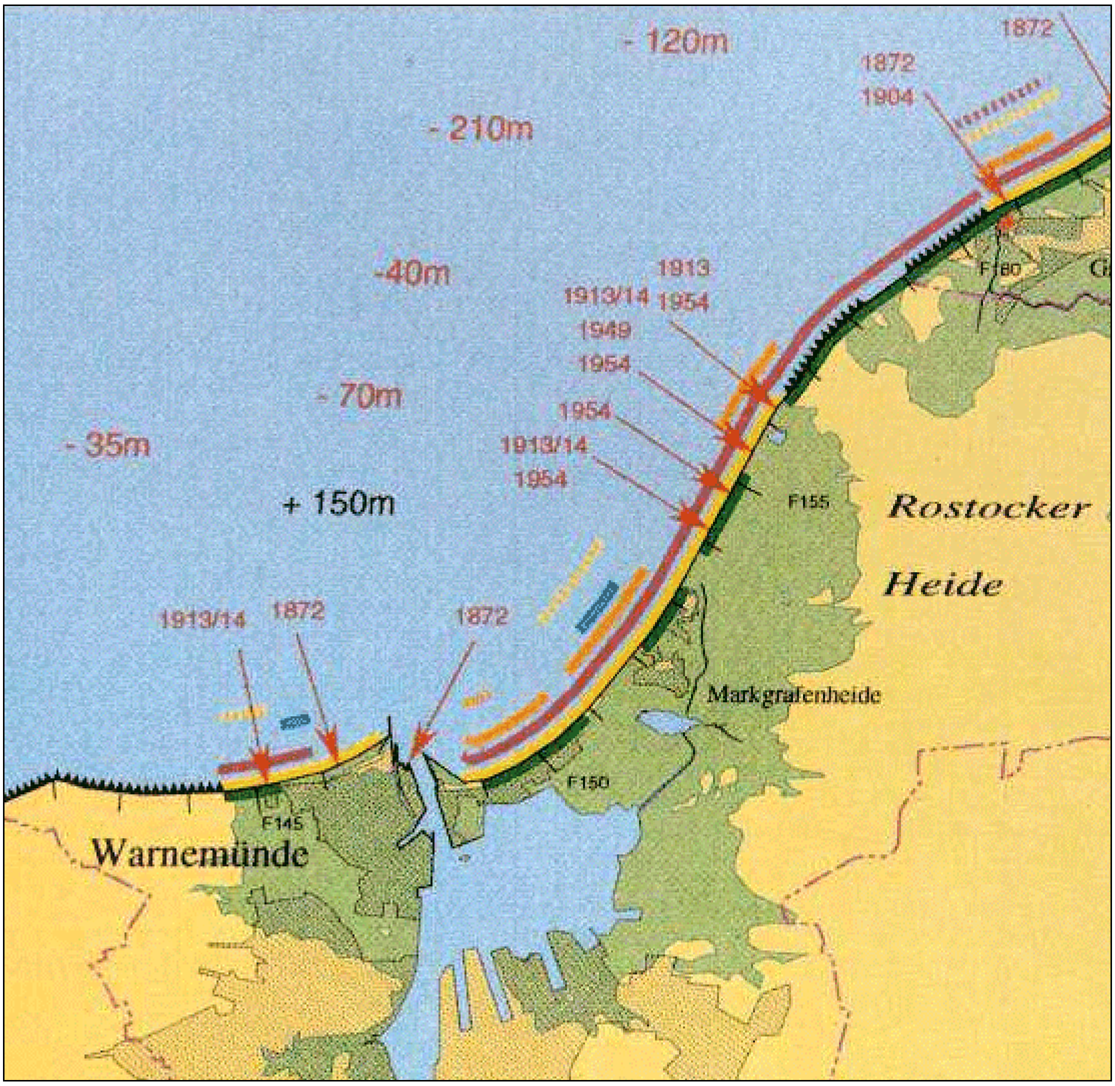
2.2 Impacts

The erosion threatens the beaches, and thereby the function recreation and tourism. Furthermore, the safety of the hinterland is threatened. This includes the people living in the threatened area (see green area in Figure 6), though the population is not so dense in this area, and the economic values in the form of the industry of the harbour. Nature conservation is not threatened by erosion; it can be stimulated by dynamic maintenance of the dune coasts.

3. SOLUTIONS / MEASURES

3.1 Policy options

Coastal dynamics has been acknowledged at the Mecklenburg-Vorpommern coast, especially in National parks. Safety should always be maintained. Within this keynote however, nature should be able to go it's own way as much as possible. The coast is therefore maintained in a dynamic way. To preserve safety, the policy option is "hold the line" and if possible "limited intervention". Within this policy a dynamic maintenance of the coast is possible.



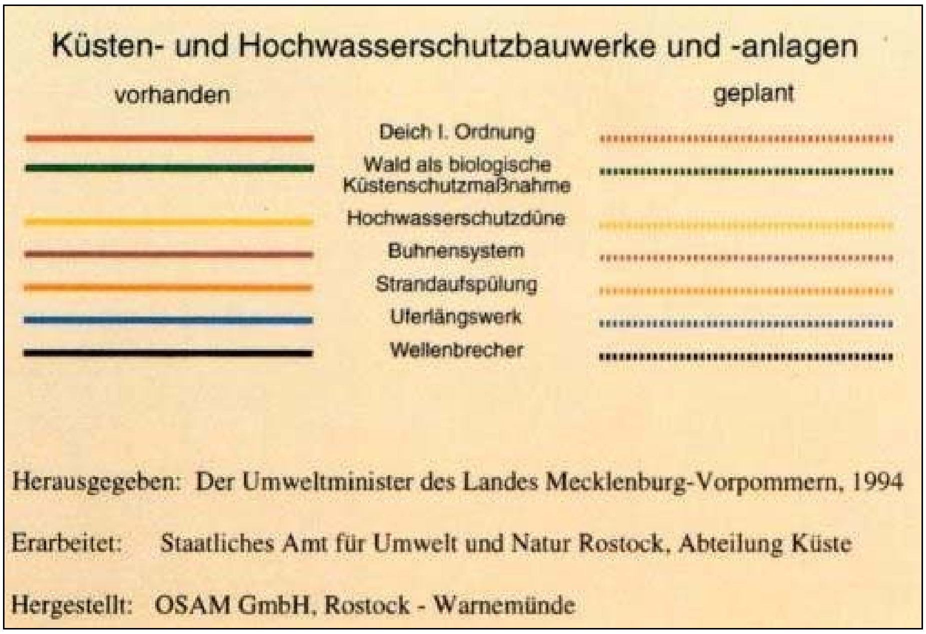


Fig. 6: Erosion at case area and taken measures against the erosion.

3.2 Strategy

The protection of this part of the coast started with the building of a seawall in 1914. In the 1960's the building of revetments and groins started. Especially the groins cover a very large part of the coast from Warnemunde to Graal. In the 1970's the building of these hard coastal protections turned out not to be sufficient for the protection of the coast. East of the harbour entrance to Rostock, at Warnemunde Hohe dune and Markgrafenheide, nourishments were needed to maintain the coastline. These nourishments have to be repeated every 2-3 years at Hohe dune and every 10 years at Markgrafenheide.

Except for the measures described above, biological measures were taken. First of all, marram grass is planted in the dunes to stabilize the dunes. Second, forestry was used behind dunes; this can act as a protection from wind and as a wave breaker at times of flooding of the dunes in front of the forest.

In the current situation, repeating nourishments are being carried out, and sometimes after a heavy storm surge the recovery of a dune or dike is necessary. There are no plans for the building of more hard coastal protection works.

3.3 Technical measures

3.3.1 Type

In Figure 3 and Table 1 all the taken measures in the case area are shown. Different colours stand for different types of coastal protection. The dashed lines imply the planned measures.

The case area was split in the following six ranges:
1. Warnemunde west F144,550-F145,650
2. Warnemunde mitte F145,650-F147,080

3. Warnemunde hohe dune F148,730-F151,800
4. Markgrafenheide F151,800-F153,250
5. Moorwiesen F153,250-F156,390
6. Rostocker Heide F156,390-F160,600

Table 1: Present measures.

Location	Dunes	Nourish-ment	Groins	Revet-ment	Sea wall	Forestry
1	X		X		X	X
2	X					
3	X	X	X			X
4	X	X	X	X		X
5	X		X			X
6			X			X

The largest part of the case area exists of dunes, only at Rostocker Heide the coast is formed of cliffs. Downstream of the harbour entrance, at Warnemunde Hohe dune and Markgrafenheide, nourishments are necessary to prevent the coastline from receding. Along almost the entire coastline groins are present, only at Warnemunde mitte there are no groins. A revetment was built at Markgrafenheide, and a sea wall at Warnemunde west. Forest is planted behind almost all dunes accept at Warnemunde west. Also, at the cliffs of Rostocker Heide forest was planted to stabilize the cliffs.

Marram grass is planted in all the dunes. The main goals of the marram grass are stabilizing the dune surface, reducing the sand drift inland, stabilizing the dune core and thereby increase the erosion resistance (“limited intervention”).

3.3.2 Technical details

Seawall

The seawall at Warnemunde west has a length of 400 m, it is made of reinforced concrete at Kkm F145,600-F146,000. The height of the seawall is 3,6 m NN, and it was built in 1914.

Revetment

950 m made of different materials at Markgrafenheide, Kkm F151,800-F152,750.
Height at 4,0 m NN, it was built in 1963/68.

Groynes

Two series of groins are present along the coastline of the case area. One small groin series is located west of the harbour entrance; this series consists of 17 groins with a length of 90 m each and at 90 meters distance from each other. The other groin series is located east of the harbour entrance (down stream of the break waters), this series consists of 133 groins in the case area (however the series continues east of the case area and therefore is even longer). These groins are also placed 90 meters from each other, the length of the groins varies from 50-80 meters. The groins were built in a time span of more than twenty years, the first ones in 1967 and the last ones (the small groin series upstream of the harbour entrance) in 1990/92.

Table 2: Details of groins at Rostock.

Location	Location [Kkm]	Number [-]	Year	Length [m]	Distance [m]
1	F144,480-F145,920	17	1990/92	90	90
3	F148,660-F149,615	1-12	1975/80	50-70	50-100
3	- F150,625	13-23	1975/80	60-70	90
3	- F151,550	24-33	1975/80	60-70	90
3,4	- F152,725	34-46	1967/68	40-50	90
4,5	- F155,070	47-72	1970/74	50-70	90
5	- F156,430	73-87	1963/64	50-80	90
6	- F157,720	88-101	1987/90	80	90
6	- F159,185	102-117	1984/87	80	90
6	- F160,630	118-133	1980/84	80	90

Nourishments

The nourishments take place downstream of the harbour entrance, at Warnemunde Hohe dune and Markgrafenheide. The technical details for the nourishments at Hohe dune are shown in Table 3. Repetition of the nourishments is needed every 2-3 years to prevent the coastline from receding. From the table it can be seen that the first nourishment was placed over a long stretch of 2,2 km, the following nourishments from 1976 were all placed as far upstream as possible (thus directly downstream of the harbour entrance) over a stretch of 100-400 meters. The average amount of sand varies from 100-400 m^3/m^1.

The technical details for the nourishments at Markgrafenheide are shown in Table 4. Repetition of the nourishment is needed every ten years, much less often than at Warnemunde Hohe dune. Three nourishments took place up until now and the fourth one is planned to happen soon. The average amount of sand does not vary a lot, from 100-150 m^3/m^1.

Table 3: Details of nourishments Hohe dune.

Year	Location [Kkm]	Stretch [km]	Amount of sand [10^3 m^3]	Average amount [m^3/m^1]
1972/73	F 148,500-F 150,700	2,2	264,4	120
1975	F 148,500-F 149,280	0,78	136,3	175
1976	F 148,500-F 148,900	0,40	37,0	93
1978	F 148,500-F 148,900	0,40	122,1	305
1981/82	F 148,500-F 148,800	0,30	83,4	278
1983/84	F 148,500-F 148,900	0,40	101,7	254
1985	F 148,500-F 148,600	0,10	37,4	374
1986	F 148,500-F 148,700	0,20	57,5	288
1988	F 148,500-F 148,900	0,40	37,5	94
1994	F 148,750-F 149,140	0,39	53,0	136

Table 4: Details of nourishment Markgrafenheide.

Year	Location [Kkm]	Stretch [km]	Amount of sand [10^3 m^3]	Average amount [m^3/m^1]
1970	F 151,800-F 153,100	1,30 km	204,0	157
1983/84	F 151,200-F 152,000	0,80 km	86,0	108
1991	F 151,700-F 153,250	1,55 km	163,0	105

3.3.3 Costs

No information was found about the costs of the executed measures at Rostock.

Extra: planned measures and estimated costs

Warnemunde west: dune reinforcement over 800 m of coast, reason is the needed recovery of the high water protection for storm surges. Estimated costs: €0.3 Million.

Warnemunde Hohe dune: nourishment of 60.000 m^3 sand over 500 m of coast, reason is the deficiency of sand at the coast that causes the need for repeated nourishments every 2-3 years. Estimated costs: €0.2 Million.

Fig. 7: Nourishment at the beach.

Markgrafenheide: nourishment to reinforce the dunes of 180.000 m^3 sand over 1800 m of coast, reason is the negative sediment balance in the beach- and dune zone that causes the need for repeated nourishments. Estimated costs: €0.75 Million.

4. EFFECTS AND LESSONS LEARNT

4.1 Effects related to erosion

The seawall stopped the erosion locally, but caused leeside erosion downstream of the seawall. The same goes for the revetment. Apparently the building of the groins did not work sufficiently everywhere to stop the coastline from receding, nourishments are still needed at Warnemunde Hohe dune and Markgrafenheide. The nourishments do not stop the erosion, but they do stop the coastline from receding.

4.2 Effects related to socio-economic aspects

The taken measures all together insure the safety of the hinterland. Furthermore, the beaches are restored by the nourishments, which is stimulating for the tourism and recreation function at Warnemunde.

4.3 Effects in neighbouring regions

No effects in neighbouring regions were observed.

4.4 Relation with ICZM

Within the Baltic Sea, the natural network by the sea can be retraced quite well, since it is a marginal sea and almost completely enclosed by economically very dynamic and active neighbouring states.

The Baltic Sea water therefore connects the municipality of Trelleborg in southern Sweden with Rügen in Germany, thus both regions are causers of, but also do suffer from the problem of eutrophication. On the other hand, the installation of oil-platforms in the coastal waters of Lithuania affects the hydrological and ecological condition of Latvia´s coast. Structural interventions in the coastal zone can lead to considerable changes in neighbouring or more distant coastal zones.

Integrated Coastal Zone Management in the Baltic Sea Region – BALTCOAST

In the coastal zone of the Ostsee cities, harbours, natural landscapes, industry, tourism and other activities are concentrated. Often, sensitive and valuable flora and fauna has to be taken into account next to these activities. Conflicts between the protection of the coast on the one hand and it's development on the other hand are frequent. An increasing use of the off-shore area (for example by fishery, aquaculture, pipelines etc) and nature reserves in the neighbourhood of that area develop without any corresponding planning and without coordination with the planning of the space on land. This is the base for the need to expand the planning to the offshore area and to develop methods and fine tuning proceedings to control the development of the different uses of the coast.

To prevent conflicts between safety and other functions, a protected strip of the coastal zone is defined by law for Mecklenburg-Volpommern:

1. 100 m inland from the slope of a hard coastal protection
2. 200 m inland from the average water mark at coastal plains, and at least 50 m inland from the foot of a dike or dunes
3. the beach

4.5 Conclusions

Effectiveness

In the 1970's the building of the hard coastal protections turned out not to be sufficient for the protection of the coast at certain locations. East of the harbour entrance to Rostock, at Warnemunde Hohe dune and Markgrafenheide, nourishments were needed to maintain the coastline. At the rest of the coastline the hard coastal measures apparently succeeded in stopping the erosion. The nourishments have to be repeated every 2-3 years at Hohe dune and every 10 years at Markgrafenheide. The nourishments succeed in stopping the coastline from receding.

Possible undesirable effects

As was described, the hard coastal measures locally have some negative effects. No undesirable effects were observed because of the nourishments.

Gaps in information

No information was found on the costs of the executed measures.

5. REFERENCES

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Figures:

Figure 1: http://www.icm.noaa.gov/country/germany.html
Figure 2: http://www.io-warnemuende.de/general/map_hro.html
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Figure 6: http://www.um.mv-regierung.de/kuestenschutz/bplan/
Figure 7: ???????

Tables:

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